NEST SURVIVAL AND POST-FLEDGLING SURVIVAL, MOVEMENT, AND HABITAT USE OF BENDIRE'S THRASHERS (*Toxostoma bendirei*) IN THE CHIHUAHUAN DESERT

BY

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"NEST SURVIVAL AND POST-FLEDGLING SURVIVAL, MOVEMENT, AND HABITAT USE OF BENDIRE'S THRASHERS (*Toxostoma bendirei*) IN THE CHIHUAHUAN DESERT," a Thesis prepared by Allison J. Salas in partial fulfillment of the requirements for the degree Master of Science, has been approved on behalf of the faculty of New Mexico State University, and it is acceptable in quality and form for publication:

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ABSTRACT

NEST SURVIVAL AND POST-FLEDGLING SURVIVAL, MOVEMENT, AND HABITAT USE OF BENDIRE'S THRASHERS (*Toxostoma bendirei*) IN THE CHIHUAHUAN DESERT

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Passerine species within the continental United States and Canada are declining at rapid rates. One species exhibiting steep population declines is the Bendire's Thrasher (*Toxostoma bendirei*), an arid land passerine endemic to the Southwest. To properly conserve for species in decline, investigation into the demographics of local populations is required, especially measures of reproduction. In this study, I modeled Bendire's Thrasher nest survival in relation to temporal variables, and vegetation variables at the nest site and within the breeding territory and monitored post-fledgling survival, movement and habitat use. For nest survival, I monitored Bendire's Thrasher nests (n = 75) across Hidalgo and Grant counties in New Mexico and Cochise county in Arizona during the 2018 and 2019 breeding seasons. Nest initiation differed by a month between the two years of study, where average initiation date was later in 2018 compared to 2019. The daily nest survival estimate was 0.969 ± 0.005 (95% CI = 0.956-0.978), resulting in cumulative nest survival estimate of 0.414 ± 0.040 (95% CI = 0.339-0.450)

for a single 28-day nesting attempt. Predation pressure was strong and multiple predators were documented consuming eggs and nestlings. Nest survival was primarily influenced by temporal variation, including year, time, and nest age, but not strongly influenced by vegetation characteristics within the nest site and territory. Findings from this study highlight an important breeding hotspot within the bootheel of New Mexico, plasticity in nest initiation dates, and annual and seasonal differences in nest survival. This study will serve as a baseline estimate for nest survival of Bendire's Thrashers and may be used for comparison of estimates in other habitats and in future years.

I also examined juvenile Bendire's Thrasher survival during the post-fledgling period, movement patterns from the nest site and habitat use. I attached transmitters to 25 nestlings and tracked 19 fledglings using radio-telemetry. I modeled fledgling survival in relation to year, time, and body condition. I also modeled habitat use in relation to vegetation characteristics at both used and paired-available sites. Fledgling weekly survival was estimated as 0.800 ± 0.05 (95% CIs 0.694-0.876), resulting in a cumulative survival rate of 0.38 ± 0.10 (95% CIs 0.197-0.570) (38% chance of survival) for 4.3 weeks (30 days) post-fledging, based on the average age of dispersing fledglings. Predation pressure was strong on fledglings as they were not capable of flight for the first few days after leaving the nest site and were vulnerable to predators. Distances moved from the nest site increased with fledgling age, and in general, fledglings remained with family units (siblings and adults) on the breeding territory until the family unit dispersed. Fledgling habitat use was positively influenced by overall shrub cover and tall shrubs, and negatively influenced by overall shrub density, which resulted in less bare ground for foraging. The overlap in habitat use from the nesting and post-fledging stages highlights the need to conserve breeding hotspots.

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INTRODUCTION

Recent research has brought to light the rapid decline of North American avian species and the threat of extinction (Sauer et al. 2017, Rosenberg et al. 2019). However, documenting population declines alone is not sufficient to justify conservation action; understanding causes of declining trends is often warranted to determine appropriate management measures (Dunn 2002). In order to understand broad scale population declines, local population demographics must be examined, including the production and survival of offspring (Anders and Marshall 2005). For example, the Florida Grasshopper Sparrow (*Ammodramus savannarum floridanus*), a sub-species of Grasshopper Sparrow endemic to southern Florida has experienced declines due to the conversion of grasslands to citrus crops. An overall reduction of an already limited range has prompted an intense management regime to promote population growth of this declining subspecies (Perkins et al. 2008). Short-lived species, such as the Florida Grasshopper Sparrow, benefit from increased reproductive output for population growth, which requires conservation of breeding sites to preserve local populations (Mills 2012).

Nest survival estimates produce a daily rate of breeding output that can be directly linked to predictors of habitat quality, food resources and predation pressure (Armstrong et al. 2002, Grendelmeier et al. 2015). Reduced nest survival of passerines has been associated with numerous factors including oil and gas development, urbanization, introduction of exotic vegetation, and habitat fragmentation (Reidy et al. 2009, DeGregorio et al. 2014, Hethcoat and

Chalfoun 2015). For example, the nest survival of Brewer's Sparrows (*Spizella berwei*), Sagebrush Sparrows (*Artemisiospize nevadensis*), and Sage Thrashers (*Oreoscoptes montanus*) in Wyoming was negatively impacted by loss of sagebrush habitat due to expansion of energy extraction (Hethcoat and Chalfoun 2015), and nest survival of Golden-cheeked Warblers (*Setophaga chrysoparia*) declined with increased measures of vegetation edge and fragmentation associated with increasing urbanization (Reidy et al. 2009). Identifying the causes of nest failure are critical to understanding population declines and developing appropriate conservation strategies.

Several studies have shown that nest survival varies with temporal influences such as nest age and annual, and seasonal variation in climate, food, and other factors (Davis 2005, Grant et al. 2006, Kerns et al. 2010, Grant and Shaffer 2012). Nests that initiate earlier in the breeding season may experience high rates of nest survival compared to nests initiated later in the breeding season due to changes in resource availability and/or increased predation pressures (Davis 2005, Grant et al. 2006, Segura et al. 2012). Additionally, nest survival often decreases with nest age, as nestlings grow and become more conspicuous to predators (Lloyd and Martin 2005, Grant et al. 2006). Nest age has been observed to influence the nest survival of Clay-colored (*Spizella pallida*) and Savannah Sparrows (*Passerculus sandwichensis*). In North Dakota, nest survival for both species was lowest mid-nestling stage and highest during incubation (Kerns et al. 2010). Determining time-specific patterns in nest survival can provide insight into identifying links between biotic variables such as predation risk at the nest site and available resources throughout the breeding season (Both et al. 2009, McKinnon et al. 2012).

Vegetation and food resources at the nest and the surrounding territory have been documented to influence nest survival of passerines. At the nest site, vegetation characteristics are often associated with measures of nest concealment or predator avoidance. For instance, nest survival rates of Red-crested Cardinals (*Paroaria coronata*) were positively influenced by foliage cover (Segura et al. 2012). Nest survival may be influenced by the availability of resources; competition is more likely to occur where resources are limited, especially within vegetation communities with low complexity and structure (Davis 2005, Calizza et al. 2017) or intensified by phenological mismatches (Both and Visser 2001). Mismatches in the timing of nesting and prey availability have been documented for insectivorous passerines and are linked to climate change (Mares et al. 2017). For species of conservation concern, it is critical to understand the phenological link between time-specific variables, such as nest initiation and age with available resources that have the greatest impact on nest survival.

In North America, species belonging to grassland and arid land assemblages are exhibiting particularly strong population declines (NABCI, 2014). In the arid land assemblage, one obligate species, the Bendire's Thrasher (*Toxostoma bendirei*) has not been well studied. Historically, Bendire's Thrashers were confused with Curve-billed Thrashers (*Toxostoma curvirostre*) and were not described as a separate species until the late 1800s (England and Laudenslayer 1993) as they tend to be secretive and cryptic by nature. Therefore, little is known about this species including basic natural history and reproductive biology. Although not well documented, theories for population decline of Bendire's Thrashers include loss of habitat (Ambrose 1963, England and Laudenslayer 1993), likely due to desertification where prolonged

drought and overgrazing has led to a reduction of shrubs (Kerley and Whitford 2000) or increasing urbanization in some areas. Competition for breeding sites may occur in these areas where resource have been reduced (Calizza et al. 2016). Additionally, changing climate conditions may limit the distribution of Bendire's Thrashers within their range (Sutton 2020) and could also cause mismatches in breeding phenology (McKinnon et al. 2012, Mares et al. 2017).

Although little published information is available for Bendire's Thrashers, recent research has addressed habitat selection during the breeding season which includes tall shrubs for nesting, vertical vegetation structure, and bare ground for foraging within large heterogeneous landscapes (Sutton 2020). However, it is not understood if these vegetation variables influence measures of fitness (Shochat et al. 2005) including nest survival. I modeled daily nest survival of Bendire's Thrashers in relation to variables at three scales to address the effects of temporal variation, nest site characteristics, and territory characteristics. I hypothesized that predation would be the main cause of nest failure resulting in a decrease in survival as the season progressed and vegetation characteristics at the nest and territory scales would influence vulnerability to predation (Etterson et al. 2007). I predicted a positive relationship between nest survival and measures of concealment at the nest and within the breeding territory like shrub cover or vertical vegetation structure (Segura et al. 2012, Grendelmeier et al. 2015, Duchardt et al. 2020). Additionally, I hypothesized that nest survival would be related to food availability and the presence of competitors on or near Bendire's Thrasher breeding territories. I predicted arthropod abundance would be positively related to nest survival, while the presence of Curve-billed Thrashers would be negatively related to nest survival (Ambrose 1963, Morrison and

Bolger 2002). Understanding the relationships these variables have with the nest survival of Bendire's Thrashers can provide more insight into the sensitivities to seasonal and annual differences, changes in habitat, and the overall vulnerability of future population growth for this declining species.

METHODS

Study Area

This study was conducted in the Chihuahuan Desert range of the Bendire's Thrasher from February to June in 2018 and 2019, with fieldwork in Hidalgo (32.346322, -108.967526 and 31.828346, -108.802302) and Grant Counties (32.017173, -108.370402), New Mexico, and Cochise County (31.637671, -109.687045), Arizona (Figure 1). Elevation within the study area spanned 1,200-1,400-m and topography included playas or large expanses of dry lake beds that collect rainwater during monsoons but quickly evaporate due to alkali soils (Bolen et al. 1989). The average daily precipitation across the three counties during the 2018 and 2019 breeding season (March – June) was 0.31mm ± 0.08 (SE). Average daily temperature across the 2018 and 2019 breeding seasons (March –June) was 17.29°C ± 0.47 (SE) and ranged from 6.43-27.73°C. Average daily precipitation and temperature, respectively, varied between the two years of study at 0.85mm ± 0.18 (SE) and 21.81°C ± 0.44 (SE) for 2018 and 0.39mm ± 0.12 (SE) and 18.56°C ± 0.49 (SE) for 2019 (PRISM Climate Group 2020).

