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Reproductive ecology of Gould's Wild Turkeys (*Meleagris gallopavo mexicana*) in Arizona

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ABSTRACT—Gould's Wild Turkeys (*Meleagris gallopavo mexicana*) are the least-studied subspecies of Wild Turkey. Restoration efforts to establish sustainable populations of the subspecies continue throughout portions of the historical range in New Mexico and Arizona. Wild Turkey population viability is driven by reproductive success, yet information on aspects of the reproductive ecology of Gould's Wild Turkey is either scant or nonexistent. We used GPS telemetry to detail reproductive ecology of 23 females during 2017 in southeastern Arizona. We observed a nest initiation rate of 65% and nest success of 58%. Average estimated date for the onset of laying for initial nests was 17 May, which was later than for other subspecies of Wild Turkey. Estimated clutch size ($\bar{x}$ = 5.6 eggs) across 14 nests and vegetative characteristics at nests were comparable to nest sites selected by Eastern and Rio Grande subspecies, but did not appear to influence nest fate. Mean size of incubation recess ranges was 21 ha (SD = 99), but was highly variable across individual females and we found no evidence of habitat sampling by female Gould's Wild Turkeys before initiating laying of eggs. Females used open/herbaceous habitats and pine-oak woodlands throughout the reproductive period but type of conditions used varied between the laying, incubation, and brooding period. While based on 1 year of field data, our work represents the only assessment of the reproductive ecology of the Gould's Wild Turkey in the United States and should prompt further investigations into the biology of this iconic southwestern species. *Received 31 October 2018. Accepted 21 December 2018.*

Key words: Arizona, Gould's Wild Turkey, incubation, *Meleagris gallopavo mexicana*, nesting ecology, reproduction

Ecología de la reproducción del pavo silvestre *Meleagris gallopavo mexicana* en Arizona

RESUMEN (Spanish).—*Meleagris gallopavo mexicana* es la subespecie de pavo silvestre menos estudiada. Los esfuerzos de restauración para establecer poblaciones sostenibles de esta subespecie continúan a lo largo de su rango de distribución histórica en New Mexico y Arizona. La viabilidad de la población del pavo silvestre es conducida por su éxito reproductivo, aunque la información sobre la ecología reproductiva de esta subespecie en particular es escasa o inexistente. Usamos telemetría de GPS para conocer a detalle la ecología reproductiva de 23 hembras durante 2017 en el sureste de Arizona. Observamos una tasa de iniciación de 65% y un éxito de nido de 58%. La fecha estimada promedio para el inicio de la puesta de los primeros nidos fue 17 de mayo, la cual fue más tardía para otras subespecies de pavo silvestre. El tamaño de puesta estimado ($\bar{x}$ = 5.6 huevos) en 14 nidos, y las características vegetativas en los nidos, fueron comparables a las de los sitios de anidación seleccionados por las subespecies del este y del río Grande, aunque no parecen influenciar el destino de los nidos. El tamaño medio de los rangos de receso de incubación fue 21 ha (DE = 99), aunque fue altamente variable entre hembras. No encontramos evidencia de muestreo de hábitat por las hembras de esta subespecie antes del inicio de la puesta de huevos. Las hembras usan hábitats abiertos/herbáceos y arbolados de pino-encino a lo largo del periodo reproductivo, pero el tipo de condiciones usadas varió entre la puesta, incubación y periodo de cuidado parental. Si bien nuestro trabajo se basa en 1 año de datos de campo, representa la única determinación de la ecología reproductiva de *Meleagris gallopavo mexicana* en los Estados Unidos y debiera estimular más investigaciones sobre la biología de esta icónica especie del suroeste.

Palabras clave: Arizona, ecología de la anidación, incubación, reproducción

The Gould's Wild Turkey (*Meleagris gallopavo mexicana*) was once distributed from central Mexico into southwestern portions of the United States. Specifically, its native range included the sky island complex of southeastern Arizona and southwestern New Mexico (Schemnitz and Zeedyk 1992, Lerich and Wakeling 2011). Gould's Wild Turkeys were extirpated from Arizona in the 1920s, whereas a remnant subpopulation remained in southern New Mexico (Schemnitz and Zeedyk 1992). Restocking efforts using birds from Mexico were directed by the Arizona Game and Fish Department (AZGFD) in the late 1980s through the early 2000s (Maddrey and Wakeling 2005, Lerich and Wakeling 2011, Wakeling and Heffelfinger 2011). These efforts have reestablished

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Gould's Wild Turkeys to regions of Arizona such that subsequent translocations to native areas in New Mexico occurred during 2014–2017 (AZGFD, unpubl. data).

The successful restoration of Gould's Wild Turkeys in Arizona mimicked restoration of Wild Turkeys throughout other areas of North America (Kennamer et al. 1992), but recent evidence of declining populations of Eastern Wild Turkeys (*Meleagris gallopavo silvestris*) throughout portions of that subspecies' range (Byrne et al. 2015a) has raised concerns that per capita recruitment may be declining for Wild Turkey populations post-restoration. Wild Turkeys exhibit some life history traits similar to *r*-selected species, such as early age to maturity and high reproductive potential, and population growth rate is typically most rapid when population size is small (McGhee and Berkson 2011). The literature is replete with evidence that reproductive output is the primary driver of population dynamics for Wild Turkeys (Vangilder and Kurzejeski 1995, Pollentier et al. 2014). However, the limited spatial distribution of Gould's Wild Turkeys combined with the fact that restocking activities have only recently been accomplished has led to a paucity of basic life history data on the subspecies. For instance, the only published information on reproductive ecology within the Gould's native U.S. range is based on a single nest and opportunistic poult survey data from New Mexico (Figert 1984, Schemnitz et al. 1990, Schemnitz and Zeedyk 1992, Zornes 1993; but see Lafon and Schemnitz 1995 for data on 6 nests in Mexico).

