Hunting Activity and Male Wild Turkey Movements in South Carolina

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Abstract: Anthropogenic pressure can have significant impacts on how wildlife move and how they use habitats. During 2014–2016, we deployed 41 GPS transmitters on male wild turkeys on the South Carolina Department of Natural Resources Webb Wildlife Management Area (WMA) Complex to evaluate effects of hunting intensity on male wild turkey movement ecology. Daily mean movement distance was 3,254 m day^{-1}, but there was significant variation in our mean estimate (SD = 1,478) with movements ranging from 137 to 14,599 m on any given day. Male wild turkeys slightly decreased their movements in response to hunting intensity, but differences in movement distances were <300m and not biologically significant. We found that the primary driver of male wild turkey movements was neither hunting season timing/intensity nor reproductive period timing. Our findings revealed considerable inter-individual variation in movements during spring hunting and reproductive seasons, and drivers of this variation are unclear. Hence, we suggest that management strategies based on average movements or range estimates may be inappropriate, and a more individual-level evaluation may be warranted.

Key words: Eastern wild turkey, hunting, movement ecology, range size, utilization distribution

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The response of wildlife to anthropogenic activities, particularly related to the probability of interactions during hunting activities and the potential for impacts on both target (Karns et al. 2012) and non-target (Kilgo et al. 1998, Janis and Clark 2002) species, has increasingly been of interest to wildlife managers. Disturbance studies also provide information on the short and long-term impacts on demography and behaviors (Godwin et al. 1990, Conner et al. 2001, Holdstock et al. 2006, Karns et al. 2012), and habitat selection and range adjustments (Root et al. 1988, Conner et al. 2001, Karns et al. 2012). The hunting public maintains interest in whether wildlife adjust their movement ecology relative to activities such as hunting intensity (Karns et al. 2012, Gross et al. 2015).

Movement ecology of male Eastern wild turkeys (*Meleagris gallopavo silvestris*) has been of considerable interest to managers because of potential influence on breeding propensity (Badyaev et al. 1996) and mortality risk (Godwin et al. 1990, Holdstock et al. 2006). Studies of movement ecology will also provide the foundation for identifying and developing habitat management activities (Godwin et al. 1994, Collier and Chamberlain 2011). However, these data historically have been difficult to collect given the logistical constraints of intensive radio-tracking needed to identify movement paths at a useful temporal and spatial scale for accurate movement estimation (Byrne et al. 2014).

Recent advances in technology available for remote tracking of wild turkeys (Guthrie et al. 2010) have increased the ability to evaluate various aspects of wild turkey movement ecology with respect to external stimuli (Collier and Chamberlain 2011, Byrne et al. 2014, Gross et al. 2015). Recent movement ecology studies on wild turkeys have provided increased detail in methods used to evaluate habitat selection and use (Byrne et al. 2014, Oetgen et al. 2015) and evaluated potential factors that may impact demography (Byrne et al. 2014, Conley et al. 2015, Cohen et al. 2015). Additionally, increasingly managers have become interested in information on how male turkeys move in response to hunting related activities (Gross et al. 2015).

Our objective was to evaluate changes in movements and shifts in ranges over a period encompassing both the reproductive and hunting season of male wild turkeys in South Carolina. We evaluated movement trajectories daily to evaluate whether daily hunting intensity or site-specific reproductive period influenced daily movements of male wild turkeys, and evaluated changes in weekly range size to determine whether reproductive period or hunting intensity influenced changes in range size.

Study Area

We conducted our research on three contiguous wildlife management areas (WMAs; Webb, Hamilton Ridge, and Palachucola—hereafter Webb WMA Complex) managed by the South Carolina

Department of Natural Resources (SCDNR). The Webb WMA Complex was located in Hampton and Jasper counties and was 10,483 ha with approximately 22 km of Savannah River frontage comprising the southern border. Webb WMA was 2,373 ha with approximately 917 ha of bottomland hardwoods typical of the southeastern river floodplains and 1,458 ha of upland (Atlantic coast flatwoods) consisting of longleaf (*Pinus palustris*), loblolly pine (*Pinus taeda*), and slash pine (*Pinus elliottii*) with hardwood stands along riparian corridors. Hamilton Ridge was 5,374 ha with approximately 2,664 ha of predominantly bottomland hardwood wetlands. The 2,710 ha of upland habitat on Hamilton Ridge was dominated by industrial loblolly pine forest with intermittent slash and longleaf pine present. The 2,734-ha Palachucola WMA was dominated by approximately 1,618 ha of planted loblolly pine currently under conversion to longleaf pine with the remaining 1,092 ha primarily composed of bottomland hardwoods. The Webb WMA Complex was managed with an emphasis on hunting, mainly white-tailed deer (*Odocoileus virginianus*), Eastern wild turkey, and Northern bobwhite (*Colinus virginianus*). Primary management activities included both dormant and growing season prescribed fire, an active timber management program, fallow field management and maintenance of agricultural food plots.

