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Reproductive Parameters and Female Breeding Season Survival of Rio Grande Wild Turkeys in South Central Texas

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REPRODUCTIVE ECOLOGY AND FEMALE BREEDING SEASON SURVIVAL OF RIO GRANDE WILD TURKEYS IN SOUTH CENTRAL TEXAS

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To my grandparents, Bud and Joyce White and Charles and Gean Horn, whose stories and love of the outdoors inspired me to pursue a career in the natural resources field.

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ABSTRACT

Historically, Rio Grande wild turkeys in south central Texas have been at lower densities than other portions of the state. Within the Oak-Prairie Wildlife District of Texas, Rio Grande wild turkey regulatory restrictions are different for counties in the eastern and western portions of the ecoregion. Due to perceived increases in turkey density in the eastern portion of the ecoregion (hereafter 1-bird zone), Texas Parks and Wildlife Department (TPWD) considered increasing the bag limit to match counties in the western portion of the district (hereafter 4-bird zone) in order to increase hunting opportunities. However, if regulatory changes are to be considered in the absence of estimates of abundance and harvest rate, then estimates of demographic parameters will provide the basis for regulatory decision-making. Therefore, we evaluated reproductive metrics and breeding season survival for 138 radio-marked female Rio Grande wild turkeys in 4 counties in the 1-bird zone and 2 adjacent counties in the 4-bird zone. We also evaluated the influence of 6 nest- and female-specific covariates on survival of 131 nests. We found that reproductive timing varied little between zones and across years. Nesting and renesting rates were higher in the 1-bird zone (74% and 49%, respectively) than the 4-bird zone (63% and 25%, respectively). Conversely, nest and female success rates were higher in the 4-bird zone (18% and 15%, respectively) than in the 1-bird zone (2% and 3%, respectively). Nest survival analysis indicated higher daily nest survival in the 4-bird (0.94, SE = 0.01) than 1-bird zone (0.90, SE = 0.009). Female survival was similar between zones and was best explained by our model associated with daily distance moved. While causation is unclear, our results suggest that biologically significant differences potentially occur in basic reproductive parameters between regions within the Oak-Prairie Wildlife District of Texas, and that the proposed regulations change may not be appropriate given reproductive rates observed in the 1-bird zone.

CHAPTER 1. INTRODUCTION

In the management of game populations, a key factor in influencing population trajectory is the development and implementation of harvest regulations. Game harvest regulations are tools whereby managers can partially control game population abundance, allowing the removal of excess individuals or preventing population declines due to overharvest. However, finding the regulatory scheme that maximizes hunter opportunities while achieving the desired balance in a population requires current data on the population, as populations fluctuate over time due to a variety of anthropogenic and environmental factors. A regulatory framework that once maintained the desired population balance may lead to declines in later years if conditions change.

Thanks in part to harvest regulations, Rio Grande wild turkey (RGWT) populations have been restored to much of their former range in Texas after being nearly extirpated from the state in the early 1900s (Beasom and Wilson 1992). Today, Texas Parks and Wildlife Department (TPWD) allows RGWT harvest in nearly every county across its range. Historically, in the southern Oaks and Prairies ecoregion of Texas (D7), harvest has been restricted to 1 bird in selected counties due to lower RGWT abundance in these counties as compared to adjacent counties (with a 4-bird bag limit). Due to recent perceived increases in these populations detected by local TPWD biologists, TPWD wanted to explore the possibility of removing the restrictions in these counties such that they matched other counties in the area but needed data to determine if local turkey populations could sustain such an increase.

Typically, estimates of abundance are used as the impetus driving changes in local harvest regulations of game species (Fafarman and DeYoung 1986, Heusmann and Sauer 2000, Seamans et al. 2012). However, such techniques have yet to be developed for estimating turkey abundance on a regional/statewide scale (Butler et al. 2007a), and historic turkey population monitoring techniques (production and harvest indices) may not provide reliable data (Butler et al. 2007b). Thus, if changes in harvest regulations are to be made, estimates of natality and mortality are of paramount importance as these can help predict population trajectory over time. Therefore, our objectives were to 1) assess reproductive parameters and nest survival of turkeys in the 1-bird and 4-bird counties and 2) assess female breeding season survival in the 1-bird and 4-bird counties.

1.1. Study Area

We conducted research in 6 counties in the Post Oak Savannah, Blackland Prairie, and South Texas Plains ecoregions of Texas (Figure 1.1; McMahan et al. 1984, Gould et al. 2011). The post-oak savannah ecoregion was characterized by vegetative communities consisting of post oak (*Quercus stellata*), live oak (*Q. virginiana*), yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), longleaf woodoats (*Chasmanthium sessiliflorum*), and Texas wintergrass (*Nassella leucotricha*). The blackland prairie region was characterized by vegetative communities consisting of live oak, sugarberry (*Celtis laevigata*), mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), yaupon, western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), Texas wintergrass, and silver bluestem (*Bothriochloa saccharoides*). The South Texas plains region was characterized by vegetative communities consisting predominately of mesquite, Texas persimmon (*Diospyros texana*), algerita (*Mahonia trifoliolata*), lotebush (*Ziziphus obtusifolia*), pricklypear (*Opuntia engelmannii*), tasajillo (*Opuntia leptocaulis*), and Texas wintergrass. Similar to other regions of Texas, roosting locations in all regions occurred primarily in riparian corridors (Byrne et al. 2015) which consisted of species such as pecan (*Carya illinoinensis*), elm (*Ulmus spp.*), and live oak. Non-native grasses such as bermudagrass (*Cynodon dactylon*), rescuegrass (*Bromus catharticus*), and

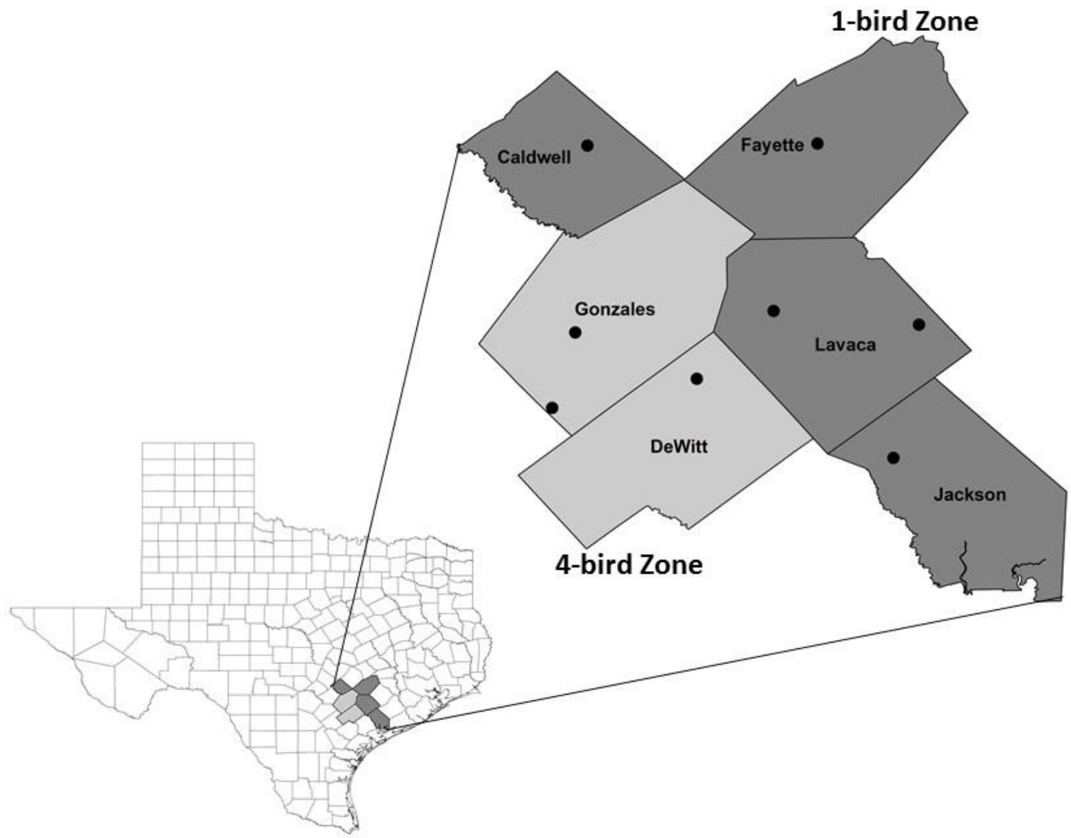


Figure 1.1. Location of study sites in relation to regulatory zones in south-central Texas, 2016-2018.

King Ranch bluestem (*Bothriochloa ischaemum var. songarica*) were abundant in all sites, often forming large pasture monocultures.

We conducted research on private lands widely distributed across the 6-county study area. Average property size was 121 ha (SD = 57.5) and properties were used for a variety of purposes including livestock grazing, crop and hay production, oil and gas development, and wildlife-related recreation. Wildlife management cooperatives throughout the study area were primarily managed for white-tailed deer (*Odocoileus virginianus*) hunting. Counties including Caldwell, Fayette, Lavaca, and Jackson were within the 1-bird zone, whereas DeWitt and Gonzales counties were within the 4-bird zone (Figure 1.1). We note that Gonzales County has a

4-bird bag limit and is split into the north zone in the fall and in the south zone in the spring (males and bearded females). DeWitt County is in the south zone and has a spring season only with a 4-bird bag of males and bearded females. While there was considerable variation in land use practices within each zone, the 1-bird zone was generally dominated by smaller property sizes, more row-crop agriculture, less open rangelands, and a lower percentage of the region classified as rural than the 4-bird zone (Table 1.1).

Table 1.1. Land use statistics for study area counties in south-central Texas, 2016-2018. Data compiled from the USDA National Agricultural Statistics Service (2012) and the US Census Bureau (2010).

