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Evaluation of Space Use and Movement by Wild Turkey (Meleagris gallopavo) During Extreme Climatic Disturbances and Annual Phenological States

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EVALUATION OF SPACE USE AND MOVEMENT BY WILD TURKEY (*MELEAGRIS GALLOPAVO*) DURING EXTREME CLIMATIC DISTURBANCES AND ANNUAL PHENOLOGICAL STATES

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To my loving family who has supported me through every endeavor and to all those who have influenced my life–you continue to do so in so many ways. Thank you for giving me the courage to pursue my passion.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Space use is driven by both intrinsic and extrinsic factors across space and time. Meaning a species demography and habitat requirements may vary across landscapes. Recent studies on wild turkeys (*Meleagris gallopavo* spp., hereafter turkey) have shown both direct and indirect demographic impacts of climatically driven events on turkey populations. Similarly, there is an abundance of information documenting turkey demographic parameters and space use, but few studies have addressed breeding phenology in great detail. We evaluated the impact on space use and movement patterns of Eastern wild turkeys (*M. g. silvestris; n* = 20) and Rio Grande wild turkeys (*M. g. intermedia; n* = 22) during two hurricane events in South Carolina and Texas, respectively. We had one direct mortality in South Carolina and 2 direct mortalities during Hurricanes Matthew and Harvey, respectively. Mean core area used by turkeys decreased by 75% during both hurricane events. We did not find evidence of changes in roost fidelity or distance between daily roost clusters after either hurricane.

We assessed the variation of space use and movement for phenological-based reproductive states of Rio Grande wild turkeys (*n* = 256 females, 39 males) in Texas from 2009−2018. Estimated space use during the wintering period decreased, suggesting the use of a smaller core area may contain reliable food resources. Most interestingly, females in each pre-laying state used larger areas than all other phenological states. Such large movements were suggestive of exploratory movements related to breeding activities throughout the pre-laying state. Incubation ranges declined rapidly for each subsequent nesting attempt, with movements during incubation being primarily recess activities. We concluded that habitat structure and quality across sites is highly variable. This suggest that in some fragmented areas individuals may be restricted to core areas, while in other areas of low quality, individuals may make larger

movements to meet daily requirements. We recommend wildlife managers evaluate habitat damage after a disturbance to address any legacy effects on turkey populations. Similarly, integrating the timing of turkey life history events into our understanding of the scale at which turkeys select habitats will aid in directing habitat improvement projects.

CHAPTER 1. INTRODUCTION

Once widely distributed, the wild turkey (*Meleagris gallopavo* spp.; hereafter turkey) was nearly extirpated by the mid-1900s from the United States due to unregulated harvesting and lack of effective habitat management practices (Kennamer et al. 1992). Turkey populations were brought back to sustainable numbers after extensive restoration effort by state, federal, and non-profit organizations making it one of the most successful conservation stories in North America (Kennamer et al. 1992). Populations in the southeastern United States increased from nearly half a million birds to over 2 million turkeys from 1970 to 1999 (Dickson 2001), but overall, some turkey populations are in decline due to decreased productivity (Byrne et al. 2015, Eriksen et al. 2015). As such, wildlife researchers and land managers alike agree there is an immediate need to identify potential drivers of population declines in order to maintain sustainable populations.

Space use and movement during various life history events (e.g. breeding) is a significant factor influencing population-level demography (Manly et al. 2002), but is a complex process driven by both environmental factors (e.g. climate, seasonality; Healy and Dickson 1992, Miller et al. 2007) and individual phenological states (e.g. foraging, breeding, Poulin et al. 1992). Thus, understanding how individuals within a population use their habitat across space and time can assist in identifying and implementing effective wildlife management practices (Nichols and Pollock 1990, Phillips 2004).

The spatial accuracy provided by GPS transmitters to calculate space use and movement patterns has provided a substantial improvement over the historical use of VHF telemetry (Guthrie et al. 2011, Byrne et al. 2014*a*). VHF telemetry often exhibits high variance due to errors in triangulation, and tracking frequency (Guthrie et al.2011). With the incorporation of improved accuracy from the use of GPS technology, a reinvigoration of turkey research has given us new insights into turkey space use and movement (Collier and Chamberlain et al. 2011, Conley et al 2016, Bakner et al 2019, White et al. 2019).

Because previous estimates of space use derived from studies using VHF telemetry are limited in spatial and temporal scale, biologically relevant inferences of space use estimates were likely broad. Thus, few researchers have collected spatio-temporal data to address space use during disturbances (e.g. floods, drought) or for a suite of phenological-based states across an individual's annual cycle (e.g. breeding, foraging). Disturbance events can have short-term acute impacts and leave lasting long-term legacy effects on turkey demographics. Similarly, space use may vary between phenological states based on the immediate environmental factors and reproductive status. Spatial scale of inference is dependent on the choice of time scales at which data are both collected and interpreted (Cohen et al. 2018). A better understanding of both processes provides insight into population processes that ultimately influence wild turkey demographics.

Using data collected during on-going research projects in South Carolina and Texas, we described direct mortality of wild turkeys from two hurricane events of different intensity and we compared movement patterns, home range sizes, and roost site fidelity before, during, and after the hurricanes (Chapter 2). We also created utilization distributions for each phenologically-based state, and we compared variations in core area, range size, and daily distances moved across geographically distinct locations using GPS data (Chapter 3). Our data provided a unique opportunity to assess the spatial ecology of turkeys across a fine temporal and broad spatial scales, which is not currently available in the peer-reviewed literature. Chapter 4 provides a summary of our conclusions, along with management implications and suggestions for future research.

CHAPTER 2. HURRICANE IMPACTS TO WILD TURKEY SURVIVAL, DAILY MOVEMENTS, AND ROOST FIDELITY.

2.1. Introduction

Extreme disturbances, including wildfires, snowstorms, flooding, and drought can have direct and indirect consequences to wildlife populations. Demographic consequences of disturbance are manifested via both short-term and long-term effects (Battisti et al. 2016). For example, direct mortality due to wildfire has acute impacts, whereas the alterations to community structure, composition, and availability of vegetation of the disturbed landscape can have a prolonged impact (Soulé 1991, Battisti et al. 2016). The relative impact of disturbance, both short term and long-term, may hinge on an individual's fitness, size, and age (Coulson et al. 2001). Dependent on the timing, frequency, severity, and type of disturbance, immediate behavioral affects or a legacy effects may become evident. For example, waterfowl are reported to shift their distribution after anthropogenic hunting pressure (Madsen 2004). Whereas, fire, both natural and prescribed, can improve habitat (Whelan 1995, Moreira et al. 2003) while promoting the production and access of food resources at the community level (Buckner and Landers 1979, Chitwood et al. 2017). Thus, organisms can have population growth post-disturbances such as that found for macroarthropods post forest fire (Chitwood et al. 2017) or the Puerto Rican frog (*Eleutherodactylus coqui*, Woolbright 1996) and Key deer (*Odocoileus virginianus clavium*, Lopez et al. 2003) after a hurricane event. Alternatively, disturbance may negatively impact wildlife, such as storm surge events reducing fresh water availability (Lopez et al. 2003) or flooding events decreasing offshore salinity levels (Pollack et al. 2011).

Hurricanes are a regular occurrence across the Caribbean and southeastern United States. Acute effects on a wildlife population resulting from hurricanes (high wind, heavy rains) can be an increase in mortality or a shift in spatial distribution due to the impact of the event on the landscape (e.g. flooding). White-tailed deer (*Odocoileus virginianus*) regularly move to upland areas during high storm surges (Samuel and Glazener 1970), but are known to return to pre-hurricane ranges in the following years (Labisky et al. 1999). Chronic effects of hurricanes may change future reproductive success driven by habitat reductions (Gannon and Willig 1994). Alternatively, modification of forest conditions from wind damage after Hurricane Lothar increased forest heterogeneity and roe deer (*Capreolus capreolus*) responded via home ranges decreasing in response (Saïd and Servanty 2005). Increased duration and intensity of hurricanes are expected as a result of climate change (Schiermeier 2005, Kunkel et al. 2017, Wuebbles et al. 2017, Carter et al. 2018). Thus, given that wildlife response to hurricanes is dependent upon individual species and site location, documentation of the impacted population's responses to hurricanes is rare, but of interest as extreme weather events can underlie future projections of range requirements and species demography.

Wild turkeys (*Meleagris gallopavo* spp., hereafter turkey) are a widely distributed ground nesting galliform species in North America. Turkey population trajectory is driven via recruitment (Healy 1992) which in turn is partially dependent upon adult over-winter survival, which is driven by winter severity, local site characteristics, and individual fitness (Wunz and Hayden 1975, Porter et al. 1983, Vander Haegen et al. 1988). Beginning in the fall and lasting through the winter months (September-March), turkeys aggregate into large groups, wherein daily movements comprised primarily of foraging activities and rest periods, returning nightly to nearby roost sites, representative of decreased daily movements and reduced area of use (Crockett 1973, Caveny et al 2011). Roost habitat is an important aspect of turkey ecology during this period as it provides refuge from ground predators and protection from poor weather (Vander Haegen et al. 1989, Byrne et al. 2015, Sasmal et al. 2018).

Recent work on the impact of environmental disturbance to turkeys in the southeast have shown both direct and indirect demographic impacts of climatically driven events (Chamberlain et al. 2013, Oetgen et al. 2015). While environmentally driven winter mortality of turkeys in northern environments are a result of chronic food shortages (e.g., starvation, Healy and Dickson 1992), hurricanes events in southern regions are short duration, high impact periods (Hartman and Wunz 1974, Celey 1991) for which acute turkey mortality has historically been assumed negligible (Cely 1991). However, to date little research effort has focused on evaluating the impact of intense, but rare events on wild turkey demography. We, fortuitously, had ongoing wild turkey demography studies in South Carolina and Texas, which each was impacted by hurricanes of different intensity. Hurricane Matthew made landfall on the South Carolina coast as a Category I storm on 8 October 2016, with rain totals exceeding 254 mm and wind speeds exceeding 107 kph over the course of 3 days (Stewart 2017). In 2017, Hurricane Harvey made landfall at San José Island, Texas on 25 August as a Category IV storm, with maximum sustained winds reaching 238 kph and maximum rain totals $\geq$1.5 m (Blake and Zelinsky 2018). As such, our objectives are to describe direct mortality of wild turkeys from each hurricane event. We also sought to compare movement patterns, home range sizes, and roost site fidelity before, during, and after the hurricanes. Our research will contribute to our knowledge of turkey habitat use and behavior, particularly during extreme weather events, and set a protocol to help evaluate local turkey populations for immediate and lasting impacts.

2.2. Study Area

Our research in South Carolina was conducted on 3 wildlife management areas (Webb, Hamilton Ridge and Palachucola Wildlife Management Areas; hereafter Webb WMA Complex, Figure 2.1), managed by South Carolina Department of Natural Resources. Overall, the Webb WMA Complex encompassed 10,438 ha total with approximately 22 km bordering the Savannah River on the WMAs southern border. The Webb WMA Complex was managed intensively with hunting in mind, especially to increase habitat and opportunities for white-tailed deer, turkey, and northern bobwhite quail (*Colinus virginianus*) (Wightman et al. 2019). The largest of the 3 WMAs was Hamilton Ridge, which was 5,374 ha composed of approximately 2,664 ha of bottomland hardwood wetlands with typical southeastern river floodplains vegetation and 2,710 ha of upland industrial pine forest. Main harvest trees included loblolly pine (*Pinus taeda*), as well as slash pine (*P. elliottii*), and longleaf pine (*P. palustris*). The next largest WMA was Palachucola at 2,734 ha; it is roughly half (approximately 1,618 ha) planted loblolly pine under active harvest and conversion to longleaf pine and half (approximately 1,092 ha) bottomland hardwood swamp. The Webb WMA was 2,373 ha composed of approximately 1,458 ha of upland pine including longleaf, loblolly and slash pines and 917 ha of bottomland hardwoods.

Our research in Texas was conducted on a suite of private lands widely distributed across a 6-county study area within Texas Parks and Wildlife District 7 (hereafter Texas), within the Post Oak Savannah, Blackland Prairie, and South Texas Plains ecoregion (Figure 2.1) described by White et al. (2019). Property sizes averaged 350 ha and were used for a variety of purposes including livestock grazing, crop and hay production, oil and gas production, and wildlife-related recreation. The general vegetative communities consist of post oak (*Quercus stellata*), live oak (*Q. virginiana*), yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*),

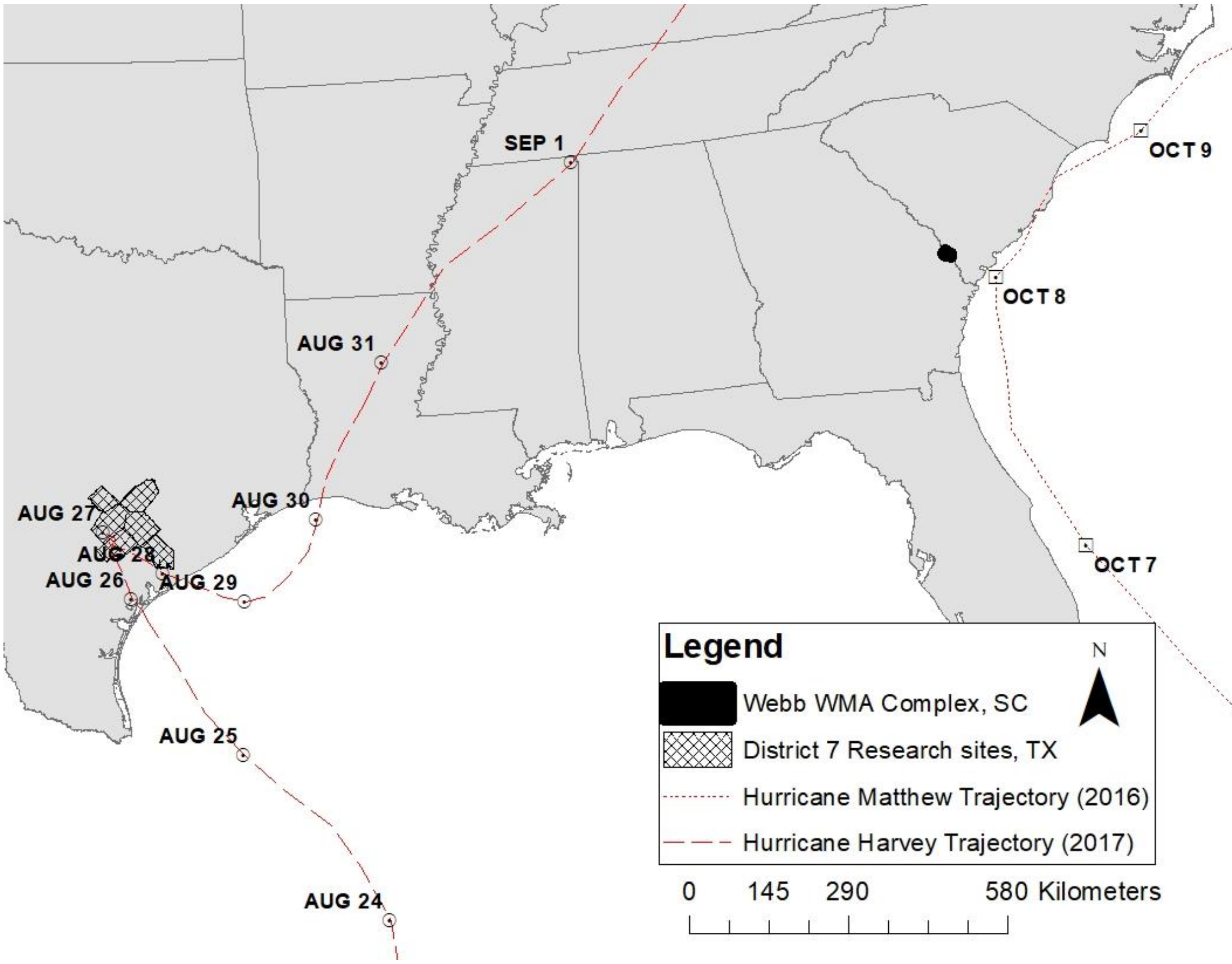

Figure 2.1. Location of wild turkey study sites, associated hurricane tracks and estimated hurricane location used to evaluate hurricane impacts during 2016–2017.

mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), longleaf woodoats (*Chasmanthium sessiliflorum*), Texas wintergrass (*Nassella leucotricha*), and silver bluestem (*Bothriochloa saccharoides*). Bermudagrass (*Cynodon dactylon*), rescuegrass (*Bromus catharticus*), and King Ranch bluestem (*B. ischaemum var. songarica*) were abundant across all sites forming large pasture monocultures. The southern portion of the regions were predominantly characterized by mesquite, Texas persimmon (*Diospyros texana*), agarita (*Mahonia trifoliolata*), lotebush (*Ziziphus obtusifolia*), pricklypear (*Opuntia engelmannii*) and tasajillo (*O. leptocaulis*). Roosting locations occurred primarily in riparian corridors and consisted of species such as pecan (*Carya illinoinensis*), elm (*Ulmus* spp.), and live oak (Byrne et al. 2015).