Vegetation in the Chihuahuan Desert is sparse, and thrasher territories are composed of distinct stands of shrubs and cacti with large areas of bare ground interspersed with patches of

native grasses. Dominant shrubs across the study area included soaptree yuccas (*Yucca elata*), honey mesquite (*Prosopis glandulosa*), broom snakeweed (*Gutierrezia sarothrae*), and rabbitbrush (*Chrysothamnus* spp). Less common shrub and cacti species included longleaf ephedra (*Ephedra trifurca*), whitethorn acacia (*Vachellia constricta*), little leaf sumac (*Rhus microphylla*), graythorn (*Ziziphus obtusifolia*), allthorn (*Koeberlinia spinosa*), wolfberry (*Lycium barbarum*), apache plume (*Fallugia paradoxa*), prickly pear cactus *(Opuntia* spp.), cane cholla (*Cylindropuntia imbricata*), and desert willow (*Chilopsis linearis*). Grass species consisted of tobosa grass (*Pleuraphis mutica*) as well as giant (*Sporobolus wrightii*) and alkali sacaton (*Sporobolus airoides*).

Field Methods

Area searches and territory mapping. Area searches for Bendire's Thrashers were initiated in mid-February of 2018 and early March of 2019 and were conducted at locations where this species is known to occur based on previous research (Sutton 2020) and current and historical eBird locations (Ralph et al. 1993, Sullivan et al. 2009, eBird 2018). Call-playback was used to increase detections (Mathewson et al. 2013, Sutton 2020). Once singing males were located, territory mapping ensued using the flush-mapping technique (Reed 1985, Sutton 2020), in which each perching location was marked with a handheld GPS unit (GARMIN 64s; Garmin, Olathe, Kansas - accuracy ~3m) using Universal Transverse Mercator (UTM) coordinates. To define a breeding territory, a minimum of 30 perching locations were marked and recorded by

observers over a minimum of 3 separate visits. Territory boundaries were then created with convex hulls in ArcMap GIS (ESRI 2011).

Nest searching and monitoring. Once territories were delineated, nest searching was initiated. Nests were located primarily by parental cues (i.e., adults with nesting material, a food carry, etc.) where adults were followed to a nest site or by incidentally flushing incubating females. Additionally, shrubs within territories were systematically searched for nests on active territories (Ruehmann et al. 2011). Nests were defined as containing at least one egg. Once nests were located, they were marked with a GPS and a viewing point was also marked at a minimum of 80-m away from the nest site for future nest checks to reduce disturbance at the nest (Ralph et al. 1993). The distance of 80-m was determined by observing adult behavior, as adults would not return to nests if observers were closer than 80-m to nest sites. Nests were not marked with flagging or other visual markers to reduce predation risk, as corvid (Family: Corvidae) species are known to associate markers and nest sites (Nichols et al. 1984), and nests were monitored every 2-5 days until successful fledging or failure. While checking nests, observers followed standard nest monitoring techniques (Martin and Geupel 1993). First, observers would monitor parental behavior to determine nest stages (building, laying, incubating, brooding, etc.) from the 80-m viewing point. When transition stages were expected, or behavioral observations were not conclusive, observers would approach the nest to check nest contents. Observers made sure never to leave a dead-end trail to the nest, never used their hands to check nest contents, and never checked the nest in the presence of predators. During nest checks, observers recorded if the nest was active or not and the nest contents (i.e., eggs, nestlings, or empty). Observers attempted

to age nestlings when present and recorded a description of nestlings (i.e., eyes open, feather tracts present, feathers emerging from sheaths, gaping, etc.) to assist in aging. Evidence of nest failure included eggs or nestlings missing from the nest before the expected fledge date, nests that were torn apart by predators, and nests containing remains of broken eggshells or rodent feces (Etterson et al. 2007). Evidence of fledging young included intact nests that were empty at the approximate fledge date, nestling feces within the nest and visual confirmation of fledged young near the nest site (Martin and Geupel 1993).

Identification of Predators. Camera traps were used on a subset of nest sites to assist with nest monitoring and identification of nest predators. Trail cameras (Reconyx Hyperfire PC 900) were attached to a fence post or a rebar stake and placed in the ground within 3-5-m of the nest site and were set-up during a nest check. To reduce the influence of predation, cameras were disguised with branches of vegetation (Richardson et al. 2009). Cameras were set to a motion sensor setting and checked every 2-3 days, the estimated battery life span, during nest checks. Photos were viewed after collection and predators were identified in cases of nest failure (Luepold et al. 2015, Hammond et al. 2016).

Predictors of Nest Survival

I examined variables expected to influence Bendire's Thrasher nest survival at a temporal scale and the nest and territory spatial scales (Table 1) using my sample of first nest attempts across two years of data collection. The temporal scale evaluates time dependent variables, while the nest site scale consists of measures of nest concealment and predator avoidance, and the

territory scale consists of measures of food availability and foraging space, broader measures of predation avoidance, and the presence of Curve-billed Thrashers as potential competitors.

Temporal variables. I examined temporal variables known to influence passerine nest survival. These variables include the effects of year, day of the season, and nest age (Grant et al. 2006, Reidy et al. 2009, Winiarski et al. 2017). Nest age was calculated by counting back from the estimated initiation date of the first nest found and is relative to each breeding season (Davis 2006, Grant et al. 2006, Segura and Reboreda 2012).

Nest site scale variables. At the nest site scale, I examined variables commonly found to influence nest survival at this scale. This included, the shrub species used for nesting, measurements of nest height (m), shrub height (m), distance to edge (cm), and percent nest concealment (Segura et al. 2012, Jenkins et al. 2016). Concealment was measured visually with the aid of a circular disc, divided into eight sections, which was viewed from a 1-m distance in each cardinal direction from the nest site at a standard height of 1-m and then rated from 0-8 (0=0%, 1=12.5%, 2=25%, 3=37.5%, 4=50%, 5=62.5%, 7=87.5%, 8=100%) (Schill and Yahner 2009). Vegetation data was collected after the nesting attempt ended to avoid interfering with ongoing nesting efforts.

Territory scale variables. At the territory scale I measured vegetation characteristics, food abundance, and presence of Curve-billed Thrashers within the defended territories of breeding pairs.

Vegetation characteristics. Vegetation data was collected along six 25-m transects randomly placed within each breeding territory using standard rangeland assessment protocols (Herrick et al. 2005, Sutton 2020) after nesting was complete. The canopy gap intercept method was used to measure foraging space available within the territory. The belt transect method was used to determine the average height of tall shrubs (>1.5-m) and density of tall shrubs (>1.5-m) within the belt. Visual obstruction reading (VOR) is a measure of vegetation structure that measures vegetation height and vertical density by using a Robel pole placed at every 5-m along the transect and viewed from a height of 1-m from 5-m away in each direction along the transect line. Observers recorded the number of the Robel pole segments covered by vegetation (Herrick et al. 2005). The average value from all six transects was incorporated as a continuous variable for data analysis.

Estimation of food abundance. Two 100-m parallel transects set 10-m apart were placed within each breeding territory with an active nest. To reduce disturbance, transects were placed at least 100-m away from the nest site. Food abundance data was collected once during incubation stage and twice during the nestling stage of active nests along these transects. Sampling for terrestrial arthropods occurred using sweep nets and beat nets. Sweep-netting occurred by walking the length of the transect and sweeping the net low to the ground and fast, making a figure-8 shape at each 1-m mark along the 100-m transect (Jamison et al. 2002, Brust et al. 2009, Steward et al. 2013). This method was used to target the order Orthoptera, the main prey of Bendire's Thrashers (England and Laudenslayer 1993). Arthropods captured in the sweep nets were placed in a kill jar with ethyl acetate, then transferred to gallon plastic bags,

labeled, and stored frozen until sorting. Additionally, eight shrubs were also sampled along the two transects using a beat net, to capture arthropods. Four shrubs were beaten along each transect at approximately every 25-m. Beat-netting occurred by placing a beat net under a shrub branch and hitting the branch to knock arthropods out of the vegetation. Four branches from each of the 8 shrubs were beaten 4 times each (McDermett and Wood 2016). Insects were collected in 50mL centrifuge tubes containing ethyl acetate, labeled, and stored in a freezer until sorting. Arthropod identification and sorting was conducted at New Mexico State University (NMSU) main campus after each nesting season. Each sampling event was sorted and identified to order, and individuals within each order were counted and recorded. All sorted samples were placed in 70% ethyl alcohol, labeled, and stored (Whipple et al. 2010). The average value from all sampling events was incorporated as a continuous variable in data analysis.

Presence of Curve-billed Thrashers. To determine presence of Curve-billed Thrashers, point count surveys were conducted once during the incubation and nestling stages of active Bendire's Thrasher nests (Gorton 1977, Prescott 1987, Hill and Lein 1989). Point count surveys were designed to capture detections of Curve-billed Thrashers nearest to active Bendire's Thrasher territories and a total of four points were surveyed for each Bendire's Thrasher territory based on territory mapping delineation. Two points were placed at the farthest opposite ends of active Bendire's Thrasher territories with one additional point added to each of the ends, 400-m away in a direction determined by a random bearing, from the territory ends. Surveys consisted of a 3-minute silent point count where all avian species seen and heard were recorded, followed by a 3-minute call-playback of a Curve-billed Thrasher song. All mimids (Family: Mimidae)

species detected were recorded with a bearing and distance to location (Sutton 2020). If Curve-billed Thrashers were detected during the silent point count, call-playback was not conducted to reduce disturbance. A binary variable was created as “presence” or “absence” of Curve-billed Thrashers detected on active Bendire’s Thrasher territories for data analysis.