			Farm/Ranch						
Zone	County	% Farm/Ranch	No.	Total Area (ha)	Avg. Size (ha)	% Pasture	% Crops	% Woodland	% Other
1-bird	Caldwell	89	1623	125628	77	60	18	18	4
	Fayette	81	2822	199122	70	63	19	15	3
	Jackson	83	811	178802	221	53	34	11	2
	Lavaca	88	2617	221180	85	67	15	16	2
4-bird	DeWitt	92	1711	217079	127	80	9	8	3
	Gonzales	89	1674	246774	147	70	11	16	2
Totals	1-bird	85	7873	724732	92	61	22	15	3
	4-bird	91	3385	463853	137	75	10	12	2

CHAPTER 2. REPRODUCTIVE PARAMETERS AND NEST SURVIVAL OF RIO GRANDE TURKEYS IN SOUTH CENTRAL TEXAS

Wild turkey regulatory decisions are typically developed based on indices of abundance using harvest statistics (Lint et al. 1995), road surveys (Menzel 1975), hunter observations (Menzel 1975, Welsh and Kimmel 1990), production indices from brood surveys (Schwertner et al. 2003, Butler et al. 2007b), estimates of appropriate habitat (Thogmartin 1999), or population models used to estimate population size (Clawson 2015). However, estimates of abundance (Butler et al. 2007a) and harvest rate (Chamberlain et al. 2012) are typically unavailable to inform management at regional or statewide scales (Butler et al. 2007b). Although managers across the United States use a variety of mechanisms to set turkey harvest regulations, certainty in turkey harvest management is limited because of partial controllability (outcomes of attempts to regulate harvest are uncertain) and partial observability (estimates of population demographics are lacking). Controllability is only possible in limited situations where variation due to environmental or anthropogenic factors does not occur or significant data collection efforts are ongoing (e.g., waterfowl banding). Therefore, if regulatory adjustments that potentially impact harvest are to be considered, it is incumbent on managers to address partial observability and evaluate demographic parameters of wild turkeys.

Since the late 1970s, Rio Grande wild turkeys have exhibited various population trends across their range in Texas (Reagan and Morgan 1980, Ransom Jr et al. 1987, Beasom and Wilson 1992, Smith-Blair 1993, Collier et al. 2007, 2009, Conley et al. 2015, 2016) with most harvest occurring on widely distributed and relatively stable Rio Grande wild turkeys (hereafter turkeys) in the central and western regions of the state (Figure 2.1). Within the Oaks and Prairies Ecoregion (hereafter D7), along the ecosystem boundary, wild turkey regulatory restrictions have

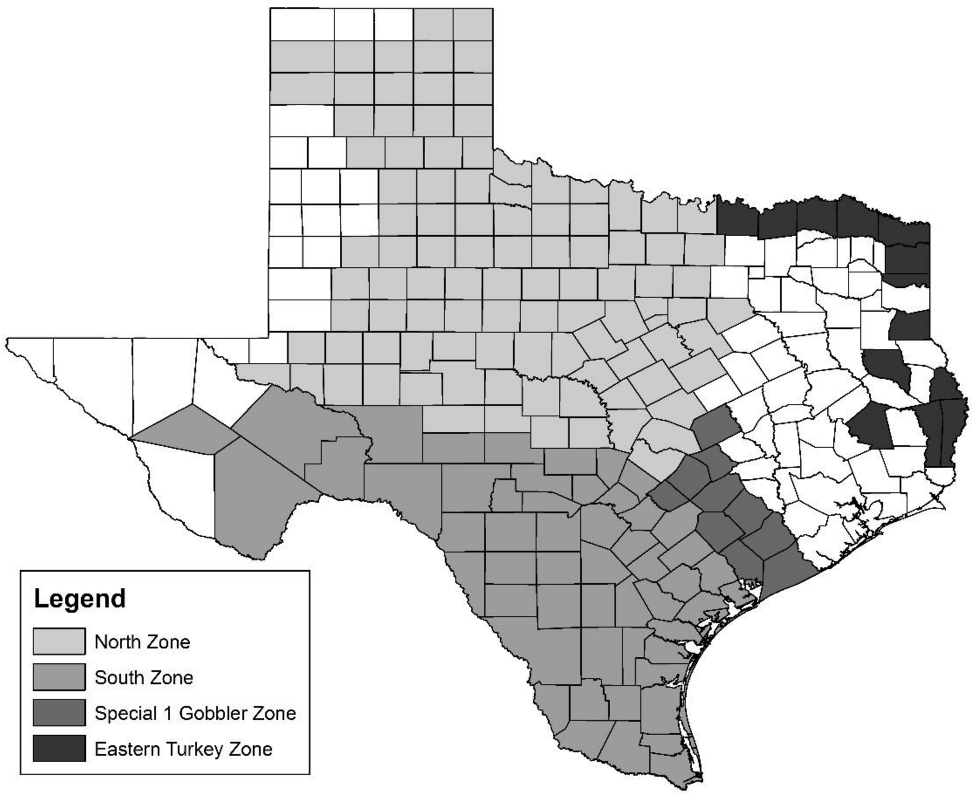


Figure 2.1. Spring turkey season regulatory zones in Texas, 2016-2018. Season dates vary by zone. The annual bag limit for turkeys, in the aggregate for all counties, is four, no more than one of which may be an Eastern wild turkey or a Rio Grande wild turkey harvested in the Special 1 Gobbler Zone counties

differed between counties in the eastern and western portions, typically set based on historic monitoring of production and harvest indices (J. Hardin, Texas Parks and Wildlife, unpublished data). Counties in the eastern portion of D7 fall within the Special 1-Male (hereafter 1-bird) regulatory zone, where there is no fall season and spring season harvest is limited to one male per year. Counties in the western portion of D7 fall within the South (hereafter 4-bird) regulatory zone, where the legal harvest is 4 per year (male and bearded females in spring, either sex in fall). Recently, due to perceived increases in turkey abundance in south central Texas, Texas Parks and Wildlife Department (TPWD) considered changing the bag limit from 1 to 4 in the 1-bird zone to increase hunting opportunities.

If regulatory changes are to be considered in the absence of annual estimates of abundance and harvest rate, then estimates of demographic parameters will provide the basis for regulatory decision-making (Roberts and Porter 1996). As wild turkey population sustainability and trajectory is driven by annual production (Vangilder and Kurzejeski 1995, Roberts and Porter 1996, Pollentier et al. 2014), variation in reproductive output is of particular interest as it substantively influences population stability (Pianka 1970, Roberts et al. 1995). Therefore, informed management requires information on how reproductive parameters, such as nesting rate, nest survival, and female success vary locally and regionally (Everett et al. 1980, Palmer et al. 1993b, Vangilder and Kurzejeski 1995, Melton et al. 2011). To determine if sufficient evidence existed that turkey populations in the 1-bird zone could sustain additional harvest, Texas Parks and Wildlife Department (TPWD) wanted evaluate population productivity between the 2 regulatory zones to determine if regulation changes were warranted. Thus, our objective was to evaluate reproductive parameters in spatially adjacent counties within both zones to detail various aspects of female reproductive ecology and population productivity.

2.1 Methods

We captured female turkeys during January – March 2016-2018 using drop-nets (Glazener et al. 1964) and walk-in traps (Davis 1994, Peterson et al. 2003) baited with cracked corn or milo. Individuals were fitted with a uniquely identifiable aluminum rivet leg band labeled with a TPWD phone number and address (National Band and Tag Company, Newport, Kentucky) and a GPS-VHF backpack transmitter unit (Biotrack Limited, Wareham, Dorset, UK; Guthrie et al. 2011). We programmed units to record 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 immediately released turkeys at the capture location following processing. We monitored live-dead status ≥2 times per week from capture to August (monthly from August–December) during 2016-2018 using a Biotracker receiver (Biotrack Ltd., Wareham, Dorset, UK) and handheld Yagi antennas. We downloaded GPS locations ≥2 times per month via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). We derived mortality rates for females during the reproductive period, first date of laying, first date of nest incubation, and nest location for nesting females from VHF tracking and spatio-temporal GPS locational data (Guthrie et al. 2011, Conley et al. 2015, Yeldell et al. 2017). Specifically, we determined laying dates based off the first estimated visit to the nest site from the GPS data (Chamberlain et al. 2018) and we viewed GPS locations and considered a female to be incubating when locations became concentrated around a single point (Wood et al. 2018) Nesting females were not disturbed or flushed from nest sites during monitoring but were live-dead checked via VHF from a distance of >20m. We defined the date of onset of nest incubation as the first day the nightly roost location was recorded on the nest site. Our capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permit A2015-07).

Following Yeldell et al. (2017), after nest termination we located nest sites to confirm the precise nest location for future analyses. We were unable to accurately determine nest fate based on egg remains in the nest bowl (Melton et al. 2011), as nests known to have hatched often contained only egg fragments. Wild turkeys require approximately 27 days of continuous incubation to complete nesting (Williams Jr et al. 1971), but incubation can vary from 25 to 29 days (Healy and Nenno 1985). Therefore, we classified nests terminated prior to day 25 as failed. If nest termination occurred after day 25 of incubation, we conducted brood surveys to determine nest fate, brood survival, and evaluate habitats used by brooding females (Streich et al. 2015, Wood et al. 2018). We conducted brood surveys the day after hatch and every 3-5 days after until day 28 post-hatch. During a brood survey, we located the female via homing and attempted to determine the presence of poults. We defined nests as successful if ≥1 poult was detected during at least one brood survey (Chamberlain et al. 2018). We did not attempt to classify predated nests according to predator type, as multiple predators can contribute to a single nest loss event (Dreibelbis et al. 2008). Broods were considered successful if ≥1 poult was detected on day 28 post-hatch. We defined nesting rate as the proportion of females alive at the beginning of the nesting season (March 1) that attempted a first nest, and renest rate as the proportion of females available for a renesting attempt (i.e. not brooding or dead) who nested a second or third time (Everett et al. 1980). We defined female success as a female successfully hatching a nest during the nesting season, regardless of the number of nesting attempts (Melton et al. 2011).