2.3. Methods

We captured male and female wild turkeys using rocket nets and drop nets baited with cracked corn or milo from January–March in 2016 and 2017. We fitted each individual with a uniquely identifiable aluminum rivet band (National Band and Tag Company, Newport, Kentucky) and radio-tagged each individual with a backpack-style GPS-VHF combination backpack (Biotrack Limited, Wareham, Dorset, UK, Guthrie et al. 2011). Each GPS tag was scheduled to record at least one location per hour, from 05:00 to 20:00 daily, and one roost location at night (23:59:58) until the battery died or the unit was recovered (Cohen et al. 2018). All turkeys were released at the capture location immediately following processing. We monitored live-dead status ≥2 times per week from capture to August (monthly from August–December) using a Biotracker receiver (Biotrack Ltd., Wareham, Dorset, UK) and handheld Yagi antenna. We downloaded GPS information ≥2 times per month via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). We derived date of mortality from VHF tracking and spatio-temporal GPS locational data (Guthrie et al. 2011, Conley et al. 2015, Yeldell et al. 2017). Our capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permit A2015-07).

We predicted that turkey movements would be greatly reduced, as individuals would remain within or very near roosts sites for the duration of the storm. Therefore, we compared daily core area (50% utilization distribution, hereafter UD) and range size (99% UD), for 14 days before and after the hurricane and for the days during the duration of the hurricane. We also compared the core area and range size for the entire period as a whole, for the 14 days before and after the hurricane, and for the period during the hurricane (hereafter before period, during period and after period). Our evaluation included the daily distance traveled for both the daily area used and period area used. We also predicted that the resulting floods from the storm might force turkeys from roosting areas selected before the hurricane into new areas (Cobb et al 1993, Chamberlain et al. 2013). Therefore, we identified pre-hurricane roosting areas that were selected for before the storm to compare to the roosting locations after the storm and evaluated each individual for any changes in use.

To identify the exact dates and duration of each hurricane we reviewed the available climate data. Rain and wind recordings were inconsistent, especially during the hurricane event, whereas barometric pressure was consistent and provided a good indication of hurricane duration at our study sites. When a hurricane began to move into the area of our study site the barometric pressure decreased immediately, similarly, as hurricanes moved away barometric pressure increased. This trend in the barometric pressure data enabled us to estimate accurate periods for before, during and after the hurricane event. Thus, for spatial analysis, we used 31 total days of GPS data for Hurricane Matthew and 33 total days of GPS data for Hurricane Harvey. We used dynamic Brownian Bridge Movement Models (hereafter, dBBMM) to estimate range sizes in program R (R Core Team 2019) and the R package move (Kranstauber et al. 2019), to derive 50% and 99% UDs (Cohen et al. 2018). For daily estimates of core area and range size we used a margin size of 5, a window size of 17, and a location error of 15 based on Guthrie et al. (2011) and Collier et al. (2019). However, we conditioned our estimates using a fixed variance for each time step ensuring adequate estimation of daily core area and ranges (Cohen et al. 2018). We estimated mean daily distance traveled and distances between consecutive roost sites (Byrne et al. 2015, Gross et al. 2015*b*) using R package geosphere (Hijmans 2019). Following Byrne et al.

(2015), we calculated a roost index (hereafter RI) to quantify a change in roost site fidelity and reuse before and after the storm. Our roost index was calculated as the number of individual roost sites used divided by the number of nights monitored (Byrne et al. 2015), which we used R package cluster (Maechler et al. 2019) to differentiate clusters of roosting locations and considered >50 m between clusters as a change in roost location (Byrne et al. 2015). We tested for differences between mean core and range areas, mean daily distance traveled, average RI and mean distance between daily roost clusters, using paired *t*–test's with a α-level of ≤ 0.05 in program R (R Core Team 2019).

2.4. Results

We monitored 21 (3 M, 18 F) Eastern wild turkeys (*M. g. silvestris*) during Matthew and 24 (1 M, 23 F) Rio Grande wild turkeys (*M. g. intermedia*) during Harvey. We observed 2 direct mortalities of females (8%) during Harvey and 1 (5%) during Matthew which we censored from subsequent spatial analysis. We collected 7,398 spatial locations during Matthews and 9,979 spatial locations during Harvey, which included nightly roost locations for all monitored birds during Matthew (n = 585) and Harvey (n = 715).

On the day of peak meteorological intensity for Matthew, mean daily core area was 2.89 ha (SD = 1.7 ha, Range = 1.8–11.6 ha) which was approximately 62% smaller compared to the previous day's daily core area used (Figure 2.2, Table 2.2). Periods mean core area and range size showed a significant decrease (75%) during Matthew with core area used declining from 14.3 to 3.6 ha (SD = 2.38, range 2.8–43.9 ha; t_{19} = 5.11, $P \leq 0.001$; Table 2.1) and range area used declined 74% from 263.1 to 68.1 ha (SD = 40.6, range = 20.1–792.1 ha; t_{19} = 5.90, $P \leq$ 0.001; respectively, Table 2.1). Mean core area increased 274% after Hurricane Matthew from 3.6 to 13.5 ha (SD = 7.8, range = 0.7–30.2 ha; t_{19} = -6.49, $P \leq 0.001$; Table 2.1), and mean range size increased by 231% from 68.1 to 225.4 ha (SD = 98.4, range = 20.0–397.4 ha; $t_{19} = -7.26$, $P \leq 0.001$; Table 2.1). After Matthew, period core area and range size were lower (6% and 14% respectively) than before the hurricane (Table 2.1), but were not significantly different (t_{19} = 0.36, $P = 0.726$; $t_{19} = 0.99$, $P = 0.336$, respectively).

We found similar results during Harvey, where mean daily core area was lowest (0.61 ha, SD = 0.61, range = 0.07–2.21) during the peak of Harvey, which was a 72% decline in mean core area use from the previous day, and coincided with the largest recorded drop in barometric pressure (Figure 2.3, Table 2.2). Period mean core area and range size significantly decreased during Harvey by 75% from 15.5 to 3.9 ha (SD = 1.9, range 0.8–28.9 ha; $t_{21} = 10.21$, $P \leq 0.001$; Table 2.1) and 47% from 169.7 to 90.3 ha (SD = 34.7, range = 35.2–346.3 ha; $t_{21} = 5.14$, $P \leq 0.001$; respectively, Table 2.1). After Harvey, period mean core area increased by 311% from 3.9 to 16.0 ha (SD = 8.0, range = 0.8–30.4 ha; $t_{21} = -6.58$, $P \leq 0.001$; Table 2.1), and mean range size increased by 77% from 90.3 to 160.1 ha (SD = 71.8, range = 35.2–280.6 ha; $t_{21} = -4.85$, $P \leq 0.001$; Table 2.1). After Harvey period core area increased 4% while period range size decreased 6% (Table 2.1), but neither differed from before Harvey (t_{21} =- 0.35, $P = 0.729$ and $t_{21} = 0.68$, $P = 0.504$, respectively).

When Matthew was at peak intensity near our research site, we estimated a 38% reduction in mean daily distance traveled (Table 2.3) which was significant less than the previous day ($t_{19} = 5.48$, $P \leq 0.001$). Similarly, when Harvey was at peak intensity over our research sites mean daily distance traveled significantly decrease by 49% from the previous day ($t_{21} = 5.21$, $P \leq 0.001$, Table 2.3). During both storms, daily distance that turkeys traveled was lowest when barometric pressure was lowest (Table 2.3, Figures 2.4 and 2.5). Monitoring of movements during Harvey's 5-day impact indicated that daily distance traveled decreased for the

Table 2.1. Mean daily distance (m), mean daily roost distance (m), mean 50% and 99% utilization distribution (UD) for both the grouped period area (ha) and mean daily area (ha) estimates, with associated standard deviation.

Location	Time	Daily Distance (SD)	Daily Roost Distance (SD)	Kernel	Period area[1] (SD)	Daily area[2] (SD)
South Carolina	Before	2,096 (452)	506 (328)	50%	14.32 (11.11)	4.64 (1.59)
	During	2,095 (499)	520 (311)		3.60 (2.38)	5.28 (2.52)
	After	2,025 (591)	626 (175)		13.49 (7.80)	5.36 (2.66)
	Before			99%	263.07 (149.81)	32.73 (12.35)
	During				68.05 (40.64)	38.42 (16.20)
	After				225.42 (98.44)	47.87 (26.60)
Texas	Before	2,206 (435)	311 (190)	50%	15.45 (5.97)	1.55 (0.63)
	During	1,860 (382)	340 (196)		3.89 (1.93)	3.47 (2.06)
	After	2,367 (529)	265 (141)		15.99 (8.95)	2.65 (0.94)
	Before			99%	169.67 (79.20)	15.80 (7.23)
	During				90.32 (34.70)	24.60 (12.67)
	After				160.13 (71.68)	22.93 (8.14)

[1]Period area are estimated UDs based on all locations collected across multiple days in that time-period (before, during and after).
[2]Daily areas are mean estimates from UD's that were calculated using locations from a single day for every day that time-period (before, during and after).

Table 2.2. Mean daily barometric pressure (in Hg), mean daily core area, and range (ha) estimates for Hurricane Matthew, South Carolina (2016) and Hurricane Harvey, Texas (2017).

Location	Kernel	Date	Pressure	Area (SD)
South Carolina	50	10/7/2016	29.66	7.51 (5.16)
		10/8/2016	29.48	2.89 (1.70)
		10/9/2016	30.00	5.32 (3.83)
	99	10/7/2016	29.66	57.84 (27.14)
		10/8/2016	29.48	22.54 (14.04)
		10/9/2016	30.00	35.29 (25.03)
Texas	50	8/25/2017	29.55	5.24 (2.62)
		8/26/2017	29.41	2.21 (1.74)
		8/27/2017	29.40	0.61 (0.61)
		8/28/2017	29.54	2.48 (2.08)
		8/29/2017	29.65	6.80 (9.11)
	99	8/25/2017	29.55	35.31 (17.80)
		8/26/2017	29.41	13.67 (8.87)
		8/27/2017	29.40	8.77 (17.19)
		8/28/2017	29.54	19.65 (14.46)
		8/29/2017	29.65	45.09 (50.26)

first 3 days while Harvey remained on our study sites, and as Harvey moved out of the area daily distance traveled increased the last two days (Table 2.3). Mean distance traveled during Matthew decreased 14% from 2,090 to 1,806m (SD = 454, range 1,047–2,854 m; t_{19} = 0.009, P = 0.993, Figure 2.5). After Matthew, the daily distance traveled increased 12% from 1,806 to 2,032 m (SD = 572, range 1167–3143m: t_{19} = 0.61, P = 0.550, Figure 2.5) returning to similar levels before Matthew (Table 2.1; t_{19} = 0.67, P = 0.511). For Harvey, mean distance traveled during the hurricane decreased 28% from 2,565 to 1,860 m (SD = 382, range 1,077–2,792 m; t_{21} =-3.07, P= 0.006), whereas mean daily distance traveled after Harvey increased 27% from 1,860 to 2,367 m

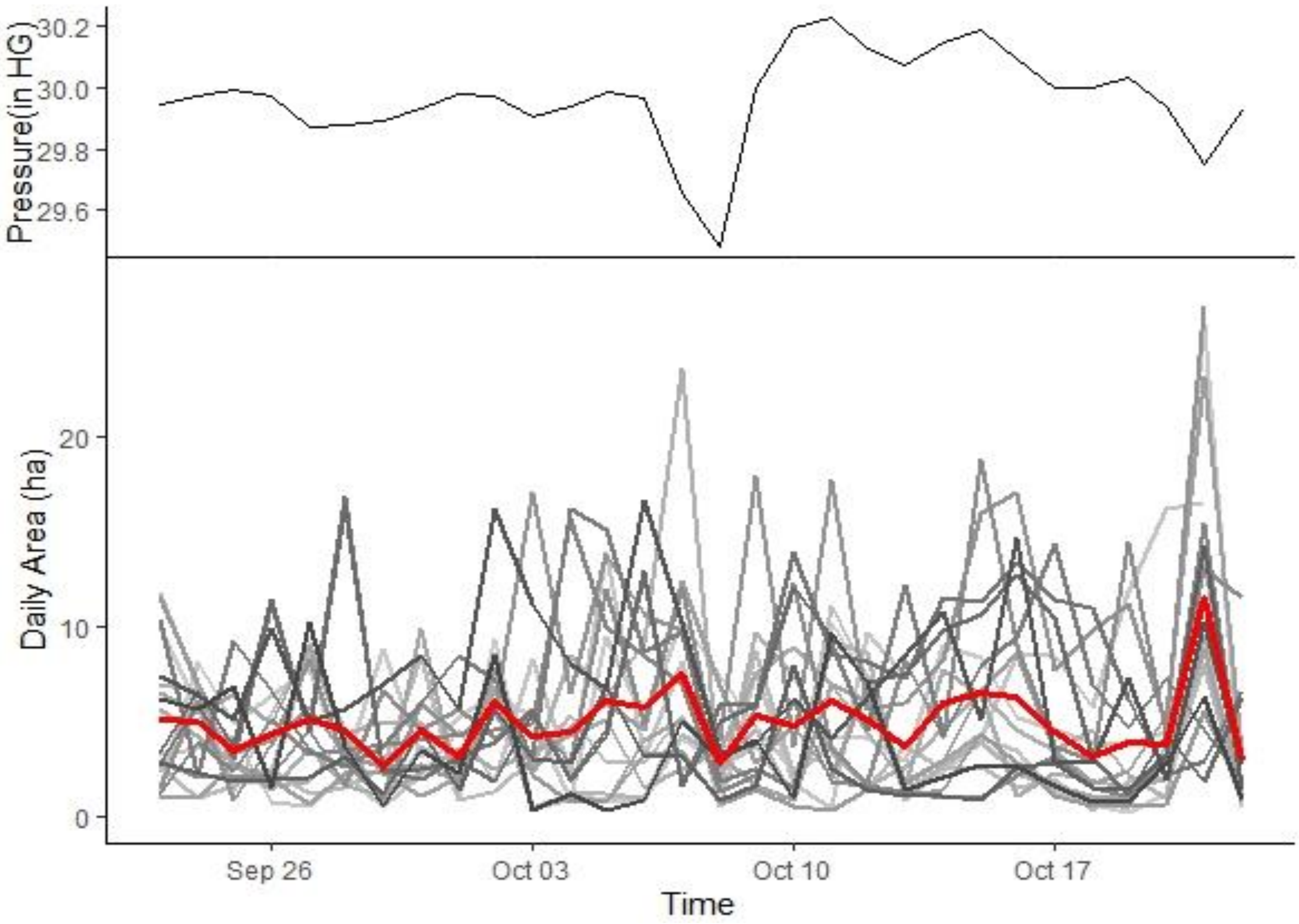

Figure 2.2. Daily core area (50% utilization distribution) estimates for GPS tagged Eastern wild turkeys (*Meleagris gallopavo silvestris*) relative to mean daily barometric pressure (inHg) for Hurricane Matthew in 2016 on the Webb WMA Complex, South Carolina.