Nest Survival Analysis

Variables from each scale considered for nest survival analysis from both years of data were combined and Pearson’s correlation coefficient was used to check for collinearity between continuous predictor variables prior to analysis. When variables were correlated (> |0.65|) one of the two was removed for analysis (Schober et al. 2018). The remaining continuous variables were standardized by subtracting the mean and dividing by the standard deviation (Becker et al. 1988) and organized into three separate scales for model analysis: 1) temporal scale, 2) nest site scale, and 3) territory scale. Daily nest survival analysis was calculated using the nest survival model implemented with Program MARK (White and Burnham 1999) through the RMark package (Lakke 2013) in R (R Core Team 2020). The nest survival model uses the logistic-exposure method to calculate daily nest survival rates (DSR) based on exposure days and the binary outcome of nest success or failure and can incorporate variables using a logit link function (Rotella et al. 2004, Shaffer 2004). A set of candidate models including the null and global model were defined for each scale (Appendix Table 5) and model selection was conducted using Akaike’s Information Criterion adjusted for small sample size (AIC_c). Models in each set are considered to have strong empirical support when they fall within 2 ΔAIC_c, and variables were considered to have a strong effect when 95% confidence intervals did not bound zero (Burnham

and Anderson 2002). Model averaging was conducted to estimate averaged parameter estimates in the case of high model uncertainty and included all models within the model set (Arnold 2010, Grueber et al. 2011). The cumulative nest survival rate (CNS), or the probability of a nest surviving was calculated by raising the DSR estimate from the intercept-only model to the power of the length of a single nesting attempt in days (28 days). The standard error for the CNS estimate was calculated using the Delta Method (Powell 2007). All mean values are reported with ± standard error (Anderson et al. 2001).

RESULTS

Breeding Biology

I monitored 75 first nesting attempts for Bendire's Thrasher throughout New Mexico and Arizona for both years of data collection. Nests were initiated almost an entire month earlier in 2019, compared to 2018 (Figure 2). The majority of nests were found in the incubation stage (n = 43). The incubation period averaged 13 days (12.79 ± 0.19), and the nestling period was approximately 15 days (15.28 ± 0.28) (Table 2). Interestingly, nests that successfully raised young to fledging on average, had clutch and brood sizes of three and raised all three to fledgling age. In 2018, 12 of 30 first nest attempts successfully raised young to fledge, whereas, in 2019, 31 of 45 first nest attempts fledged successfully. In 2018, I documented 9 second nesting attempts and 3 third nesting attempts, all of which failed. In 2019, there were 10 second nesting attempts, 5 of which successfully fledged young, and no third nesting attempts were observed.

Causes of nest failure. Cameras were placed on 31 active nest sites opportunistically over the two breeding seasons. Depredation was a major cause of nest failure and the most identified nest predator was Chihuahuan Ravens (*Corvus cryptoleucus*) followed by coyotes (*Canis latrans*), collared peccary (*Dicotyles tajacu*), and unidentified rodents (Order: Rodentia). In 2018, three first nesting attempts were not included in the data set since egg-laying could not be confirmed (i.e. if eggs were laid, the nest was predated or abandoned and then predated prior to confirmation of egg-laying). An additional nest from 2018 was not included as predation was suspected prior to discovery of the nest (i.e. eggshells were found in the nest upon discovery), and as a result the nest could not be aged. One nest from 2019 was suspected of failing by a competitor, as eggs were destroyed in the nest but not consumed. No evidence of parasitism by Brown-headed Cowbirds (*Molothrus ater*) was observed during the two breeding seasons.

Daily Nest Survival

Nest survival analysis was based on 162 exposure days from a sample of 75 first nesting attempts over two years (2018-2019). The overall nest success of Bendire's Thrashers was 57% and was lower in 2018 (40%) compared to 2019 (69%). The daily nest survival estimate based on the intercept-only model was 0.969 ± 0.005 (95% CI = 0.956-0.978), resulting in cumulative nest survival estimate of 0.414 ± 0.040 (95% CI = 0.339-0.450) for a single 28-day nesting attempt.

Temporal Scale. The top ranked model in the abiotic scale included the additive effects of year, time, and nest age, as well as the interaction terms of year with nest age (Table 3). This

model carried 24% of the cumulative weight. However, several additional models were competitive with ΔAIC_c values < 2. The model averaged results demonstrate a strong relationship between time and nest survival estimates between the two years with 95% CIs that did not bounding zero (Figure 3, Table 4). DSR was high early in the 2018 season and declined throughout the breeding season (range: 0.670-0.986, mean: 0.906 ± 0.010), while survival in 2019 remained high throughout the season (range: 0.962-0.979, mean: 0.975 ± 0.0004) (Figure 3).

Nest Site Scale. The model including the effect of nest concealment was the top ranked model at the nest site scale (Figure 4); however, several additional models were competitive with ΔAIC_c values < 2 (Table 6). Both nest concealment and distance to edge measurements showed a positive relationship with nest survival whereas, nest height and shrub height showed a negative relation to survival (Table 4). However, the 95% CIs of the model averaged results for all variables at this scale bounded 0 (Table 4). Of all the shrub species used, 56% of nests were located within soaptree yuccas, however, nesting in soaptree yuccas showed a negative relation to nest survival (Table 4).

Territory Scale. At the territory scale, the top ranked model included the variables of canopy gap sizes and arthropod abundance, although there were four other competitive models in this set, including the null model (Table 3). Both measures of canopy gap sizes and arthropod abundance showed a positive relationship with nest survival, although the 95% CIs bound zero (Table 4, Appendix Figure 5a & b). The number of tall shrubs and average height of tall shrubs both showed a negative relationship with nest survival and 95% CIs bound zero (Table 4). Model

averaged results for these variables bounded zero indicating the effects of these variables on nest survival were not statistically significant.

DISCUSSION

The findings from this research highlight the potential for low and variable nest survival rates that could limit the population growth of Bendire's Thrashers within the Chihuahuan Desert, but also identified an important breeding hotspot within southwestern New Mexico. The nest survival of Bendire's Thrashers was not explained by habitat characteristics at the nest site or the territory, but by nest initiation dates in relation to seasonal and annual differences. Like other arid land passerines (Borgman and Wolf 2016), Bendire's Thrashers appear capable of delaying nest initiation likely during drought conditions but may be flexible when conditions are favorable. Predation pressures were strong as multiple predators took advantage of eggs and nestlings, possibly shortening the time nestlings develop in the nest. This observed short nesting period is likely an evolutionary response to strong predation pressure and has been observed in other arid land mimid species including Curve-billed Thrashers (Fischer 1980, 1984, Murphy and Fleischer 1986). Since long-term data are lacking, this data will serve as a baseline for future comparisons, but further research is warranted for management strategies and conservation efforts of Bendire's Thrashers.

The nesting ecology of this little-studied species was found to be comparable to other thrasher species. Desert thrashers initiate nests early in the spring (Hill 1980). Although some suggest Bendire's Thrashers will nest as early as February (Brown 1901), the earliest nest

initiation date I estimated over the two-year period was 15 March. The length of the incubation and nestling periods were similar to reports of other thrashers (Fischer 1980, Murphy and Fleischer 1986); Bendire's Thrashers have incubation and nestling stages that are approximately two weeks each and on average, lay three eggs. This species, similar to the LeConte's Thrashers, commonly had second clutches especially in the year with high nest failure (England and Laudenslayer 1993, Sheppard 2018). Bendire's Thrashers appear to occupy the same territory for successive nesting attempts, often with juveniles still present from the previous nest. This has also been observed in LeConte's Thrashers, in which fledglings remain within the adult breeding territories up to 30 days post-fledging while adults begin to re-nest (Sheppard 2018). Although Bendire's Thrashers typically built a new nest for a second, or third, nesting attempts, I did observe one pair reuse the same nest for a second nest attempt, something only previously documented once before (Gilman 1915). In desert environments, Bendire's Thrashers have been documented to nest in a variety of shrub species (Darling 1970, England and Laudenslayer 1993), however, soap tree yucca was the most abundant and dominant shrub used for nest sites by Bendire's Thrashers in this study.

Nest survival varied between years and, interestingly, nests were initiated almost a month later in 2018 compared to 2019. Given the difference in nest initiation between years, it is not surprising that nest survival was most strongly affected by year and time; nests in 2018 with later mean nest initiation dates had lower survival compared to nests in 2019. Bendire's Thrasher nest survival was not strongly influenced by variables at the nest site or territory scale. Nest concealment has been strongly related to nest survival for many passerines (Ruehmann et al.

2011, Segura et al. 2012, Grendelmeier et al. 2015) however, I only observed a weak influence. This is likely in part attributed to tree-like structure of soaptree yuccas used for nesting and the fact that the dominant nest predator, Chihuahuan Ravens, are not limited by nest height. Anecdotally, Bendire's Thrashers would sometimes select nest sites with multiple layers of concealment by more than one species of shrub or shrubs covered in dead Russian thistle (*Kali tragus*) that had built up over time to increase concealment (Image 1). Previous research has documented differences in nest survival for passerines in various nest shrub species, often higher survival in shrubs that were not the preferred or the most frequently used shrubs species within the study site (Mezquida and Marone 2001). I did detect lower survival for nests in soaptree yucca, the most common shrub species, however this was not strongly supported. Research has shown that Bendire's Thrashers are attracted to areas with tall shrubs and overall greater shrub height (Sutton 2020), however, this was not observed to have a strong influence on nest survival. Within the territory, food availability, both direct arthropod abundances and foraging space in the territory, positively influenced nest survival, albeit this relationship was weak. Other studies have found nest survival to be related to invertebrate biomass. In New Zealand, North Island Robin (*Petroica longipes*) nest survival increased with increasing invertebrate biomass measure (Boulton et al. 2008). Furthermore, Cactus Wrens (*Campylorhynchus brunneicapillus*) supplemented with food during the nesting season produced offspring in greater body condition (higher weights) and allowed for multiple broods (Simons and Martin 1990).

Competition with closely related species has been documented to influence nest site selection and breeding for passerines (Ahola et al. 2007). Curve-billed Thrashers were not

commonly detected on Bendire's Thrasher territories at my study site and may nest at slightly different times based on available resources (Steward et al. 2013). Potential competitive pressures from Curve-billed Thrashers may density-dependent or may be stronger in more artificial settings such as urban areas and ranchettes (Shochat et al. 2004, Sheppard 2018). Other mimids were more commonly detected and may also be competitors, including Northern Mockingbirds (*Mimis polyglottos*) and Crissal Thrashers (*Toxostoma crissale*). Cactus Wrens are known to destroy competitors' eggs (Simons and Simons 1990) and were detected on almost every Bendire's Thrasher territory during this study. Sheppard (2018) observed eggs of a LeConte's Thrasher nest destroyed by a competitor. I also observed one nest that had been destroyed by a competitor, possibly by Cactus Wrens.