Habitat use is thought to influence survival and reproduction of Wild Turkeys across their range (Chamberlain and Leopold 2000, Dreibelbis et al. 2015). Whereas macro- and micro-habitat evaluations have been regularly conducted for several subspecies of Wild Turkeys at multiple spatial scales (Lehman et al. 2002, Miller and Conner 2007, Pollentier et al. 2017), only coarse evaluations of habitat use by Gould's Wild Turkeys (Wakeling et al. 2001, York and Schemnitz 2003) are available to guide our collective understanding of habitat use. Notably, because no reproductive ecology data on Gould's Wild Turkeys exists, no information is available on habitat use by reproductively active females or broods. As such, our knowledge of both the reproductive ecology and habitat use of Gould's Wild Turkeys is likely the most incomplete for any upland game bird in North America.

Given the paucity of information on reproductive ecology of Gould's Wild Turkeys, along with recent opportunities provided by the advent of global positioning system (GPS) transmitters for Wild Turkeys (Collier and Chamberlain 2011, Guthrie et al. 2011), we conducted research to characterize basic parameters of reproductive ecology, including nesting chronology, rates of nest initiation and success, brood survival, and movements and habitat use during reproductive periods by female Gould's Wild Turkeys in Arizona.

Methods

Study area

We conducted research in the Coronado National Forest in southeastern Arizona within the northwest section of the Sierra Madre Occidental (Fig. 1). Our study sites were within the sky islands extension of the Sierra Madre Occidental in Mexico, and included the Pinaleño, Chiricahua, Huachuca, and Patagonia mountains located in Graham, Cochise, and Santa Cruz counties. Semidesert grasslands consisting of catclaw acacia (*Acacia greggii*), Parry's agave (*Agave parryi*), and soaptree yucca (*Yucca elata*) were found at elevations between 1,100 and 1,700 m. Madrean evergreen woodland consisting of Emory oak (*Quercus emoryi*), Arizona white oak (*Q. arizonica*), and alligator juniper (*Juniperus deppeana*) occurred at 1,200–2,300 m elevation. Petran montane conifer forest consisting of ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and New Mexico locust (*Robinia neomexicana*) occurred at 2,000–3,050 m elevation. Petran subalpine conifer forest consisting of Engelmann spruce (*Picea engelmannii*) and Douglas fir occurred at 2,450–3,800 m elevation. Riparian corridors were also found along steep slopes and ravines often consisting of Arizona sycamore (*Platanus wrightii*) and Fremont cottonwood (*Populus fremontii*). Grassland communities in our region were transitional semi-desert native grasslands with low to moderate shrub cover and a suite of species including needlegrass (*Achnatherum* spp.), grama (*Bouteloua* spp.), and wheatgrass (*Elymus* spp.).

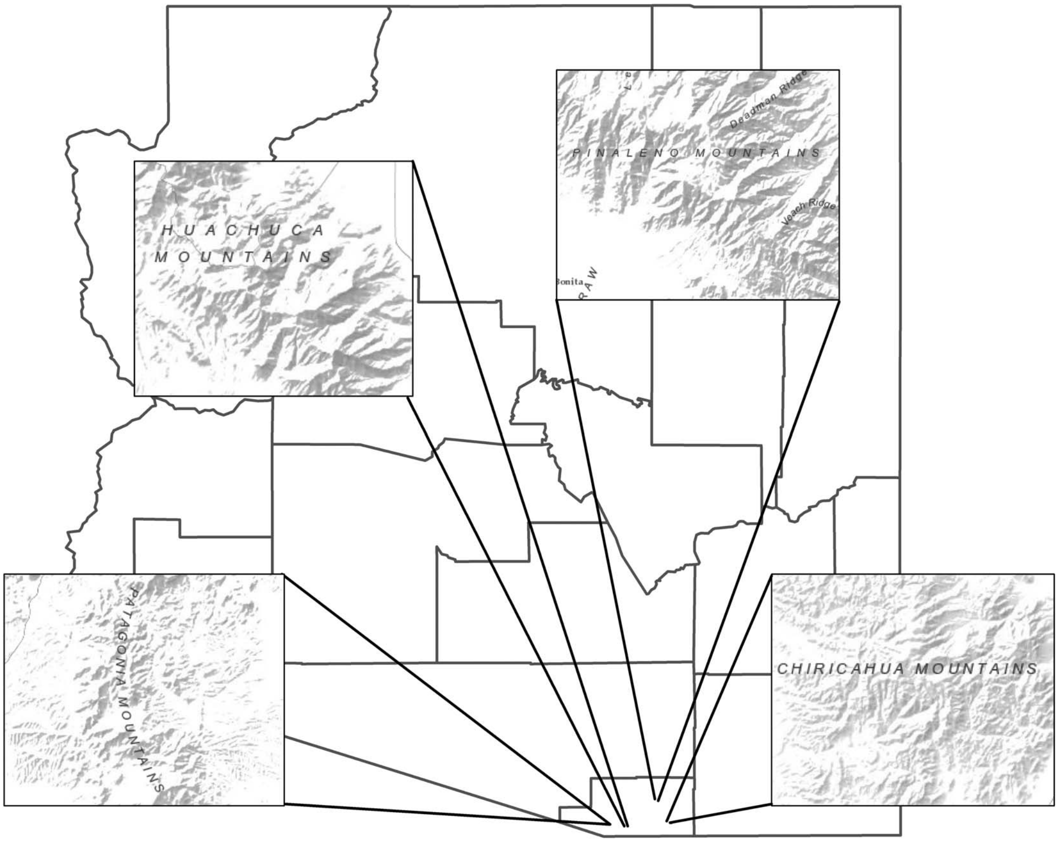

Figure 1. The study region in Arizona in 2017.