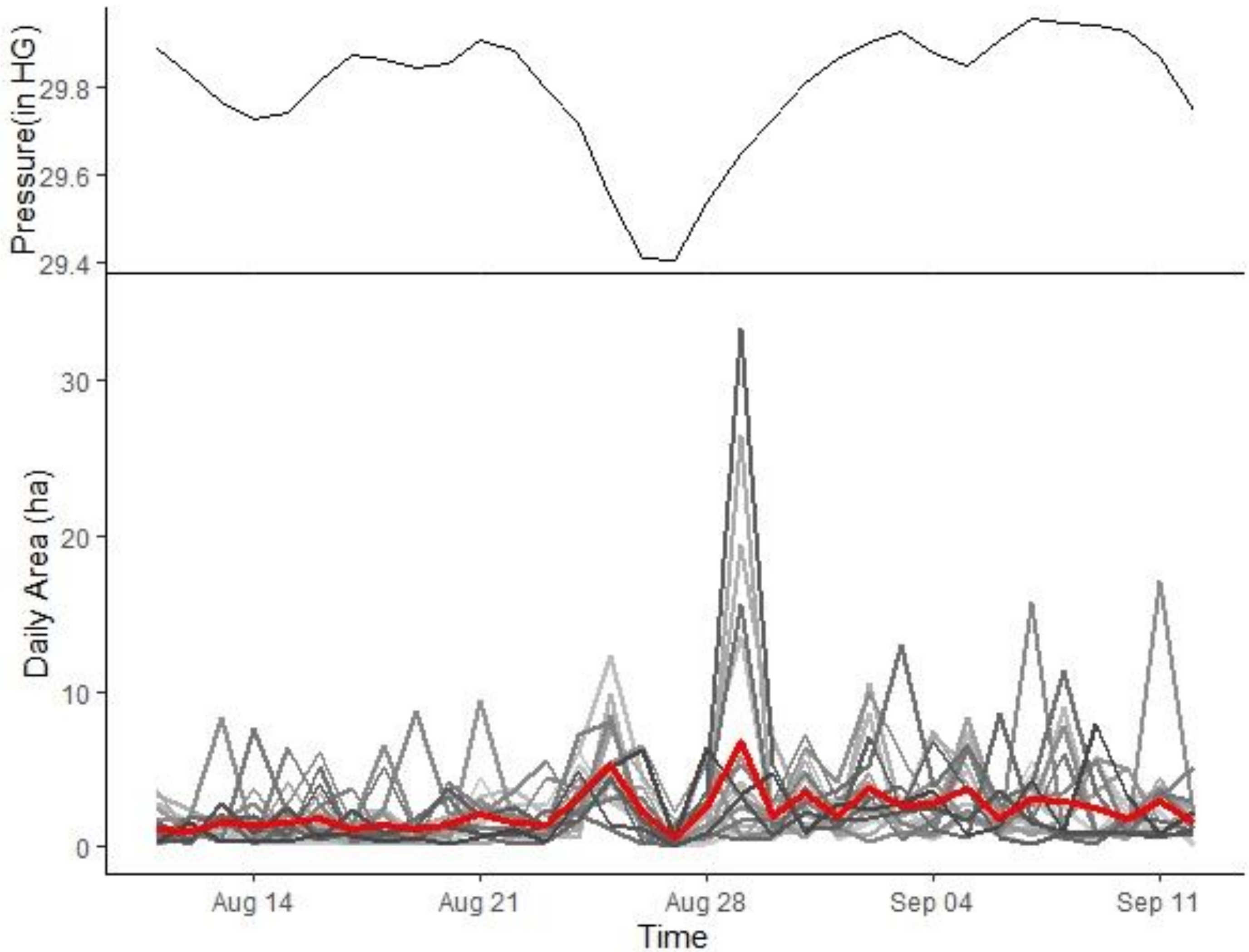

Figure 2.3. Daily core area (50% utilization distribution) estimates for GPS tagged Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) relative to mean daily barometric pressure (inHg) for Hurricane Harvey in 2017 in Texas.

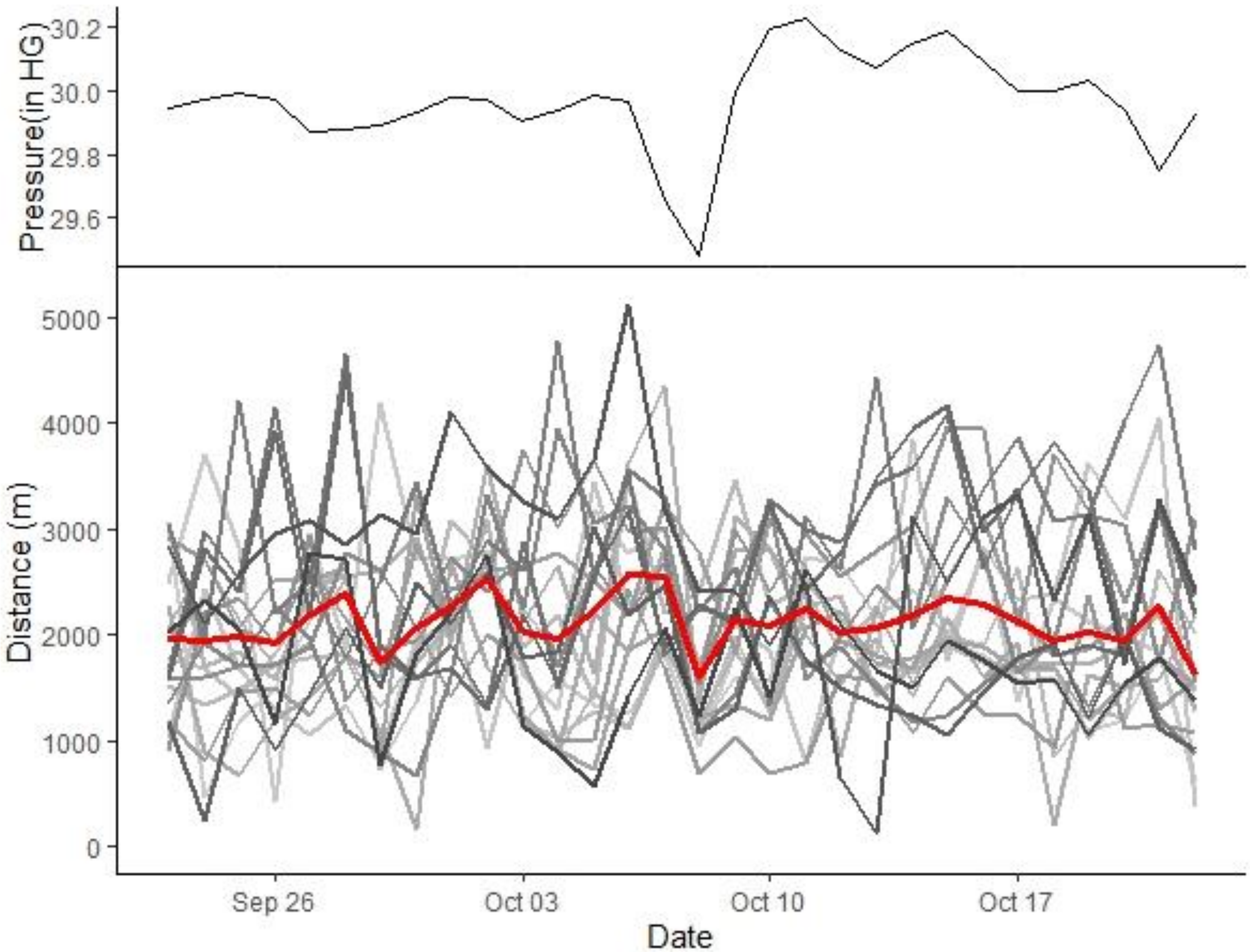

Figure 2.4. Daily distance (m) estimates for GPS tagged Eastern wild turkeys (*Meleagris gallopavo silvestris*) relative to mean daily barometric pressure (inHg) for Hurricane Matthew in 2016 on the Webb WMA Complex, South Carolina.

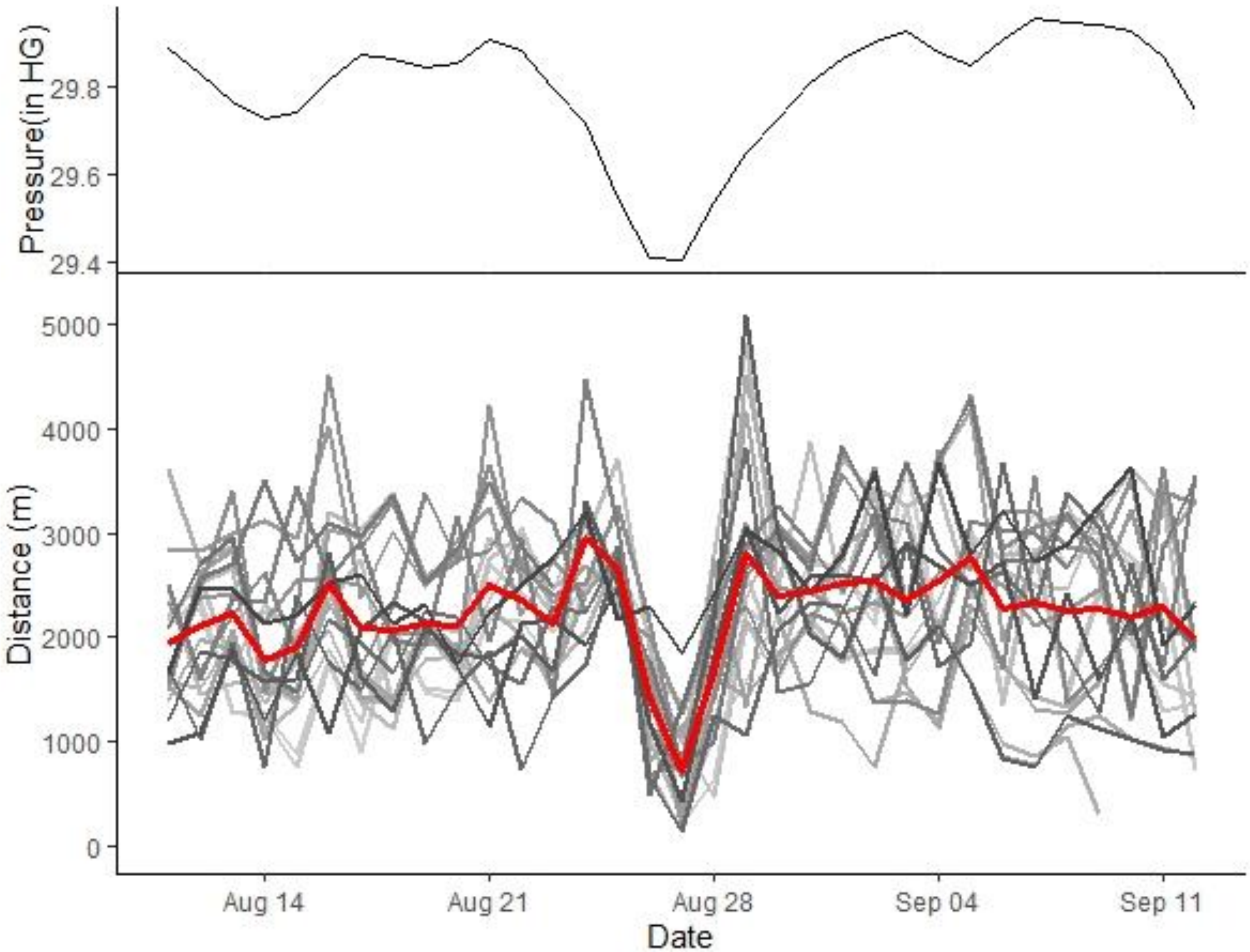

Figure 2.5. Daily distance (m) estimates for GPS tagged Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) relative to mean daily barometric pressure (in Hg) for Hurricane Harvey in 2017 in Texas.

Table 2.3. Mean daily barometric pressure (in Hg) and mean daily distance (m) estimates for Hurricane Matthew, South Carolina (2016) and Hurricane Harvey, Texas (2017).

Location	Date	Pressure	Distance (SD)
South Carolina	10/7/2016	29.66	2,555 (683)
	10/8/2016	29.48	1,592 (599)
	10/9/2016	30.00	2,138 (649)
Texas	8/25/2017	29.55	2,670 (363)
	8/26/2017	29.41	1,407 (533)
	8/27/2017	29.40	722 (476)
	8/28/2017	29.54	1,687 (640)
	8/29/2017	29.65	2,809 (1,103)

(SD = 529, range 1,273–3,041 m; t_{21} = - 3.80, P = 0.001). After Harvey, mean daily distance moved did not differ from mean daily distance before the hurricane (Table 2.1; t_{21} = -1.59, P = 0.127).

At the Webb WMA Complex, we identified 23 unique roost clusters and found that roost cluster use ranged from 1–14 before Matthew to 5–12 after Matthew. Mean number of unique roost clusters increased from 7.2 before Matthew to 8.7 (SD = 1.8, range = 1–14) after Matthew. Mean RI increased 21% from 0.53 before Matthew to 0.64 (SD = 0.13, Figure 2.6) after Matthew, which was not significant (t_{19} = -1.95, P = 0.066). Daily distances traveled between roost locations was similar before Matthew (506 m) to after Matthew (626 m, SD = 174, range 13–1323 m, t_{19} = -1.42, P = 0.173). At our Texas site we identified 15 individual roost clusters,

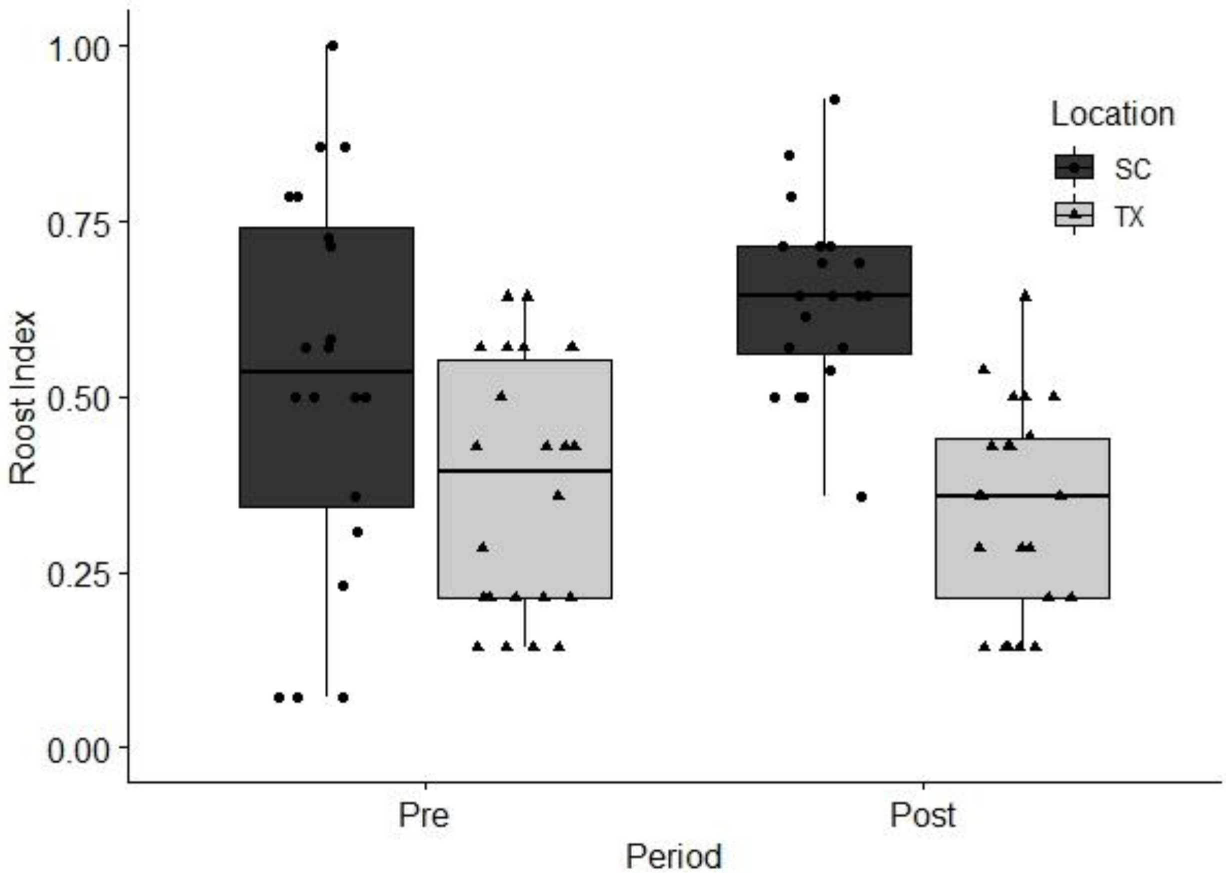

Figure 2.6. Box plots of roost index values before and after hurricane event for Web WMA Complex, South Carolina and Texas research areas (2016, 2017 respectively).

and individuals used between 2–9 roosts clusters before and after Harvey. Mean number of roost clusters used decreased by 10% from 5.1 before Harvey to 4.6 (SD = 2.1, range = 2–9) after Harvey. We observed a decrease of 7% in mean RI from 0.37 before Harvey to 0.34 (SD = 0.15, range = 0.14–0.64, Figure 2.6) after Harvey, which was not significant (t_{21} = 1.05, P = 0.306). Daily distance traveled between roost locations did not differ for the period before Harvey (312 m) and after Harvey (265 m, SD = 141, range 0.87–1705 m, t_{21} = 1.34, P = 0.194).

2.5. Discussion

Heavy and prolonged periods of rain and wind associated with hurricanes resulted in several acute impacts to turkeys. Direct mortality was potentially significant as losses of 5 and

8% due to a single event is potentially noteworthy although impacts to future population state is unknown (Wunz and Hayden 1975, Baumann et al. 1996). The single mortality in South Carolina was the result of falling branches; however, we were unable to determine the exact cause for the 2 mortalities in Texas. Our results indicated that turkeys continued to use areas within their pre-hurricane ranges, albeit, at a significantly reduced amount of area used. As we have no comparable data from other wild turkey movement studies during a hurricane, our results suggest that turkeys were mobile during the hurricane event. Our initial hypothesis was that turkeys would remain stationary, effectively waiting the storm out. However, our results indicated that turkeys remained active during the storm, where movements were severely constrained during the apex of the hurricane, of which we can only speculate may be due to avian species ability to detect changes in barometric pressure and adjust their behaviors accordingly (Lehner and Dennis 1971, Breuner et al. 2013). Turkey movements returned to before hurricane levels after the event, suggesting that turkeys had the ability to obtain resources. We note that during an extensive flooding event in Louisiana, turkeys movements were reduced relative to daily movements, as individuals were confined to treetops for the duration of the flood (Chamberlain et al. 2013). Similarly, snowstorm include low temperatures and deep snow, which hinders movements and access to food sources and have been shown to lead to starvation (Wunz and Hayden 1975).