In 2017-2018, we measured vegetative characteristics at nest sites within approximately 1 week of the predicted (for failed nests) or actual (for successful nests) hatch date using methods described in Streich et al. (2015) and Yeldell et al. (2017). All measurements were taken at the nest site and at an associated random site located < 200-m from the nest site. We determined tree density by counting all trees >10.1 cm diameter at breast height (DBH) within a 15-m radius from the nest bowl. We measured percent canopy cover at the nest bowl and 15 m in each cardinal direction using a convex spherical densiometer (Lemmon 1956). We then averaged these 5 readings to provide a single value. We measured percent understory ground cover using a 1-m^2 Daubenmire frame centered on the nest bowl and at locations 15-m from the nest bowl in 4 cardinal directions. At each location, we estimated percent of ground within the quadrat obstructed by vegetation. To evaluate height of understory vegetation and quantify visual obstruction, we used a 2-m Robel pole placed in the nest bowl and took readings from 15-m in each cardinal direction (Robel et al. 1970). We measured visual obstruction as the lowest point on the pole where the pole was completely obstructed by vegetation, when viewing from a height of 1-m above the ground, and estimated average and maximum height of understory vegetation along our line of sight. We averaged Robel pole readings to estimate mean vegetation height and visual obstruction.

We used the nest survival approach in program MARK (White and Burnham 1999) to estimate daily nest survival. We modeled nest survival as a function of 6 nest and female-specific covariates: year, zone, days since March 15, nest site vegetative characteristics, roost site to nest site distance the day of nest initiation, and total distance traveled by each female during the laying period and area used by the female during incubation (incubation range, Conley et al. 2015). We did not attempt to interpret any site-specific models as our nesting females were found across a wide array of private lands under different management strategies. We hypothesized that nest survival would vary by year based on a variety of intrinsic temporal factors including weather (Roberts and Porter 1998, Schwertner et al. 2007), predator populations (Baker 1978, Schwertner et al. 2004), and the availability, density, and height of vegetative cover (Cook 1972, Fuller et al. 2013). Similarly, we hypothesized that nests occurring later in the season (days since March 15) would see decreased daily nest survival rates, due to potential predator search image calibration (Pietrewicz and Kamil 1979, Curio 2012). As roosting habitats in our study area were typically limited to riparian corridors used as travel corridors for a variety of avian and mammalian predators (Vander Haegen and Degraaf 1996, Hilty and Merenlender 2004), we hypothesized that nest survival would increase with increasing distance from the roost location, and for our analysis we used the last roost location for the morning before incubation began. We estimated daily distances moved during the laying period by summing distances between successive hourly locations for each day females were known to be laying via observation of GPS locations (Yeldell et al. 2017, Wood et al. 2018, Chamberlain et al. 2018). We hypothesized that greater female movements would be positively correlated with nest survival in that females may avoid areas immediately surrounding nest locations during laying, thereby reducing potential nest exposure to predators. Finally, we examined the potential effect of female recess movements on nest survival using the size of the 99% utilization distribution (UD) area for each nesting attempt. We used a dynamic Brownian Bridge movement model (hereafter, dBBMM) to build the incubation period utilization distributions (UD) for each female during incubation (Byrne et al. 2014). We calculated all UDs (Kranstauber et al. 2018) in R (v. 3.2.5, R, Core Development Team 2018) with R package move (Kranstauber and Smolla 2013) using a window and margin size equal to 7 and 3 respectively, and a location error of 20 m (Byrne et al. 2014). We kept window and margin size constant to account for changes in GPS sampling frequency because we failed to see any measurable effects of altering these values when we began our analysis (Cohen et al. 2018). We hypothesized that smaller female incubation ranges would be negatively correlated with daily nest survival, as smaller ranges would be associated with females recessing near nest sites and potentially increasing detectability by predators (Bakner 2019).

2.2 Results

We captured and monitored 138 females over the 3 year study; 51 in the 4-bird zone and 87 in the 1-bird zone. We censored 14 individuals (8 in the 4-bird zone and 6 in the 1-bird zone) from our analysis due to capture myopathy (3%; *n* = 5) or GPS backpack malfunctions (6%; *n* = 9). We monitored 131 nesting attempts; 27% (*n* = 35) in the 4-bird zone and 73% (*n* = 96) in the

1-bird zone. We censored 1 nesting attempt in 2017 in the 1-bird zone as we were unable to accurately monitor nest activities due to GPS backpack failure.

Mean onset of incubation across all years was 16 April, with a mean hatch date of 14 May. Dates of nest incubation ranged from 21 March to 17 July, with hatch dates ranging from 18 April to 14 August (Table 2.1). Mean onset of renesting attempts was 22 May (range 22 April to 24 June), with a mean hatch date of 19 June (range 20 May to 22 July; Table 2.1). Average nest and renesting incubation dates were similar between the 1-bird and 4-bird zones (Table 2.2) and peak incubation occurred in mid to late April (Figure 2.2).

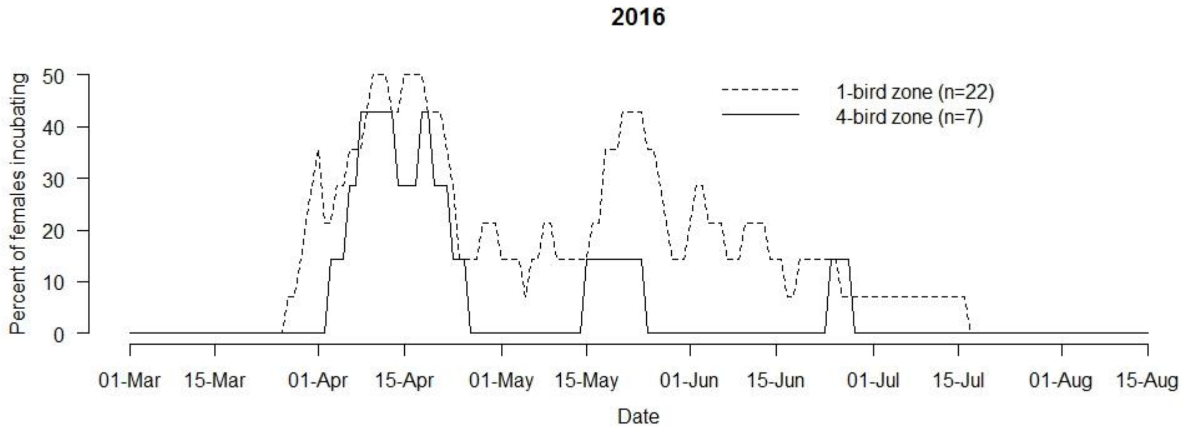
Mortality rate was 23% (19/81) of tagged females in the 1-bird zone and 32% (14/43) of tagged females in the 4-bird zone during the breeding season (1 March-14 Aug). Nesting rates were higher in the 1-bird zone (74%) than the 4-bird zone (63%), as were renesting rates (49% and 25%, respectively). However, both nest success (2% and 18%) and female success rates (3% and 15%; Table 2.3) were lower in the 1-bird zone than the 4-bird zone, respectively (nest success: $\chi^2 = 19.764$, df = 5, $p < 0.01$, female success, $\chi^2 = 21.589$, df = 5, $p < 0.01$). Overall, 92% of nesting attempts failed and all but 1 nest showed signs of predation. Average number of days spent incubating was 14 in the 4-bird zone and 9 in the 1-bird zone. Fifty percent of nest failures occurred by the 7th day of incubation in the 1-bird zone and 10th day of incubation in the 4-bird zone (Figure 2.3). On average, females moved a total of 40.5 km (SD = 13.4, Range = 18 – 85) during the laying period. Females roosted an average of 712 m (SD = 490.7, Range = 62 – 2659) away from the nest site on the night before incubation began. Average incubation range size was 6.2 ha (SD = 16.1, Range = 0.21 – 108).

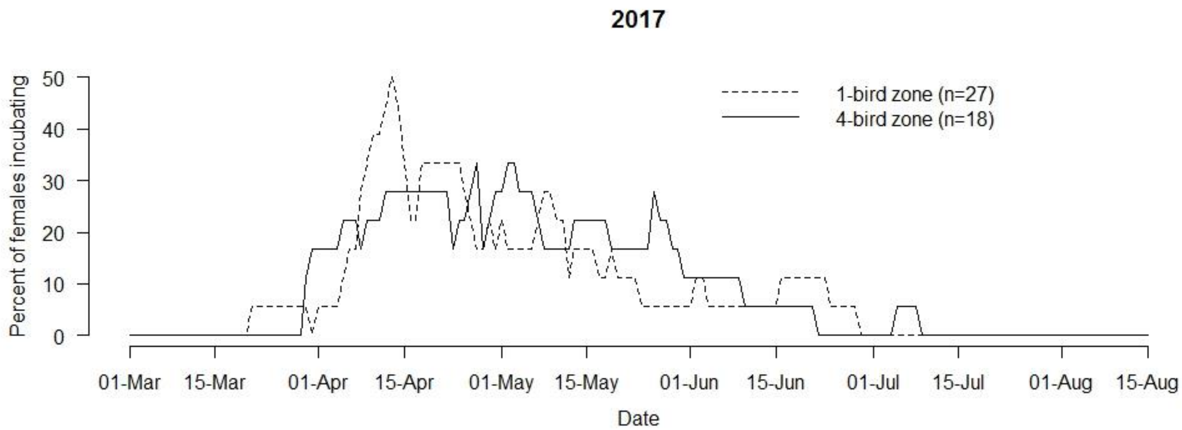
Table 2.1. Range and mean values of nest and renesting initiation, incubation initiation, and hatch dates by year for female Rio Grande wild turkeys in south-central Texas, 2016-2018.