Field methods

We captured turkeys with walk-in traps baited with cracked corn and peanuts during January–March 2017. We determined sex and age of captured individuals based on appearance of secondaries and presence of barring on the ninth and tenth primaries (Pelham and Dickson 1992). All individuals were radio-tagged with a backpack-style GPS-VHF transmitter (Guthrie et al. 2011; Biotrack, Wareham, Dorset, UK). We programmed transmitters to take 1 location nightly (2358:58 h), and hourly locations between 0500 and 2000 h until the battery died or the unit was recovered, typically 14–16 months (Cohen et al. 2018). We immediately released turkeys at the capture location following processing. We monitored live–dead status >1 time weekly during the reproductive season using handheld Yagi antennas and R4000 receivers (Advanced Telemetry Systems, Isanti, Minnesota, USA). We downloaded GPS information from fixed wing aircraft via a VHF/UHF handheld command unit receiver (Biotrack). We derived first date of laying and nest location for nesting females from VHF tracking and spatiotemporal GPS locational data (Collier and Chamberlain 2011, Conley et al. 2015, Yeldell et al. 2017) and nesting females were not disturbed or flushed from nest sites, but instead were live–dead checked >3 times per week via VHF from a distance of >20 m. Our capture and handling protocols were approved by the Louisiana State University Agricultural Center Animal Care and Use Committee (Permit A2015-07).

After nest termination, we visually inspected nests to estimate clutch size, determine hatching rate of eggs, and collect measurements of vegetative characteristics at nest sites. We evaluated vegetative characteristics at each nest site within 3 d of the predicted (for failed nests) or actual (for successful nests) date of hatch following methodology outlined in Yeldell et al. (2017). Specifically, we estimated percent canopy cover, percent total ground cover, average understory vegetation height (cm), visual obstruction (cm), and tree density (trees/ha) to facilitate comparison to previous studies on other subspecies (Streich et al. 2015, Little et al. 2016, Yeldell et al. 2017, Wood et al. 2018). We measured canopy cover using a convex spherical densiometer (Lemmon 1956) at the nest site and at a distance of 15 m in each cardinal direction. We measured percent understory ground cover using a 1 m^2 Daubenmire frame centered on the nest bowl, and estimated percent of ground cover within the quadrat obstructed by vegetation and repeated this measurement at locations 15 m from the nest bowl in 4 cardinal directions. 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 we could see when viewing the pole from a height of 1 m above ground. We estimated average and maximum height of understory vegetation along our line of sight between the nest bowl and points 15 m from the nest in each cardinal direction. We averaged Robel pole readings to estimate mean vegetation height and visual obstruction. We used a 10 factor prism to estimate tree density in a 15 m circle around the nest site. Additionally, for each nest site, we quantified nest elevation (a.s.l., above sea level), slope, and aspect at 10 m resolution using digital elevation models from the USGS National Elevation Dataset (https://lta.cr.usgs.gov/NED). Following Melton et al. (2011), we classified nest fate as successful if $\geq$1 egg hatched and unsuccessful if the nest was depredated (nest or eggs showed signs of disturbance) or abandoned (female left nest area and eggs remained unhatched). Due to our limited sample size of nesting females ($n = 16$), we evaluated whether nest fate (successful and failed nests) was affected by vegetative characteristics using a logistic regression framework in program R (R Core Team 2018). We defined successful nests as 1 and failed nests as 0 in our generalized linear model. We did not attempt to address age differences in nest success because we had a single juvenile female that was radio-tagged.

No behavioral data have been published on reproductively active Gould's Wild Turkeys (Schemnitz et al. 1990). Therefore, we described basic movements and other behaviors of females during various phases of reproduction (laying, incubation, brooding) to provide a baseline understanding of these behaviors. Specifically, we estimated daily distances moved during laying by summing distances between successive hourly locations for each day females were known to be laying via observation of GPS locations and movement tracks associated with the eventual nest site. Likewise, we estimated the total duration of laying and nesting combined by summing the number of days females were laying based on GPS locations and movement tracks, and number of days each female incubated a nest (Conley et al. 2016, Yeldell et al. 2017).

To describe nesting behavior, we first buffered each nest site by 27 m based on static tests using stationary backpacks conducted during 2018 in southeastern pine-hardwood forests (BAC, unpubl. data), which demonstrated that the 90th quantile of GPS locations collected during incubation were within 27 m. Stated differently, we assumed that 90% of GPS locations on the nest site would fall within 27 m of the known nest site (see also Guthrie et al. 2011). We then classified movements >27 m as recess movements, and determined daily frequency of recesses and distance of each recess from the nest site. Then, following Skutch (1962), we estimated a measure of nest attentiveness as a surrogate for incubation constancy. Once incubation began, we determined the percentage of GPS locations at the nest site relative to total number of locations collected. Furthermore, the frequency and distance of recesses during incubation (hereafter recess movements) may be tied to resource availability (Williams et al. 1971).

Space use during laying and incubation periods can be linked to primary drivers of reproductive success (Thogmartin 2001). To determine range sizes during the laying and incubation periods, we estimated 50%, 75%, and 99% utilization distributions (UD) during the laying and incubation recess periods following logic outlined in Conley et al. (2015). We generated range estimates using a dynamic Brownian bridge movement model with a raster size of 1, a window size of 7, a margin size of 3, and a location error of 10 (Kranstauber et al. 2012) implemented using the move package

(Kranstauber et al. 2018) in R (R Core Development Team 2018). Badyaev et al. (1996) and Chamberlain and Leopold (2000) both suggested that female Wild Turkeys conducted habitat sampling prior to nest initiation, but this suggestion was disputed by Conley et al. (2016), who observed little evidence for habitat sampling by either Eastern or Rio Grande (*Meleagris gallopavo intermedia*) Wild Turkeys. To evaluate whether Gould's Wild Turkeys behaved similarly, we followed methodology outlined by Conley et al. (2016) by estimating the average minimum distance from a nest site daily for each female during the 30 d period before the female laid her first egg.