Although there was extensive flooding during both hurricanes, albeit short-lived, we had no evidence that it impacted turkeys similarly to results by Chamberlain et al. (2013) and Cobb et al. (1993). Both the South Carolina and Texas sites had roost indexes that fell within the range reported in Byrne et al. (2015) during undisturbed conditions. Although our estimated daily distance traveled between roosts reported for South Carolina were higher than reported by Byrne et al. (2015), mean distances moved between roost sites at our Texas site fell within ranges reported by Byrne et al. (2015). We has assumed that individuals would move away from riparian areas, especially in Texas, where roost trees are typically confined to riparian areas (Byrne et al. 2015). However, our results indicated there was no change in roost cluster fidelity during either hurricanes and we speculate that flooding surrounding roost trees was likely over a short enough period that no deleterious impacts occurred.

Our results indicated that primary acute impacts to turkeys during the hurricanes were direct mortality. Although turkeys response to hurricanes may have some similarity to other disturbance events, such as reduced space use (Chamberlain et al. 2013) our results suggest that individual response may be dependent on the duration and intensity of the event. Turkeys appear resistant to the short-term perturbations caused by the individual hurricanes we evaluated, but may show increased response to hurricane events as intensity and duration increase, as expected in the wake of climate change (Schiermeier 2005, Kunkel et al. 2017, Wuebbles et al. 2017, Carter et al. 2018).

CHAPTER 3. PHENOLOGICALLY-BASED ESTIMATES OF SPACE USE BY RIO GRANDE WILD TURKEYS.

3.1. Introduction

Effective wildlife management is dependent on understanding key factors among species occurrence, resource utilization, and habitat needs (Boyce and McDonald 1999, Winder et al. 2015). Species that inhabit broad geographic ranges likely contend with a suite of intrinsic demographic factors (e.g. sex, age, survivorship) causing significant variation in phenology (Brown 1980, Patten et al. 2011), that are likely driven by extrinsic ecological factors across the natural gradient of climate, landscape configuration and composition (Winder et al. 2015). Thus, species demography and habitat requirements vary across landscapes based on both intrinsic and extrinsic factors (Wiens and Milne 1989, Allen et al. 2014, Winder et al. 2015). Therefore, effective management of generalist species requires an understanding of how each uses the environment, particularly during times of various phenological reproductive state in order to provide insight into population-level processes (Brown 1980, Winder et al. 2015).

Accurately delineating space use of wildlife is important as biological needs are driven by individual phenological states (e.g. foraging, nesting, Poulin et al. 1992), which also influence species demography at broader spatial and temporal scales (Smith et al. 2011). For ground–nesting avian species, demography is inherently linked to breeding, nesting, and often brooding activities (Deeming 2002, Doherty et al. 2014, Conley et al. 2015). Hence, space use during reproductive periods is an important, spatially constrained demographic driver. Thus, accurate identification of biologically relevant time-periods for estimating space use is critical to identifying factors driving local demographic success (Franke et al. 2004, Sawyer and Kauffman 2011).

Wild turkeys (*Meleagris gallopavo* spp.) are a ground nesting uniparental Galliform widely distributed across North America. Since restoration, an abundance of information documenting Eastern wild turkeys (*M. g. silvestris*) demographic parameters and space use is available (Brown 1980, Godwin et al. 1991, Miller et al. 2001, Cohen et al. 2018), but fewer studies have addressed breeding phenology in great detail (see Miller et al. 1997). Notably, the standard approach to quantify space use for comparative purposes is to identify a temporal period within an annual cycle (e.g., breeding period), and evaluate resource use and demography of animals during that period (Mayor et al. 2009). Studies on Rio Grande wild turkeys (*M. g. intermedia*; hereafter turkey), have followed the above, regularly describing turkey behaviors relative to general temporal periods during the annual cycle (e.g., winter, fall, spring, breeding, Keegan and Crawford 1997, Holdstock et al. 2005, Hall et al. 2007, Ramirez et al 2012, but see Conley et al. 2015, 2016). However, space use is known to vary seasonally (Badyaev et al. 1996, Thogmartin 2001) and within reproductive periods as an individual may transition between multiple phenological states based on both environmental factors and reproductive status (Conley et al. 2015, 2016, Bakner et al. 2019). As such, it is plausible that previous conclusions of how turkeys utilize space, which would underlie resource selection and use during the reproductive period may be overly generalized for management planning.

Repeatable studies examining phenology specific information over several years are rare (Miller et al. 1998, Sandercock et al. 2005, Winder et al. 2015) but can significantly increase the strength and accuracy of biological inferences about space use and, by definition, resource selection (Börger et al. 2006, van Beest et al. 2011). The primary objective of our work was to investigate variability in space use of turkeys across a suite of phenological-based periods in different landscapes throughout the annual cycle. Our analysis utilized a unique spatially explicit data set collected at 16 field sites in Texas over a 10-year span. We used our spatially explicit data to create utilization distributions (UDs) for each phenologically-based state to compare and contrast sizes of core area, range size, and daily distances moved across Texas Parks and Wildlife Department (hereafter TPWD) management districts.

3.2. Study area

We conducted our research on a suite of private and public lands distributed across 5 TPWD wildlife management districts spanning 8 ecoregions of the Rio Grande wild turkey's range in Texas (Figure 3.1). We worked in District 2 (hereafter D2) which was in the TPWD High Plains and Panhandle Wildlife District and we conducted research on the Matador Wildlife Management Area (WMA) in Cottle County during 2017–2018 (Figure 3.1). The Matador WMA is a 11,307 ha property at the confluence of the Middle and South Pease Rivers within the Rolling Plains ecoregion and is bisected by intermittent streams (Spears et al. 2005). Land cover was approximately 30% open, 66% brushland, and 4% woodland, with the primary land use in the area being cattle grazing (Brunjes 2005) and agriculture (Hall et al. 2007). Open areas consisted of native grasses dominated by bluestems (*Andropogon* spp.) and gramas (*Bouteloua* spp.). Primary vegetation consisted of hackberry (*Celtis occidentalis*), western soapberry (*Sapindus saponaria var. drummondi*), honey mesquite (*Prosopis glandulosa*), skunkbush sumac (*Rhus aromatica*), eastern cottonwood (*Populus deltoides*), and shin oak (*Quercus havardii*).

We worked in District 3 (hereafter D3) which was in TPWD's Cross Timbers Wildlife District. We conducted our research on 3 private properties within Stevens, Eastland and Palo Pinto counties and on a public property in Wise County during 2012–2017 (Figure 3.1). Sites within D3 consisted of rolling hills and steep canyons, with elevations ranging between 122–518 m above sea level (Gould 1962). D3 was predominately rangeland with various species of bluestem, grama, and panicum (*Panicum* spp.) with common overstory species including live oak (*Q. virginiana*), Ashe juniper (*Juniperus ashei*), Post oak (*Q. stellata*), while along riparian areas mesquite (*Populus* spp.), Cedar elm (*Ulmus crassifolia*), Pecan (*Carya illinoinensis*), and cottonwood were common. All our sites were managed for outdoor related recreation, primarily tied to white-tailed deer (*Odocoileus virginianus*), wild turkey, and northern bobwhite (*Colinus virginianus*) hunting using native grassland restoration and riparian corridor maintenance (Conley et al. 2015, 2016). Livestock grazing under different stocking rates occurred on all study sites (Byrne et al. 2014*b*, Conley et al. 2015).

We worked in District 4 (hereafter D4) which was in TPWD's Hill Country Wildlife District in the Edwards Plateau ecoregion. We conducted our research on 2 private ranches in Bandera and Mason County during 2016–2017 (Figure 3.1). Sites were within the Edwards Plateau and Llano Uplift, which consisted of rolling hills and steep canyons (Gould 1962). Fire suppression and over grazing had gradually converted our study areas to brushlands, with native grass species dominated of bluestem, grama, and panicum. Common overstory species including live oak mottes and thickets of Ashe juniper. Along riparian corridors bald cypress (*Taxodium distichum*), cottonwood, and pecan were found (Larkin and Bomar 1983, Locke et al. 2013). Study sites were primarily rangeland utilized for livestock grazing and managed for white tailed deer and the hunting of exotics ungulates (Locke et al. 2013).

We worked in District 7 (hereafter D7) which was in the Oak-Prairie Wildlife District and we conducted our research on 8 privately owned properties from 2016–2018 (Figure 3.1) within Caldwell, DeWitt, Fayette, Jackson, Gonzales and Lavaca County. Our study sites encompassed an array of Texas ecosystems including the Oaks and Prairies, Blackland Prairie, Gulf Coast Prairies and Marshes and the South Texas Brush Country ecoregions. Our study sites

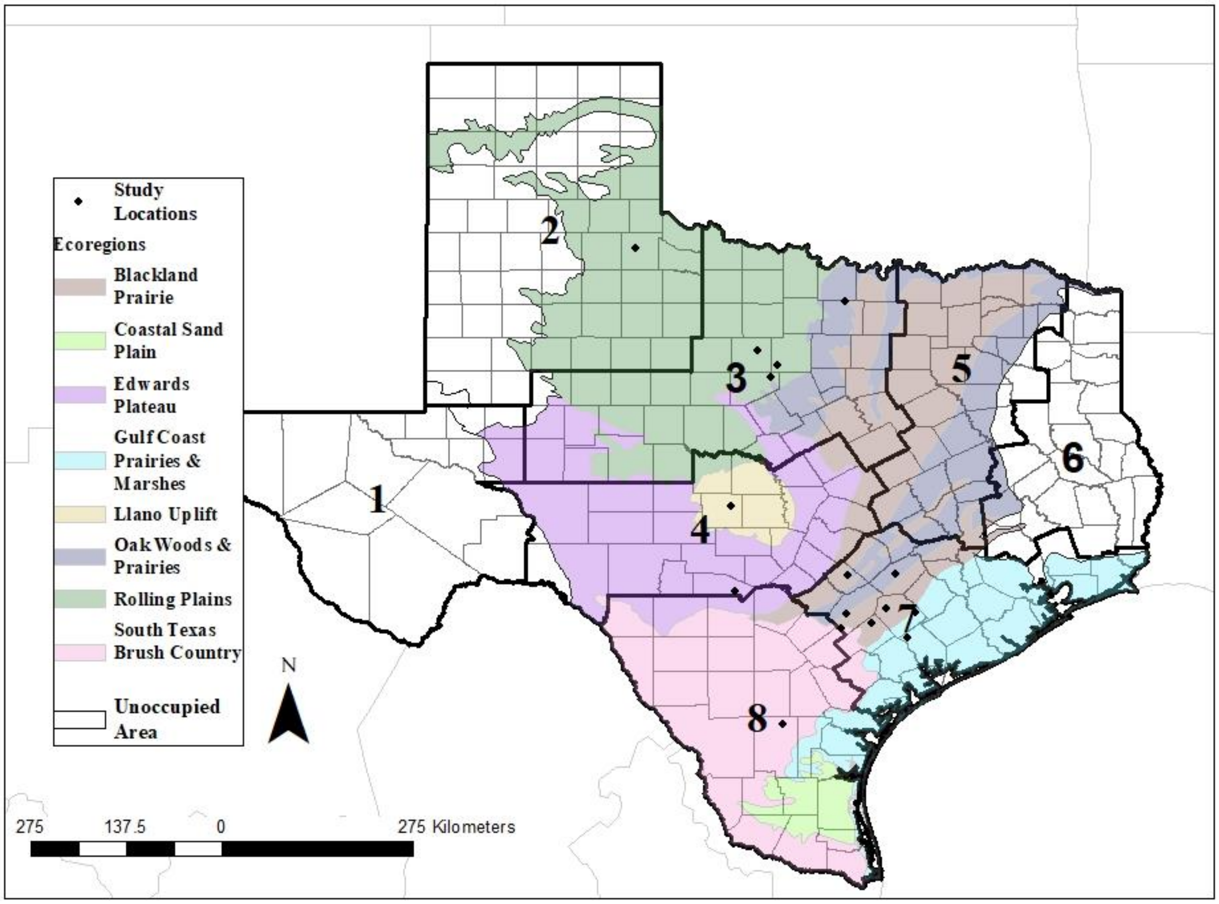

Figure 3.1. Distribution of ecoregions and research locations within the 8 Texas Parks and Wildlife management districts from 2009-2018, in Texas, USA.

were primarily used for livestock grazing, crop and hay production, oil and gas development, and wildlife-related recreation (White et al. 2019). Vegetative communities consisted of Texas wintergrass (*Nassella leucotricha*), silver bluestem (*Bothriochloa saccharoides*), and non-native grasses were abundant in all sites, forming large pasture monocultures, dominated by bermudagrass (*Cynodon dactylon*) and King Ranch bluestem (*B. ischaemum var. songarica*). Understory brush was dominated with yaupon (*Ilex vomitoria*), interspersed between American beautyberry (*Callicarpa americana*), mesquite, huisache (*Acacia farnesiana*), and pricklypear (*Opuntia engelmannii*). Overstory species included post oak and live oak, while riparian overstory included species such as pecan and cedar elm.

Our research in District 8 (hereafter D8) was conducted in 2009–2010 at a single site in the South Texas Plains Wildlife District on a 5,261 ha private ranch located in Duval County (Collier et al. 2017, Figure 3.1). Our D8 site was bisected by a broad riparian corridor (San Diego Creek) was intensely managed for white-tailed deer and northern bobwhite (Byrne et al. 2014*b*, Gross et al. 2015*a*). Our D8 study site was characterized by South Texas Plains ecoregion vegetative communities including thin paspalum (*Paspalum setaceum*), fringed signal grass (*Urochloa ciliatissima*), red grama (*B. trifida*), and coastal sandbur (*Cenchrus incertus*) (Archer 1990). Woodlands consisted primarily of honey mesquite, hackberry, and Texas persimmon (Archer 1990) and were limited to riparian corridors (Byrne et al. 2014*b*).

3.3. Methods

We captured Rio Grande wild turkeys across our study regions between January and March 2009–2018 using drop-nets and walk-in traps baited with cracked corn or milo. Individuals captured were fitted with a uniquely numbered aluminum butt-end or rivet leg band (National Band and Tag Company, Newport, Kentucky, Butler et al. 2011), and a GPS-VHF backpack transmitter unit (Biotrack Limited, Wareham, Dorset, UK, Guthrie et al. 2011). Units are programmed to record at least one location per hour from 05:00 to 20:00 daily and one roost location at night (23:59:58) until the battery died or the unit was recovered (Cohen et al. 2018). We released turkeys immediately at the capture location following processing. We monitored live-dead status ≥2 times per week using a Biotracker receiver (Biotrack Ltd., Wareham, Dorset, UK) and handheld Yagi antenna for the life of the collar or until recovery via mortality or recapture. We downloaded GPS information ≥2 times per month via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). We derived date of mortality from VHF tracking and spatio-temporal GPS locational data (Guthrie et al. 2011, Conley et al.

2015, Yeldell et al. 2017). We censored the first 14 days post capture from our analysis, which ensured that we removed any potential capture related impacts (Nenno and Healy 1979, Wright et al. 1996, Morellet et al. 2009). Both Louisiana State University Agricultural Center Animal Care and Use Committee and Texas A&M University Institutional Animal Care and Use Committee approved our capture and handling protocols (Permit A2015-07 and Permits 2005-5, 2007-5 as amended, 2010-287 and 2014-0058, respectively).

Space use estimates for turkeys have failed to address well-defined variation in species phenology by aggregating activities into broad categories until recently (Healy 1992, Conley et al. 2015, Bakner et al. 2019). For instance, the biological reproductive period (March–July, Miller and Conner 2007) is regularly used to evaluate habitat utilization during the reproductive period. However, the reproductive period includes several, mutually exclusive, life history stages such as the time immediately before breeding activities commence (Conley et al. 2015, Chamberlain et al. 2018), breeding activities (Collier et al. 2017), laying, incubation (Conley et al. 2015, 2016), periods post-nest failure (Conley et al. 2016, Bakner et al. 2019), additional laying and incubation periods, brooding periods (Conley et al. 2015, 2016), or perhaps no reproductive activities at all (Collier et al. 2009). Thus, during each period, male and female wild turkeys exhibit a suite of specific behavioral activities (Conley et al. 2015, 2016, Chamberlain et al. 2018, Bakner et al. 2019, Wightman et al. 2019) that should underlie the amount of area used (Börger et al. 2006, Byrne et al. 2014*a*).