Plasticity in nest initiation dates have been previously documented in arid land passerines and have been linked to precipitation and temperature (McCreedy and van Riper 2015). Nest initiation is driven by the phenology of primary production and food availability as breeding pairs time nesting with the highest availability of prey to feed nestlings and fledglings (Hill 1980, van Noordwijk et al. 1995, Polis et al. 1997). Unlike passerines in temperate climates that tend to nest earlier in response to warmer spring weather (Both and Visser 2001; Crick 2004), arid land passerines tend to delay nest initiation during high temperatures and drought conditions (Preston and Rotenberry 2006, McCreedy and van Riper 2015, Borgman and Wolf 2016). Previous research has shown that drought conditions have delayed nest initiation for 13 species of passerines in the Sonoran Desert by up to 3 weeks and that these delays had a strong negative influence on nest survival (McCreedy and van Riper 2015). Analogously, a negative correlation

was observed between nest initiation with increasing measures of precipitation from the previous winter for 13 species of arid land passerines, including Bendire's Thrashers (McCreedy et al. 2015).

In my study, differences in nest survival between years appeared to be related to timing of nest initiation with lower nest survival in 2018 when Bendire's Thrashers initiated nests almost a month later than 2019, likely linked directly or indirectly to climate variables. These findings are similar to a study in the Sonoran Desert that documented lower nest survival for Loggerhead Shrikes (*Lanius ludovicianus*), Black-tailed Gnatcatcher (*Polioptila melanura*) and Phainopepla's with later nesting dates (McCreedy and van Ripper 2015). In that study, Phainopeplas failed to nest completely during extreme drought conditions (McCreedy and van Riper 2015). In my study, we observed fewer nests in 2018 when nests were initiated later in the season compared to 2019. Bendire's Thrashers experience temperature extremes during the breeding season, and exposure could have deleterious impacts on nesting (Conradie et al. 2019, Nord and Giroud 2020). The differences in average temperature observed between the two years of this study for the breeding season was 3.24°C (21.81°C ± 0.44 for 2018 and 18.56°C ± 0.49 for 2019). Oscillations in temperature extremes between breeding seasons may have a strong impact on arid land species like desert thrashers that are already pushing their physiological limits in habitats with scare resources (Conrey et al. 2016). Seasonal variation in nest survival has been associated with timing of nest initiation for other arid land passerines, linked to previous winter precipitation, drought conditions, and associated predation pressures (McCreedy et al. 2015). Grassland passerines were found to have lower nest survival in warmer and drier

years and experienced increased predation pressures due to food scarcity (Conrey et al. 2016, Mares et al. 2017). Future climate projections anticipate increasing temperatures and prolonged drought in the southwest United States (Seager et al. 2007), which could negatively impact nest survival and productivity of Bendire's Thrashers by delaying nest initiation thereby decreasing nest survival.

Variation has been observed in nest survival rates across thrasher species and influenced by predation risk (Hethcoat and Chalfoun 2015, Sheppard 2018). Nest survival of Bendire's Thrashers varied over the breeding season and between the two years of study. A study on Sage Thrashers over 4 years had a more consistent nest survival rate that was similar to Bendire's Thrasher DNS in 2019 (Hethcoat and Chalfoun 2015). Predation is the most common cause of nest failure in passerines (Aldringer et al. 2015, Grendelmeier et al. 2015, Jenkins et al. 2016) and my research was no exception, as predation accounted for almost all nest failures. Similar to other studies (Benson et al. 2010, Cox et al. 2012, Thompson and Ribic 2012, DeGregorio et al. 2014), multiple species of predators were documented depredating Bendire's Thrasher nests, although the most common predator within my study site was Chihuahuan Ravens. Within the Chihuahuan Desert, stands of soaptree yuccas have grown along drainages and yucca growth can be altered due to foraging from cattle (Kerley et al. 1993). This growth pattern is apparent within my study site where stands of yuccas grow along drainages from the Peloncillo Mountains into the Lordsburg Playa, creating habitat for Bendire's Thrashers. However, these patches of vegetation may make it easier for predators to search which could make nests vulnerable (Patten and Bolger 2003). The formation of these stands of vegetation at this site may be natural but may

also be negatively influenced by grazing pressures. Desertification, as a result of prolonged drought and overgrazing, may continue to isolate these stands of vegetation or alter the growth of shrubs (Kerley and Whitford 2000), potentially limiting habitat for Bendire's Thrashers.

Recent research has highlighted the risk of extinction of Bendire's Thrashers within the New Mexico extent of their range based on climate projects (Sutton 2020). Sutton (2020) discovered that maximum temperature and bioyear precipitation (accumulation of precipitation from the previous winter) contribute to the distribution of Bendire's Thrashers during the breeding season and identified the southwest and southcentral New Mexico as potential breeding hotspots. This research confirms that the southwestern "bootheel" of New Mexico is an important breeding hotspot for Bendire's Thrashers. However, Sutton's (2020) climate projects indicate the potential for range reduction from these breeding hotspots due to increasing temperatures, decreased precipitation, and prolonged drought. Arid land thrashers are associated with warm and dry conditions, however increasing unpredictability of weather patterns in the southwest creates higher risks to the potential for mismatches in the phenology of resources and environmental cues required for successful breeding (Both and Visser 2001, Crick 2004). Increasing temperatures and prolonged drought could influence vegetation and prey abundance, as arthropods are dependent on precipitation (Bolger et al. 2005, Lightfoot 2018). Our results suggest that reproductive output of Bendire's Thrashers could be sensitive to seasonal and annual variation based on the observed differences in nest initiation and survival between the two years of data collection for this study. Therefore, further investigation into future climate projections

and vulnerability is warranted as climate issues can create complications for management decisions (Bateman et al. 2020).

Bendire's Thrashers would benefit from research that fills in remaining knowledge gaps for this rare and secretive species, which could further enhance appropriate management decisions. Within the Chihuahuan Desert, I have identified an important breeding hotspot for Bendire's Thrashers and have documented the highest number of breeding pairs in the state of New Mexico, to the best of my knowledge. Hotspots for rare and declining species require protection from disturbance; further identification and conservation of important breeding sites for Bendire's Thrashers in the Chihuahuan Desert is warranted. Comparisons of nest survival estimates across different habitat types, like pinyon-juniper or grassland scrub, would broaden understanding of Bendire's Thrashers nest survival throughout its range. Additional knowledge gaps need to be documented, such as adult annual survival and fidelity to breeding hotspots, post-fledging survival and habitat use, migratory pathways, and wintering habitat. Long-term studies of the plasticity of nest initiation dates and the impacts of climate variables on nest survival will enhance our knowledge of the potential climate risks Bendire's Thrashers could face in the future.

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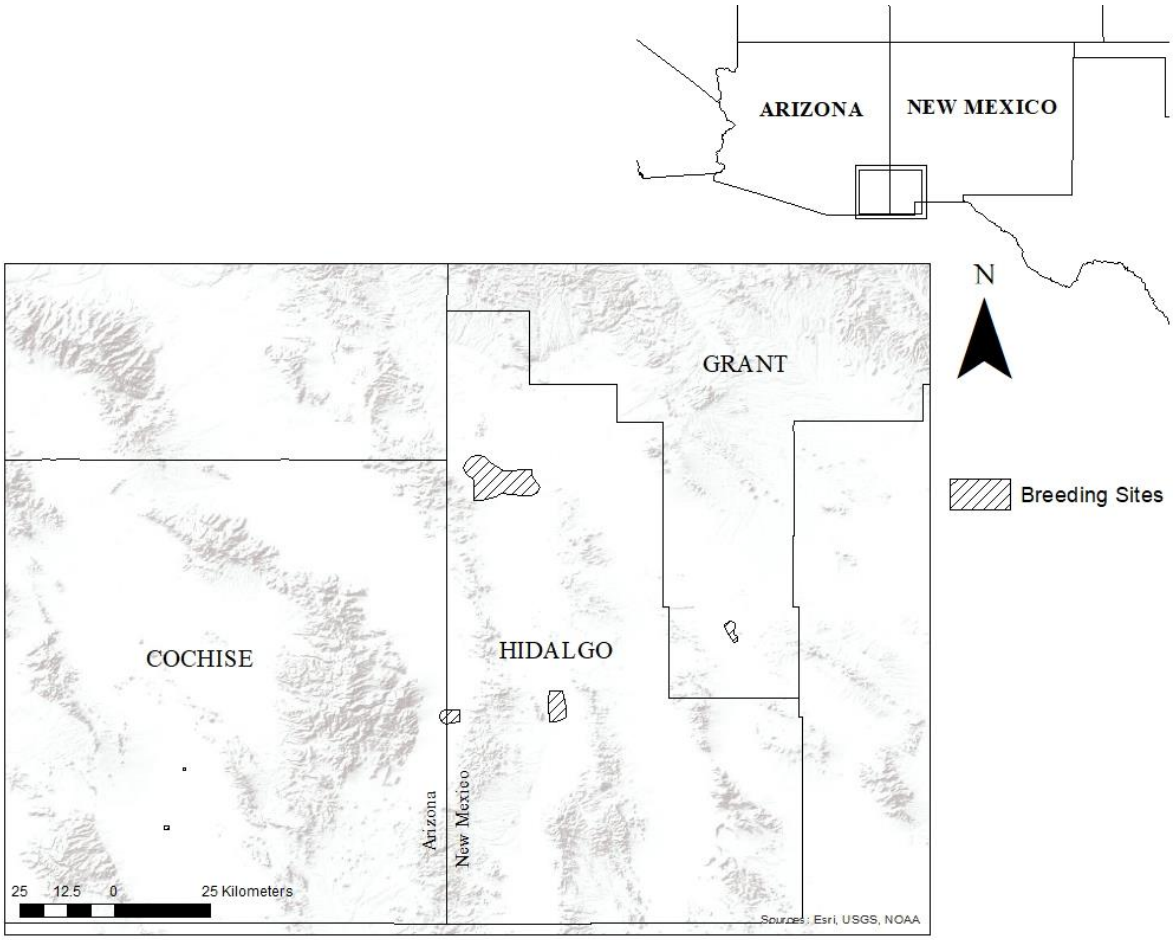

FIGURE 1. Study site locations for breeding Bendire's Thrashers in Grant and Hidalgo Counties, New Mexico in 2018 and 2019 and Cochise County, Arizona in 2018. Approximate areas surveyed and documented nesting locations for Bendire's Thrashers were found within the shaded areas.

TABLE 1. Variables incorporated into nest survival analysis with definitions and model notation for each scale of analysis, including the temporal scale, nest site scale, and territory scale, during the 2018-2019 breeding seasons of Bendire's Thrashers in the Chihuahuan Desert. Each scale includes an intercept only model (*null*), or the constant model, a global model (*global*), which is the most complex model, additive terms, and interaction terms.