Survival and movements of broods are among the least understood demographic parameters for Wild Turkeys in general, and are unknown for Gould's Wild Turkeys. So, for each successful nest we attempted to monitor brooding females up to 28 d post-hatch to evaluate brood survival and movements. We performed brood surveys every 3–4 d by locating each brooding female via VHF homing to confirm presence of poults (Wood et al. 2018). We considered a brood to be present and the female as brooding if $\geq$1 poult was seen or heard, and we continued brood survey attempts until we failed to detect poults during 2 consecutive attempts. To describe daily movements of broods, we estimated daily movement distances for brooding females and used a dynamic Brownian bridge movement model to estimate core use (50%) and range size (75% and 99% utilization distributions) for the period each brood was active (Wood et al. 2018).

Finally, understanding of habitat use by Gould's Wild Turkeys has been based primarily on coarse-scale evaluations of habitat suitability (Wakeling et al. 2001, Wakeling and Heffelfinger 2011) or evaluations using VHF telemetry and scant numbers of relocations (Willging 1987, Zornes 1993, Lafon and Schemnitz 1995, York and Schemnitz 2003). Therefore, we sought to describe habitat use by females throughout the reproductive period. We first delineated primary habitat types on our study areas using USGS Landsat-8 Operational Land Imager. We then created an unsupervised habitat classification using 30 m pixel LANDSAT 8 Operational Land Imager (OLI) based on imagery from May 2017 because this period represented the closest period for which LANDSAT 8 cloud-free data was available for our entire study region. We used ERDAS Image software to delineate 5 unique habitat classes (open-herbaceous, pine-juniper woodland, infrastructure, water, and pine-oak woodland) following previous evaluations of habitat use detailed in Potter (1984), Schemnitz et al. (1990), Lafon and Schemnitz (1995), and York and Schemnitz (2003). Using these classifications, we estimated the proportion of each habitat class within laying, incubation recess ranges, and ranges of brooding females based on the UDs we created for those periods (Conley et al. 2016, Wood et al. 2018).

Results

We captured 29 females (1 juvenile, 28 adults) during January–March 2017. Because of capture-related mortality ($n = 2$), natural mortality ($n = 3$), and transmitter malfunction ($n = 1$), we monitored 23 females into the reproductive season. We monitored 17 nests (15 first attempts and 2 renest attempts), resulting in a 65% nesting rate, and noted that 10 nests (58%) were successful including 1 renest attempt. Mean date of nest initiation (laying initiated) was 17 May (median 15 May), with a mean nest incubation start date of 27 May (median 29 May), and a range of 19 May to 15 June for first nest attempts. We estimated a mean hatch date of 28 June for all nests combined. We were unable to reach 3 nests due to access restrictions, so we estimated clutch size based on 14 nests (13 initial nests, 1 renest). Mean clutch size was 5.6 (SD = 4.4; median = 5, range = 1–17). Based on numbers of unhatched eggs at each successful nest (Supplemental Table S1), we estimated an egg hatching rate of 78%. The average incubation length for successful nests was 26.9 d, ranging from 25 to 28 d. Average number of days females incubated nests before either failure or hatch ranged from 2 to 29 d ($\bar{x} = 21$; SD = 9). Mean time from nest initiation (laying first egg) to hatch was 41 d (SD = 1.4). Females showed a high rate of nest attentiveness, with 93% (SD = 0.04) of locations at the nest site during incubation. We observed an average of 17 (SD = 13; range 1–45) unique recess movements per female during incubation (Fig. 2a). We failed to note any trends in number of unique incubation recesses by day of incubation (Fig. 2b).

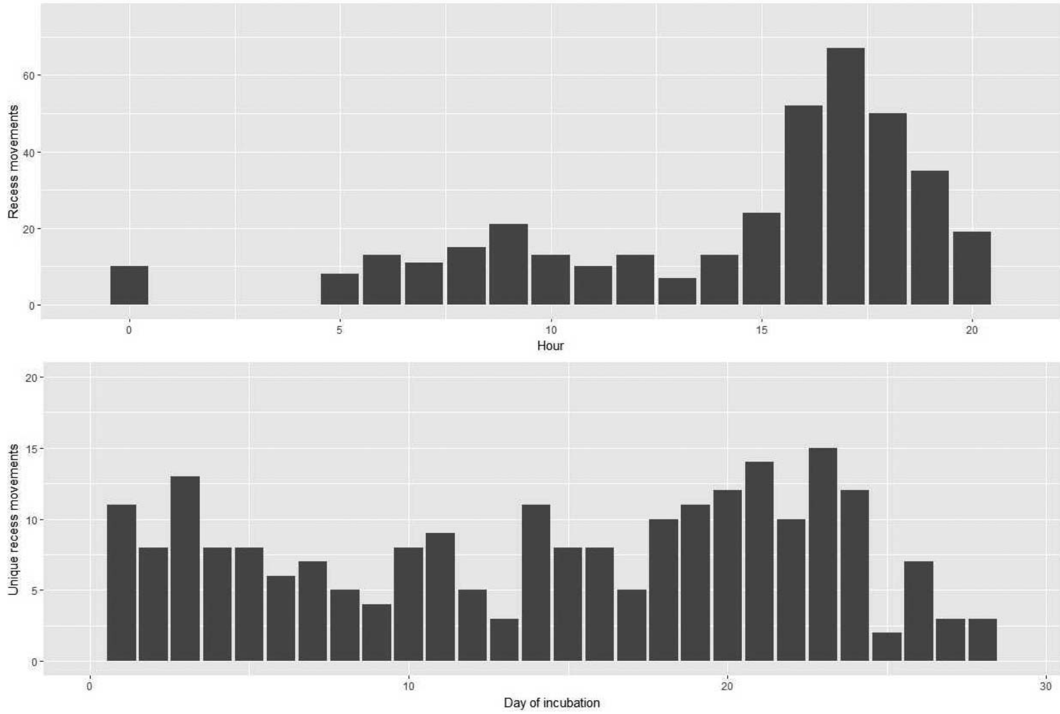

Figure 2. Frequency of unique recess movements by nesting Gould's Wild Turkeys nesting attempts ($n = 17$) monitored in Arizona in 2017 by hour of day (a) and by day of incubation (b).