Based on historic (Healy 1992) and updated knowledge of wild turkey behaviors (Conley et al. 2015, 2016, Bakner et al. 2019) herein we defined the wild turkey annual cycle as a suite of distinct, identifiable periods using spatial information. First, we defined the monitoring period range as the period for the life of either the GPS tag, or the individual, which in general provides a baseline estimate of the individual ranges over the entirety of the monitoring period, akin to the home range provided in a wide range of studies (Hall et al. 2007, Ramirez et al. 2012). We developed a coarse definition for the breeding period, akin to earlier works, as the reproductive period range, which began on 15 March (Chamberlain et al. 2018, Collier et al. 2019) and continued until the last documented reproductive event [e.g. final day of nesting (success/fail) or brooding to day 30 by the last reproductively active female] specific to each study location each year (Table 3.1). Next, we defined the period following the end of the breeding period, until the onset of the next breeding period as the wintering period, which encompassed fall and winter for each individual, under the assumption that the only activities during this period were behaviors associated with survival (Glazener et al. 1990, Nguyen et al. 2003). As wild turkey population sustainability and trajectory is driven by annual production (Pollentier et al. 2014), the reproductive period is of particular interest as a driver of population stability (Vangilder and Kurzejeski 1995). Thus, we further developed more restrictive periods based on phenological status that a female turkey may experience during a typical breeding season. First, we defined the pre-laying range as the period from the initiation of the breeding season (15 March, Collier et al. 2019) or, in the case of a failed first reproductive attempt (whether it be nest initiation, incubation, or brooding), the period from the day after the failure of the previous attempt until the start of an individual's next nest initiation period within that year. We defined the nest initiation period as the period when a female initiated a nest via laying the first egg (Conley et al. 2016) until incubation was initiated or nest failure. We defined the incubation period as the day the female began incubating the nest actively, which we identified using VHF tracking and GPS data as well as evaluating the date the first roost location was found at the nest site (Conley et al. 2015, Bakner et al. 2019). The incubation period lasted until either nest abandonment, nest or female predation, or hatch, and each incubation attempt was visually identified based on VHF tracking and GPS data and evaluated after the nest was determine to be failed or hatched (Yeldell et al. 2017). We defined the brooding period as the period a female was known to be actively brooding based on repeated brood surveys for each GPS tagged female who successfully hatched (M. J. Chamberlain, unpublished data). Finally, we defined the post-breeding range at the individual level, as the period after all reproductive behaviors had ceased for that individual until the start of the wintering period.

In conjunction with our daily VHF tracking, we utilized the GPS data collected from each individual at the time of radio tracking to visualize and confirm start and finish dates for each individual's phenological period. To estimate phenological-specific range sizes at the individual level, we used our GPS data and a dynamic Brownian Bridge Movement Models (hereafter, dBBMM) to construct individual core area and range size (50 and 99% UD's respectively; Cohen et al. 2018). We calculated all UDs using the program R (Version 3.5.1, R Development Core Team 2019) and the package move (Kranstauber et al. 2019). We left the margin and window size (5 and 21 respectively) constant and used a location error of 15 m (Guthrie et al. 2011, Collier et al. 2019). We did not vary dBBMM input settings to account for changes in GPS sampling frequency because we failed to see any measurable effects of altering input values when we began our analysis (Cohen et al. 2018). As female turkeys have been found to travel extensive distances within smaller ranges (Conley et al. 2016, Schofield 2019), we estimated mean daily distance traveled using R package geosphere (Hijmans 2019) as an additional metric to complement our space use estimates. We then used a one–way analysis of variance (ANOVA) to evaluate how core area, range size or daily distance traveled varied among study areas for each phenological period. We used utilization and daily distance traveled estimates as our

Table 3.1. Yearly breeding season end dates for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*) in each county of study within the Texas Parks and Wildlife Department districts, Texas, USA, 2012–2018[2].

District	County[1]	2012	2013	2015	2016	2017	2018
D02	Cottle	–	–	–	–	5/24/2017	7/20/2018
D03	Eastland	–	–	7/6/2015	7/1/2016	–	–
D03	Wise	5/16/2012	7/29/2013	7/2/2015	–	–	–
D03	Stephens	5/20/2012	7/16/2013	7/17/2015	6/24/2016	–	–
D03	Palo Pinto	6/23/2012	6/7/2013	–	–	–	–
D04	Bandera	–	–	–	6/25/2016	–	–
D04	Mason	–	–	–	–	–	–
D07	Caldwell	–	–	–	–	6/03/2017	5/7/2018
D07	Lavaca	–	–	–	6/25/2016	6/23/2017	6/14/2018
D07	DeWitt	–	–	–	6/27/2016	7/21/2017	6/4/2018
D07	Gonzales	–	–	–	–	6/20/2017	5/28/2018
D07	Jackson	–	–	–	7/26/2016	5/11/2017	6/28/2018
D07	Fayette	–	–	–	–	6/28/2017	6/23/2018

[1] Duvall County in Texas park and wildlife management district 8 had no females captured to determine breeding end dates.

[2] For 2009–2011 no females were captured to determine breeding dates.

dependent variable and study district as our predictor variable. For phenological periods showing evidence of significant variation, we conducted a Tukey's post hoc test to identify the direction and calculated the magnitude of change. For all phenological periods, we pooled estimated space use and daily distance travelled together by sites (e.g., D3) for all years to ensure ample sample size for analysis.

3.4. Results

We used 768,656 GPS locations collected from 39 males and 256 females distributed across Texas in D2 (*n* = 16 F), D3 (*n* = 21 M, *n* = 123 F), D4 (*n* = 6 M, *n* = 4 F), D7 (*n* = 5 M, *n* = 113 F), and D8 (*n* = 7 M). We calculated 1,638 individual core and range area utilization distributions as well as estimates for daily distance traveled across multiple seasons (*n* = 295 monitoring, *n* = 268 breeding, *n* = 255 pre-laying, *n* = 267 initiation, *n* = 219 incubation, *n* = 20 brooding, *n* = 143 post breeding, *n* =171 wintering). We had 11 initiation attempts that failed to reach the incubation period, while 37 incubation attempts were censored due to failure before 2 days of incubation (Bakner et al. 2019). We censored 2 pre-laying periods, 1 initiation period, 3 post-breeding periods, and a single wintering period due to collar failure. Note that our reproductive period estimates were limited to the 252 females tracked in Districts 2, 3, and 7.
In general, monitoring period ranges and breeding period ranges (Table 3.2, Figures 3.2, 3.3) were similar across studies sites. Incubation periods had the lowest core and range size estimates relative to all other periods (Table 3.2, Figures 3.2, 3.3), and while brooding core areas were consistent, range sizes varied considerably. Post breeding and wintering periods showed decrease size relative to the breeding period (Table 3.2, Figures 3.2, 3.3). Mean daily distance was similar through most periods except for incubation and brooding periods, which had the lowest distance

Table 3.2. Mean core area (50%), range (99%) utilization distribution (UD) and daily distance traveled over all sites for each phenological period with standard errors and mean days used to calculate UDs.

Period	*n*	$\bar{x}$ area[1] (SE)	$\bar{x}$ area[2] (SE)	$\bar{x}$ Distance[3] (SE)
Monitoring	295	48.40 (8.88)	1,017.08 (125.22)	2,869 (191)
Breeding	268	39.25 (12.07)	806.30 (110.84)	2,966 (169)
Pre-Laying 1	175	45.55 (9.09)	644.38 (130.93)	3,439 (134)
Initiation 1	186	19.89 (1.20)	232.82 (14.51)	2,983 (327)
Incubation 1	147	8.80 (8.60)	118.87 (105.42)	956 (486)
Pre-Laying 2	68	54.57 (20.70)	692.49 (179.38)	3,276 (120)
Initiation 2	69	38.31 (17.62)	417.89 (205.66)	3831 (630)
Incubation 2	55	0.83 (0.39)	70.64 (43.02)	819 (225)
Pre-Laying 3	13	42.03 (9.79)	634.27 (61.03)	3,832 (171)
Initiation 3	13	27.97 (4.20)	322.22 (93.86)	3416 (172)
Incubation 3	11	0.05 (0.00)	33.97 (1.02)	529 (111)
Brood D15	13	3.17 (0.10)	42.73 (7.26)	788 (129)
Brood D30	7	6.47 (1.66)	89.46 (26.04)	1113 (0)
Post Breeding	143	30.58 (3.83)	442.59 (30.50)	2409 (49)
Wintering	171	25.55 (2.36)	565.91 (119.02)	2299 (215)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean daily distance traveled in m

traveled (Table 3.2, Figure 3.4). Movements during the post breeding and wintering periods movement was lower than the rest of our study periods (Table 3.2, Figure 3.4).

Monitoring period estimates differed for 50% core use areas and daily distance traveled ($F_{4,289}$ = 4.79, $P \leq 0.001$, $F_{4,289}$ = 6.88, $P \leq 0.001$ respectively, Figures 3.2, 3.4), however we did not find evidence of range size differences between districts ($F_{4,289}$ = 1.32, P = 0.263, Figure 3.3). Monitoring period core area sizes were 26.2 ha greater in D3 than D2, 43.1 ha greater in D4 than D2, and 27.6 ha greater in D7 than D2 (Table B.1) while mean daily distance traveled in D8 was larger than D3 and D7 by 919 and 1124 m, respectively (Table B.1). Similarly, core area used and daily distance traveled for the breeding period significantly differed ($F_{2,270}$ = 5.22, P = 0.006, $F_{2,270}$ = 3.08, P = 0.05 respectively, Figures 3.2, 3.4) while the breeding period range size did not differ between districts ($F_{2,270}$ = 1.51, P = 0.223, Figure 3.3). Core areas for D2 during

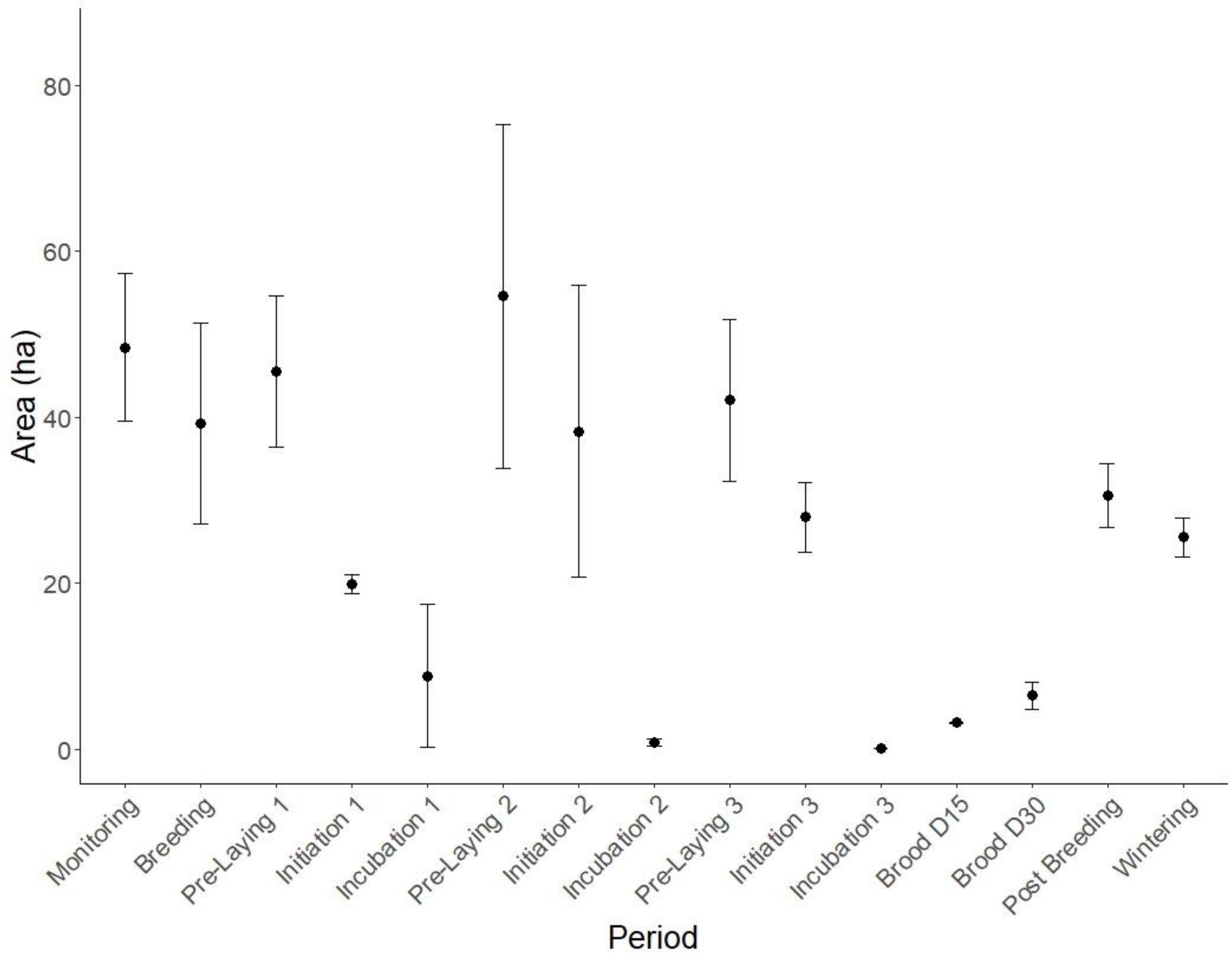

Figure 3.2. Mean core area [50% utilization distribution, ha (±SE)] size for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*) across all study sites in Texas, USA, 2009-2018.

the breeding period was 31.4 ha less than D3 and 30.9 ha less than D7, while daily distance traveled was 465 m less in D7 and 342 m less in D3 than D2 (Table B.2).

Our results indicate that the first pre-laying period had significantly different estimates for core area, range size and daily distance traveled ($F_{2,\,172} = 10.61$, $P \leq 0.001$; $F_{2,\,172} = 7.80$, $P \leq 0.001$, $F_{2,\,172} = 8.68$, $P \leq 0.001$, respectively, Figures 3.2 – 3.4). We found that the first pre-laying period core area used in D7 was 60.2 ha lower than D2 and 30.8 ha lower than D3 (Table B.3). Similarly, D7 pre-laying range size was 602.8 ha smaller than D2 and 441.4 ha smaller than D3 (Table B.3). Daily distance traveled in D7 was significantly less than D3 by 457 m

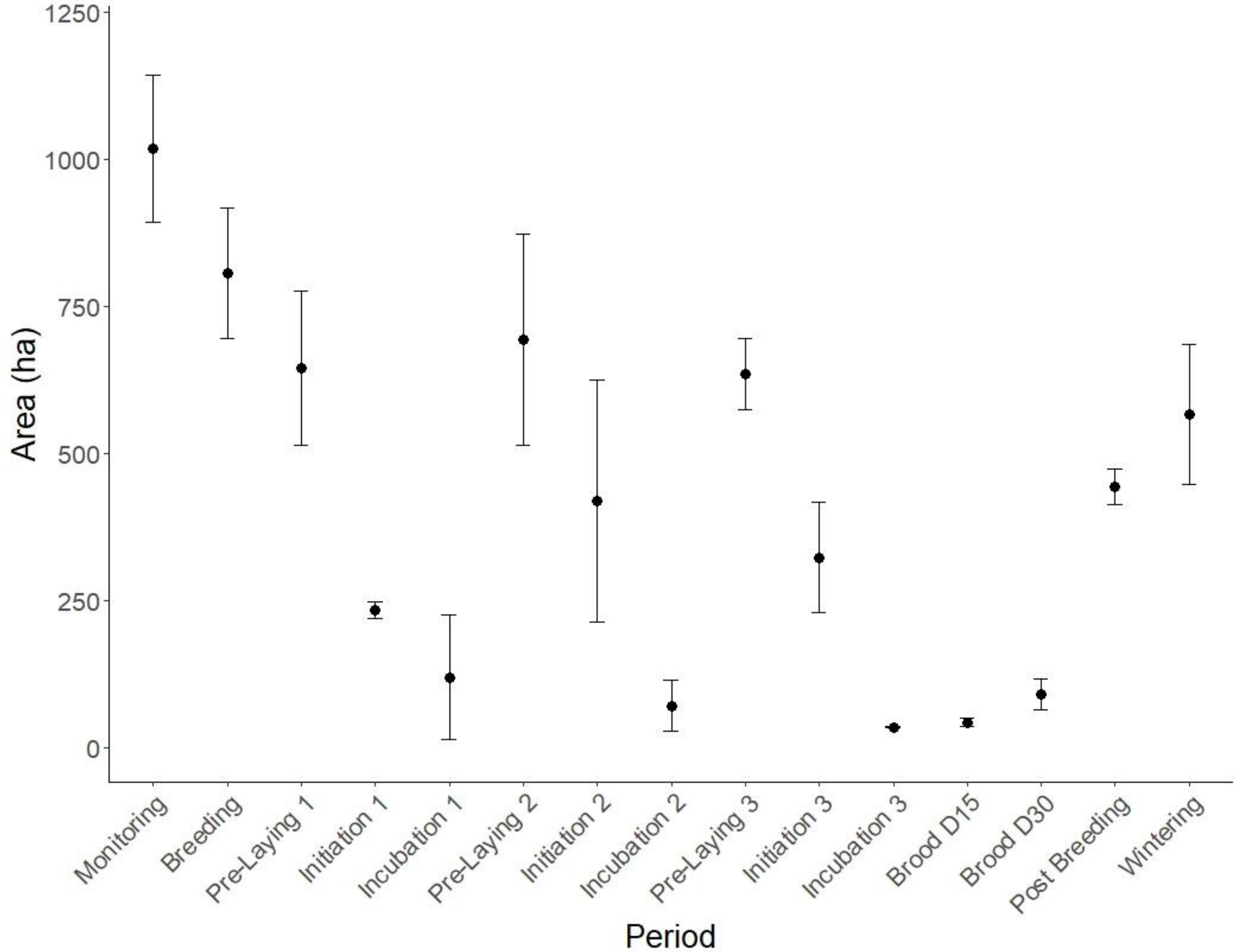

Figure 3.3. Mean range (99% utilization distribution, ha[±SE]) size for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*) across all study sites in Texas, USA, 2009-2018.