	Variable	**Model Notation**	**Definition**
Temporal	Year*	Year	Day of the season, starts when the first nest is found
	Time Trend	Time	Time trend model, day of the season based on the first nest found
	Nest Age	Nest_Age	The age of the nest at the first occasion use to incorporate nest age
Nest	Nest height	Nest_Hgt	Measure of height of the nest (m) from ground to bottom of the nest
	Shrub height	Shrb_Hgt	Measure of the height of the shrub the nest site is in (m) from ground to height point of shrub
	Concealment	Conc	Measure of cover directly around, above, and below nest site measured in (%)
	Distance to edge	DTE	Measure of depth, or how deep into the nest shrub the nest is located, measures (m) from edge of nest to the end of the longest supporting branch
	Shrub Species*	Species	Record of the species of shrub used for nesting
Territory	Average canopy gap size	Can_Gaps	Average measure of gaps (cm) between plant canopies along 25-m transects
	Visual Obstruction Reading	VOR	Average measure of vertical cover (%) along 25-m transects
	Average Shrub Height	Ave_Hgt	Average height of shrubs in size class "C" (>1.5-m in height) for shrubs within belt transects
	Density of Tall Shrubs	Tall_Shrbs	Density of shrubs/ha of size class "C" (>1.5-m in height)
	Average Arthropod Abundance	Arthro	Average abundance of arthropod collections on territories during nesting
	Presence of Curve-billed Thrasher*	CBTH	Detections to measure possible competition over resources

*Categorical variable

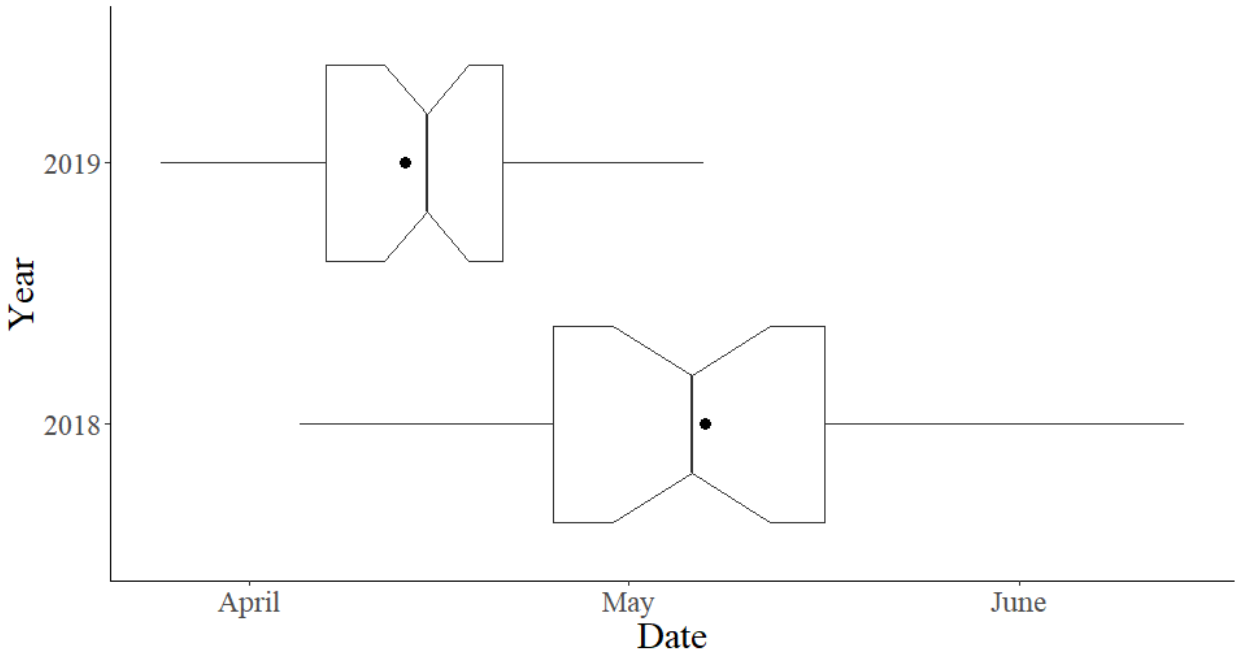

FIGURE 2. Nest initiation dates of Bendire's Thrashers for first nest attempts by year (2018, n=30; 2019, n=45). The horizontal black lines indicate the median value, the notch represents the 95% confidence intervals for median values, and the mean value is represented by the black circles.

TABLE 2. Baseline breeding biology estimates for Bendire's Thrashers in the Chihuahuan Desert, including the length of the incubation and nestling stage, the average clutch size, brood size, and fledglings produced per nest. Mean ($\bar{X}$), standard error (SE), minimum (Min) and maximum (Max) values recorded (n=75).

	$\bar{X}$	SE	Min	Max
Incubation Stage (days)	12.79	0.19	11	20
Nestling Stage (days)	15.28	0.28	12	22
Clutch Size	3.28	0.11	1	5
Number of Nestlings	2.97	0.12	1	5
Number of Fledglings	2.88	0.15	1	4

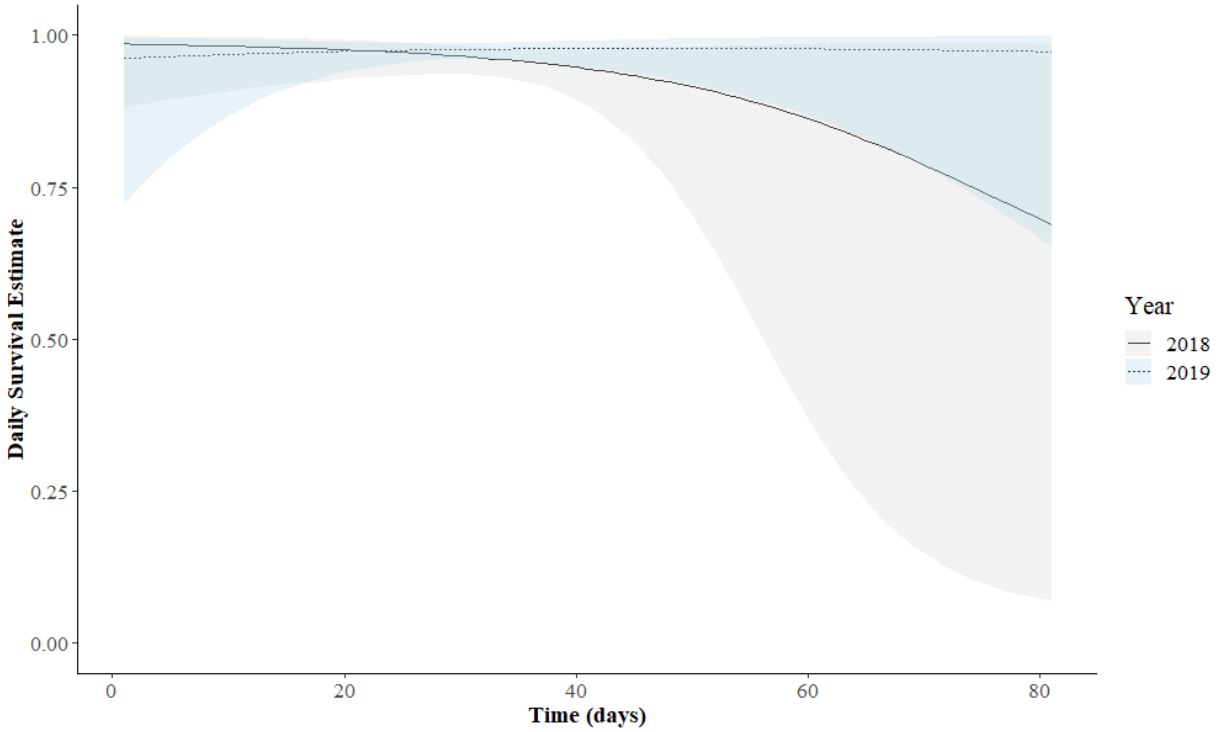

FIGURE 3. Model averaged daily survival estimates from the temporal scale, estimated using the average value of nest age, presented with 95% confidence intervals for Bendire's Thrashers nest during the 2018-2019 breeding seasons within the Chihuahuan Desert.

TABLE 3. Daily nest survival model selection results of Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert, adjusted for small sample size. Only the top models within each scale are presented; complete model results can be found in the appendix.

Scale	**Model**	***K***	**ΔAIC_c**	**w_i**	***dev***
Temporal	S(~Year + Time + Nest_Age + Year*Nest_Age)	5	0.00	0.24	201.08
	S(~Year + Time + Year*Time)	4	1.44	0.12	204.55
	S(~Year + Time)	3	1.44	0.12	206.57
	S(~Global)	6	1.63	0.11	200.69
	S(~Year + Nest_Age + Year*Nest_Age)	4	2.00	0.09	205.11
Nest	S(~Conc)	2	0.00	0.17	212.08
	S(~Null)	*1*	*0.39*	*0.14*	*214.48*
	S(~DTE)	2	0.58	0.13	212.66
	S(~Conc + DTE)	3	0.67	0.12	210.74
	S(~Nest_Hgt)	2	0.96	0.10	213.07
	S(~Shrb_Hgt)	2	1.74	0.07	213.82
	S(~Species)	2	1.86	0.07	213.94
	S(~Nest_Hgt + Conc + DTE)	4	2.11	0.06	210.17
Territory	S(~Can_Gaps + Arthro)	3	0.00	0.21	208.66
	S(~Ave_Hgt + Tall_Shrbs + Can_Gaps + Arthro)	5	1.19	0.12	205.82
	S(~Can_Gaps + Arthro + Tall_Shrbs)	4	1.54	0.10	208.18
	S(~Arthro)	2	1.70	0.09	212.37
	S(~Null)	*1*	*1.80*	*0.09*	*214.48*
	S(~Ave_Hgt)	2	2.19	0.07	212.86

K = number of parameters in the model
ΔAIC_c = the difference in AIC_c values from the top model
w_i = weight of the model
dev = deviance, or how well the response variable is predicted by a model that includes only the intercept
Null = intercept only model, or constant
Global = most complex model

