Evaluating Reproductive Parameters of Rio Grande Wild Turkeys to Guide Policy Decisions in Texas

Jacob H. White[1], *School of Renewable Natural Resources, Louisiana State University, Baton Rouge, LA 70803*

David J. Moscicki, *School of Renewable Natural Resources, Louisiana State University, Baton Rouge, LA 70803*

David Forrester, *Texas Parks and Wildlife Department, Austin, TX 78744*

Jason Hardin, *Texas Parks and Wildlife Department, Austin, TX 78744*

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

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

Abstract: Historically, Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) in south central Texas have been at lower densities than in 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 region. Due to perceived increases in turkey density in the eastern portion of the ecoregion, Texas Parks and Wildlife Department (TPWD) considered increasing the bag limit in the Rio Grande wild turkey spring-only 1-bird zone counties 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 for 138 radio-marked female Rio Grande wild turkeys in four of the 10 counties in the Oak-Prairie Wildlife District's 1-bird harvest zone and two counties in the District's 4-bird harvest zone during 2016–2018. We also evaluated the influence of six nest- and female-specific covariates on survival of 131 nests. We found that reproductive timing varied little between zones and across years. Nesting rates were higher in the 1-bird zone (74%) than the 4-bird zone (63%), and re-nesting rates were higher in the 1-bird zone (49%) than the 4-bird zone (25%). 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) than 1-bird zone (0.90). While causation is unclear, our results suggest that biologically significant differences potentially occur in basic reproductive parameters 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.

Key words: nest survival, nest rate, female success, hunting regulations, Rio Grande wild turkey, *Meleagris gallopavo intermedia*

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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 habitat quality (Thogmartin 1999), or 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; William 1997). Therefore, if regulatory adjustments that potentially impact harvest of wild turkeys are to be considered, it is incumbent on managers to address their partial observability and evaluate demographic parameters.

Since the late 1970s, Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) have exhibited various population trends across their range in Texas (Reagan and Morgan 1980; Ransom 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 turkey populations in the central and western regions of the state (Figure 1). Within the Oak-Prairie Wildlife District (Texas Parks and Wildlife-Wildlife Division District 7; hereafter, D7) wild turkey

1. Current affiliation: Texas Parks and Wildlife Department, Austin, Texas 78744

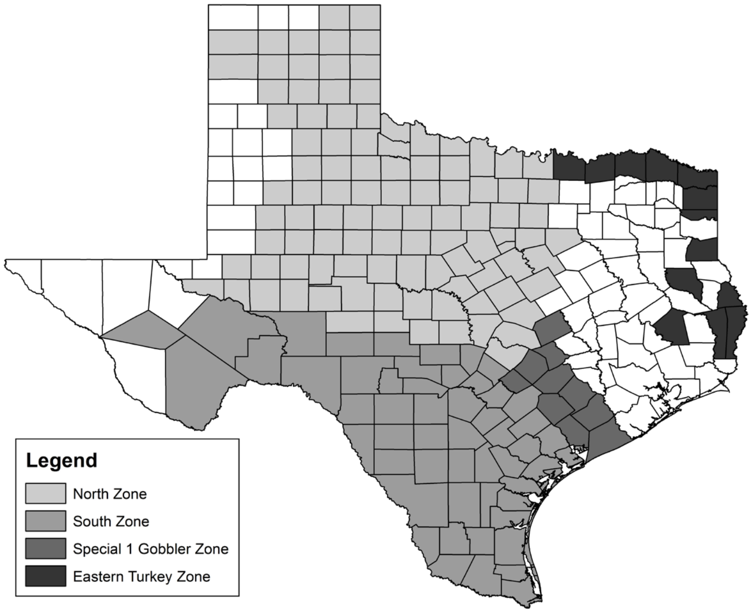

Figure 1. Spring turkey season regulatory zones in Texas, 2016–2018. Season dates vary by zone. The annual bag limit for turkeys, in the aggregate for all counties, is four, no more than one of which may be an eastern wild turkey (*Meleagris gallopavo silvestris*) or a Rio Grande wild turkey (*M. g. intermedia*) harvested in the Special 1-Gobbler Zone counties.