		Initiation		**Incubation initiation**		**Hatch**	
Attempt	Year	Range	Mean	Range	Mean	Range	Mean
Nest	2016	10 Mar-9 May	31 Mar	27 Mar-18 May	12 Apr	24 Apr-15 Jun	10 May
	2017	5 Mar-11 Jun	6 Apr	21 Mar-19 Jun	17 Apr	18 Apr-17 Jul	15 May
	2018	13 Mar-6 Jul	7 Apr	25 Mar-17 Jul	19 Apr	22 Apr-14 Aug	17 May
Renest	2016	16 Apr-9 Jun	14 May	28 Apr-24 Jun	26 May	26 May-22 Jul	23 Jun
	2017	19 Apr-27 Jun	11 May	30 Apr-16 Jun	21 May	28 May-14 Jul	18 Jun
	2018	13 Apr-11 Jun	12 May	22 Apr-16 Jun	21 May	20 May-14 Jul	18 Jun

Table 2.2. Range and mean values of nest and renesting initiation, incubation initiation, and expected hatch dates by zone for Rio Grande wild turkeys in south-central Texas, 2016-2018.

		Initiation		**Incubation initiation**		**Hatch**	
Attempt	Zone	Range	Mean	Range	Mean	Range	Mean
Nest	1-bird	5 Mar-6 Jul	6 Apr	21 Mar-17 Jul	18 Apr	18 Apr-14 Aug	16 May
	4-bird	13 Mar-16 May	3 Apr	25 Mar-26 May	14 Apr	22 Apr-23 Jun	12 May
Renest	1-bird	13 Apr-11 Jun	12 May	22 Apr-16 Jun	22 May	20 May-17 Jul	19 Jun
	4-bird	22 Apr-27 Jun	14 May	30 Apr-24 Jun	27 May	28 May-22 Jul	24 Jun





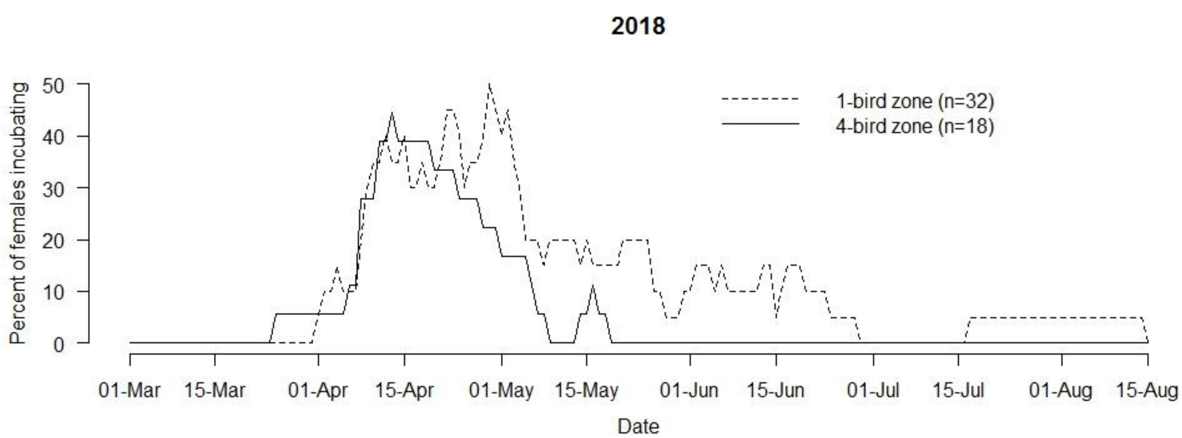


Figure 2.2. Daily percentage of female Rio Grande wild turkeys incubating nests from 1 March to 15 August in the 1-bird and 4-bird zones in south-central Texas, 2016-2018. Spring hunting season dates are Mar 21-May 3 for the 4-bird zone and April 1-30 for the 1-bird zone.

Table 2.3. Demographic parameters (% (n)) for Rio Grande turkeys in south-central Texas, 2016-2018.

Demographic Parameter	Site	Year			Combined
		2016	2017	2018	
Nest Rate	4-Bird	57 (7)	72 (18)	61 (18)	63%
	1-Bird	64 (22)	78 (27)	81 (32)	74%
Renest Rate	4-Bird	25 (4)	36 (11)	14 (7)	25%
	1-Bird	71 (14)	37 (19)	39 (23)	49%
Nest Success	4-Bird	0 (6)	29 (17)	25 (12)	18%
	1-Bird	4 (25)	0 (30)	3 (40)	2%
Hen success	4-Bird	0 (7)	28 (18)	17 (18)	15%
	1-Bird	5 (22)	0 (27)	3 (32)	3%

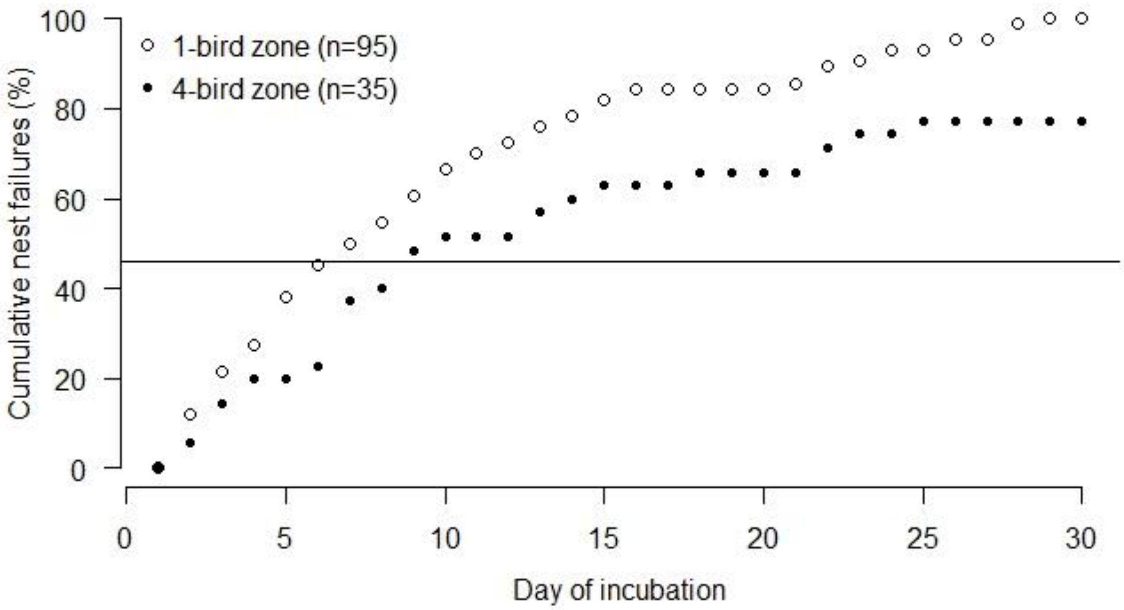


Figure 2.3. Cumulative percentage of nest failures of female Rio Grande wild turkeys over the incubation period in the 1-bird (open dots) and 4-bird (black dots) zones in south-central Texas, 2016-2018. Line denotes 50% cumulative nest failure.

Our daily nest survival analysis indicated that the most parsimonious model was one where daily nest survival varied between zones (AIC_c = 823.76, *w* = 0.44; Table 2.4) with the 1-bird zone having a lower (0.90, SE = 0.009, CI = 0.88-0.92) daily survival estimate than the 4-bird zone (0.94, SE = 0.01, CI = 0.92-0.96). Estimated nest survival for the incubation period was 0.06 and 0.21 for the 1-bird and 4-bird zones, respectively, which was similar to our naïve estimates of nest success (0.02 and 0.18, respectively). We found no evidence (ΔAIC_c >5) that vegetative characteristics at nest sites influenced nest survival (Tables 2.5 and 2.6).

Table 2.4. Candidate models used to estimate daily survival of Rio Grande wild turkey nests in south-central Texas, USA, during 2016-2018.

Model notation	k	Deviance	ΔAIC_c	w_i
S (Constant over time, different between bag limit zones)	2	819.75	0	0.44
S (Varies by number of days since 15 March)	2	821.79	2.03	0.16
S (Varied roost distance to nest)	2	821.87	2.11	0.15
S (Constant over time, differs by bag limit zones and years)	6	814.17	2.46	0.12
S (Maximum vegetation height at nest site)	2	824.93	5.17	0.03
S (Constant)	1	827.45	5.69	0.02
S (Percentage of ground cover at nest site)	2	826.19	6.43	0.01
S (Actual hectares)	2	826.59	6.83	0.01
S (Daily distance moved during the laying period)	2	827.11	7.36	0.01
S (Percentage of canopy cover at the nest site)	2	827.41	7.65	<0.01
S (Constant over time, but different between years)	3	827.42	9.67	<0.01

Table 2.5. Mean and standard deviation values for vegetation measurements collected at hatched nests, failed nests, and associated random sites in south-central Texas, 2017-2018. Measurements include maximum (max), average (avg), and visual obstruction height (vo), canopy cover, trees per hectare (tph), and ground cover (gc).

		Nest		Random	
Fate	Variable	Mean	SD	Mean	SD
Hatch	max (cm)	164.7	37.8	131.8	52.4
	avg (cm)	103.1	40.9	76.7	34.6
	vo (cm)	78.6	35.8	52.6	27.5
	Canopy (%)	25.7	17.9	20.8	26.7
	tph	5.7	6.4	4.7	7.2
	gc (%)	17.1	16.5	23.9	26.6
Fail	max (cm)	156.1	49.8	120.0	65.9
	avg (cm)	104.1	44.1	75.7	51.3
	vo (cm)	70.8	36.9	51.0	42.7
	canopy (%)	26.3	22.9	21.4	24.3
	tph	5.7	10.0	4.6	7.1
	gc (%)	25.9	27.1	28.4	23.7

Table 2.6. Mean and standard deviation values for vegetation measurements on nests and associated random sites in the 4-bird and 1-bird zones in south-central Texas, 2017-2018. Measurements include maximum (max), average (avg), and visual obstruction height (vo), canopy cover, trees per hectare (tph), and ground cover (gc).