Mean elevation at nest sites was 1,558 m (SD = 82; range = 1,467–1,768 m) and mean slope was 13.8° (SD = 10.9; range = 0.9–37.8°), with 9 nests found on eastward- and 8 nests found on westward-facing slopes. We were able to collect vegetation data for 16 nesting attempts (Table 1). Modeling results based on measurements of ground and canopy cover, mean vegetation height, and visual obstruction indicated a negative effect for predicted nest success, whereas maximum vegetation height and trees/ha indicated a positive effect for predicted nest success. However, we found no statistically significant effect of vegetation on nest success of failure ($n = 16$; Supplemental Table S1, Table 2).

Daily movements by individual females during laying averaged 3,246 m (SD = 1,052; range = 1,833–5,312 m) with females often remaining within 400 m of the nest site for several hours during the laying period (Fig. 3). We noted that females were on average no closer than 2,263 m (range = 10–8,829 m) of the eventual nest site during the 30 d period before the female attempted to nest, hence we observed no evidence of reproductive habitat sampling. However, we noted that the minimum distance from the nest site began to decrease beginning ~4 d before the first egg was laid (Fig. 4). The UDs for females during the laying period varied; 50% UDs averaged 33 ha (SD = 38, range = 5–133 ha), 75% UDs averaged 90 ha (SD = 108, range = 14–412 ha), and 99% UDs averaged 444 ha (SD = 525, range = 66–2,122 ha; Supplemental Table S1). Based on our unsupervised classification, core (50% UD) areas for laying ranges were on average classified as 26% (SD = 5, range = 13–37%) open/herbaceous habitat and 71% (SD = 4, range = 62–81%) pine-oak woodlands, and the same general proportions held for the 99% UD with 28% (SD = 4, range = 18–33%) in open/herbaceous habitat and 69% (SD = 3, range = 64–76%) pine-oak woodlands.

Mean incubation recess range size (99% UD) was 21 ha (SD = 99, range = 0.22–331 ha) irrespective of nest success. Based on our unsupervised classification, incubation recess ranges were on average classified as 65% (SD =

Table 1. Nest-site vegetation characteristics collected at Gould's Wild Turkey (*Meleagris gallopavo mexicana*) nest sites ($n = 16$) in Arizona during 2017.

	$\bar{x}$ (SD)	Min	Median	Max
Canopy cover (%)	64.4 (8.4)	19	69	95
Ground cover (%)	88.8 (8.4)	66	90	99
Maximum vegetation height (cm)	197 (5.4)	182	200	200
Average vegetation height (cm)	126 (23)	82	129	162
Visual obstruction (cm)	75 (39)	18	66	150
Trees per hectare	20 (13)	3	20	43

9, range = 46–82%) open/herbaceous habitat and 33% (SD = 9; range = 18–53%) pine-oak woodlands. We observed that 9 broods from the 10 successful nests either failed (n = 8) or amalgamated with other females (n =1) by day 21. Mean number of days a female brooded was 9 (SD = 5.4, range = 5–21). The mean 50% UD for brooding females was 1.89 ha (SD = 1.8, range = 0.2–5.1 ha), whereas mean size for the 75% UD was 9.57 ha (SD = 6, range = 1.4–16.4 ha). Average size of the 99% UD for brooding females was 82 ha (SD = 49, range = 7.9–168 ha; Fig. 5, Supplemental Table S1). Based on our unsupervised classification, core (50% UD) areas for brood ranges were on average classified as 66% (SD = 30, range = 13–100%) open/herbaceous habitat and 33% (SD = 30, range = 0–86%) pine-oak woodlands, and the same general proportions held for the 99% UDs with 67% (SD = 26, range = 15–100%) in open/herbaceous habitat and 33% (SD = 26, range = 0–84%) pine-oak woodlands.

Discussion

We recognize that our findings are constrained by limited sample size, and are limited to Gould's Wild Turkeys sampled during only a single year. Despite these relevant limitations, we provide the most comprehensive evaluation of reproductive ecology for Gould's Wild Turkeys to date. Within the published and gray literature, we noted that only 6 initial nests and 1 renest had been confirmed and described prior to our work, one in New Mexico in 1988 (Figert 1984, Schemnitz et al. 1990, Schemnitz and Zeedyk 1992) and 6 (including 1 renest) in Chihuahua, Mexico, in 1994 (Lafon and Schemnitz 1995). Descriptions of nesting included in Zornes (1993) assumed a nest based on location and behavior of a female before she was found dead, but only feather down in a suspected nest bowl was found. Regardless, comparisons between our findings and previous works are tenuous, as previously reported nest success was 100% and 83% based on 1 and 5 initial nesting attempts in New Mexico (Figert 1984, Schemnitz et al 1990) and Mexico (Lafon and Schemnitz 1995), respectively, and 100% for the single renesting attempt detailed in Lafon and Schemnitz (1995). We observed initial nest success and renest success rates greater than estimates from recent research on Eastern (Yeldell et al. 2017, Wood et al. 2018) and Rio Grande (Conley et al. 2015, 2016) Wild Turkeys. Conversely, we observed a nesting rate (65%) markedly lower than recently published reports for other subspecies using GPS telemetry. We speculate that a potential driver of high initial nest success for

Table 2. Logistic regression analysis between successful and failed Gould's Wild Turkey (*Meleagris gallopavo mexicana*) nests ($n = 16$) based on nest-site vegetation characteristics collected in Arizona during 2017.