regulatory restrictions have 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 Regulatory Zone (hereafter, 1-bird zone), where spring season harvest is limited to 1 male per county during a 1–30 April harvest season and there is no fall turkey hunting. Counties in the western portion of D7 fall within the South regulatory zone, where the legal harvest is four per year (male and bearded females in spring, either sex in fall except no fall season in Dewitt, Guadalupe, or Victoria counties; hereafter, 4-bird zone). Recently, due to perceived increases in turkey density in the eastern portion of the Oak-Prairie Wildlife District Texas (Figure 2), Texas Parks and Wildlife Department (TPWD) considered liberalizing the spring season 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 pop-

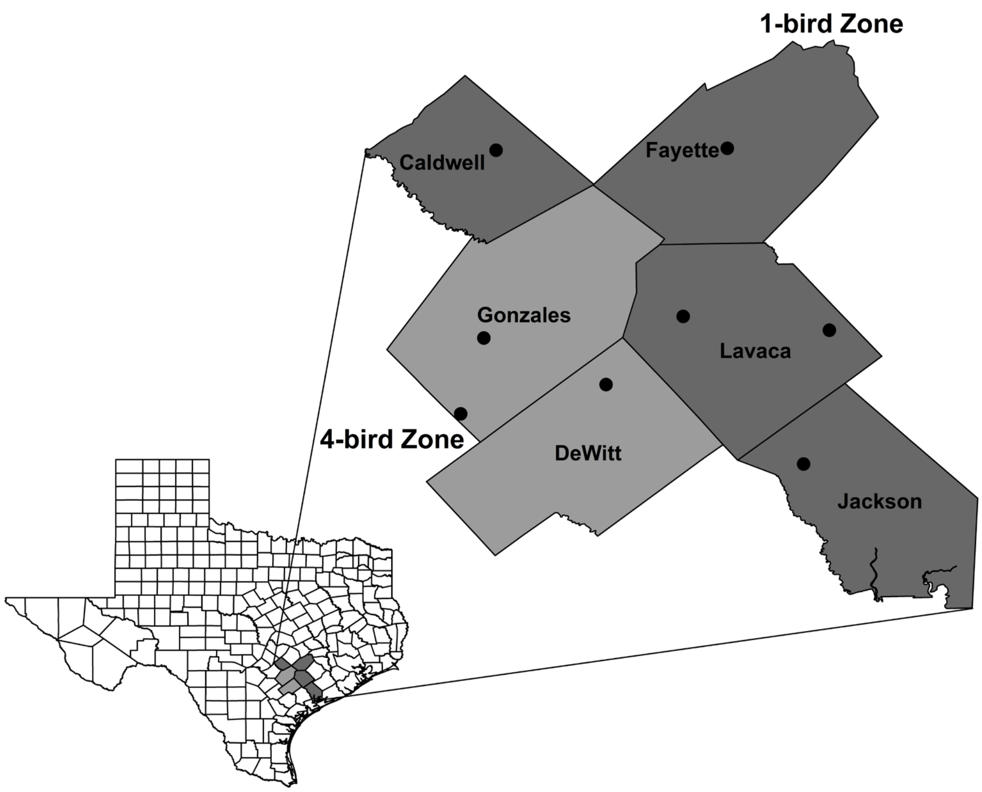

Figure 2. Location of study sites in relation to the 1- and 4-bird regulatory zones in south-central Texas, 2016–2018.

Table 1. Land use statistics for study area counties in south-central Texas, 2016–2018 (U.S. Department of Agriculture 2018).