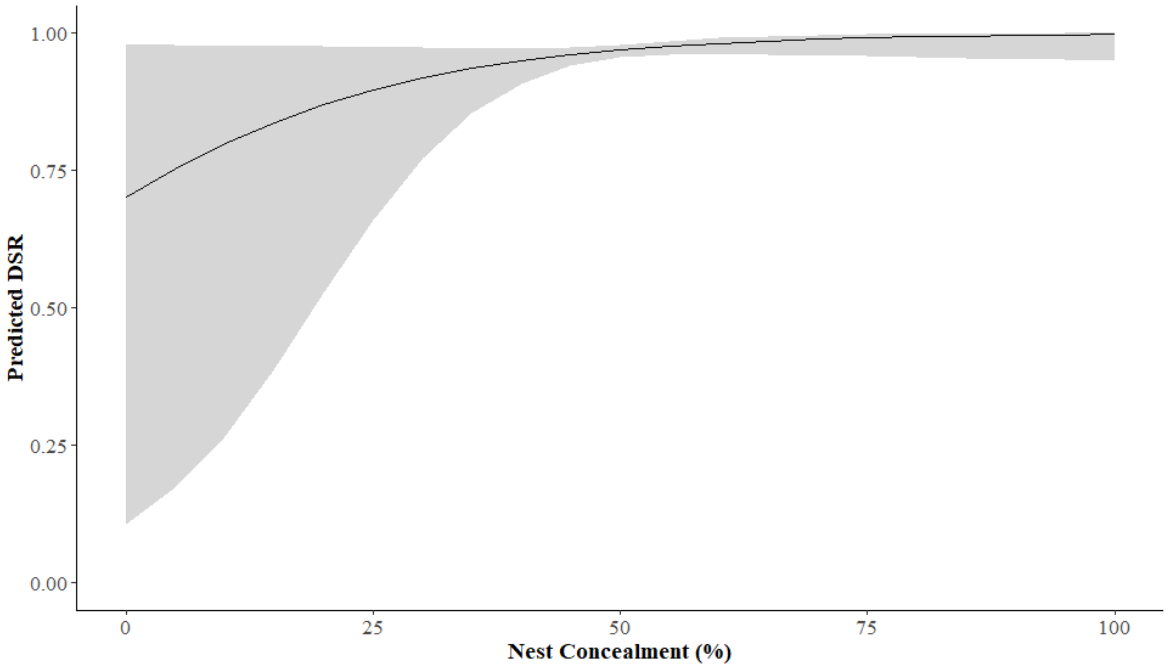

FIGURE 4. Model averaged survival estimates from the top model within the nest site scale showing the relationship between concealment at the nest site and nest survival presented with 95% confidence intervals for Bendire's Thrashers nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

TABLE 4. Full model averaged parameter coefficient estimates (β), unconditional standard error (SE) for the nest site and territory scales of daily nest survival analysis of Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert presented with 95% confidence intervals (CIs), LCL = lower confidence level, UCL = upper confidence level.

Scale	Parameter	β	SE	LCL	UCL
Temporal	Year	-0.5051	1.1297	-2.7193	1.7092
	Time	-0.0263	0.0131	-0.0519	-0.0006
	Nest Age	-0.0372	0.0427	-0.1208	0.0464
	Year*Time	0.0287	0.0283	-0.0268	0.0842
	Year*Nest_Age	0.1048	0.2106	-0.3079	0.5175
Nest	Conc	0.2548	0.1670	-0.0756	0.5793
	DTE	0.2824	0.2741	-0.2548	0.8197
	Nest_Hgt	-0.1810	0.2037	-0.5802	0.2182
	Shrb_Hgt	-0.0817	0.1946	-0.4631	0.2997
	Species	-0.2761	0.3998	-1.0597	0.5076
	Species*Conc	-0.2462	03417	-0.9164	0.4240
	Species*DTE	-0.6438	0.5357	-1.6937	0.4061
	Species*Nest_Hgt	0.0090	0.4252	-0.8243	0.8423
Territory	Can_Gaps	0.3496	0.1852	-0.0134	0.7127
	Arthro	0.4292	0.2725	-0.1049	0.9973
	Tall_Shrbs	8.4e-05	1.4e-04	-1.9e-04	3.6e-04
	Ave_Hgt	-0.2583	0.1707	-0.5928	0.0762
	VOR	0.0261	0.2209	-0.4069	0.4590
	CBTH	0.0235	0.8131	-1.3587	1.8285

IMAGE 1. Examples of Bendire's Thrashers nest sites located within a soaptree yucca (left), and a honey mesquite (right) that had accumulated additional nest concealment from dead Russian thistle built up over time.

APPENDIX

TABLE 5. Average ($\bar{X}$) number of arthropods collected by order presented with standard error (SE), minimum (Min) and maximum (Max) number recorded, per breeding territory of Bendire's Thrashers during the 2018-2019 breeding seasons within the Chihuahuan Desert.

Order	$\bar{X}$	SE	Min	Max
Araneae	23.80	1.59	1	57
Acari	1.08	0.32	0	19
Coleoptera	56.40	10.31	1	682
Diptera	16.05	2.41	0	126
Hemiptera	132.95	13.69	4	589
Hymenoptera	45.43	4.21	3	161
Lepidoptera	11.67	1.31	0	58
Mantodae	0.56	0.21	0	13
Neuroptera	0.73	0.21	0	12
Orthoptera	14.68	1.07	0	269
Phasmatodea	0.27	0.07	0	3
Unknown	0.59	0.16	0	6

TABLE 6. Complete daily nest survival model set of Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

Scale	Model
Temporal	S(~1) *Null*
	S(~Year)
	S(~Time)
	S(~Nest_Age)
	S(~Year + Time)
	S(~ Year + Nest_Age)
	S(~ Time + Nest_Age
	S(~Year + Time + Nest_Age)
	S(~Year + Nest_Age + Year * Nest_Age)
	S(~ Year + Time + Year * Time)
	S(~Year + Time + Nest_Age + Year * Nest_Age + Year * Time) *Global*
Nest	S(~1) *Null*
	S(~Nest_Hgt)
	S(~Shrb_Hgt)
	S(~Conc)
	S(~DTE)
	S(~Species)
	S(~Conc + DTE)
	S(~Conc + DTE + Nest_Hgt)
	S(~Conc + Nest_Hgt+ Shrb_Hgt)
	S(~Conc + DTE + Nest_Hgt + Shrb_Hgt)
	S(~Species + DTE + Species *DTE)
	S(~Species + Conc + Species * Conc)
	S(~Conc + DTE + Nest_Hgt + Shrb_Hgt + Species + Species * DTE + Species *Conc) *Global*
Territory	S(~1) *Null*
	S(~Can_Gaps)
	S(~VOR)
	S(~Ave_Hgt)
	S(~Tall_Shrbs)
	S(~Arthro)
	S(~CBTH)
	S(~Can_Gaps + VOR)
	S(~Ave_Hgt + Tall_Shrbs)
	S(~VOR + Arthro)
	S(~Tall_Shrbs + Arthro)
	S(~Can_Gaps + Tall_Shrbs + Arthro)
	S(~Can_Gaps + VOR + Ave_Hgt + Tall_Shrbs + Arthro + CBTH) *Global*

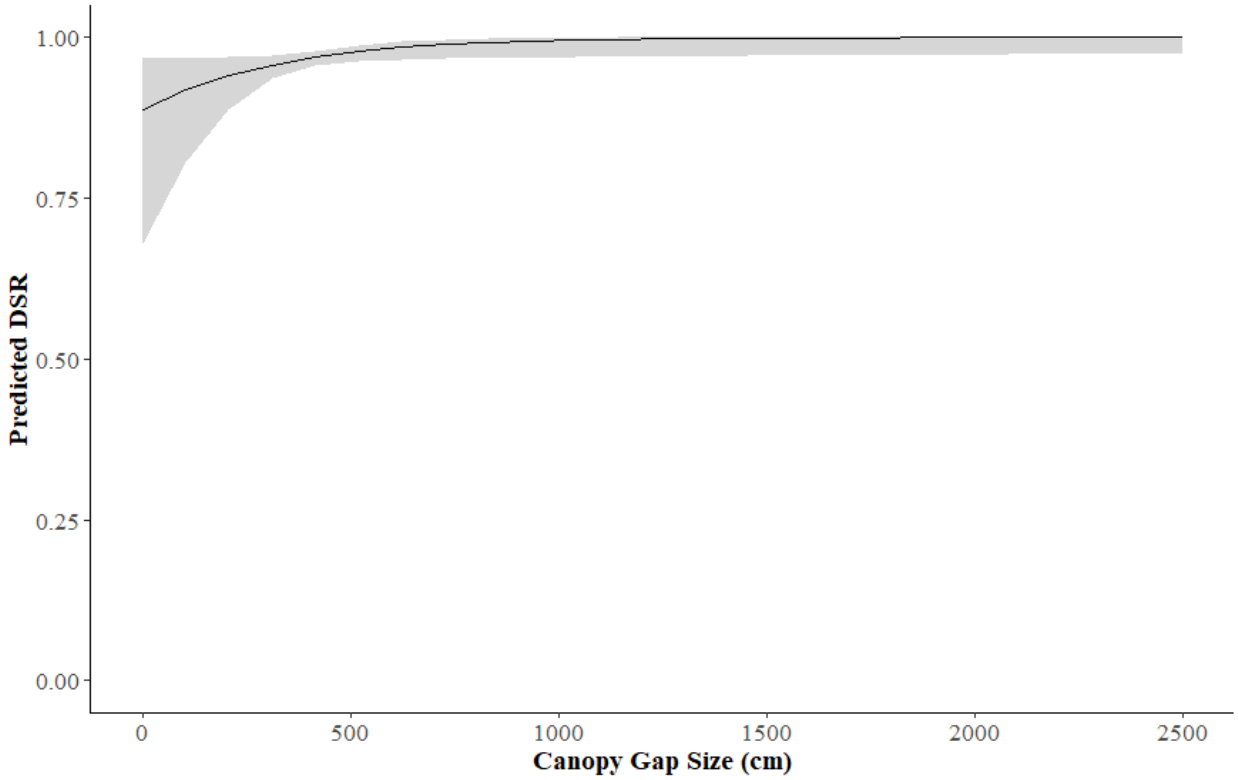

FIGURE 5a. Model averaged daily survival estimates from the top model within the territory scale showing the relationship between canopy gap sizes (cm) and nest survival presented with 95% confidence intervals for Bendire's Thrashers nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