Methods

Following standard capture methods for wild turkeys, we used rocket nets baited with milo and corn. We aged all captured individuals and banded each with an aluminum rivet leg band (National Band and Tag Company, Newport, Kentucky). We radio-tagged each individual with a backpack-style GPS-VHF transmitter (Guthrie et al. 2010) produced by Biotrack Ltd. (Wareham, Dorset, UK). Each GPS transmitter was programmed to take 1 location nightly (23:58:58), hourly locations from 15 February–14 March between 0500 and 2000, every 30 minutes from 15 March–15 May, and hourly beginning 16 May until the battery died or the unit was recovered. We monitored all individuals via VHF radio-telemetry >3 times per week and downloaded data bi-monthly from units via a handheld VHF/UHF receiver. Capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permit A2014-013 and A2015-07).

We used the period 1 March–31 May 2014–2016 as our inference window as this period included 1 month on either side of the hunting season on the Webb WMA Complex and it also incorporated most (2014–85%; 2015–88%; 2016–75%) nest initiations for radio-tagged females on the Webb WMA Complex during 2014–2016 (B. A. Collier, unpublished data). We used a dynamic Brownian bridge movement model (dBBMM; Kranstauber et al. 2012) to calculate ranges for individuals during the inference period and weekly ranges for all weeks where complete data were available. We used R v3.3.0 (R Development Core Team 2016) and the R package "move" (Kranstauber and Smolla 2016) to create the dBBMM ranges with a margin size of 5, a window size of 21, and a location error of 15 based on initial evaluations by Guthrie et al. (2010) and field tests at the study site (B. A. Collier, unpublished data). From each period's dBBMM, we derived 50%, 75%, and 99% utilization distributions that represented weekly core areas and inference period range. We used a 99% level as opposed to a 95% level as spatial location error has significantly been reduced via GPS as opposed to VHF, and hence a 99% utilization distribution likely provides a more complete picture of space use. As such, because the dBBMM accounts for temporal autocorrelation and is useful for estimating ranges when significant spatio-temporal data are available, and as our data consists of highly accurate spatial locations (Guthrie et al. 2010, Byrne et al. 2014), our weekly and period range estimates represent a significantly more accurate assessment of the utilization distribution relative to minimum convex polygons or kernel density estimators previously used to evaluate male movement ecology (Hoffman 1991, Godwin et al. 1994). We estimated the area (ha) of individual utilization distributions and computed summary statistics, and evaluated those metrics among individuals and temporally using generalized additive regression.

We evaluated daily movements of male wild turkeys via generalized additive models using R package mgcv (Wood 2006). We summed total distances between each sequential locations to calculate total daily distance moved for each male each day. We used the response variable of total daily movement distance by an individual turkey on day *t* and used linear and local polynomial regression to evaluate the total daily movement distance relative to measurements of hunting intensity (total hours hunted day^{-1} and total hunter numbers day^{-1}). Other than three days in early March and three days in mid-May when feral pig hunting was allowed, hunting outside of turkey season did not occur on the Webb WMA Complex during our study. As such, for any day not within the turkey season (range 28 March to 5 May), there were no measurements of hunting intensity and as such those days have been excluded from our analysis so as not to artificially bias low (when zero) any impacts of hunting intensity on male wild turkey movements. We conducted local polynomial regression analysis using day of year by year to evaluate trends in male movements over the inference period and during the hunting season to provide a comparison of pre, during, and post-hunting movements. Day of year encompassed both periods before the hunting season (1 March, ~1 month prior) and after the hunting season (31 May, ~1 month post).

Results

We captured and GPS tagged 41 male wild turkeys (1 juvenile, 40 adults) on the Webb WMA Complex between 2014 and 2016. We monitored males a mean of 71 days (SD = 24, range 13–92). For range estimation, either 117 or 224 locations were collected each week dependent on the GPS data collection, resulting in approximately 2,026 locations individual^{-1} across the 71 days. Complete data were not available for 19 (46%) individuals for the entire 1 March–31 May time period due to predation, legal harvest, or transmitter loss.