		Nest		Random	
Zone	Variable	Mean	SD	Mean	SD
4-bird	max (cm)	164.2	41.3	157.1	51.8
	avg (cm)	109.9	41.0	99.6	43.8
	vo (cm)	75.9	34.8	60.8	45.0
	canopy (%)	29.8	20.8	28.7	26.6
	tph	8.0	13.4	6.7	8.9
	gc (%)	20.9	30.3	20.8	19.2
1-bird	max (cm)	153.5	51.8	103.3	63.0
	avg (cm)	101.1	44.8	63.9	48.3
	vo (cm)	69.6	37.7	46.4	38.6
	canopy (%)	24.5	23.0	17.6	22.6
	tph	4.5	6.9	3.5	5.7
	gc (%)	27.0	24.0	31.5	25.3

2.3 Discussion

Our data suggest that reproductive parameters for Rio Grande wild turkeys are different between the 1-bird and 4-bird regulatory zones in D7. Our results indicate that nesting rates were higher in the 1-bird zone, but we found lower overall potential for production as daily nest survival and nest success, hen success, and average number of days incubating were all lower in the 1-bird than 4-bird zone. Nest success in the 1-bird zone was markedly lower than most other published studies on Rio Grande wild turkeys (39%, Cook 1972; 29%, Phillips 2004; 35%, Randel et al. 2005) whereas nest success in the 4-bird zone was similar to regions with stable turkey subpopulations in the Edwards Plateau region of Texas (19%; Melton et al. 2011) and south Texas (21%; Locke et al. 2013). We note that estimates of nest success in a declining population detailed by Melton et al. (2011) were higher (12%) than our observed estimates in the 1-bird zone of D7 (2%).

Nest predation was the primary cause of nest failure in our study, as all failed nests in our study showed signs of predation, which is substantially higher than the 57-69% predation rates reported in Dreibelbis et al. (2008). Dreibelbis et al. (2008) estimated an 18% abandonment rate, but we note that Dreibelbis et al. (2008) used VHF telemetry to assess nesting behavior/success, which often results in inadvertent disturbance to nesting females. By using GPS, we did not have to disturb nest sites at any point during the incubation period, and we did not document any cases of nest abandonment caused by observer influence. Furthermore, although previous studies have attempted to link vegetative characteristics at the nest site to nest survival, often producing contradictory results (Schmutz et al. 1989, Seiss et al. 1990, Badyaev 1995, Wallace 2001, Randel et al. 2005, Fuller et al. 2013), vegetative conditions at the nest site had little importance for predicting daily nest survival relative to zone and behavioral parameters.

Turkey populations existing in agricultural landscapes often have lower nest success (Vangilder et al. 1987, Vander Haegen et al. 1988, Paisley et al. 1998, Fuller et al. 2013). Roberts et al. (1995) theorized for turkeys in northern latitudes that agricultural landscapes may improve adult winter survival, but may also suppress spring recruitment if agriculture reduces the amount of suitable nesting habitat and impacts nest predation rates. Our results support this view, as the 1-bird zone, which was characterized by smaller property sizes, more row-crop agriculture, less open rangeland, and less area classified as rural, showed reduced nest success and survival when compared to the 4-bird zone. Rio Grande wild turkeys are known to select for vegetative conditions wherein woody substrates are interspersed with open herbaceous vegetation (Ransom Jr et al. 1987, Randel et al. 2005, Locke et al. 2013). One would expect increased rates of nest loss in fragmented environments (Burger et al. 1994, Robinson et al. 1995, Chalfoun et al. 2002, Fischer and Lindenmayer 2007), as nest predators are typically more abundant in fragmented landscapes and often select for vegetative edges (Oehler and Litvaitis 1996). Locke et al. (2013) suggested that female wild turkeys selected areas with high edge-to-area ratios and significant levels of vegetative heterogeneity and avoided areas without vegetative edges. As nest predators are both sight and scent based, increased environmental edge-to-area ratios may reduce the efficacy of nest predator searching. Thus, as linear edges are frequent in agriculturally dominated environments, our results suggest that the reduced reproductive potential in the 1-bird zone may be due to current land use practices.

CHAPTER 3. BREEDING SEASON SURVIVAL OF FEMALE RIO GRANDE WILD TURKEYS IN SOUTH CENTRAL TEXAS

Harvest regulations use estimates of population abundance in a regulatory area to define allowable take (Fafarman and DeYoung 1986, Heusmann and Sauer 2000, Seamans et al. 2012). Wild turkey harvest regulations, however, have historically been set based on indices of abundance (Menzel 1975, Welsh and Kimmel 1990, Lint et al. 1995, Schwertner et al. 2003, Butler et al. 2007), estimates of suitable habitat (Goetz and Porter 2005), or population model-based estimates of abundance (Clawson 2015). However, all of these metrics represent indices of abundance which are typically poor predictors of true population state (Anderson 2001, Anderson 2003), and estimates of wild turkey abundance are not available at management or statewide scales (Butler 2006, Butler et al. 2007). In the absence of estimates of population size, managers often base decisions using demographic data on population parameters (Roberts and Porter 1996) as demographic estimates offer a glimpse of the underlying drivers of population trajectory, and thus can be used to inform regulatory decisions.

Wild turkey population trajectory is driven primarily via recruitment (Roberts and Porter 1996), which in turn is partially dependent upon adult female survival (Suchy et al. 1983, Vangilder and Kurzejeski 1995) as female loss impacts both immediate and long-term reproductive potential. Female mortality is typically highest during the breeding season (Everett et al. 1980, Speake 1980, Little et al. 1990) due to reproductive activities such as incubation and brooding (Palmer et al. 1993b), which require females to remain on the ground at night when terrestrial predators are most active (Andelt 1985, Bradley and Fagre 1988). As such, wild turkey female mortality during the breeding season can impact population trajectory even when production parameters such as nest success and poult survival are stable (Collier et al. 2009).

Since the late 1970s, Rio Grande wild turkeys have exhibited various population trends in Texas (Reagan and Morgan 1980, Ransom Jr et al. 1987, Beasom and Wilson 1992, Smith-Blair 1993, Collier et al. 2007, 2009, Conley et al. 2015, 2016) with harvest focused on the widely distributed and relatively stable Rio Grande wild turkeys in the central and western regions of the state (Figure 3.1). In the Oak-Prairie Wildlife District (Texas Parks and Wildlife–Wildlife Division District 7, hereafter D7) regulatory restrictions have differed between counties in the eastern and western portions of D7. These restrictions are typically set based on historic monitoring of production and harvest indices (J. Hardin, Texas Parks and Wildlife, unpublished data). Counties in the eastern portion of D7 fall within the Special 1-Male regulatory zone, where there is no fall season and spring season harvest is limited to one male per country during a 1 April – 30 April season. Counties in the western portion of D7 fall within the South regulatory zone, where the legal harvest is 4 per year (male and bearded females in spring, either sex in fall, no fall season in Dewitt, Guadalupe, or Victoria counties). Recently, due to perceived increases in turkey density in the eastern portion of D7, Texas Parks and Wildlife Department (TPWD) considered liberalizing the spring season in the Special 1-Male zone to increase hunting opportunities.

If regulatory changes are to be considered in the absence of annual estimates of abundance and harvest rate, then estimates of demographic parameters will provide the basis for regulatory decision-making (Roberts and Porter 1996). As wild turkey population trajectories are driven by annual production and adult female survival (Vangilder and Kurzejeski 1995, Roberts and Porter 1996, Pollentier et al. 2014), variation in these parameters impacts population stability (Pianka 1970, Roberts et al. 1995). White et al. (2019) reported reproductive output and nest survival were lower in the 1-bird zone versus the 4-bird zone of our study region. However, as female breeding season survival could potentially mitigate against low reproductive output (Collier et al. 2009), our objectives were to 1) evaluate female breeding season survival in counties under 1-bird and 4-bird harvest restrictions to determine if biologically relevant differences existed between the two zones and 2) determine if female survival was influenced by behavioral or environmental characteristics.

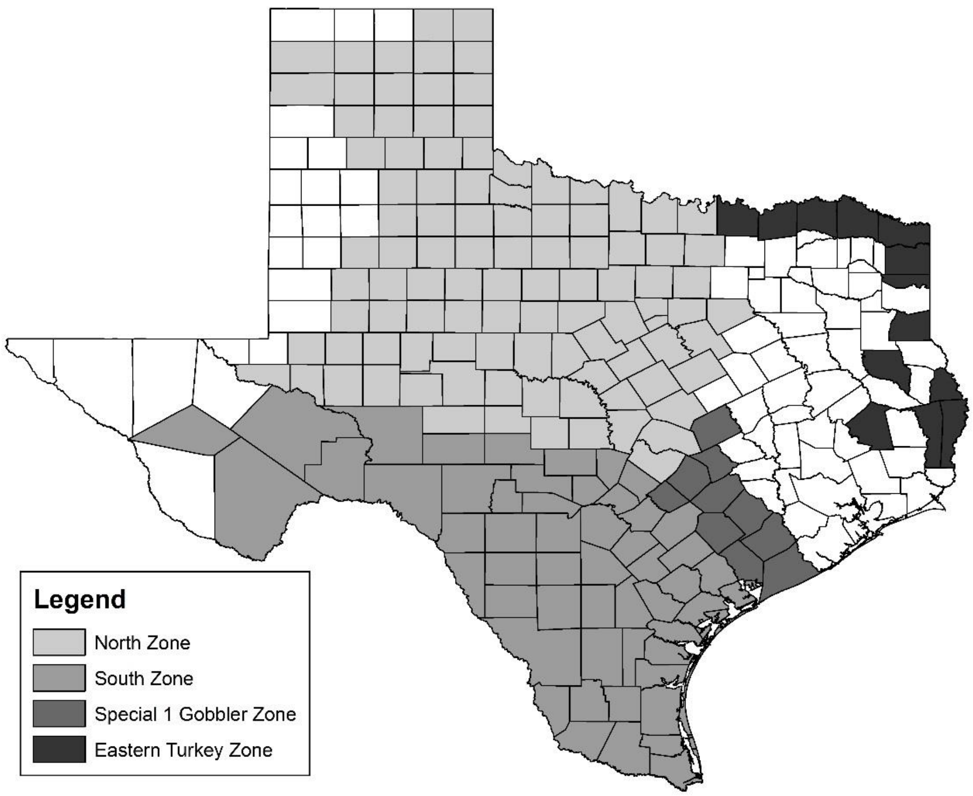


Figure 3.1. Spring turkey season regulatory zones in Texas. Season dates vary by zone. The annual bag limit for turkey, in the aggregate for all counties, if four, no more than one of which may be an Eastern turkey or a Rio Grande turkey harvested in the Special 1 Gobbler Zone counties