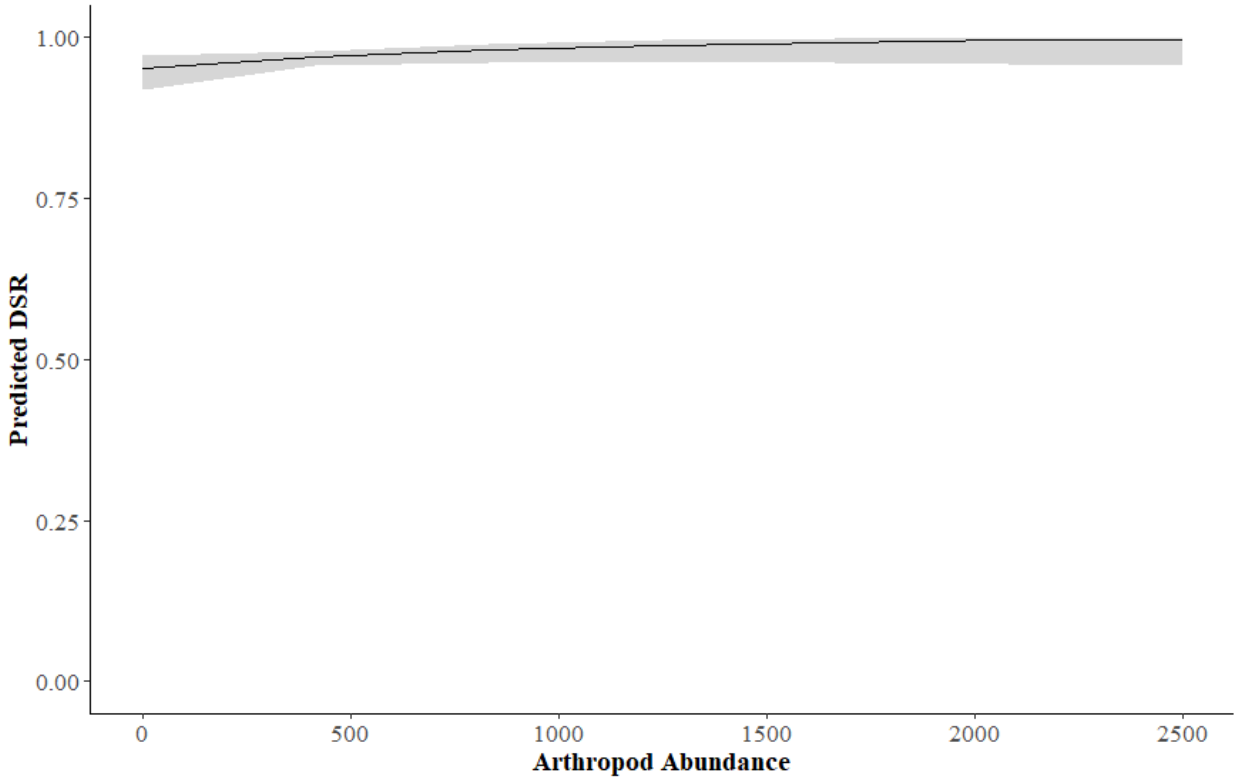

FIGURE 5b. Model averaged survival estimates from the top model within the territory scale showing the relationship between arthropod abundance and nest survival presented with 95% confidence intervals for Bendire's Thrashers nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

TABLE 7. Complete daily nest survival model selection results of Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert, adjusted for small sample size.

Scale	**Model**	***K***	**ΔAIC$_c$**	***w*$_i$**	***dev***
Temporal	S(~Year + Time + Nest Age + Year*Nest_Age)	5	0.00	0.24	201.08
	S(~Year + Time + Year*Time)	4	1.44	0.12	204.55
	S(~Year + Time)	3	1.44	0.12	206.57
	S(~Global)	6	1.63	0.11	200.69
	S(~Year + Nest_Age + Year*Nest_Age)	4	2.00	0.09	205.11
	S(~Time)	2	2.02	0.09	209.16
	S(~Year)	2	2.74	0.06	209.87
	S(~Year + Time + Nest_Age)	4	3.64	0.05	206344
	S(~Year + Time + Nest_Age + Year*Time)	5	3.47	0.04	204.55
	S(~Time + Nest_Age)	3	3.67	0.04	208.79
	S(~Year + Nest_Age)	3	4.71	0.02	209.83
	S(~Null)	*1*	*5.34*	*0.02*	*214.48*
	S(~Nest_Age)	2	7.33	0.01	214.47
Nest	S(~Conc)	2	0.00	0.17	212.08
	S(~Null)	*1*	*0.39*	*0.14*	*214.48*
	S(~DTE)	2	0.58	0.13	212.66
	S(~Conc+DTE)	3	0.67	0.12	210.74
	S(~Nest_Hgt)	2	0.96	0.10	213.07
	S(~Shrb_Hgt)	2	1.74	0.07	213.82
	S(~Species)	2	1.86	0.07	213.94
	S(~Nest_Hgt + Conc + DTE)	4	2.11	0.06	210.17
	S(~Species + Conc + Species*Conc)	4	2.66	0.04	210.72
	S(~Species + DTE + Species*DTE)	4	2.96	0.04	211.02
	S(~Shrb_Hgt + Nest_Hgt + Conc)	4	3.23	0.03	211.29
	S(~Shrb_Hgt + Nest_Hgt + Conc + DTE)	5	4.13	0.02	210.17
	S(~Species + Nest_Hgt + Species*Nest_Hgt)	4	4.88	0.01	212.94
	S(~Global)	9	9.77	<0.01	207.68
Territory	S(~Can_Gaps + Arthro)	3	0.00	0.21	208.66
	S(~Ave_Hgt + Tall_Shrbs + Can_Gaps + Arthro)	5	1.19	0.12	205.82
	S(~Can_Gaps + Arthro + Tall_Shrbs)	4	1.54	0.10	208.18
	S(~Arthro)	2	1.70	0.09	212.37
	S(~Null)	*1*	*1.80*	*0.09*	*214.48*
	S(~Ave_Hgt)	2	2.19	0.07	212.86
	S(~Can_Gaps)	2	2.46	0.06	213.13
	S(~Tall_Shrbs + Arthro)	3	3.16	0.04	211.82
	S(~CBTH)	4	3.39	0.04	209.97
	S(~VOR + Arthro)	3	3.46	0.04	212.12
	S(~Tall_Shrbs)	2	3.81	0.03	214.48
	S(~VOR)	2	3.81	0.03	214.48
	S(~Can_Gaps + VOR)	3	3.90	0.03	212.56
	S(~Ave_Hgt + Tall_Shrbs)	3	4.19	0.03	212.86
	S(~Global)	7	4.63	0.02	205.20

K = number of parameters in the model
ΔAIC$_c$ = the difference in AIC$_c$ values from the top model
w$_i$ = weight of the model
dev = deviance, or how well the response variable is predicted by a model that includes only the intercept
Null = intercept only model, or constant
Global = most complex model

TABLE 8. Full model averaged parameter coefficient estimates (β), unconditional standard error (SE) of daily nest survival analysis of Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert presented with both 95% and 85% confidence intervals (CIs), LCL = lower confidence level, UCL = upper confidence level.

Model	Parameter	β	SE	95% LCL	95% UCL	85% LCL	85% UCL
Temporal	Year	-0.5051	1.1297	-2.7193	1.7092	-2.1314	1.1212
	Time	-0.0263	0.0131	-0.0519	-0.0006	-0.0451	-0.0074
	Nest_Age	-0.0372	0.0427	-0.1208	0.0464	-0.0986	0.0242
	Year*Time	0.0287	0.0283	-0.0268	0.0842	-0.0120	0.0695
	Year*Nest_Age	0.1048	0.2106	-0.3079	0.5175	-0.1983	0.4079
Nest	Conc	0.2548	0.1670	-0.0756	0.5793	0.0113	0.4923
	DTE	0.2824	0.2741	-0.2548	0.8197	-0.1122	0.6771
	Nest_Hgt	-0.1810	0.2037	-0.5802	0.2182	-0.4742	0.1122
	Shrb_Hgt	-0.0817	0.1946	-0.4631	0.2997	-0.3618	0.1985
	Species	-0.2761	0.3998	-1.0597	0.5076	-0.8517	0.2994
	Species*Conc	-0.2462	03417	-0.9164	0.4240	-0.7385	0.2461
	Species*DTE	-0.6438	0.5357	-1.6937	0.4061	-1.4149	0.1273
	Species*Nest_Hgt	0.0090	0.4252	-0.8243	0.8423	-0.6030	0.6211
Territory	Can_Gaps	0.3496	0.1852	-0.0134	0.7127	0.0830	0.6163
	Arthro	0.4292	0.2725	-0.1049	0.9973	0.0369	0.8214
	Tall_Shrbs	8.4e-05	1.4e-04	-1.9e-04	3.6e-04	-1.2e-04	2.9e-04
	Ave_Hgt	-0.2583	0.1707	-0.5928	0.0762	-0.5040	-0.0126
	VOR	0.0261	0.2209	-0.4069	0.4590	-0.2.919	0.3440
	CBTH	0.0235	0.8131	-1.3587	1.8285	-0.9356	1.4053

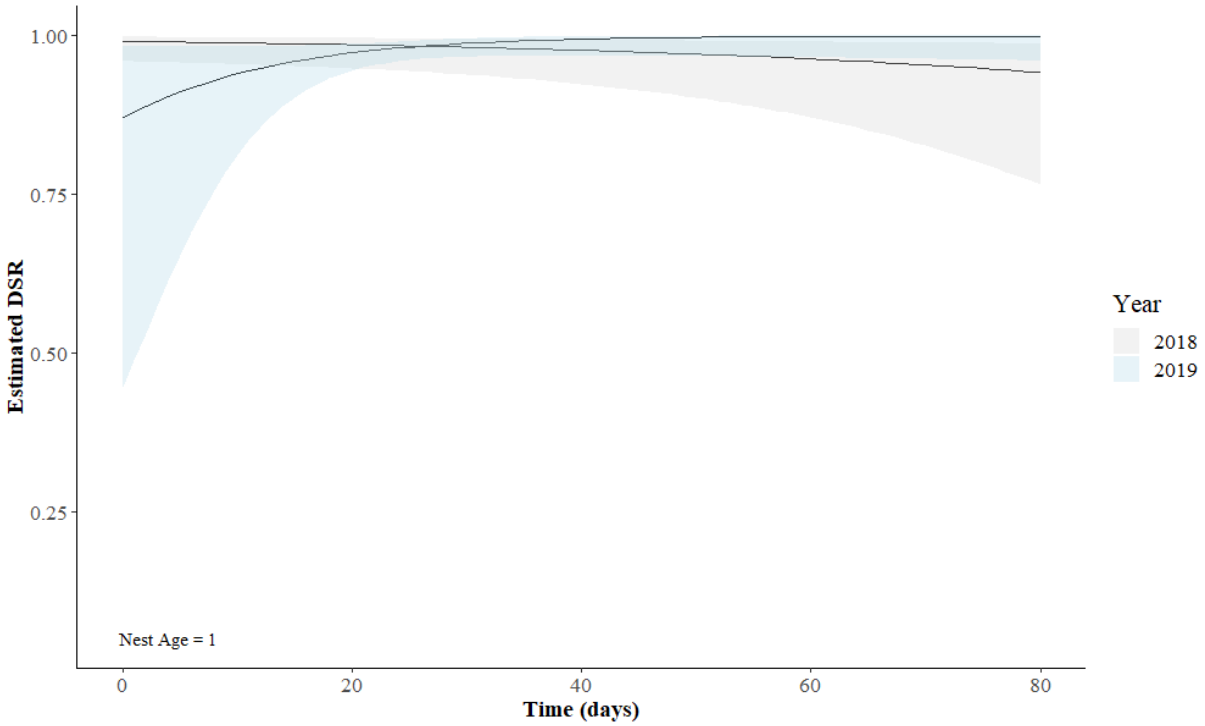

FIGURE 6A. Estimated daily nest survival of top model S(~Year + Time + Nest Age + Year*Nest Age) within the temporal scale, with nest age set at 1, which represents nests initiated earlier within the breeding season for Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