			Farm/Ranch						
Zone	**County**	**% Farm/Ranch**	***n***	**Total area (ha)**	**Avg. size (ha)**	**% Pasture**	**% Crops**	**% Woodland**	**% Other**
1-bird	Caldwell	89	1623	125,628	77	60	18	18	4
	Fayette	81	2822	199,122	70	63	19	15	3
	Jackson	83	811	178,802	221	53	34	11	2
	Lavaca	88	2617	221,180	85	67	15	16	2
4-bird	DeWitt	92	1711	217,079	127	80	9	8	3
	Gonzales	89	1674	246,774	147	70	11	16	2
Totals	1-bird	85	7873	724,732	92	61	22	15	3
	4-bird	91	3385	463,853	137	75	10	12	2

ulation 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. 1993, 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, TPWD wanted to evaluate population productivity between the 1- and 4-bird regulatory zones to determine whether 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. Our two primary hypotheses were that nest survival would be 1) positively correlated with greater female movements during incubation in that females may avoid areas immediately surrounding nest locations during laying, thereby reducing potential nest exposure to predators, and 2) negatively correlated with smaller female incubation ranges as smaller ranges would be associated with females recessing near nest sites and potentially increasing detectability by predators (Bakner 2019).

Study Area

We conducted research in six D7 counties which included the Post Oak Savannah, Blackland Prairie, and South Texas Plains ecoregions of Texas (Figure 2; McMahan et al. 1984, Gould et al. 2011). The Post-Oak savannah ecoregion is 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 ecoregion 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 ecoregion 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 across our study sites 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 Bermuda grass (*Cynodon dactylon*), rescue grass (*Bromus catharticus*), and King Ranch bluestem (*Bothriochloa ischaemum var. songarica*) were abundant in all of D7, often forming large pasture monocultures.

We conducted research on private lands widely distributed across our study area. Average property size was 121 ha, 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. Caldwell, Fayette, Lavaca, and Jackson counties were within the 1-bird zone, whereas DeWitt and Gonzales counties were within the 4-bird zone (Figure 2). Gonzales County has a 4-bird bag limit and is split into TPWD's turkey hunting regulatory 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).

Methods

We captured female turkeys during January to March 2016–2018 using drop-nets (Glazener et al. 1964) and walk-in traps (Davis 1994, Peterson et al. 2003) baited with cracked corn (*Zea mays*) or milo (*Sorghum bicolor*). Individuals were fitted with a uniquely identifiable aluminum rivet leg band (National Band and Tag Company, Newport, Kentucky) labeled with a TPWD phone number and address and a GPS-VHF backpack transmitter unit (Biotrack Limited, Wareham, Dorset, U.K.; Guthrie et al. 2011). We programmed units to record one location per hour from 0500 to 2000 h daily and one roost location at night (2359:58 h) 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 and monthly from August to December using a Biotracker receiver (Biotrack Ltd., Wareham, Dorset, U.K.) and handheld Yagi antennas. We downloaded GPS locations ≥2 times per month via a VHF/UHF handheld command unit receiver (Biotrack Ltd., Wareham, Dorset, U.K.). We derived mortality rates for females during the reproductive period, first date of laying, first date of nest incubation, and nest location 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 (Yeldell et al. 2017, 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 >20 m. 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 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 habitat used by brooding females (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 (Wood 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 (1 March) that attempted a first nest, and re-nest rate as the proportion of females available for a re-nesting 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 one 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 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 (Concave Model C, Forestry Suppliers, Lemmon 1956). We then averaged these five readings to provide a single value following Yeldell et al. (2017). We measured percent understory ground cover using a 1 m^2 Daubenmire frame (Daubenmire 1959) centered on the nest bowl and at locations 15 m from the nest bowl in four 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 data type in program MARK (White and Burnham 1999) to estimate daily nest survival. We modeled nest survival as a function of six nest and female-specific covari-

Table 2. Range and mean values of nest and re-nesting initiation, incubation initiation, and hatch dates by year for female Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) in south-central Texas, 2016–2018.