Mean (SD) period utilization distribution sizes (ha) for males were 54.3 (31.4), 157.9 (93.26), and 702.9 (490.5) respectively, for 50, 75, and 99 percentile utilization estimates for the period 1 March–31 May. We observed considerable variation in space use across years and individuals (Table 1). Average weekly utilization distribution sizes (ha) were 15.6 (10.6), 47.0 (29.4), and 219.3 (151.7) for 50, 75, and 99 percentile utilization estimates, respectively, but variation at the individual level was substantial (Table 2). We found a positive trend in weekly range size in 2014 and 2015, but a negative trend in 2016. We best fit these trends as linear and observed no relationship relative to hunting season timing across different utilization distribution levels (Figures 1–3).

Mean daily distance travelled was 3,254 m (SD = 1,478) but was extremely variable across individuals (Table 3). Graphical interpretation of our results indicated that movements tended to increase as hunting seasons began, but declined towards the end of hunting seasons and after these seasons ceased (Figure 4). However model fits were poor for 2014 (3.38% deviance explained), 2015 (7.3% deviance explained) and 2016 (0.01% deviance explained), indicating that even with a flexible non-linear approach, our attempts at modeling variation in daily distances moved across individual males was unsuccessful. Aggregating all three years of movement data, regression modeling indicated a negative relationship between daily movements and both total hunters numbers on the Webb Complex on that day ($\beta = -6.668$, SE = 2.269, $P = 0.003$, $R^2 = 0.01$) and total hunter hours spent on the Webb Complex that day ($\beta = -1.17151$, SE = 0.6141, $P = 0.005$, $R^2 = 0.01$) (Figure 5). Predicted reductions in total daily distance moved was 293 and 242 m for total hunter numbers and total hunter hours, respectively. Relative to the overall

Table 1. Mean estimates of male eastern wild turkey ($n = 41$) season range sizes (ha; 1 March–31 May) by utilization distribution on the Webb WMA Complex, South Carolina, 2014–16.

Year	Utilization Distribution (%)	Minimum	Mean (SD)	Maximum
2014	50	12.77	59.0 (20.7)	91.25
	75	41.0	167.1 (55.4)	237.27
	99	244.51	680 (265.6)	1212.09
2015	50	17.08	63.0 (40.1)	176.00
	75	45.19	180.5 (120.9)	556.64
	99	170.66	750.1 (515.8)	2403.93
2016	50	11.45	35.7 (20.8)	78.77
	75	39.17	113.4 (75.9)	320.48
	99	203.66	663.7 (682.3)	2690.20

Table 2. Summary metrics (ha (SD)) of estimated weekly utilization distributions (UD) for male eastern wild turkey (1 March–31 May) on the Webb WMA Complex, South Carolina, 2014–16.

Year	Bird ID	50% UD	75% UD	99% UD
2014	01	17.2 (4.5)	51.5 (11.2)	217.5 (53.0)
	02	20.7 (11.9)	55.7 (26.4)	235.7 (74.6)
	03	19.7 (6.2)	61.4 (13.8)	269.6 (55.1)
	04	15.5 (5.8)	44.0 (17.0)	172.6 (69.1)
	06	17.7 (13.3)	50.6 (30.6)	215.9 (96.7)
	10	15.8 (3.7)	55.4 (18.0)	227.3 (75.1)
	11	19.1 (6.3)	51.3 (18.2)	202.4 (69.4)
	14	17.8 (5.7)	50.7 (14.4)	188.0 (53.0)
	19	19.8 (8.7)	60.0 (25.7)	259.2 (119.6)
	20	10.8 (6.3)	37.3 (20.9)	205.9 (120.0)
	23	18.4 (7.4)	58.9 (29.3)	241.3 (135.5)
	24	15.0 (5.1)	43.0 (16.4)	190.2 (141.5)
	25	4.7 (3.1)	13.8 (10.7)	78.2 (94.4)
	26	17.0 (6.7)	56.8 (22.2)	322.9 (204.1)
2015	02	12.7 (5.9)	35.9 (15.0)	162.6 (74.3)
	11	12.9 (5.1)	35.3 (12.7)	154.5 (58.7)
	30	20.6 (9.9)	63.6 (35.0)	376.8 (238.5)
	31	8.5 (1.1)	26.9 (5.6)	147.7 (70.5)
	32	9.8 (4.4)	31.7 (12.5)	159.2 (108.4)
	36	10.0 (3.1)	27.4 (5.3)	110.5 (2.2)
	37	10.4 (2.6)	31.9 (7.2)	157.7 (36.4)
	39	16.2 (10.6)	50.8 (29.9)	221.6 (103.8)
	45	6.9 (4.4)	20.0 (12.0)	80.5 (50.9)
	50	39.2 (19.0)	116.3 (44.5)	539.0 (211.5)
	56	7.8 (5.0)	23.0 (14.8)	112.9 (81.8)
	57	21.7 (8.2)	64.2 (21.2)	280.2 (87.6)
	58	26.7 (12.0)	71.1 (31.8)	271.0 (116.9)
	59	13.3 (7.3)	44.3 (18.2)	233.1 (62.0)
	60	18.2 (8.1)	60.9 (19.2)	316.2 (138.1)
	62	32.0 (16.3)	85.3 (40.4)	351.9 (180.8)
2016	02	7.5 (2.7)	22.7 (7.4)	112.2 (38.3)
	65	11.6 (6.6)	40.8 (18.0)	236.6 (69.3)
	71	14.1 (7.1)	38.7 (18.3)	156.5 (58.0)
	72	6.0 (2.6)	21.3 (9.8)	112.2 (57.7)
	73	5.5 (4.9)	18.9 (16.3)	89.1 (69.6)
	76	5.2 (3.5)	21.0 (17.2)	148.1 (163.5)
	77	14.5 (8.3)	58.2 (36.1)	455.3 (292.5)
	78	17.1 (6.8)	51.2 (20.1)	201.8 (73.8)
	80	16.3 (5.9)	48.7 (14.3)	240.1 (92.7)
	81	11.1 (5.3)	33.4 (17.4)	151.5 (93.0)
	82	17.3 (6.0)	49.8 (15.7)	212.9 (72.6)