Model	Estimates	SE	z-value	P
Fate ~ Ground cover	$\alpha = 4.584$	6.71	0.682	0.49
	$\beta = -0.042$	0.07	−0.571	0.57
Fate ~ Canopy cover	$\alpha = 1.042$	1.76	0.590	0.556
	$\beta = -0.003$	0.02	−0.152	0.880
Fate ~ maximum vegetation height	$\alpha = -9.053$	19.0	−0.475	0.635
	$\beta = 0.0500$	0.09	0.516	0.606
Fate ~ Average vegetation height	$\alpha = 0.885$	3.00	0.294	0.768
	$\beta = -0.001$	0.02	−0.033	0.974
Fate ~ Visual obstruction	$\alpha = 1.020$	1.19	0.855	0.393
	$\beta = -0.003$	0.01	−0.220	0.826
Fate ~ Trees per ha	$\alpha = 0.483$	0.99	0.485	0.628
	$\beta = 0.015$	0.04	0.335	0.723

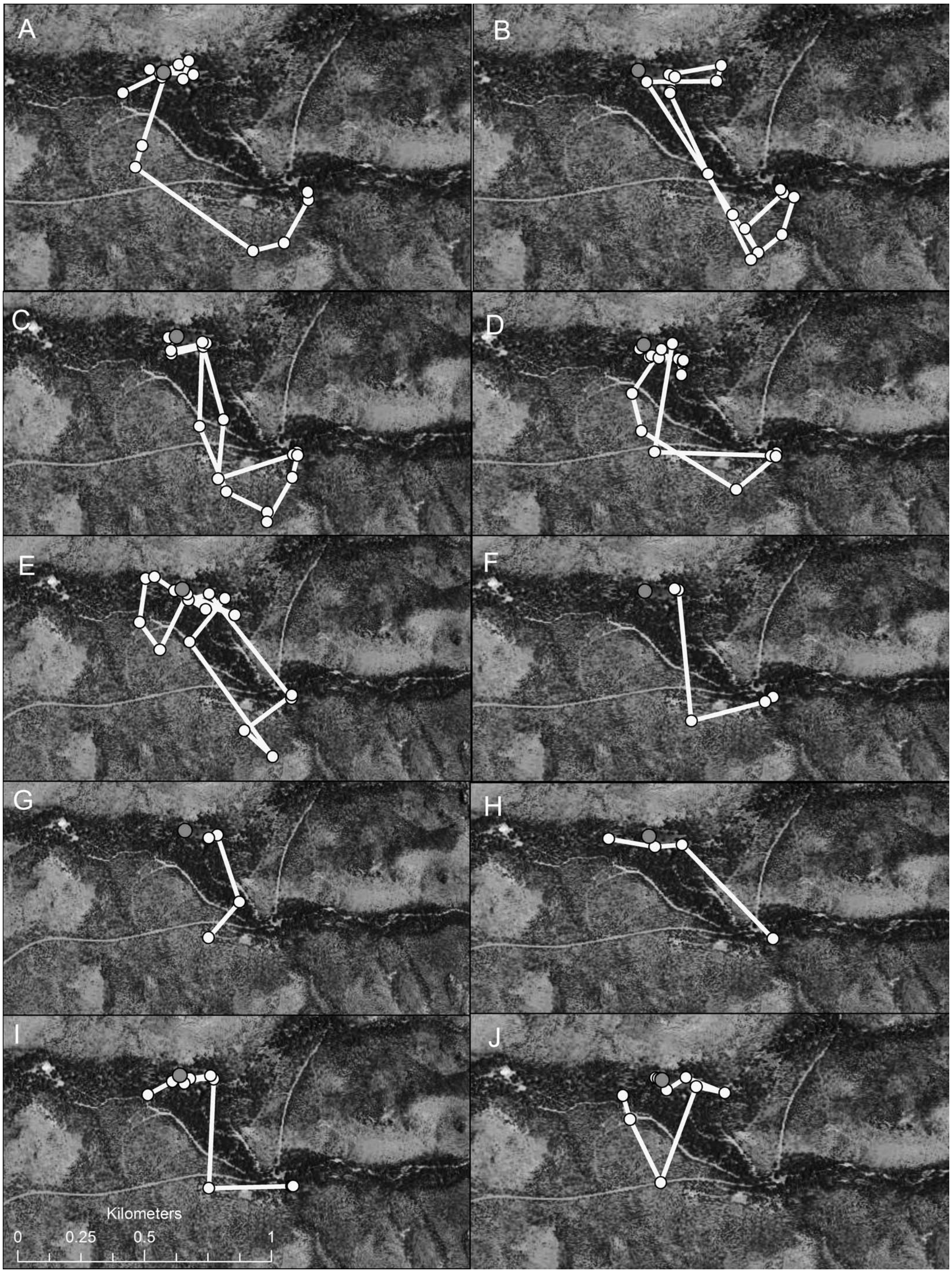

Figure 3. Example daily pre-incubation movement paths of a Gould's Wild Turkey female during the laying period (10 d) during 2017. Gray dot represents nest site.