		Initiation		Incubation initiation		Hatch	
Attempt	Year	Range	Mean	Range	Mean	Range	Mean
First 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
Re-nest	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

ates: year, zone, days since 15 March, 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 time-dependent models (e.g., all our models were constant over time) nor site-specific models as our nesting females were found across a wide array of private lands under different management strategies. We evaluated the fit of each candidate model following Burnham and Anderson (2002) using Akaike's Information Criterion corrected for small sample size (AIC_c). We considered models <2 ΔAIC_c from the top ranked model to be very competitive and models with <5 ΔAIC_c to be moderately competitive (Burnham and Anderson 2002). 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 15 March) would see decreased daily nest survival rates, due to potential predator search image calibration (Pietrewicz and Kamil 1979, Curio 2012). As roosting habitat in our study area was limited to riparian corridors which are also 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 roosting habitat, and for our analysis we used the last roost location for the morning before incubation began to estimate distance from roosting habitat. 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, Chamberlain et al. 2018, Wood et al. 2018). 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 UDs for each female during incubation (Byrne et al. 2014). We calculated all UDs (Kranstauber et al. 2012) in R (R Core Team 2019) with R package move (Kranstauber et al. 2019) 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).

Results

We captured and monitored 138 females over the three-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 because we were unable to accurately monitor nest activities for that nest 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). Mean onset of re-nesting 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). Average nest and re-nesting incubation dates were similar between the 1-bird and 4-bird zones (Table 3) and peak incubation occurred in mid to late April (Figure 3).

Breeding season (1 March–14 August) mortality rate was 23%

Table 3. Range and mean values of nest and re-nesting initiation, incubation initiation, and expected hatch dates by zone for Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) in south-central Texas, 2016–2018.

		Initiation		Incubation initiation		Hatch	
Attempt	**Zone**	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**
First 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
Re-nest	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

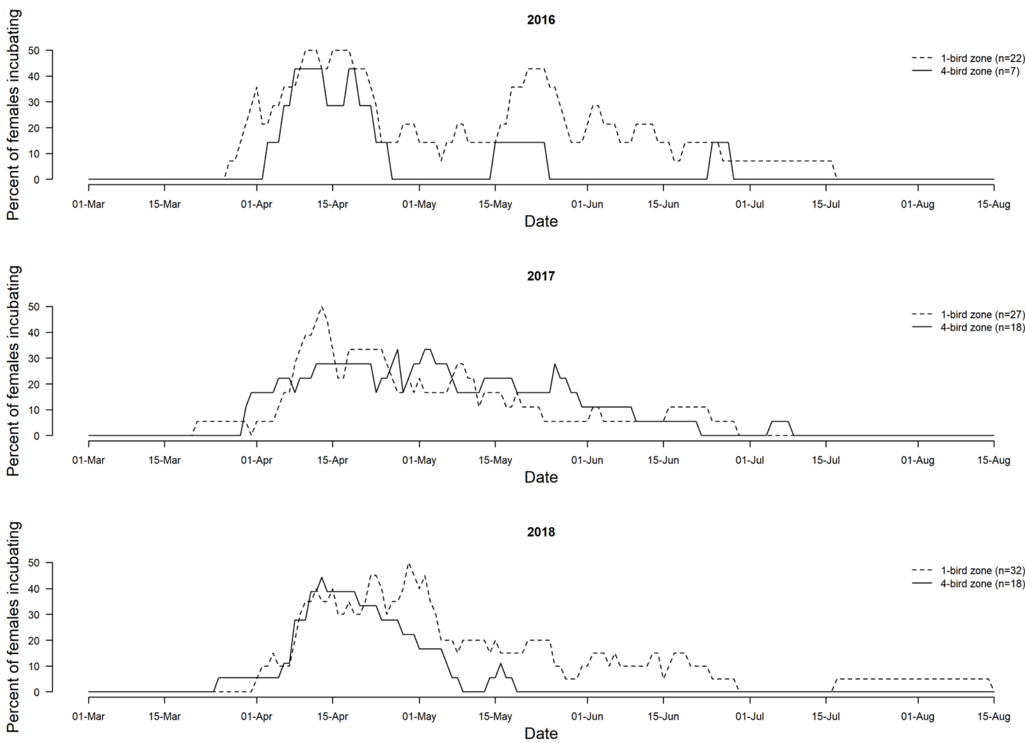

Figure 3. Daily percentage of female Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) incubating nests from 1 March to 15 August in the 1-bird and 4-bird zones in south-central Texas, 2016–2018.