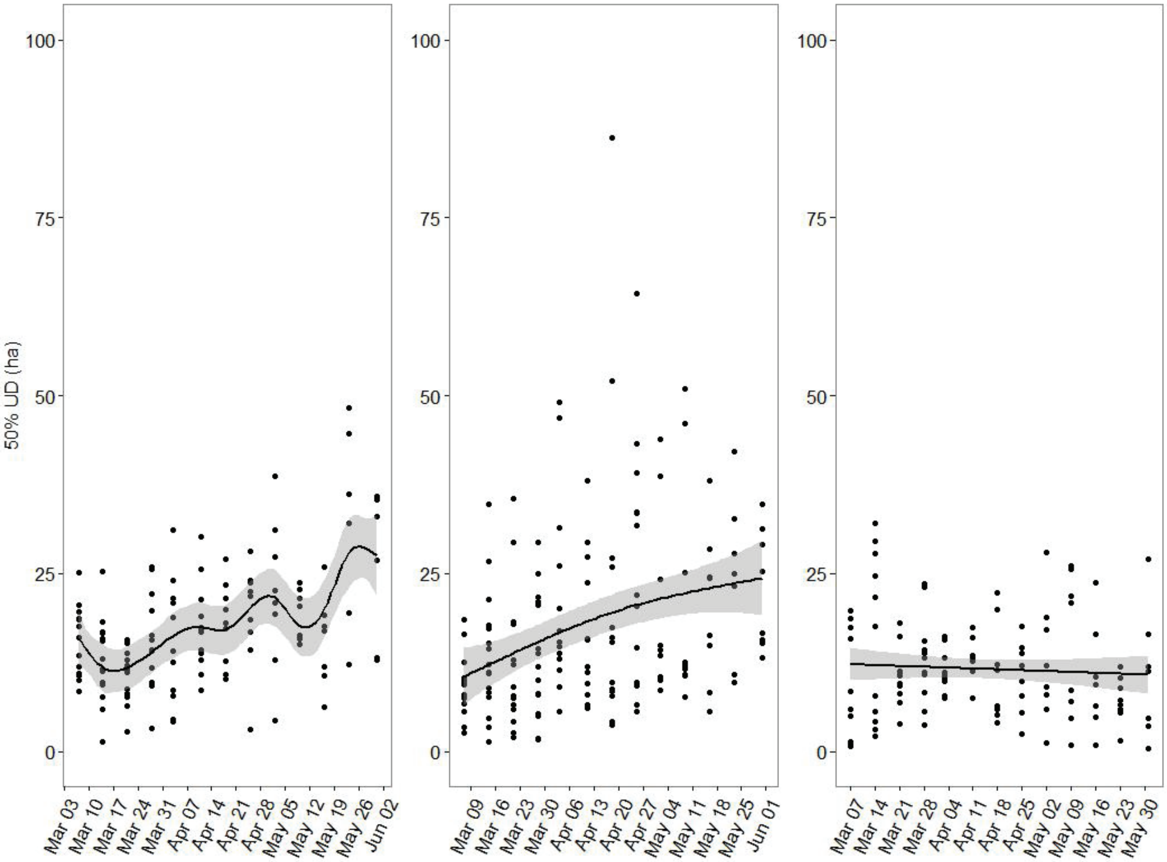

Figure 1. Generalized additive regression predictions (95% CI in gray) for estimated weekly 50% utilization distribution size (ha) for male wild turkeys tracked over the period of our study by year (2014–16) on the Webb WMA Complex in South Carolina.