3.1 Methods

We captured female Rio Grande wild turkeys across our study region from January through March 2016-2018 using drop-nets (Glazener et al. 1964) and walk-in traps (Davis 1994, Peterson et al. 2003) baited with cracked corn or milo. Individuals were fitted with a uniquely identifiable aluminum rivet leg band labeled with a TPWD phone number and address (National Band and Tag Company, Newport, Kentucky) and a GPS-VHF backpack transmitter unit (Biotrack Limited, Wareham, Dorset, UK; Guthrie et al. 2011). Units were programmed to record 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 immediately released turkeys at the capture location following processing. We monitored live-dead status ≥2 times per week from capture to August (monthly from August–December) during 2016-2018 using a Biotracker receiver (Biotrack Ltd., Wareham, Dorset, UK) and handheld Yagi antennas. We downloaded GPS information ≥2 times per month via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, UK). We derived dates of nest incubation and mortality for females from VHF tracking and spatio-temporal GPS locational data (Guthrie et al. 2011, Conley et al. 2015, Yeldell et al. 2017). Nesting females were not disturbed or flushed from nest sites during monitoring but were live-dead checked via VHF from a distance of >20m. We defined the date of nest incubation initiation as the first day the nightly roost location was recorded on the nest site, indicating the female continued incubating the nest during the night. Our capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permit A2015-07).

We used a nest survival approach in program MARK (White and Burnham 1999) to estimate daily survival (Collier et al. 2009). We coded our encounter histories for each female in the dataset using a 167-day period (Mar. 1-Aug. 14) encompassing the entire breeding period. We modeled survival based on site and female-specific covariates including year, regulatory zone, incubation status (active/inactive), cumulative days spent incubating, daily distance moved, and observed daily precipitation. We hypothesized that survival would vary annually based on a variety of intrinsic temporal factors including weather (Roberts and Porter 1998, Schwertner et al. 2007) and predator populations (Baker 1978, Schwertner et al. 2004). We hypothesized that daily survival would decrease when hens were actively incubating, as this places them at increased risk of predation (Little et al. 1990). We hypothesized that daily survival would decrease with increasing nest attempts and cumulative days spent incubating due to depleted energy reserves and potential predator search image calibration (Pietrewicz and Kamil 1979, Curio 2012). We estimated daily distances moved by summing distances between successive hourly locations between 0500 and 2000 daily following Bakner (2019) and we hypothesized that survival would be higher for longer daily distances moved. Daily precipitation values were obtained from National Oceanic and Atmospheric Administration weather stations within 26km of each location. We hypothesized that daily survival would decrease with increasing local precipitation, as previous studies have suggested that precipitation may impact population productivity (Roberts et al. 1995). However, due to convergence concerns based on limited events (mortalities) on the daily time scale when considering time-dependent covariate models, we used trend models (Franklin 2001) that assumed the effect of temporal covariates is constant across time.

3.2 Results

We captured and monitored breeding season survival for 138 females over the 3-year study; 51 in the 4-bird zone and 87 in the 1-bird zone. We censored 14 individuals (8 in the 4-bird zone and 6 in the 1-bird zone) from analysis due to capture myopathy (3%; n = 5) or GPS backpack malfunctions (6%; n = 9). We monitored 131 nesting attempts; 27% (n = 35) in the 4-bird zone and 73% (n = 96) in the 1-bird zone. We censored 1 nesting attempt in 2017 in the 1-

bird zone as we were unable to accurately monitor nest activities due to GPS backpack failure. Breeding season (1 March-14 Aug) naïve mortality rate was 23% (19/81) of tagged females in the 1-bird zone and 32% (14/43) of tagged females in the 4-bird zone. Nesting rates were higher in the 1-bird zone (74%) than the 4-bird zone (63%), as were renesting rates (49% and 25%, respectively). Average daily precipitation was 0.10 inches/day (SD = 0.38, range 0 – 11.5 inches/day) and average daily distance moved was 2,471 m (SD = 1,346, range 10 –11,300 m). The best approximating candidate model indicated that female survival varied according to daily distance moved (Table 3.1). Estimated daily survival based on an average mean daily distance moved (2,471) was 0.998, resulting in a period survival estimate of 81% for the 167-day breeding season. Based on our best fitting model, daily survival showed a biologically significant increase between approximately 1 SD below and above the mean daily movement distance (Figure 3.2).

Table 3.1. Candidate models used to examine daily survival (S) over a 167-day period (Mar. 1-Aug. 14) that encompassed the entire breeding period. We modeled survival based on site and female-specific covariates including year, regulatory zone, incubation status (active/inactive), cumulative days spent incubating, daily distance moved, and observed daily precipitation on daily survival of radio-tagged Rio Grande wild turkey females in the Oak-Prairie Wildlife District of Texas between 2016-2018.

Model notation	No. of parameters	ΔAIC^{a}_{c}	w_i
$S_{\text{[Trend model for daily distance moved (m)]}}$	2	0	0.999
$S_{\text{[Trend model for actively nesting or not actively nesting]}}$	2	26.94	<0.01
$S_{\text{[Constant]}}$	1	27.34	<0.01
$S_{\text{[Trend model for cumulative days spent nesting]}}$	2	27.45	<0.01
$S_{\text{[Constant]-differs by zone}}$	2	27.70	<0.01
$S_{\text{[Trend model for daily precipitation]}}$	2	29.33	<0.01
$S_{\text{[Constant]-differs by year, constant between zones}}$	3	30.16	<0.01
$S_{\text{[Constant]-differs by year and zone}}$	6	32.84	<0.01

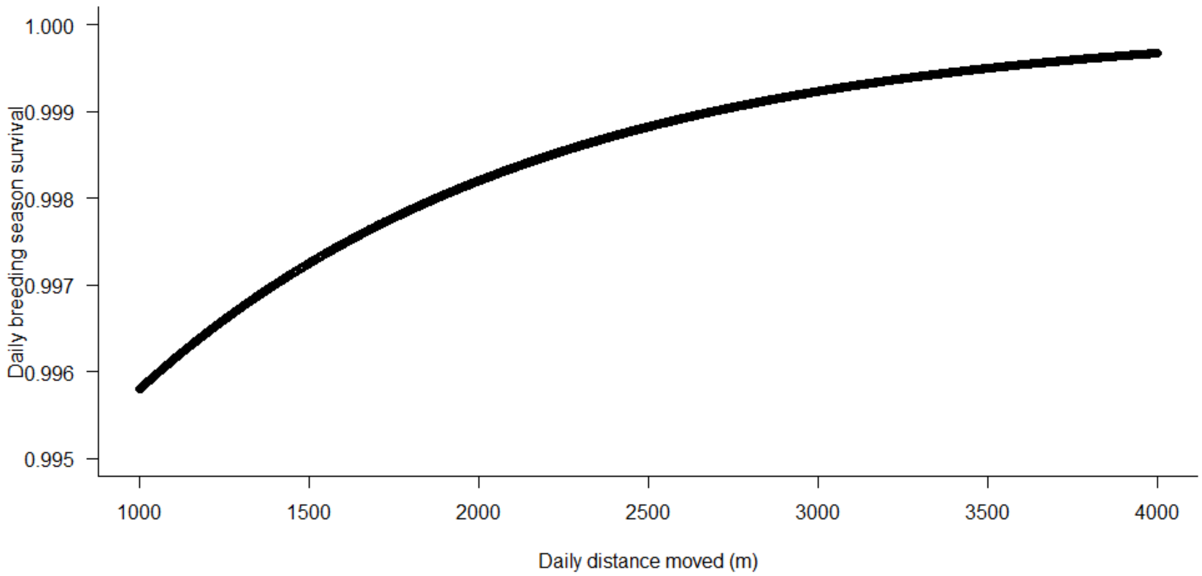


Figure 3.2. Relationship of daily breeding season survival and daily distance moved. Based on the trend model for daily distanced moved, 2016-2018.

3.3 Discussion

Our data suggest that breeding season survival of Rio Grande wild turkey females was not different between the 1-bird and 4-bird regulatory zones in D7. Rather, variation in female survival was best accounted for based on daily distance moved by monitored females across both study regions. Exposure of female and male wild turkeys to potential causes of mortality is highest during the reproductive season, typically tied to nesting activities undertaken by females (Palmer et al. 1993b, Collier et al. 2009). Thus, breeding season survival of females being driven by movement distance is not surprising, as reproductively active females, while nesting, have significantly reduced daily movements (Conley et al. 2015, Bakner 2019) and significantly higher risk of mortality (Speake 1980, Melton et al. 2011, White et al. 2019). However, we note that the model for the effect of nesting status was not competitive for explaining our data. Historically, studies addressing female survival during nesting have not had detailed behavioral information available on how nesting females act (Conley et al. 2015, 2016, Bakner et al. 2019) thus it is plausible that results from previous model sets, in which nesting status was competitive (Collier et al. 2009), consisted of a biased model set.

Typically, both male and female wild turkey survival is high, especially when individuals are less vulnerable to predation when protection is afforded by flocking behaviors occurring in fall and winter (Grzybowski 1983, Palmer et al. 1993a, Wright et al. 1996, Willsey 2004, Collier et al. 2007). Thus, much of the work regarding the impact of movements on Rio Grande wild turkey survival has been tied to dispersal from wintering areas, as roosting congregations during winter are notably common for the species (Thomas et al. 1966, Watts 1969, Logan 1973). However, results have varied as Miller et al. (1995) found no effect of winter dispersal distance on survival of either juvenile or adult Rio Grande wild turkey females. Holdstock et al. (2006) found a similar result in that male survival did not vary relative to long-distance movements, except when harvest was incorporated, which showed that individuals moving to new areas had lower survival. However, only recently have we had the ability to estimate daily movements based on technological advances (Collier and Chamberlain 2011), and as such our results have added specificity to the driver of female breeding season survival. However, reduced movements are likely a general proxy, not causation for mortality of nesting females. Rather, reduced movements during incubation, and associated predation during nesting, is likely the underlying cause of lower breeding season survival. Thus, continued effort to identify the relationship between female activities during nesting and survival remains paramount for long-term management activities to increase female survival during the breeding season.