(Table B.3). For the second and third pre-laying period we found no evidence of differences in core area, range size or daily distance traveled between districts ($F_{1, 65}$ = 1.88, P = 0.175; $F_{1, 65}$ = 0.69, P = 0.409, $F_{1, 65}$ = 2.24, P = 0.14; $F_{1, 11}$ = 2.94, P = 0.114; $F_{1, 11}$ = 0.67, P = 0.431, $F_{1, 11}$ = 1.93, P = 0.192, respectively, Figures 3.2 – 3.4).

Our results indicated that the first initiation period was significantly different for both core area and range size between districts ($F_{2, 183}$ = 5.36, P = 0.006, $F_{2, 183}$ = 4.36, P = 0.014 respectively, Figures 3.2, 3.3) while the daily distance traveled did not differ significantly

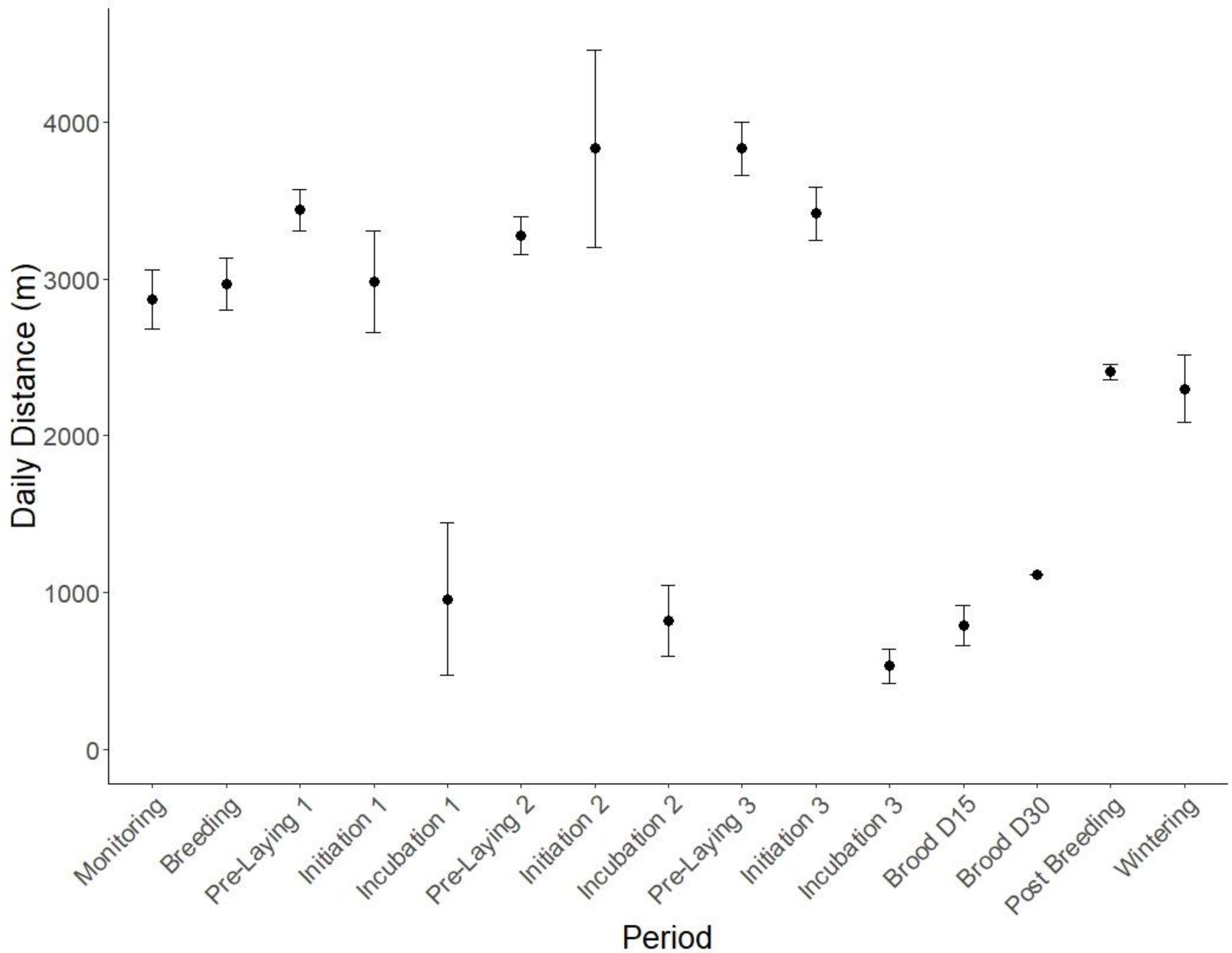

Figure 3.4. Mean daily distance traveled (m [±SE]) for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*) across all study sites in Texas, USA, 2009-2018.

($F_{2,\,183}$ = 0.18, P = 0.840, Figure 3.4). Core area and range size for D2 was larger than D3 by 12.7 ha and 118.1 ha respectively, and larger than D7 by 14.2 ha and 136.1 ha, respectively (Table B.4). For the second initiation period core area used and range size did not differ between districts, however, daily distance traveled was different ($F_{1,\,66}$ = 2.88, P = 0.094, $F_{1,\,66}$ = 2.65, P ≤ 0.109, $F_{1,\,66}$ = 4.57, P = 0.036 respectively, Figures 3.2 – 3.4) with individuals traveling 452 m more in D7 relative to D3 (Table B.5). For the third initiation period we did not find any significant difference in core area, range size and daily distance traveled ($F_{1,\,11}$ = 7.61, P = 0.402, $F_{1,\,11}$ = 3.45, P = 0.090, $F_{1,\,11}$ = 5.67, P = 0.467 respectively, Figures 3.2 – 3.4).

We found no evidence of differences in core area size for the first incubation period between districts ($F_{2, 151} = 0.54$, $P = 0.581$, Figure 3.2), whereas range size and daily distance traveled were significantly different ($F_{2, 151} = 3.72$, $P = 0.026$; $F_{2, 151} = 4.07$, $P = 0.019$ respectively, Figure 3.3, 3.4) with the first incubation period range size with D2 being 38.2 ha larger and individuals traveled on average 452 m more than in D3 (Table B.6). Similarly, our results indicated that individuals in D2 had a 31.9 ha larger range size and 364 m increase in distance moved than D7 (Table B.6). For the second incubation period we found no differences in core area and range size between districts ($F_{1, 52} = 0.99$, $P = 0.325$; $F_{1, 52} = 0.174$, $P = 0.679$ respectively, Figures 3.2, 3.3). However, daily distance traveled varied by district ($F_{1, 52} = 5.32$, $P = 0.025$, Figure 3.4) with movements in D7 being 330 m greater than D3 (Table B.7). We found no variation in core area, range and daily distance traveled for the third incubation period ($F_{1, 9} = 0.128$, $P = 0.729$; $F_{1, 9} = 0.003$, $P = 0.957$, $F_{1, 9} = 0.90$, $P = 0.367$ respectively, Figures 3.2 – 3.4).

Estimated brooding ranges for the 15 day period post hatch showed no significant difference in core area used or range size ($F_{1, 11} = 0.04$, $P = 0.855$, $F_{1, 11} = 1.29$, $P = 0.28$ respectively, Figures 3.2, 3.3), but daily distance traveled was different between districts ($F_{1, 11} = 6.55$, $P = 0.027$, Figure 3.4) with distance traveled for the 15 day brood period being 257 m more in D3 relative to D7 (Table B.8). Core area used and range size for the 30 day brooding period significantly differed ($F_{1, 5} = 9.90$, $P = 0.026$, $F_{1, 5} = 21.72$, $P = 0.006$ respectively, Figures 3.2, 3.3) where daily distance traveled did not vary between districts ($F_{1, 5} = 0$, $P = 0.999$, Figure 3.4). Our results indicate that for the 30 day brood period that D3 broods had a core area and range size that was 3.3 and 52.1 ha greater relative to D7 (Table B.8).

Post breeding estimates showed no variation in core area, range size and daily distance traveled between districts ($F_{2, 140}$ = 2.62, P = 0.077; $F_{2, 140}$ = 1.28, P = 0.28, $F_{2, 140}$ = 0.37, P = 0.689 respectively, Figures 3.2 – 3.4). For the wintering period we found no variation between districts for core area size ($F_{3, 173}$ = 1.6, P = 0.192, Figure 3.2), however, range size and daily distance traveled varied between districts (Table B.9; $F_{3, 173}$ = 10.45, $P \leq 0.001$, $F_{3, 173}$ = 12.23, $P \leq 0.001$ respectively, Figures 3.3, 3.4). Our results indicated that range size for D3 was 434.9 ha and 104.9 ha smaller than D2 and D7 respectively, and range size for D7 was 330 ha smaller than range size in D2.

3.5. Discussion

One of the greatest challenges wildlife managers face is untangling the complexities of scale for optimizing management strategies (Boyce 1991). As phenology-specific behavioral changes underlie variation in range sizes for a variety of species (Boyce 1991, Boyce et al. 2003), spatial scale of inference is dependent on the choice of time scales at which data are both collected and interpreted (Cohen et al. 2018). Examination of space use at a single, coarse temporal scale (i.e. breeding period) can lead to spurious conclusions due to the arbitrary delineation of time and are likely suboptimal for understanding space use. Our objective was to assess the variation of turkey space use based on the phenological state of each individual, for which, the dates of initiation for each state drove our estimates rather than aggregating our data to time periods based on subjective empirical knowledge or rudimentary biological season definitions (Brown 1980, Miller et al. 1997, Hall et al. 2007, Isabelle et al. 2015, Cohen et al. 2018). Thus, our approach of examining individual’s space use at a phenologically defined temporal scale mitigated against biases associated with the aggregation of spatio-temporal data that include multiple phenological states.

We found that turkey space use was considerably plastic across phenological periods. A lack of consistency among individuals within and across sites suggests that several factors are acting on an individual level to influence space use patterns (Miller et al. 2001). Space use size is often correlated to the spatial configuration of available habitats (Everett et al. 1979, Gustafson et al. 1994). When habitat availability is low, space use and distances traveled are expected to increase as turkeys use larger areas to meet resource needs (Everett et al. 1979, Brown 1980). While fragmented areas intermixed by fields and forested stands are integral to stable turkey populations (Backs and Eisfelder 1990), patches of intensely farmed areas can isolate individuals from other suitable habitats (Lewis 1964).

A majority of past Rio Grande wild turkey studies used minimum convex polygons to estimate space use (Hall et al. 2007, Ramirez et al. 2012, Conley et al. 2015, 2016, Collier et al. 2017), with dBBMM becoming more useful (Bakner et al. 2019, Schofield 2019, White et al. 2019), our estimates are likely conservative, and more accurate relative to other space use estimates (Cohen et al. 2018). Past studies on Rio Grande wild turkeys has indicated winter space use decreases (Thomas et al. 1966, Crockett 1973, Caveny et al 2011). Winter space use is driven by foraging behavior in order to acquiring adequate resources for survival (Glazener et al. 1990, Porter 1992, Nguyen et al. 2003). Similarly, as post-breeding space use size mirrored that of the wintering period, we assume that turkeys are engaging in similar behaviors. Thus, turkeys are likely using a smaller core area that contains abundant and reliable food resources and address habitat structure requirements such as requisite roosting habitat (Thomas et al. 1966, Crockett 1973, Caveny et al 2011). Winter food sources are often limited, such as in northern climates wherein mortality may be significant due to starvation (Healy and Dickson 1992). However, across our sites winters are comparably milder, with winter snows rarely remaining for extended periods. Additionally, the use of game feeders is significant across all sites, which provides a continuous source of food especially during the winter months.

Within the biological season concept, spring months or breeding season space use are driven by breeding behaviors (Miller et al. 1997), similarly for the phenologically-based approach. However the segregation of breeding behaviors incorporates a pre-laying state in which space use dramatically increases until the next known nest initiation. Space use for the breeding season was the largest phenological period for males, whereas females in all pre-laying states regardless of nesting attempts used larger areas then anytime over all their phenological states. Often, the pre-laying period was considered an exploratory period in which a female is seeking out quality habitat, replenishing food stores and seeking potential mates (Badyaev et al. 1996, Miller et al. 1999, Chamberlain and Leopold 2000). Chamberlain and Leopold (2000) suggested that females who moved farther in their pre-laying period had increased incubation periods, which may be why we had larger pre-laying core areas during the second attempt compared to the first. Females may spend more time making exploratory movements after a failed attempt, suggesting they are looking for better quality nesting habitat during their second pre-laying period. Incubation ranges declined rapidly for each subsequent nesting attempt, with movements during incubation being primarily recess activities (Bakner et al. 2019). Ramirez et al. (2012) found that nesting females had smaller 95% kernel ranges (170 ha) than non-nesting females (536 ha), which was obviously due to the activity of multiple incubation periods falling within the temporal window they evaluated (Conley et al. 2015, 2016). As most females will attempt to nest at least once (Melton et al. 2011), variation was greater in core area and range sizes during the first incubation attempt relative to the second and third attempts, which was likely a function of sample size as 36 and 7% of females attempted a second and third nest, respectively. We note that estimated brooding period core area and range sizes effectively doubled from 15 days post-hatch (3.1 and 42 ha) to 30 days post-hatch (6.5 and 89 ha), concomitant with poults increasing in size and thus required foraging activity (Randel et al. 2005, M. J. Chamberlain, unpublished data).

Individual turkeys varied widely in space use patterns. We found a general pattern across phenological behaviors for space use (Figures 3.2 – 3.4), but high variability within each period indicated that there were multiple factors operating on the individual level that likely influenced space use across sites. We suggest that the most likely proponent was a response to different vegetative conditions at the broad scale between our study sites. District 7 is a highly fragmented system with crops, pasture and forested areas dispersed across the region (see Table 1 in White et al. 2019), relative to D2 and D3, which differ significantly with large areas of shrubland/grasslands with the majority of forested area remaining close to riparian areas (Conley et al. 2015). Because of the high heterogeneity found in D7, we suggest that the heterogeneous landscape has the potential to provide turkeys with needed resources without necessitating larger space use (Miller et al. 2001). Additionally, we propose the alternative is equally plausible, that is, in highly fragmented landscapes turkeys may be isolated from other suitable habitats (Lewis 1964) leading to decreased space use. Conversely, the arid regions of Central Texas has historically maintained strong turkey populations but favorable habitat is typically found near riparian corridors (Byrne et al. 2015). This may explain why in general turkeys in the region may use larger areas, but does not necessarily explicitly explain all the variability we see across all phenological periods.

Identifying what habitats are used by individuals relative to the availability on the landscape has a long history in wildlife ecology (Manly et al. 2002, Keating and Cherry 2004).

The wild turkey literature is replete with studies that have found that that selection of various habitat conditions does not depend upon the spatial scale used (Brown 1980, Miller et al. 1997, Thogmartin 2001) while a suite of studies have suggested that selection does vary based on scale (Chamberlain and Leopold 2000, Conley et al. 2016). As identified by Johnson (1980), evaluating habitat utilization at only one scale may lead to incorrect inferences and cause us to miss important patterns. As such, our results indicate that historic approaches to range estimation for Rio Grande wild turkeys (Brown 1980, Hall et al. 2007, Isabelle et al. 2015, Cohen et al. 2018) and wild turkeys in general using the biological season concept (Miller et al. 1997) are likely suboptimal for understanding turkey space use and habitat use for directing management strategies.