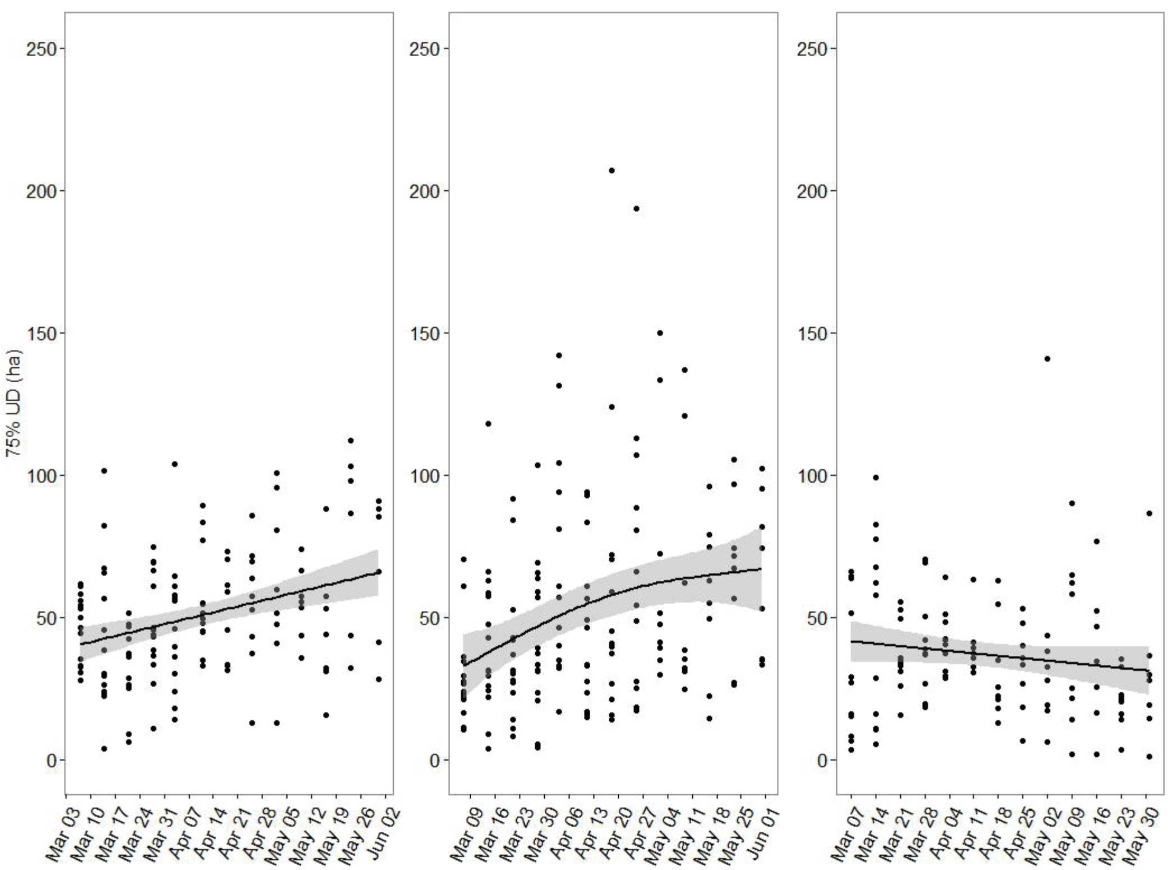

Figure 2. Generalized additive regression predictions (95% CI in gray) for estimated weekly 75% utilization distribution size (ha) for male wild turkeys tracked over the period of our study by year (2014–16) on the Webb WMA Complex in South Carolina.