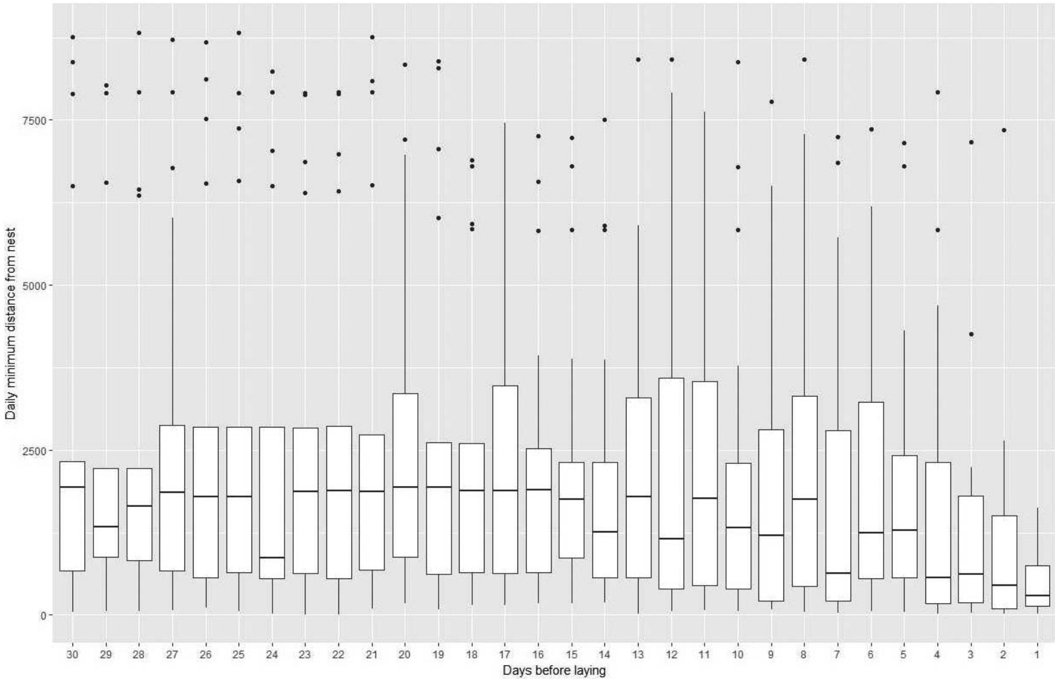

Figure 4. Boxplot of daily minimum distance the nest site for all ($n = 17$) female Gould's Wild Turkeys that attempted to nest during 2017 for the period 30 d before the first egg was laid (30 d before laying) to the day before the first egg was laid (1 d before laying) in Arizona during 2017.

Gould's Wild Turkeys may be reduced predation risk via mammalian predators despite occurrence of these predators. For instance, Fyffe et al. (2018) demonstrated significant nesting perseverance (remaining at nest site) despite repeated interactions with potential predators within meters of the female. Perhaps increased perseverance, in conjunction with the community of predators where Gould's Wild Turkeys occur (DeGregorio et al. 2016), reduces rates of nest depredation for Gould's Wild Turkeys relative to other subspecies (Lehman et al. 2008, Melton et al. 2011, Conley et al. 2015, Yeldell et al. 2017).

Using observations of opportunistic poult survey data from Potter (1984), Willging (1987), and Schemnitz and Zeedyk (1992), Schemnitz et al. (1990) noted that successful hatches by female Gould's Wild Turkeys occurred in late June (20 June on average), consistent with our findings (28 June). Incubation initiation dates were later than those reported for Eastern (28 April; Yeldell et al. 2017), Rio Grande (26 April; Melton et al. 2011), and Merriam's (*M. g. merriami*; 10 May; Lehman et al. 2008) Wild Turkeys, although we note that estimates for Rio Grande and Merriam's Wild Turkeys currently published were based on VHF telemetry, and are likely biased to later dates due to missed first nesting attempts (Yeldell et al. 2017). We suspect that the likely driver for later nest initiation by Gould's Wild Turkeys is that environmental conditions driving growth of vegetation conducive to ground-nesting wild birds (Porter 1992) occurs approximately 1–2 months later where Gould's Wild Turkeys occur than most of the continental United States (Peng et al. 2017). We also observed that most broods failed by day 8 (median = 5 d), which generally agrees with contemporary works on Eastern Wild Turkeys (Yeldell et al. 2017, Wood et al. 2018) but differs markedly from Schemnitz et al. (1990) who reported 100% brood survival ($n = 1$) for the first week after hatching. Based on a single year of data collection, our results point to low reproductive productivity in the Gould's Wild Turkey population we studied, consistent with populations of other subspecies (Byrne et al. 2015a, Casalena et al. 2015).