CHAPTER 4. CONCLUSIONS

Our findings suggest turkeys (*Meleagris gallopavo* spp., hereafter turkey) may be sensitive to storm intensity and adjust their movement patterns accordingly. Based on these data we concluded that mortality for turkey was directly caused by the hurricane event. While turkeys minimized their space use and movements, individuals returned to pre-hurricane levels immediately after. Although space use had significantly decreased for the duration of both hurricanes, the day when barometric pressure was lowest, indicating the apex of the storm event, we recorded the lowest mean space use. Turkey roost fidelity was not significantly altered by any post hurricane effects (e.g. flooding, tree damage). Individuals remained surprisingly mobile during both hurricanes indicating that they are resilient to these perturbances. A review of long-term impacts of these two hurricanes was not within the scope of this study.

We found that turkey space use was considerably plastic across phenological periods and across all Texas Parks and Wildlife Department management districts. A lack of consistency among individuals within and across sites suggests that several factors are acting interdependently or on an individual level to influence space use patterns. Estimated space use during both post breeding and wintering period decreased suggesting the use of a smaller core area may contain abundant and reliable food resources and address habitat structure requirements such as requisite roosting habitat. We reported space use for the breeding season was the largest phenological period for both sexes, whereas females in all pre-laying states regardless of nesting attempts used larger areas than all other phenological states. We associated these movements as exploratory in nature related to preparation of breeding activities throughout the pre-laying state. Incubation ranges declined rapidly for each subsequent nesting attempt, with movements during incubation being primarily recess activities. We note that our estimated brooding period core area and range sizes effectively doubled from 15 days post-hatch (3.1 and 42 ha) to 30 days post-hatch (6.5 and 89 ha), concomitant with poults increasing in size and thus required foraging activity. Our approach of examining individual's space use at a phenologically relevant temporal scale, mitigated against biases associated with the aggregation of spatial location data that includes multiple phenological states (e.g. breeding period). There was a general trend of space use and movement across sites but high variability across phenological periods indicates there are factors operating on the individual level that influenced space use across sites. We concluded that habitat structure and quality across sites are highly variable. This suggest that in some highly fragmented areas individuals may be restricted to core areas, while in other areas of low quality individuals may make larger movements to meet daily requirements.

Identifying what habitats are used by individuals relative to the availability on the landscape has a long history in wildlife ecology. Hurricanes are exceptional destructive to large areas of habitat. Thus, we suggest that in the face of severe weather, managers extend research to document long-term legacy effects on local wild turkeys demographics, and consider regulatory restrictions to allow local populations to recover in the case of significant adult mortality. Additionally, one of the greatest challenges wildlife managers face is untangling the complexities of scale for optimizing management strategies. Thus, we suggest that turkey researchers and managers have reached the point where we can move past generalizing spatio-temporal processes and take advantage of the unique suite of turkey life history information garnered to date. By better integrating timing of turkey life history events, we will be able to increase our understanding of the scale at which turkeys select habitats, which will aid managers in directing habitat improvement projects on a scale that is best defined by core areas that will support turkey reproductive ecology into the future.

APPENDIX A. SUPPLEMENTARY MATERIAL FOR CHAPTER 3

Table A.1. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the monitoring period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	38	31.70 (3.62)	(0.52 – 93.30)	768.00 (92.00)	(162.00 – 2300.00)	98	(18 – 161)
FA	D04	6	18.30 (1.68)	(14.20 – 23.30)	325.00 (74.30)	(185.00 – 668.00)	275	(107 – 359)
GRAM	D07	24	41.60 (4.47)	(4.41 – 92.10)	999.00 (123.00)	(153.00 – 2232.00)	192	(44 – 452)
HIN	D07	13	45.70 (4.18)	(17.20 – 69.50)	747.00 (78.70)	(368.00 – 1256.00)	203	(15 – 483)
LBJ	D03	41	33.80 (3.15)	(0.04 – 71.60)	603.00 (51.80)	(60.50 – 1450.00)	135	(16 – 313)
LR	D07	19	51.70 (8.75)	(0.65 – 168.00)	1249.00 (246.00)	(48.60 – 3904.00)	146	(12 – 219)
MAT	D02	16	67.10 (12.60)	(17.70 – 181.00)	1263.00 (149.00)	(291.00 – 2547.00)	204	(33 – 320)
MSN	D04	4	32.40 (9.52)	(13.70 – 58.80)	1058.00 (185.00)	(802.00 – 1607.00)	30	(NA)
MT7	D03	52	51.00 (6.29)	(5.44 – 224.00)	1402.00 (185.00)	(270.00 – 8049.00)	148	(30 – 314)
PET	D07	23	33.40 (3.49)	(8.61 – 61.60)	700.00 (71.60)	(14.70 – 1302.00)	234	(15 – 514)
RES	D07	7	20.20 (6.33)	(0.96 – 37.30)	590.00 (177.00)	(10.00 – 1096.00)	224	(52 – 454)
RICH	D07	20	25.70 (4.90)	(0.07 – 76.20)	647.00 (93.00)	(163.00 – 1762.00)	215	(52 – 441)
STR	D03	13	49.90 (10.30)	(10.40 – 129.00)	1098.00 (186.00)	(338.00 – 2693.00)	186	(39 – 253)
SUP	D07	7	66.80 (16.80)	(17.40 – 154.00)	1946.00 (390.00)	(1005.00 – 3315.00)	155	(14 – 314)
TEMP	D08	7	70.60 (15.10)	(43.80 – 158.00)	1305.00 (475.00)	(481.00 – 4066.00)	73	(44 – 188)
TIN	D07	5	37.20 (4.61)	(26.60 – 51.40)	806.00 (60.00)	(593.00 – 918.00)	198	(110 – 271)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.2. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the breeding period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	34	28.10 (3.77)	(0.52 – 91.20)	796.00 (104.00)	(155.00 – 2441.00)	82	(11 – 111)
GRAM	D07	25	54.50 (6.22)	(1.57 – 114.00)	916.00 (108.00)	(151.00 – 2300.00)	92.2	(28 – 128)
HIN	D07	15	41.40 (4.98)	(10.60 – 74.30)	621.00 (62.20)	(227.00 – 1023.00)	93.1	(11 – 128)
LBJ	D03	36	31.00 (3.49)	(0.04 – 79.40)	540.00 (57.70)	(60.50 – 1512.00)	76.5	(29 – 128)
LR	D07	18	49.50 (8.68)	(1.53 – 146.00)	1252.00 (262.00)	(328.00 – 3894.00)	109	(41 – 133)
MAT	D02	16	69.60 (13.80)	(19.60 – 197.00)	998.00 (167.00)	(271.00 – 2595.00)	74.8	(17 – 127)
MT7	D03	41	48.20 (8.26)	(0.64 – 205.00)	1404.00 (192.00)	(352.00 – 6376.00)	99.1	(27 – 124)
PET	D07	29	26.80 (3.12)	(0.56 – 61.50)	496.00 (33.10)	(188.00 – 861.00)	88.4	(14 – 133)
RES	D07	9	16.30 (4.85)	(0.85 – 40.70)	350.00 (66.20)	(10.10 – 555.00)	96.4	(51 – 128)
RICH	D07	20	24.70 (4.88)	(0.07 – 84.80)	591.00 (95.50)	(119.00 – 1980.00)	104	(43 – 129)
Strawn	D03	13	53.30 (17.60)	(1.20 – 232.00)	972.00 (181.00)	(232.00 – 2057.00)	85.5	(29 – 100)
SUP	D07	7	72.60 (22.30)	(17.50 – 168.00)	1861.00 (395.00)	(803.00 – 3595.00)	120	(44 – 133)
TIN	D07	5	29.10 (4.68)	(18.60 – 46.60)	625.00 (97.20)	(428.00 – 894.00)	105	(NA)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.3. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the first pre laying period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	30	44.60 (4.32)	(14.40 – 122.00)	770.00 (117.00)	(155.00 – 2792.00)	29	(12 – 58)
GRAM	D07	18	35.50 (4.75)	(8.48 – 85.30)	493.00 (60.50)	(117.00 – 901.00)	30	(6 – 128)
HIN	D07	10	34.80 (6.36)	(8.18 – 80.20)	512.00 (86.10)	(160.00 – 954.00)	22	(8 – 46)
LBJ	D03	16	32.90 (3.09)	(15.00 – 66.60)	383.00 (71.10)	(155.00 – 1183.00)	28	(6 – 79)
LR	D07	9	31.00 (6.63)	(11.10 – 72.30)	744.00 (408.00)	(177.00 – 3991.00)	16	(3 – 35)
MAT	D02	6	88.50 (20.90)	(36.60 – 165.00)	1057.00 (255.00)	(431.00 – 2015.00)	41	(22 – 79)
MT7	D03	33	85.00 (17.20)	(5.88 – 443.00)	1280.00 (231.00)	(92.20 – 7446.00)	31	(5 – 74)
PET	D07	19	25.60 (3.32)	(10.70 – 66.10)	382.00 (48.90)	(154.00 – 1047.00)	24	(3 – 62)
RES	D07	7	23.90 (5.05)	(4.34 – 40.00)	317.00 (65.00)	(33.90 – 514.00)	19	(3 – 46)
RICH	D07	16	20.10 (2.84)	(4.83 – 39.70)	347.00 (49.10)	(96.50 – 855.00)	24	(9 – 51)
Strawn	D03	6	58.80 (19.40)	(16.60 – 149.00)	774.00 (273.00)	(279.00 – 2112.00)	24	(7 – 38)
SUP	D07	3	33.00 (1.13)	(30.90 – 34.70)	648.00 (154.00)	(457.00 – 953.00)	13	(10 – 17)
TIN	D07	2	16.90 (6.24)	(10.70 – 23.20)	221.00 (58.40)	(163.00 – 280.00)	15	(12 – 18)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.4. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the first attempted initiation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	31	16.50 (2.03)	(0.18 – 48.40)	177.00 (14.40)	(13.50 – 395.00)	9	(3 – 15)
GRAM	D07	18	20.60 (2.24)	(2.99 – 43.50)	231.00 (29.50)	(64.90 – 543.00)	10	(6 – 17)
HIN	D07	10	12.00 (1.41)	(6.57 – 19.40)	141.00 (23.30)	(68.00 – 299.00)	12	(9 – 15)
LBJ	D03	16	17.00 (1.95)	(5.31 – 37.50)	174.00 (17.50)	(77.60 – 274.00)	11	(5 – 20)
LR	D07	11	16.30 (1.97)	(7.06 – 25.20)	237.00 (33.10)	(68.50 – 398.00)	13	(11 – 17)
MAT	D02	8	32.20 (6.95)	(7.99 – 67.80)	346.00 (78.60)	(135.00 – 689.00)	11	(6 – 15)
MT7	D03	33	20.50 (2.80)	(1.83 – 82.60)	280.00 (29.90)	(115.00 – 731.00)	11	(5 – 18)
PET	D07	20	18.50 (1.65)	(8.37 – 30.20)	192.00 (19.10)	(71.30 – 367.00)	12	(8 – 16)
RES	D07	8	21.10 (4.18)	(5.76 – 42.80)	209.00 (37.10)	(82.10 – 405.00)	11	(8 – 14)
RICH	D07	18	18.70 (2.31)	(6.40 – 38.80)	241.00 (24.00)	(65.50 – 472.00)	12	(7 – 18)
Strawn	D03	7	33.30 (5.39)	(12.60 – 53.60)	332.00 (50.20)	(171.00 – 517.00)	12	(10 – 14)
SUP	D07	4	18.90 (1.46)	(16.80 – 23.10)	216.00 (36.80)	(146.00 – 302.00)	14	(8 – 17)
TIN	D07	2	10.60 (5.70)	(4.88 – 16.30)	125.00 (44.50)	(80.90 – 170.00)	14	(13 – 14)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.5. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the first attempted incubation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	25	0.04 (0.00)	(0.03 – 0.05)	7.47 (2.35)	(0.23 – 55.70)	15	(3 – 26)
GRAM	D07	14	0.17 (0.11)	(0.03 – 1.63)	15.90 (8.67)	(0.60 – 126.00)	7	(3 – 21)
HIN	D07	9	0.05 (0.01)	(0.03 – 0.09)	8.73 (1.90)	(2.69 – 22.20)	13	(8 – 22)
LBJ	D03	11	0.05 (0.01)	(0.03 – 0.13)	5.87 (2.55)	(0.66 – 30.50)	17	(3 – 28)
LR	D07	9	0.04 (0.00)	(0.03 – 0.07)	12.60 (5.35)	(0.43 – 48.80)	12	(3 – 28)
MAT	D02	7	0.11 (0.04)	(0.03 – 0.34)	48.50 (18.90)	(1.46 – 135.00)	15	(9 – 27)
MT7	D03	26	0.05 (0.01)	(0.02 – 0.14)	14.90 (7.66)	(0.25 – 200.00)	18	(4 – 31)
PET	D07	18	0.04 (0.00)	(0.03 – 0.05)	19.90 (13.20)	(0.26 – 240.00)	15	(3 – 28)
RES	D07	8	0.07 (0.03)	(0.03 – 0.25)	10.80 (2.62)	(2.05 – 23.40)	15	(3 – 28)
RICH	D07	14	0.05 (0.01)	(0.03 – 0.22)	11.80 (6.79)	(0.50 – 98.30)	12	(3 – 27)
Strawn	D03	7	0.07 (0.01)	(0.03 – 0.10)	10.10 (2.86)	(1.46 – 25.20)	16	(3 – 25)
SUP	D07	4	5.81 (5.77)	(0.03 – 23.10)	65.70 (62.40)	(1.03 – 253.00)	16	(3 – 28)
TIN	D07	2	0.04 (0.00)	(0.04 – 0.04)	4.22 (0.71)	(3.51 – 4.93)	11	(4 – 18)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.6. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the second pre laying period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	12	41.70 (4.90)	(10.40 – 77.90)	408.00 (68.20)	(111.00 – 882.00)	21	(7 – 38)
GRAM	D07	8	41.50 (10.90)	(1.63 – 86.30)	564.00 (145.00)	(14.80 – 1224.00)	19	(4 – 44)
HIN	D07	2	26.60 (1.80)	(24.80 – 28.40)	294.00 (75.60)	(219.00 – 370.00)	10	(7 – 13)
LBJ	D03	4	34.70 (16.70)	(4.73 – 76.00)	611.00 (388.00)	(100.00 – 1759.00)	29	(9 – 58)
LR	D07	7	30.90 (12.10)	(10.60 – 102.00)	558.00 (191.00)	(277.00 – 1635.00)	28	(9 – 51)
MAT	D02	1	95.70 (NA)	(NA)	1048.00 (NA)	(NA)	37	(NA)
MT7	D03	12	33.00 (4.63)	(6.51 – 60.30)	672.00 (117.00)	(167.00 – 1486.00)	19	(7 – 47)
PET	D07	3	34.30 (10.40)	(13.60 – 46.20)	379.00 (99.00)	(184.00 – 503.00)	30	(14 – 61)
RES	D07	4	24.10 (2.08)	(20.70 – 29.80)	339.00 (36.30)	(270.00 – 409.00)	17	(6 – 24)
RICH	D07	10	20.80 (4.31)	(0.07 – 44.40)	446.00 (115.00)	(7.35 – 1212.00)	17	(5 – 27)
Strawn	D03	3	45.40 (22.70)	(22.60 – 90.80)	588.00 (191.00)	(259.00 – 919.00)	21	(12 – 30)
SUP	D07	2	39.10 (34.30)	(4.77 – 73.40)	576.00 (505.00)	(71.30 – 1081.00)	12	(4 – 20)