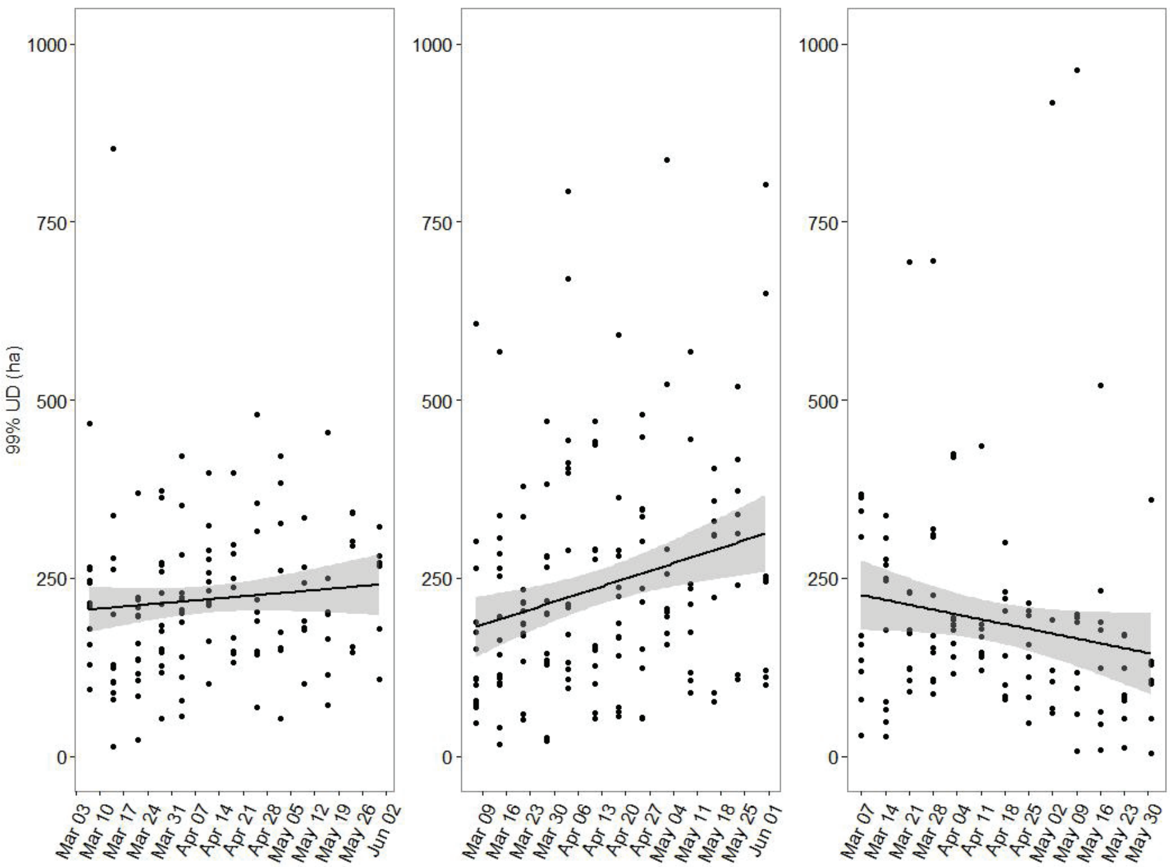

Figure 3. Generalized additive regression predictions (95% CI in gray) for estimated weekly 99% utilization distribution size (ha) for male wild turkeys tracked over the period of our study by year (2014–16) on the Webb WMA Complex in South Carolina.

Figure 4. Generalized additive regression predictions (95% CI in gray) for total daily movement distances for male wild turkeys ($n = 41$) tracked over the period of our study by year (2014–16) on the Webb WMA Complex in South Carolina.