(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 re-nesting rates (49% and 25%, respectively). However, both nest success (2% and 18%) and female success rates (3% and 15%; Table 4) 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 one failed 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 seventh day of incubation in the 1-bird zone and tenth day of incubation in the 4-bird zone (Figure 4). On average, females moved a total of 40.5 km (SD = 13.4, range: 18–85 m) during the laying period. Females

Table 4. Demographic parameters (% (*n*)) for Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) in south-central Texas, 2016–2018.

		Year			
Demographic parameter	**Site**	**2016**	**2017**	**2018**	**Combined**
First nest rate	4-bird	57 (7)	72 (18)	61 (18)	63%
	1-bird	64 (22)	78 (27)	81 (32)	74%
Re-nest 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%

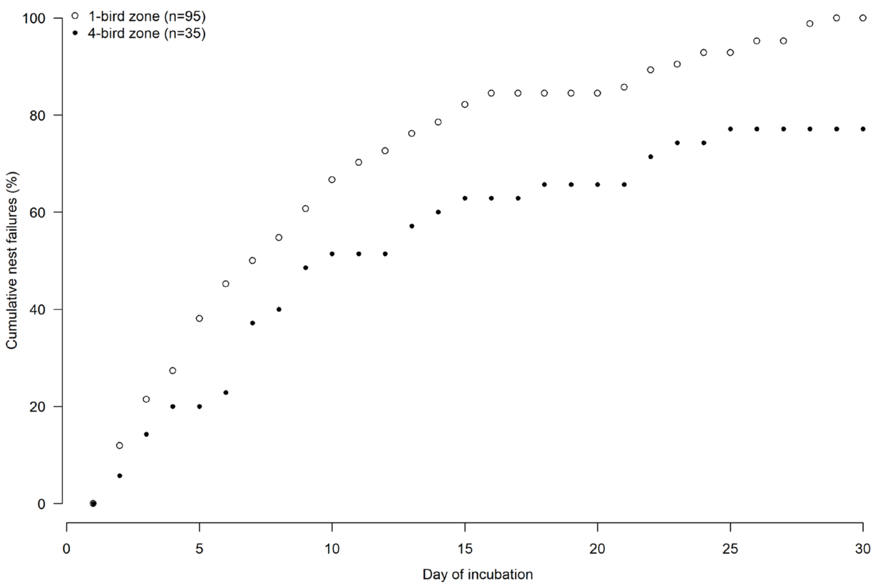

Figure 4. Cumulative percentage of nest failures of female Rio Grande wild turkeys (*Meleagris gallopavo silvestris*) over the incubation period in the 1-bird (open dots) and 4-bird (black dots) zones in south-central Texas, 2016–2018.

Table 5. Candidate models table with number of estimable parameters (k), Akaike's Information Criterion adjusted for small sample size (ΔAIC_c) and model likelihood weights (w_i) for the models used to estimate daily survival (S) of Rio Grande wild turkey (*Meleagris gallopavo intermedia*) nests in south-central Texas during 2016–2018.

Model notation	k	Deviance	ΔAIC_c	w_i
S (Constant over time, different between bag limit zones)	2	819.75	0.00	0.41
S (Varies by number of days since 15 March)	2	821.79	2.03	0.15
S (Varied roost distance to nest)	2	821.87	2.11	0.14
S (Constant over time, differs by bag limit zones and years)	6	814.17	2.46	0.12
S (Visual obstruction)	2	823.58	3.83	0.06
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 6. Mean and standard deviation (SD) values for vegetation measurements collected at hatched and failed of Rio Grande wild turkey (*Meleagris gallopavo intermedia*) nests, and associated random sites in south-central Texas, 2017–2018.