CHAPTER 4. CONCLUSIONS

Based on these data, we conclude that the production potential of the populations in the 1-bird zone are low as compared to those in the 4-bird zone. While nesting rates were high in this zone, our estimates of nest success, female success, and daily nest survival were low, resulting in reduced reproductive potential. Our estimate of nest success (2%) is markedly lower than most other published studies on the species (Cook 1972, Ransom Jr et al. 1987, Phillips 2004, Randel et al. 2005), and is lower than those recorded in a declining population (Melton et al. 2011). We hypothesize that higher levels of agricultural activity in the 1-bird zone may have reduced the quality or amount of suitable nesting habitat, leading to increased rates of predation.

Our results indicate there is no evidence that high female survival is mitigating against low reproductive output in these areas, as female breeding season survival rates were similar in the 1-bird and 4-bird zones. Our model for daily distance moved was the best approximating model. This may be due to the fact that nesting females, who spend the most time on the ground and thus are most at risk of predation, move little compared to non-nesting individuals. However, our model for nesting status was not supported by the data, which seemingly contradicts this hypothesis. Future work should focus on the relationship between nesting activities and female survival.

Given these results, TPWD should be cautious in lifting harvest restrictions in the 1-bird zone, as the population may not be able to sustain increased hunting pressure without resulting population declines. However, Rio Grande turkeys are noted as a boom-bust species and future conditions could warrant such a change, thus continued study of the population is recommended. Management efforts should be focused on increasing the availability of suitable nesting habitat in the 1-bird zone to decrease predation risk and increase reproductive output of the population.

LIST OF REFERENCES

Andelt, W. F. 1985. Behavioral ecology of coyotes in south Texas. Wildlife Monographs 94:3-45.

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29:1294-1297.

_____. 2003. Response to Engeman: index values rarely constitute reliable information. Wildlife Society Bulletin 31:288-291.

Badyaev, A. V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. The Condor 97:221-232.

Baker, B. W. 1978. Ecological factors affecting wild turkey nest predation on south Texas rangelands. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 32:126–136.

Bakner, N. W. 2019. Evaluation of reproductive phenology and ecology of Eastern Wild Turkeys (Meleagris gallopavo silvestris) across the southeastern United States. Master's Thesis, Louisiana State University, Baton Rouge, USA.

Beasom, S. L., and D. Wilson. 1992. Rio Grande turkey. Pages 306-330 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole, Mechanicsburg, Pennsylvania, USA:306–330.

Bradley, L. C., and D. B. Fagre. 1988. Coyote and bobcat responses to integrated ranch management practices in south Texas. Journal of Range Management 41:322-327.

Burger, L. D., L. W. Burger Jr, and J. Faaborg. 1994. Effects of prairie fragmentation on predation on artificial nests. Journal of Wildlife Management 58:249–254.

Butler, M. J. 2006. Evaluation of survey techniques for Rio Grande wild turkey populations in the Southern Great Plains. Dissertation, Texas Tech University, Lubbock, USA.

Butler, M. J., W. B. Ballard, M. C. Wallace, S. J. Demaso, and B. K. McGee. 2007a. Aerial surveys for estimating wild turkey abundance in the Texas Rolling Plains. Journal of Wildlife Management 71:1639–1645.

Butler, M. J., G. I. Hall, M. C. Wallace, W. B. Ballard, R. S. Phillips, J. Brunjes, R. T. Huffman, R. L. Houchin, J. C. Bullock, and S. J. DeMaso. 2007b. Utility of poult-hen counts to index productivity of Rio Grande wild turkeys. Proceedings of the National Wild Turkey Symposium 9:159–168.

Byrne, M. E., J. D. Guthrie, J. Hardin, B. A. Collier, and M. J. Chamberlain. 2014. Evaluating Wild Turkey Movement Ecology: An Example Using First-Passage Time Analysis. Wildlife Society Bulletin 38:407-413.

Byrne, M., M. Chamberlain, and B. Collier. 2015. Potential density dependence in wild turkey productivity in the southeastern United States. Proceedings of the National Wild Turkey Symposium 11:329-351.

Byrne, M. E., B. A. Collier, and M. J. Chamberlain. 2016. Roosting Behavior of Male Eastern and Rio Grande Wild Turkeys. Proceedings of the National Wild Turkey Symposium 11:175–185.

Cathey, J. C., S. L. Locke, D. Ransom, Jr., S. J. DeMaso, T. W. Schwertner, and B. A. Collier. 2007. Habitat appraisal guide for Rio Grande wild turkeys in Texas. Texas Cooperative Extension Publication SP-317, Pp. 1-24.

Chalfoun, A. D., F. R. Thompson, and M. J. Ratnaswamy. 2002. Nest predators and fragmentation: a review and meta-analysis. Conservation Biology 16:306–318.

Chamberlain, M. J., B. A. Grisham, J. L. Norris, N. J. Stafford III, F. G. Kimmel, and M. W. Olinde. 2012. Effects of variable spring harvest regimes on annual survival and recovery rates of male wild turkeys in southeast Louisiana. Journal of Wildlife Management 76:907–910.

Chamberlain, M. J., P. H. Wightman, B. S. Cohen, and B. A. Collier. 2018. Gobbling activity of Eastern wild turkeys relative to male movements and female nesting phenology in South Carolina. Wildlife Society Bulletin 42:632-642.

Clawson, M. V. 2015. Management application of statistical population reconstruction to wild game populations. Dissertation, University of Washington, Seattle, USA.

Cohen, B. S., T. J. Prebyl, B. A. Collier, and M. J. Chamberlain. 2018. Home range estimator method and GPS sampling schedule affect habitat selection inferences for wild turkeys. Wildlife Society Bulletin 42:150–159.

Collier, B. A., D. A. Jones, J. N. Schaap, C. J. Randel, B. J. Willsey, R. Aguirre, T. W. Schwertner, N. J. Silvy, and M. J. Peterson. 2007. Survival of Rio Grande wild turkeys on the Edwards Plateau of Texas. Journal of Wildlife Management 71:82–86.

Collier, B., and M. Chamberlain. 2011. Redirecting research for wild turkeys using global positioning system transmitters. Proceedings of the National Wild Turkey Symposium 10:81-92.

Collier, B. A., K. B. Melton, J. B. Hardin, N. J. Silvy, and M. J. Peterson. 2009. Impact of reproductive effort on survival of Rio Grande wild turkey Meleagris gallopavo intermedia hens in Texas. Wildlife Biology 15:370–379.

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

Conley, M. D., N. A. Yeldell, M. J. Chamberlain, and B. A. Collier. 2016. Do movement behaviors identify reproductive habitat sampling for wild turkeys? Ecology and Evolution 6: 7103-7112.

Cook, R. L. 1972. A study of nesting turkeys in the Edwards Plateau of Texas. Proceedings of the Southeastern Association of Game and Fish Commissioners 26:236–244.

Curio, E. 2012. The ethology of predation. Volume 7. Springer Science & Business Media.

Davis, B. D. 1994. A funnel trap for Rio Grande turkey. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:109–116.

Dreibelbis, J. Z., K. B. Melton, R. Aguirre, B. A. Collier, J. Hardin, N. J. Silvy, and M. J. Peterson. 2008. Predation of Rio Grande wild turkey nests on the Edwards Plateau, Texas. The Wilson Journal of Ornithology 120:906–910.

Everett, D. D., D. W. Speake, and W. K. Maddox. 1980. Natality and mortality of a north Alabama wild turkey population. Proceedings of the National Wild Turkey Symposium 4:117–126.

Fafarman, K. R., and C. A. DeYoung. 1986. Evaluation of spotlight counts of deer in south Texas. Wildlife Society Bulletin 14:180-185.

Fischer, J., and D. B. Lindenmayer. 2007. Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography 16:265–280.

Franklin, A.B. 2001. Exploring ecological relationships in survival and estimating rates of population change using program MARK. Pages 350-356 *in* Fields, R., R. J. Warren, H. Okarma, and P. R. Sievert, editors. Wildlife, Land, and People: Priorities for the 21st century. The Wildlife Society, Bethesda, Maryland.

Fuller, A. K., S. M. Spohr, D. J. Harrison, and F. A. Servello. 2013. Nest survival of wild turkeys Meleagris gallopavo silvestris in a mixed-use landscape: influences at nest-site and patch scales. Wildlife Biology 19:138–146.

Giuliano, W. M., L. N. Watine, J. M. Olson, M. Blake, and H. Ober. 2016. Florida turkey nest site selection and success. Natural Resources 7:644–654.

Glazener, W., A. Jackson, and M. Cox. 1964. The Texas drop-net turkey trap. Journal of Wildlife Management 28:280–287.

Goetz, S., and W. Porter. 2005. Statewide assessment of wild turkey habitat using satellite imagery in Arkansas. Proceedings of the National Wild Turkey Symposium 9:189-198.

Gould, F., G. Hoffman, and C. Rechenthin. 2011. Gould ecoregions of Texas. Vegetational Areas of Texas, Leaflet No 492.

Grzybowski, J. A. 1983. Sociality of grassland birds during winter. Behavioral Ecology and Sociobiology 13:211-219.

Guthery, F. S., L. A. Brennan, M. J. Peterson, and J. J. Lusk. 2005. Information theory in wildlife science: critique and viewpoint. Journal of Wildlife Management 69:457–465.

Guthrie, J. D., M. E. Byrne, J. B. Hardin, C. O. Kochanny, K. L. Skow, R. T. Snelgrove, M. J. Butler, M. J. Peterson, M. J. Chamberlain, and B. A. Collier. 2011. Evaluation of a global positioning system backpack transmitter for wild turkey research. Journal of Wildlife Management 75:539–547.