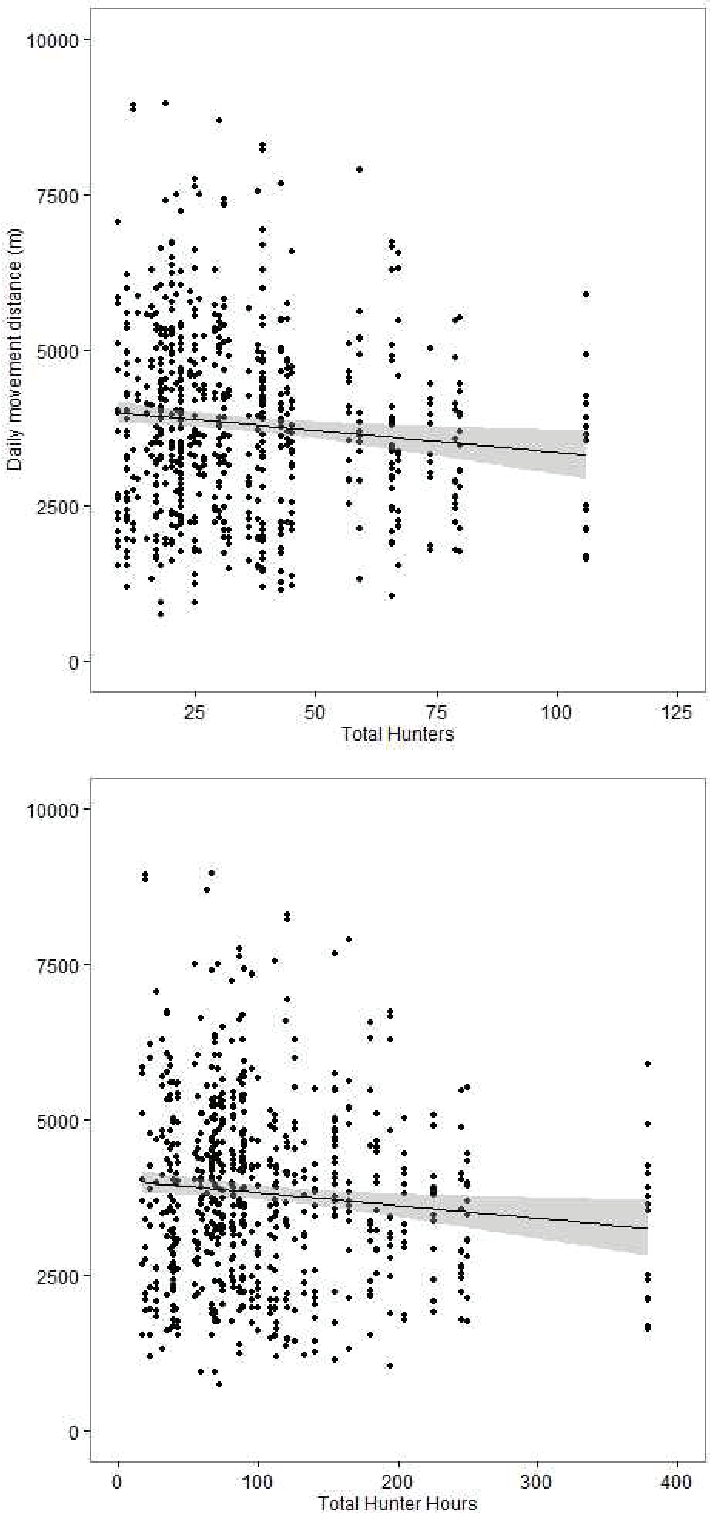

Figure 5. Linear regression fit (95% CI in gray) showing response in total daily movement distances relative to hunter density based on male wild turkeys ($n = 41$) tracked over the period of our study on the Webb WMA Complex in South Carolina.

mean daily movement distance, these changes in predicted movements represent an 8%–9% decline in the total distance moved while hunters are present. Considering that average daily movements had a standard deviation of almost 1,500 m, changes in movements of <300 m are probably not biologically relevant. Our results indicated that total daily movements tended to increase over time in 2014 ($\beta = 0.0002$, SE < 0.001, $P = 0.002$) and 2015 ($\beta = 0.003$, SE < 0.001,

Table 3. Summary of daily distances moved (m) by individual male eastern wild turkey daily (1 March–31 May) on the Webb WMA Complex, South Carolina, 2014–16.

Year	Bird ID	Minimum	Mean (SD)	Maximum
2014	01	807	3347 (1077)	5765
	02	1204	3823 (1377)	8933
	03	745	3598 (1151)	5984
	04	449	3192 (1142)	5694
	06	1356	3474 (1338)	8856
	10	1018	3091 (1393)	7907
	11	1075	3439 (1023)	5775
	14	1410	3400 (1057)	5825
	19	1107	3567 (1382)	7666
	20	310	2832 (1384)	6767
	23	1056	3346 (1431)	6337
	24	466	3309 (1284)	5514
	25	286	1561 (786)	3906
	26	511	3501 (1675)	9581
2015	02	1315	3490 (1212)	6676
	11	285	2729 (993)	5296
	30	851	4078 (1689)	10007
	31	1387	2726 (915)	5202
	32	1492	2969 (940)	5079
	36	444	1865 (723)	3224
	37	733	2657 (1099)	5902
	39	1300	3646 (1350)	7411
	45	494	2037 (923)	5310
	50	122	3544 (1437)	8971
	56	269	2178 (1091)	6713
	57	245	4200 (1610)	8281
	58	826	3173 (1131)	6699
	59	546	3580 (1323)	6566
	60	826	4147 (1635)	8222
	62	556	3311 (1437)	6934
2016	02	164	2567 (923)	5071
	65	155	2873 (1323)	5179
	71	137	3376 (1106)	6521
	72	304	2031 (866)	4432
	73	303	2102 (1480)	6662
	76	298	2185 (1216)	5711
	77	970	4560 (2541)	14599
	78	1408	4148 (1064)	6504
	80	824	3843 (1424)	7197
	81	395	3344 (1632)	8517
	82	1381	3994 (1182)	8306

Figure 6. Generalized additive regression predictions (95% CI in gray) showing response in total daily movement distances based on male wild turkeys ($n = 41$) relative to the primary nest initiation period tracked over the period of our study on the Webb WMA Complex in South Carolina.