[1] 50% Utilization distribution in ha

[2] 99% Utilization distribution in ha

[3] Mean range of days in range count

Table A.7. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the second attempted initiation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	12	13.40 (2.98)	(0.73 – 36.40)	133.00 (17.50)	(58.90 – 247.00)	8	(4 – 10)
GRAM	D07	9	22.90 (4.06)	(6.93 – 49.70)	257.00 (53.40)	(57.30 – 607.00)	10	(6 – 13)
HIN	D07	2	23.10 (6.16)	(17.00 – 29.30)	144.00 (28.60)	(116.00 – 173.00)	12	(11 – 13)
LBJ	D03	4	13.50 (3.60)	(5.85 – 22.10)	131.00 (30.10)	(65.60 – 193.00)	9	(5 – 12)
LR	D07	7	30.20 (4.57)	(12.90 – 46.10)	271.00 (45.10)	(85.00 – 383.00)	11	(9 – 16)
MAT	D02	1	73.40 (NA)	(NA)	828.00 (NA)	(NA)	7	(NA)
MT7	D03	12	20.60 (5.34)	(5.28 – 55.90)	237.00 (38.40)	(61.10 – 499.00)	10	(7 – 13)
PET	D07	3	24.30 (6.16)	(16.10 – 36.30)	265.00 (13.90)	(244.00 – 291.00)	11	(7 – 18)
RES	D07	4	25.00 (5.30)	(14.90 – 35.40)	251.00 (57.80)	(159.00 – 402.00)	10	(8 – 12)
RICH	D07	10	17.50 (2.96)	(7.35 – 39.30)	174.00 (31.80)	(63.60 – 377.00)	8	(3 – 11)
Strawn	D03	3	32.90 (8.55)	(21.40 – 49.60)	298.00 (82.30)	(189.00 – 459.00)	9	(8 – 10)
SUP	D07	2	27.50 (8.31)	(19.20 – 35.80)	357.00 (117.00)	(240.00 – 474.00)	11	(10 – 11)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.8. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the second attempted incubation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	11	0.12 (0.08)	(0.03 – 0.94)	9.30 (4.01)	(0.22 – 47.00)	12	(3 – 27)
GRAM	D07	6	0.09 (0.02)	(0.04 – 0.19)	9.51 (3.55)	(0.23 – 23.30)	5	(4 – 6)
HIN	D07	1	0.03 (NA)	(NA)	2.83 (NA)	(NA)	26	(NA)
LBJ	D03	3	0.05 (0.01)	(0.03 – 0.08)	9.36 (0.24)	(8.97 – 9.80)	14	(5 – 18)
LR	D07	6	0.06 (0.01)	(0.03 – 0.07)	33.90 (10.20)	(1.70 – 67.50)	24	(5 – 47)
MAT	D02	1	1.01 (NA)	(NA)	157.00 (NA)	(NA)	27	(NA)
MT7	D03	11	0.05 (0.01)	(0.03 – 0.12)	43.50 (30.30)	(0.23 – 344.00)	18	(6 – 27)
PET	D07	3	0.05 (0.01)	(0.04 – 0.08)	5.31 (3.04)	(2.11 – 11.40)	13	(3 – 28)
RES	D07	2	0.22 (0.18)	(0.04 – 0.40)	10.20 (4.53)	(5.69 – 14.80)	15	(3 – 27)
RICH	D07	7	0.08 (0.04)	(0.04 – 0.32)	9.66 (2.49)	(1.31 – 16.40)	6	(3 – 12)
Strawn	D03	2	0.19 (0.12)	(0.07 – 0.31)	9.21 (8.67)	(0.55 – 17.90)	7	(5 – 9)
SUP	D07	2	17.90 (17.90)	(0.06 – 35.80)	250.00 (223.00)	(26.80 – 474.00)	7	(3 – 11)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.9. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the third pre laying period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	3	34.10 (1.73)	(30.60 – 35.80)	460.00 (61.00)	(352.00 – 563.00)	12	(8 – 15)
GRAM	D07	2	62.50 (28.70)	(33.70 – 91.20)	672.00 (46.80)	(625.00 – 719.00)	15	(10 – 19)
LR	D07	1	50.90 (NA)	(NA)	983.00 (NA)	(NA)	11	(NA)
MT7	D03	2	33.50 (0.83)	(32.60 – 34.30)	789.00 (5.93)	(784.00 – 795.00)	9	(6 – 12)
PET	D07	1	37.80 (NA)	(NA)	504.00 (NA)	(NA)	31	(NA)
RICH	D07	3	49.70 (20.20)	(17.00 – 86.60)	679.00 (290.00)	(241.00 – 1227.00)	11	(9 – 13)
Strawn	D03	1	24.30 (NA)	(NA)	480.00 (NA)	(NA)	12	(NA)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.10. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the third attempted initiation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	3	15.70 (3.78)	(8.30 – 20.80)	161.00 (71.00)	(62.30 – 299.00)	10	(7 – 13)
GRAM	D07	2	29.80 (0.76)	(29.10 – 30.60)	408.00 (174.00)	(235.00 – 582.00)	10	(9 – 10)
LR	D07	1	54.40 (NA)	(NA)	449.00 (NA)	(NA)	10	(NA)
MT7	D03	2	38.70 (29.00)	(9.68 – 67.80)	371.00 (269.00)	(101.00 – 640.00)	11	(10 – 11)
PET	D07	1	31.60 (NA)	(NA)	302.00 (NA)	(NA)	20	(NA)
RICH	D07	3	26.50 (6.47)	(18.90 – 39.40)	448.00 (90.30)	(304.00 – 614.00)	10	(8 – 11)
Strawn	D03	1	18.10 (NA)	(NA)	147.00 (NA)	(NA)	8	(NA)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.11. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the third attempted incubation period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	2	0.04 (0.00)	(0.04 – 0.05)	2.32 (0.93)	(1.39 – 3.24)	8	(6 – 10)
GRAM	D07	1	0.05 (NA)	(NA)	1.51 (NA)	(NA)	7	(NA)
LR	D07	1	0.05 (NA)	(NA)	151.00 (NA)	(NA)	10	(NA)
MT7	D03	2	0.05 (0.01)	(0.04 – 0.06)	77.40 (68.90)	(8.55 – 146.00)	15	(4 – 25)
PET	D07	1	0.14 (NA)	(NA)	3.88 (NA)	(NA)	3	(NA)
RICH	D03	3	0.03 (0.01)	(0.02 – 0.04)	17.90 (7.76)	(2.69 – 28.20)	13	(9 – 16)
Strawn	D03	1	0.05 (NA)	(NA)	5.26 (NA)	(NA)	3	(NA)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.12. Metrics for mean core area (50%) utilization distribution (UD) for 15 day brooding period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]
LR	D07	1	2.95 (NA)	(NA)	16.20 (NA)	(NA)
MT7	D03	5	2.54 (0.92)	(0.63 – 5.93)	45.00 (11.30)	(6.20 – 66.00)
PET	D07	4	3.13 (1.10)	(0.06 – 5.06)	41.00 (13.70)	(7.62 – 63.70)
RES	D07	1	2.94 (NA)	(NA)	32.70 (NA)	(NA)
Strawn	D03	2	5.07 (0.01)	(5.06 – 5.09)	62.40 (5.75)	(56.60 – 68.10)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha

Table A.13. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for 30 day brooding period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]
PET	D07	4	4.71 (0.75)	(2.69 – 6.13)	62.60 (8.15)	(43.80 – 80.30)
RES	D07	1	5.18 (NA)	(5.18 – 5.18)	66.80 (NA)	(66.80 – 66.80)
Strawn	D03	2	8.13 (0.73)	(7.39 – 8.86)	115.00 (6.30)	(109.00 – 122.00)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha

Table A.14. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for post breeding period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	23	25.70 (3.99)	(1.23 – 66.80)	402.00 (89.60)	(12.40 – 1584.00)	31	(4 – 76)
GRAM	D07	17	33.10 (4.27)	(14.40 – 83.90)	607.00 (65.90)	(230.00 – 1182.00)	47.9	(5 – 83)
HIN	D07	9	39.30 (5.30)	(22.10 – 71.20)	465.00 (69.50)	(189.00 – 841.00)	61.1	(34 – 93)
LBJ	D03	11	33.30 (5.57)	(1.68 – 56.70)	364.00 (68.60)	(23.20 – 675.00)	34	(7 – 71)
LR	D07	9	22.50 (3.65)	(7.28 – 46.20)	382.00 (94.90)	(96.50 – 1045.00)	46.6	(31 – 71)
MAT	D02	5	37.20 (8.99)	(2.70 – 55.30)	464.00 (148.00)	(34.80 – 960.00)	29.4	(3 – 54)
MT7	D03	24	19.20 (4.15)	(0.30 – 77.90)	399.00 (89.20)	(34.10 – 1541.00)	33.6	(3 – 72)
PET	D07	14	37.00 (4.51)	(9.83 – 64.10)	428.00 (58.70)	(116.00 – 801.00)	56.7	(9 – 98)
RES	D07	7	16.00 (4.03)	(0.22 – 27.40)	268.00 (60.50)	(20.70 – 388.00)	41.6	(10 – 89)
RICH	D07	15	23.10 (5.01)	(3.75 – 69.10)	316.00 (58.90)	(65.00 – 816.00)	47.7	(14 – 95)
Strawn	D03	3	14.50 (9.69)	(2.14 – 33.60)	164.00 (119.00)	(20.80 – 399.00)	23.3	(8 – 49)
SUP	D07	4	50.90 (17.10)	(31.60 – 102.00)	1337.00 (271.00)	(837.00 – 2104.00)	80.2	(61 – 99)
TIN	D07	2	27.80 (7.60)	(20.20 – 35.40)	587.00 (190.00)	(397.00 – 777.00)	65.5	(61 – 70)

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Mean range of days in range count

Table A.15. Metrics for mean core area (50%) and range (99%) utilization distribution (UD) for the wintering period with standard errors and mean days used to calculate UDs for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), at each study site (location) within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018.

Location	District	*n*	$\bar{x}$ area[1] (SE)	Range[1]	$\bar{x}$ area[2] (SE)	Range[2]	$\bar{x}$ day	Range[3]
CCRF	D03	17	19.00 (1.59)	(9.70 – 30.90)	243.00 (30.20)	(38.20 – 551.00)	30	(10 – 56)
GRAM	D07	15	21.30 (3.15)	(5.58 – 54.70)	393.00 (100.00)	(109.00 – 1538.00)	112	(29 – 237)
HIN	D07	10	18.20 (3.31)	(5.85 – 37.30)	229.00 (41.90)	(50.00 – 434.00)	95	(5 – 237)
LBJ	D03	16	26.50 (3.82)	(2.67 – 49.70)	483.00 (99.20)	(109.00 – 1777.00)	119	(33 – 192)
LR	D07	13	18.70 (2.88)	(7.94 – 42.80)	225.00 (36.70)	(77.70 – 486.00)	58	(4 – 168)
MAT	D02	13	26.30 (4.34)	(4.77 – 59.00)	746.00 (113.00)	(94.50 – 1590.00)	157	(7 – 287)
MT7	D03	32	16.60 (2.26)	(0.41 – 62.90)	247.00 (33.70)	(33.60 – 829.00)	55	(10 – 176)
PET	D07	17	31.60 (4.36)	(8.98 – 64.10)	587.00 (102.00)	(129.00 – 1358.00)	137	(12 – 237)
RES	D07	4	29.30 (3.68)	(18.90 – 36.00)	866.00 (172.00)	(351.00 – 1056.00)	174	(50 – 237)
RICH	D07	14	19.00 (3.39)	(0.04 – 51.30)	364.00 (55.80)	(20.70 – 704.00)	136	(28 – 237)
Strawn	D03	11	27.60 (4.56)	(4.88 – 48.40)	355.00 (40.20)	(145.00 – 567.00)	98	(24 – 143)
SUP	D07	4	30.10 (7.97)	(15.20 – 47.80)	485.00 (125.00)	(241.00 – 713.00)	130	(67 – 210)
TIN	D07	5	24.90 (7.85)	(4.79 – 42.50)	508.00 (139.00)	(223.00 – 969.00)	93	(5 – 166)

[1] 50% Utilization distribution in ha

[2] 99% Utilization distribution in ha

[3] Mean range of days in range count

APPENDIX B. SUPPLEMENTARY MATERIAL FOR CHAPTER 3

Table B.1. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the monitoring period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]
3-2	-26.2	(-49.5 – -2.8)	0.019	-212	(-699 – 275)	0.755
4-2	-43.1	(-78.9 – -7.4)	0.009	150	(-595 – 895)	0.981
7-2	-27.6	(-51.2 – -4.0)	0.013	-417	(-910 – 76)	0.140
8-2	3.5	(-36.7 – 43.7)	0.999	707	(-131 – 1544)	0.143
4-3	-17.0	(-46.0 – 12.0)	0.494	362	(-242 – 966)	0.471
7-3	-1.4	(-12.5 – 9.6)	0.996	-205	(-435 – 25)	0.106
8-3	29.7	(-4.6 – 64.0)	0.125	919	(203 – 1634)	0.004
7-4	15.5	(-13.7 – 44.8)	0.590	-567	(-1176 – 42)	0.081
8-4	46.7	(3.0 – 90.4)	0.030	557	(-354 – 1467)	0.450
8-7	31.1	(-3.4 – 65.7)	0.099	1124	(405 – 1843)	≤ 0.001

[1] 50% Utilization distribution in ha
[2] Daily distance traveled in m

Table B.2. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the breeding period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]
3-2	-31.4	(-54.8 – -8.0)	0.009	-342	(-808 – 124)	0.311
7-2	-30.9	(-54.3 – -7.6)	0.010	-465	(-931 – 1)	0.088
7-3	0.4	(-10.7 – 11.6)	0.995	-123	(-344 – 98)	0.556

[1] 50% Utilization distribution in ha
[2] Daily distance traveled in m

Table B.3. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the first pre-laying period.

District	Diff[1]	95% CI[1]	p adj[1]	Diff[2]	95% CI[2]	p adj[2]	Diff[3]	95% CI[3]	p adj[3]
3-2	-29.4	(-78.7 – 19.9)	0.337	-161.4	(-923.2 – 600.4)	0.871	-228	(-987 – 530)	0.757
7-2	-60.2	(-109.6 – -10.9)	0.012	-602.8	(-1364.9 – 159.3)	0.151	-685	(-1444 – 74)	0.086
7-3	-30.8	(-48.8 – -12.8)	≤ 0.001	-441.4	(-718.9 – -163.9)	0.001	-457	(-733 – -180)	≤ 0.001

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha
[3] Daily distance traveled in m

Table B.4. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the first initiation period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]
3-2	-12.7	(-23.0 – -2.5)	0.011	-118.1	(-228.1 – -8.1)	0.032
7-2	-14.2	(-24.4 – -3.9)	0.004	-136.1	(-245.9 – -26.3)	0.011
7-3	-1.4	(-5.6 – 2.7)	0.695	-17.9	(-62.6 – 26.7)	0.610

[1] 50% Utilization distribution in ha
[2] 99% Utilization distribution in ha

Table B.5. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the second initiation period, for daily distance traveled.

District	Diff	95% CI	*p* adj
7-3	452	(30.0 – 873.4)	0.036

Table B.6. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the first incubation period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]
3-2	-38.2	(-71.9 – -4.5)	0.022	-452.3	(-839.7 – -65.0)	0.018
7-2	-31.9	(-65.4 – 1.6)	0.066	-364	(-748.7 – 21.8)	0.069
7-3	6.3	(-7.7 – 20.4)	0.537	89	(-72.5 – 250.3)	0.395

[1] 99% Utilization distribution in ha
[2] Daily distance traveled in m

Table B.7. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the second incubation period for the daily distance traveled.

District	Diff	95% CI	*p* adj
7-3	330	(43.0 – 616.9)	0.025

Table B.8. Tukey HSD output for districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the 15 day and 30 day brooding period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]	Diff[3]	95% CI[3]	*p* adj[3]
7-3	-3.3	(-6.0 – -0.6)	0.025	-52.1	(-80.8 – -23.3)	0.006	257	(36.1 – 478.7)	0.027

[1] 50% Utilization distribution in ha for 30 day brooding period
[2] 99% Utilization distribution in ha for 30 day brooding period
[3] Daily distance traveled in m for 15 day brooding period

Table B.9. Tukey HSD output for all districts with significant variation for Rio Grande wild turkeys (*Meleagris gallopavo silvestris*), within the Texas Parks and Wildlife Department districts, Texas, USA, 2009-2018 during the wintering period.

District	Diff[1]	95% CI[1]	*p* adj[1]	Diff[2]	95% CI[2]	*p* adj[2]
3-2	-434.9	(-678.9 – -190.9)	≤ 0.001	-566	(-930.4 – -201.9)	≤ 0.001
7-2	-330.0	(-572.7 – -87.3)	≤ 0.001	-385	(-747.2 – -22.7)	0.032
7-3	104.9	(-24.5 – 234.4)	≤ 0.001	181	(-12.1 – 374.4)	0.075

[1] 99% Utilization distribution in ha
[2] Daily distance traveled in m

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VITA

David J. Moscicki, born in Binghamton, New York in 1981, grew up spending his summers camping throughout upstate New York. After graduating High school, he spent several years exploring and photographing the United States, achieving his dream of exploring faraway places such as Alaska and Hawaii.

In 2004, he attended community college with the goal of transferring into film school. In 2006 he transferred to the Seattle Film Institute and by 2008 was working on a grip and lighting crew in Los Angeles, California. Although he had a passion for his work, he always wanted to work on nature documentaries. Eventually David returned to school to get a background in wildlife ecology and pursue his passion of providing knowledgeable films on the wildlife of North America. At the California State University at Long Beach, David learned firsthand about the scientific method, how to collect data and at this point learned he had a true passion for research. David transferred to the University of Nebraska-Lincoln (UNL) in 2012 where as an undergraduate he worked on several research projects regarding the remediation of lakes. After graduating from UNL David would take a position with Nebraska Cooperative Fish and Wildlife Research Unit working on a Ringed-necked Pheasant project in western Nebraska. Garnering a passion for upland game bird research, he accepted a master's position in Louisiana State Universities School of Renewable Natural Resources focusing wild turkeys. Upon completion of his master's degree, David will begin a PhD program at North Carolina State University continuing his research on wild turkeys.