Healy, W., and E. Nenno. 1985. Effect of weather on wild turkey poult survival. Proceedings of the National Wild Turkey Symposium 5:91–101.

Heusmann, H., and J. R. Sauer. 2000. The northeastern states' waterfowl breeding population survey. Wildlife Society Bulletin 28:355-364.

Hilty, J. A., and A. M. Merenlender. 2004. Use of riparian corridors and vineyards by mammalian predators in northern California. Conservation Biology 18:126–135.

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

Kranstauber, B., M. Smolla, and A. Scharf. 2013. Move: visualizing and analyzing animal track data. R package version 1:r365.

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

Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2:314–320.

Lint, J. R., B. D. Leopold, and G. A. Hurst. 1995. Comparison of abundance indexes and population estimates for wild turkey gobblers. Wildlife Society Bulletin 23:164–168.

Little, T. W., J. M. Kienzler, and G. A. Hanson. 1990. Effects of fall either-sex hunting on survival in an Iowa wild turkey population. Proceedings of the National Wild Turkey Symposium 6:119-125.

Locke, S. L., J. Hardin, K. Skow, M. J. Peterson, N. J. Silvy, and B. A. Collier. 2013. Nest site fidelity and dispersal of Rio Grande wild turkey hens in Texas. Journal of Wildlife Management 77:207–211.

Logan, T. H. 1973. Seasonal behavior of Rio Grande wild turkeys in western Oklahoma. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 27:74-91.

McMahan, C. A., R. G. Frye, and K. L. Brown. 1984. The vegetation types of Texas. Texas Parks and Wildlife Department, Austin, Texas, USA.

Melton, K., J. Dreibelbis, R. Aguirre, J. Hardin, N. Silvy, M. Peterson, and B. Collier. 2011. Reproductive parameters of Rio Grande wild turkeys on the Edwards Plateau, Texas. Proceedings of the National Wild Turkey Symposium 10:227–233.

Menzel, K. 1975. Population and harvest data for Merrian's turkeys in Nebraska. Proceedings of the National Wild Turkey Symposium 3:184–188.

Miller, M. S., D. J. Buford, and R. S. Lutz. 1995. Survival of female Rio Grande turkeys during the reproductive season. Journal of Wildlife Management 59:766-771.

Oehler, J. D., and J. A. Litvaitis. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology 74:2070–2079.

Paisley, R. N., R. G. Wright, J. F. Kubisiak, and R. E. Rolley. 1998. Reproductive ecology of eastern wild turkeys in southwestern Wisconsin. Journal of Wildlife Management 62:911–916.

Palmer, W. E., G. A. Hurst, J. E. Stys, D. R. Smith, and J. D. Burk. 1993a. Survival rates of wild turkey hens in loblolly pine plantations in Mississippi. The Journal of wildlife management 57:783-789.

Palmer, W., S. R. Priest, R. Seiss, P. Phalen, and G. Hurst. 1993b. Reproductive effort and success in a declining wild turkey population. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 47:138–147.

Peterson, M. N., R. Aguirre, T. A. Lawyer, D. A. Jones, J. N. Schaap, M. J. Peterson, and N. J. Silvy. 2003. Animal welfare-based modification of the Rio Grande wild turkey funnel trap. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 57:208–212.

Phillips, R. S. 2004. Movements, survival, and reproduction of Rio Grande wild turkeys in the Texas Panhandle. Thesis, Texas Tech University, Lubbock, USA.

Pianka, E. R. 1970. On r-and K-selection. The American Naturalist 104:592–597.

Pietrewicz, A. T., and A. C. Kamil. 1979. Search image formation in the blue jay (Cyanocitta cristata). Science 204:1332–1333.

Pollentier, C. D., S. D. Hull, and R. S. Lutz. 2014. Eastern wild turkey demography: Sensitivity of vital rates between landscapes. Journal of Wildlife Management 78:1372–1382.

Randel, C. J., R. Aguirre, D. A. Jones, J. N. Schaap, B. J. Willsey, M. J. Peterson, and N. J. Silvy. 2005. Nesting ecology of Rio Grande wild turkey in the Edwards Plateau of Texas. Proceedings of the National Wild Turkey Symposium 9:237–243.

Ransom Jr, D., O. J. Rongstad, and D. H. Rusch. 1987. Nesting ecology of Rio Grande turkeys. Journal of Wildlife Management 51:435–439.

Reagan, J., and K. Morgan. 1980. Reproductive potential of Rio Grande turkey hens in the Edwards Plateau of Texas. Proceedings of the National Wild Turkey Symposium 4:136–144.

Robel, R., J. Briggs, A. Dayton, and L. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Roberts, S., and W. Porter. 1996. Importance of demographic parameters to annual changes in wild turkey abundance. Proceedings of the National Wild Turkey Symposium 7:15–20.

Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of female wild turkeys in New York. Journal of Wildlife Management 59:437–447.

Roberts, S. D., and W. F. Porter. 1998. Relation between weather and survival of wild turkey nests. Journal of Wildlife Management 62:1492–1498.

Robinson, S. K., F. R. Thompson, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987–1990.

Schmutz, J. A., C. E. Braun, and W. F. Andelt. 1989. Nest habitat use of Rio Grande wild turkeys. The Wilson Bulletin 101:591–598.

Schwertner, T. W., M. J. Peterson, and N. J. Silvy. 2004. Raccoon abundance and Rio Grande wild turkey production in central Texas. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 58:238–247.

Schwertner, T. W., M. J. Peterson, and N. J. Silvy. 2007. Effect of precipitation on Rio Grande wild turkey poult production in Texas. Proceedings of the National Wild Turkey Symposium 9:127–132.

Schwertner, T. W., M. J. Peterson, N. J. Silvy, and F. E. Smeins. 2003. Brood-count power estimates of Rio Grande turkey production in Texas. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 57:213-221.

Seamans, M., R. D. Rau, and T. A. Sanders. 2012. Mourning dove population status, 2012. U.S. Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Washington, D.C.

Seiss, R. S., P. S. Phalen, and G. A. Hurst. 1990. Wild turkey nesting habitat and success rates. Proceedings of the National Wild Turkey Symposium 6:18-24.

Smith-Blair, A. E. 1993. Rio Grande wild turkey hen habitat and edge use, survival, and reproductive characteristics in the Texas Rolling Plains. Thesis, Texas Tech University, Lubbock, USA.

Speake, D. W. 1980. Predation on wild turkeys in Alabama. Proceedings of the National Wild Turkey Symposium 4:86-101.

Streich, M. M., A. R. Little, M. J. Chamberlain, L. M. Conner, and R. J. Warren. 2015. Habitat characteristics of eastern wild turkey nest and ground-roost sites in 2 longleaf pine forests. Journal of the Southeastern Association of Fish and Wildlife Agencies 2:164–170.

Suchy, W. J., W. R. Clark, and T. W. Little. 1983. Influence of simulated harvest on Iowa wild turkey populations. Proceedings of the Iowa Academy of Science 90:98-102.

Thogmartin, W. E. 1999. Landscape attributes and nest-site selection in wild turkeys. The Auk 116:912–923.

Thomas, J. W., C. Van Hoozer, and R. G. Marburger. 1966. Wintering concentrations and seasonal shifts in range in the Rio Grande turkey. Journal of Wildlife Management 30:34-49.

Vander Haegen, W. M., and R. M. Degraaf. 1996. Predation on artificial nests in forested riparian buffer strips. Journal of Wildlife Management 60:542–550.

Vander Haegen, W. M., W. E. Dodge, and M. W. Sayre. 1988. Factors affecting productivity in a northern wild turkey population. Journal of Wildlife Management 52:127–133.

Vangilder, L. D., and E. W. Kurzejeski. 1995. Population ecology of the eastern wild turkey in northern Missouri. Wildlife Monographs 130:3–50.

Vangilder, L. D., E. W. Kurzejeski, V. L. Kimmel-Truitt, and J. B. Lewis. 1987. Reproductive parameters of wild turkey hens in north Missouri. Journal of Wildlife Management 51:535–540.

Wallace, M. C. 2001. Nesting and Survival of Rio Grande Turkeys in Northcentral Texas. Proceedings of the National Wild Turkey Symposium 8:85-91.

Watts, C. R. 1969. The social organization of wild turkeys on the Welder Wildlife Refuge, Texas. Dissertation, Utah State University, Logan, Utah.

Welsh, R. J., and R. O. Kimmel. 1990. Turkey sightings by hunters of antlerless deer as an index to wild turkey abundance in Minnesota. Proceedings of the National Wild Turkey Symposium 6:126–133.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120–S139.

White, J. H., D. J. Moscicki, D. Forrester, J. Hardin, M. J. Chamberlain, and B. A. Collier. 2019. Reproductive parameters of Rio Grande wild turkeys in south central Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, In Press.

Williams Jr, L., D. H. Austin, T. E. Peoples, and R. W. Phillips. 1971. Laying data and nesting behavior of wild turkeys. Proceedings of the Southeastern Association of Game and Fish Commissioners 25:90–106.

Willsey, B. J. 2004. Survival and mammalian predation of Rio Grande Turkeys on the Edwards Plateau, Texas. Dissertation, Texas A&M University, College Station, Texas.

Wood, J. D., B. S. Cohen, L. M. Conner, B. A. Collier, and M. J. Chamberlain. 2018. Nest and brood site selection of eastern wild turkeys. Journal of Wildlife Management 83:192–204.

Wright, R. G., R. N. Paisley, and J. F. Kubisiak. 1996. Survival of wild turkey hens in southwestern Wisconsin. Journal of Wildlife Management 60:313-320.

Yeldell, N. A., B. S. Cohen, A. R. Little, B. A. Collier, and M. J. Chamberlain. 2017. Nest site selection and nest survival of eastern wild turkeys in a pyric landscape. Journal of Wildlife Management 81:1073–1083.

VITA

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