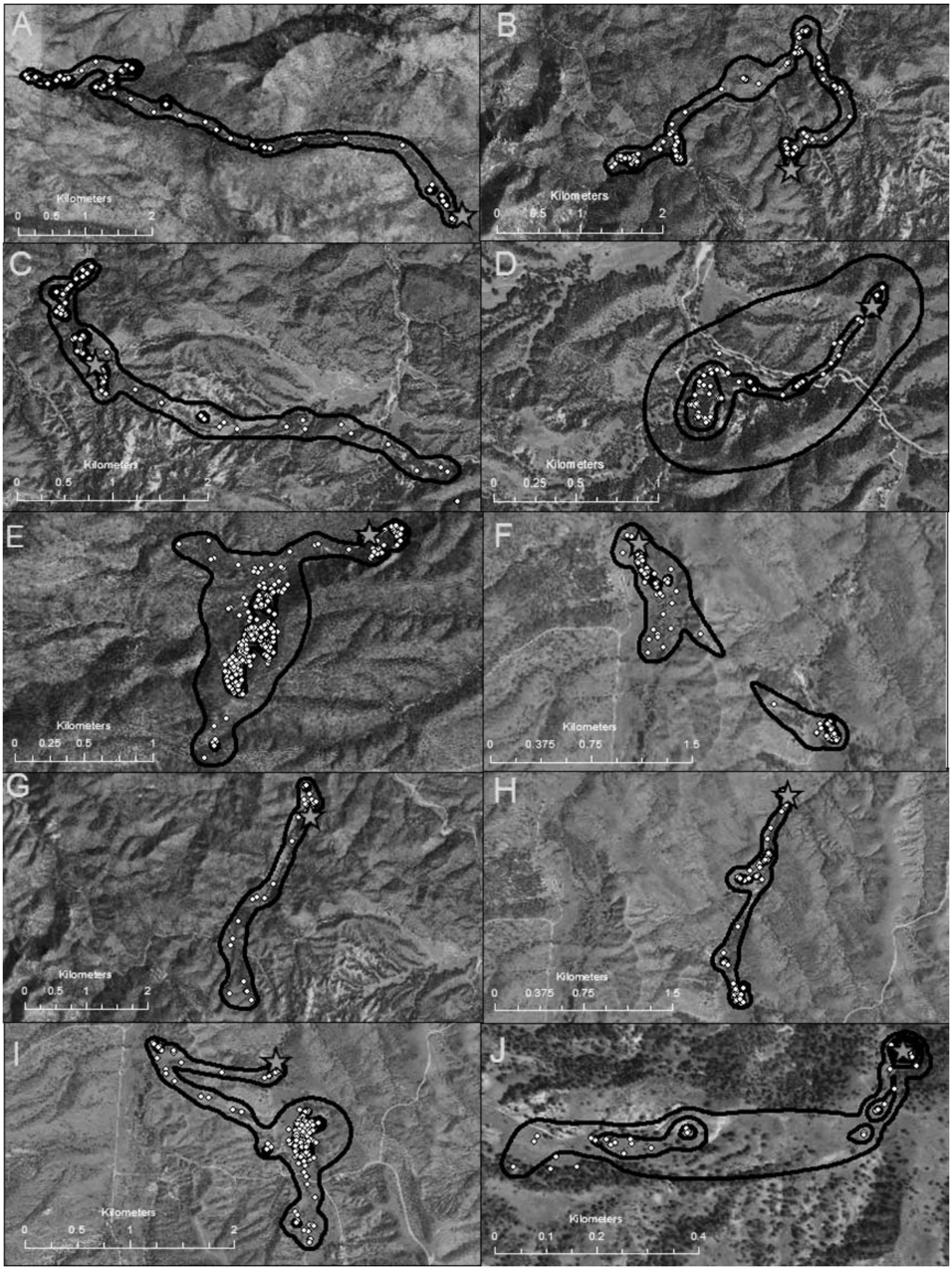

Figure 5. Successful nest site (gray star), GPS locations for brooding females (white dots), and 99% utilization distributions for brood ranges for the 10 Gould's Wild Turkey females that brooded >1 d in Arizona during 2017.

We found that vegetative characteristics at nest sites were similar to metrics reported for other Wild Turkey subspecies. Estimates of concealment vegetation, primarily ground and overstory cover, have regularly been identified as limiting factors for nesting Wild Turkeys (Melton et al. 2011, Yeldell et al. 2017). Vegetative characteristic information at known nests of female Gould's Wild Turkeys (Lafon and Schemnitz 1990) is based on 7 nests (6 of which were in Mexico), and only 2 characteristics (canopy cover and estimated concealment distance using a decoy) were measured at all nests. We observed percent canopy cover at nests comparable to Lafon and Schemnitz (1990), and estimates of ground cover, visual obstruction, maximum vegetation height, and mean vegetation height similar to findings reported at nest sites of other subspecies (Lehman et al. 2002, Dreibelbis et al. 2015, Yeldell et al. 2017, Wood et al. 2018). At coarser spatial scales, we noted that pine-oak woodlands and open/herbaceous habitats were selected throughout the reproductive period, which generally agrees with previous studies noting the importance of these habitats (Schemnitz et al. 1990, York and Schemnitz 2003, Wakeling and Heffelfinger 2011), but we also noted an apparent shift from pine-oak woodlands used during the laying period to open/herbaceous habitats being used during laying and brooding. As finer resolution spatial data become available, we encourage future efforts to improve the resolution at which habitat selection is assessed for Gould's Wild Turkeys (Yeldell et al. 2017, Wood et al. 2018).

We estimated movements via GPS telemetry and offer that these findings provide a foundation for which future hypotheses can be developed, and research designed, to address the lack of available information on movement ecology of Gould's Wild Turkeys. The lack of comparable information in the literature precludes our ability to compare our observations of daily movements to previous research, but extant literature on other aspects of reproductive behaviors offers a unique opportunity to compare our findings to those published on other subspecies. For instance, we found little evidence that female Gould's Wild Turkeys sample habitats before initiation of laying, which supports Conley et al. (2016) who reported no evidence of sampling for either Eastern and Rio Grande Wild Turkeys and differs from earlier studies (Badyaev et al. 1996, Chamberlain and Leopold 2000) that used VHF to infer habitat selection during the pre-laying period. Likewise, we noted that female Gould's Wild Turkeys began using areas closer to the eventual nest site 4 d before the first egg was laid, a similar behavior described by Conley et al. (2016). Conversely, we observed substantial movements by individual females during the egg laying period, with daily movements averaging 3,246 m. Females also maintained laying ranges that varied noticeably among individuals, and incubation ranges 4 times larger than those reported by Conley et al. (2015) for female Rio Grande Wild Turkeys. It is important to note that Conley et al. (2015) removed all locations <10 m from the nest and used a different range estimator (kernel), hence the observed differences could at least partially result from differences in methodology. Alternatively, Gould's Wild Turkeys exist in a moderately arid system with a late and rapid period of green-up (Peng et al. 2017), so movements during nesting could be driven by distance to necessary, and potentially limited, resources such as water (Rosentock et al. 1999). Regardless, future evaluations of reproductive ecology of Gould's Wild Turkeys should consider quantifying resources available to nesting females within the regions used for recess movements.

Gould's Wild Turkeys are the least studied subspecies of Wild Turkey. York and Schmenitz (2003) suggested that future work on Gould's Wild Turkeys should include creation and synthesis of existing research data to further our understanding of habitat requirements and population dynamics. Since this suggestion, only limited research has occurred, with most being primarily tied to restoration efforts (Wakeling et al. 2001, Wakeling and Heffelfinger 2011). Furthermore, a wide variety of environmental and anthropogenic factors such as land use (Dreibelbis et al. 2015), periodic drought and water availability (York and Schemnitz 2003), and wildfire (Oetgen et al. 2015; BAC, 2017, unpubl. data) could impact Gould's Wild Turkeys. We recommend future research focus on identifying potential demographic limiting factors, including roosting habitat selection and use (Byrne et al. 2015b), female breeding season survival (Miller et al. 1998, Collier et al. 2009), age-specific nesting propensity (Rumble et al. 2003), movement ecology of Gould's Wild Turkey relative to other Wild Turkey subspecies (Byrne et al. 2014a, 2014b), and improved classification and quantification of habitat selection indices (Schemnitz et al. 1990, York and Schemnitz 2003, Wakeling and Heffelfinger 2011) in support of future conservation and management activities.

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