		Nest		Random	
Fate	Variable	Mean	SD	Mean	SD
Hatch	Maximum vegetation height (cm)	164.7	37.8	131.8	52.4
	Average vegetation height (cm)	103.1	40.9	76.7	34.6
	Visual obstruction (cm)	78.6	35.8	52.6	27.5
	Canopy cover (%)	25.7	17.9	20.8	26.7
	Trees per hectare	5.7	6.4	4.7	7.2
	Ground cover (%)	17.1	16.5	23.9	26.6
Fail	Maximum vegetation height (cm)	156.1	49.8	120.0	65.9
	Average vegetation height (cm)	104.1	44.1	75.7	51.3
	Visual obstruction (cm)	70.8	36.9	51.0	42.7
	Canopy cover (%)	26.3	22.9	21.4	24.3
	Trees per hectare	5.7	10.0	4.6	7.1
	Ground cover (%)	25.9	27.1	28.4	23.7

roosted an average of 712 m (SD = 490.7, range: 62–2659 m) away from the nest site on the night before incubation began. Average daily movement distance during the laying period was 3221 m (SD = 775, range: 1794–5801 m). Average incubation range size was 6.2 ha (SD = 16.1, range: 0.21–108 ha).

Our daily nest survival analysis indicated that the most parsimonious model was one where daily nest survival was constant over time but varied between zones ($AIC_c = 823.76$, $w = 0.44$; Table 5) 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 less supporting evidence (ΔAIC_c >5) that vegetative characteristics at nest sites influenced nest survival (Tables 6 and 7). Finally, we note that although we hypothesized a potential impact of weather-related factors on nest survival, we were unable to adequately fit models incorporating time-dependent precipitation values and their relative impact on nest survival.

Table 7. Mean and standard deviation (SD) values for vegetation measurements on of Rio Grande wild turkey (*Meleagris gallopavo intermedia*) nests and associated random sites in the 4-bird and 1-bird zones in south-central Texas, 2017–2018.

		Nest		Random	
Zone	Variable	Mean	SD	Mean	SD
4-bird	Maximum vegetation height (cm)	164.2	41.3	157.1	51.8
	Average vegetation height (cm)	109.9	41.0	99.6	43.8
	Visual obstruction (cm)	75.9	34.8	60.8	45.0
	Canopy cover (%)	29.8	20.8	28.7	26.6
	Trees per hectare	8.0	13.4	6.7	8.9
	Ground cover (%)	20.9	30.3	20.8	19.2
1-bird	Maximum vegetation height (cm)	153.5	51.8	103.3	63.0
	Average vegetation height (cm)	101.1	44.8	63.9	48.3
	Visual obstruction (cm)	69.6	37.7	46.4	38.6
	Canopy cover (%)	24.5	23.0	17.6	22.6
	Trees per hectare	4.5	6.9	3.5	5.7
	Ground cover (%)	27.0	24.0	31.5	25.3

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, female 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 (Cook 1972, Ransom et al. 1987, Phillips 2004, 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 nearly all failed nests showed signs of predation, which was 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. We note that 2016–2018 were fairly droughty in our study area, and lack of precipitation during the reproductive period causes female Rio Grande wild turkeys to seemingly prioritize survival over reproduction (Collier et al. 2009).

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 survival during winter 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 in the 1-bird zone—which was characterized by smaller property sizes, more row-crop agriculture, less open rangeland, and less area classified as rural—we observed 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 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). Work by 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.

Management Implications

Our results suggest that reproductive output and nest survival was lower in the 1-bird zone versus the 4-bird zone. Rio Grande wild turkey populations are known to frequently exhibit boom-bust cycles, hence we recommend additional research focus on estimating annual and breeding season survival of females to determine if survival-reproduction tradeoffs are occurring in the 1-bird zone. Our results indicate that TPWD should be cautious in recommending an increased bag limit in the 1-bird zone of D7 until it is clear that annual production and female survival are sufficient to support additional harvest opportunities.

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