$P = 0.001$), but not 2016 ($\beta = -0.0004$, SE < 0.001, $P < 0.001$) when movements significantly declined during the breeding season (Figure 6). However, although statistically significant, the beta parameter estimates for day were so small that no measurable relationship between day or season and movements was identifiable, thus indicating a small overall impact of hunting season period on turkey movements.

Discussion

Our results indicated that daily distances moved (3,254 m day^{-1}) were generally consistent with average combined morning and afternoon movement distance of 3,639 m estimated by Godwin et al. (1994) but were larger than those of Martin (1984), Smith et al. (1989) and Holdstock et al. (2006). Variation in estimates of daily movements is likely due to different tracking methods used across studies. Godwin et al. (1994) used repeated VHF triangulation on randomly selected individuals for each day, whereas Holdstock et al. (2006) inferred daily movements based on distance between roost locations and found a significantly lower average than our work. However, we noted considerable variation around our mean estimate (SD = 1,478) and movements ranged from 137 to 14,599 m on any given day, greater than other estimates of daily movement variation (Godwin et al. 1994, Holdstock et al. 2006). Inter-individual variation had notable influences on our results as the data showed very little structure and non-linear regression analysis provided very poor fits to the movement data. In other words, individual males were highly variable in distances moved on a daily basis and there was no consistency in distances moved by an individual from one day to the next. Thus, we concur with suggestions by Oetgen et al. (2015), who noted that as researchers continue to collect data with a higher spatial and temporal resolution, evaluating or predicting what is or is not used based on mean estimates may be sub-optimal when considerable variation between individuals exists.

We found mixed results on how male wild turkeys were potentially impacted by hunting activities. First, movement distances increased (2014 and 2015) and decreased (2016) relative to the general timing of hunting season. Although statistically significant, the overall impact of day of season was minimal with β estimates <0.005 in all cases, meaning a 1 unit increase in date changed the distance moved only slightly in either direction. Thus, the primary driver of movement variation across all birds from our study was unrelated to hunting season timing. This was further supported when we regressed movements relative to intensity of hunting activities. Although we did find a statistically significant, negative influence of total hunters and total hunter hours on turkey movements, the biological relevance of our regression modeling results was questionable in that at the 75th percentile for both total hunters and total hunter hours, the magnitude of the hunter effect was minimal (8%–9%; <300 m). Furthermore, our results were in contrast to the only other work detailing influences of hunting activities on male movements (Gross et al. 2015) which found a net positive impact of hunting on movements of approximately 8%. We found similar trends in utilization distribution size (50%, 75%, and 99%) in that during 2014 and 2015, space use generally increased during times when hunting occurred, but we observed a negative relationship between hunting activity and space use in 2016. As such, we concur with Gross et al. (2015) and previous work by Everett et al. (1978) and Williams et al. (1978) that male movements are not directly influenced by hunting pressure. Additionally, we found only a few instances (<3%) where birds moved off the wildlife management area during hunting season, in contrast to 34% of males tracked at Tallahala Wildlife Management Area (Mississippi), where long-distance movements were suggested as a behavioral response to hunting pressure (Godwin et al. 1990).

Male wild turkeys have long been thought to move more during spring than during other periods of the annual cycle, which is thought to be driven by reproductive activities (Hurst et al. 1991). During the primary reproductive period on our study site (approximately 1 April–18 May for first nest initiations), daily distance moved by male wild turkeys increased in 2014 and 2015, yet decreased during 2016. This between-year inconsistency suggests that the primary driver of male wild turkey movements during our study was neither hunting season timing/intensity nor reproductive period timing.

The underlying need to understand why male wild turkeys move is to identify management activities with the greatest potential benefit (Godwin et al. 1994) and to keep the hunting public informed (Gross et al. 2015). However, based on our work, there is considerable variation over time and at the individual level in the movement ecology of male wild turkeys during spring. Our results concur with Oetgen et al. (2015) in that no turkeys are exactly the same, and aggregation of information across multiple individuals is sub-optimal from a management perspective. Additionally, the drivers of wild turkey movement are likely multi-faceted and site/individual specific (e.g., local environmental conditions at time t, flock density and composition, and reproductive status, etc.). Thus, management strategies based on generalized movement or range estimates may be inappropriate (Oetgen et al. 2015).

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