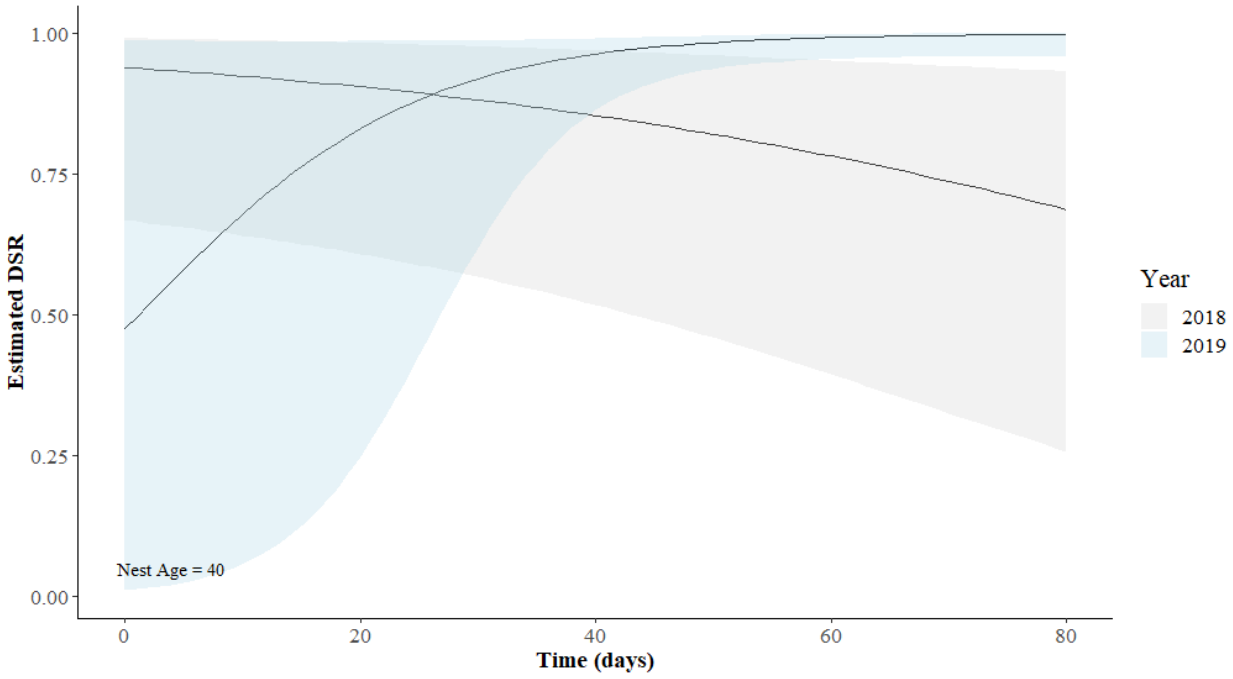

FIGURE 6B. Estimated daily nest survival of top model S(~Year + Time + Nest Age + Year*Nest Age) within the temporal scale, with nest age set at 40, which represents nests initiated in the middle of the breeding season for Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

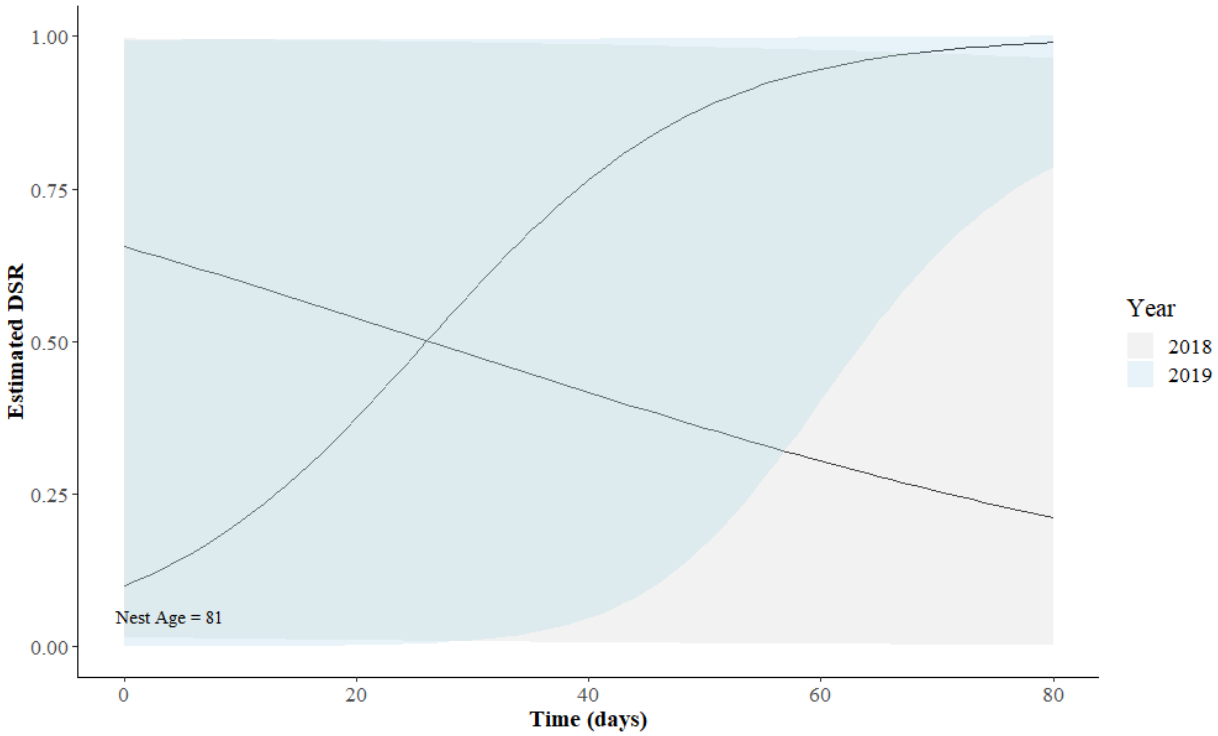

FIGURE 6C. Estimated daily nest survival of top model S(~Year + Time + Nest Age + Year*Nest Age) within the temporal scale, with nest age set at 81, which represents nests initiated later within the breeding season for Bendire's Thrasher nests during the 2018-2019 breeding seasons within the Chihuahuan Desert.

CHAPTER 2: POST-FLEDGLING SURVIVAL, MOVEMENT PATTERNS, AND HABITAT USE OF BENDIRE'S THRASHERS (*Toxostoma bendirei*) IN THE CHIHUAHUAN DESERT

INTRODUCTION

The post-fledgling period is the most vulnerable period in the life cycle of a bird, yet for most passerines this life stage is relatively unknown (Cox et al. 2014). Recent advances in technology have created an opportunity for more detailed studies of this life stage for passerines resulting in increases in knowledge of post-fledgling survival and ecology. Historically juvenile survival was estimated to be approximately 25-50% of adult survival (Martin et al. 1995), however, recent studies have shown that post-fledgling survival is variable, related to individual growth (Vitz and Rodewald 2011, Naef-Daenzer and Grüebler 2016), movement (Yackel Adams et al. 2001, Kershner et al. 2004), and available habitat (Jenkins et al. 2016, Jones et al. 2017). Studies have shown higher survival for nestlings with greater body condition (Suedkamp Well et al. 2007, Vitz and Rodewald 2011) and other studies have suggested this is linked to habitat quality, including food availability or cover from predators (Rush and Stutchbury 2008, Tarof et al. 2011). A greater understanding of the post-fledgling stage will provide important information on behavior and habitat characteristics that may influence survival (Anders and Marshall 2005, Streby et al. 2014).

The post-fledgling stage is a particularly sensitive time for juvenile birds as they have not yet developed predator avoidance and foraging skills. Many altricial species leave the nest prior to completion of primary feathers and are unable to fly for the first few days after fledging making them vulnerable to predation (Ausprey and Rodewald 2001, Yackel-Adams et al. 2001, Naef-Daenzer and Grüebler 2016). During this period, adults caring for fledglings have been observed to demonstrate different strategies including brood splitting which has been observed in

Lark Buntings (*Calamospiza melanocorys*) (Yackel-Adams et al. 2001) and Cerulean Warblers (*Setophaga cerulea*) (Raybuck et al. 2020) or keeping the family unit together as observed in Wood Thrushes (*Hylocichla mustelina*) (Vega Rivera et al. 2000) and LeConte's Thrashers (*Toxostoma lecontei*) (Sheppard 2018). Interestingly, however, some species exhibit plasticity in caring for broods depending on availability of resources (Yackel-Adams et al. 2002). The length of the post-fledging period also varies by species, where some, like the tropical Western Slaty-Antshrike (*Thammophilus atrinucha*) care for broods for up to 12 weeks post-fledging (Tarwater and Brown 2010), while others, such as Cerulean Warblers, care for broods for only 21-36 days (Raybuck et al. 2020). Because this life cycle stage is variable by species, a closer examination of the survival, movement patterns, and habitat use of fledglings is critical to document for species of conservation concern (Anders et al. 1997).

Fledgling survival has been observed to differ substantially across studies and is often influenced by the ability of fledglings to seek cover and avoid predation (Kershner et al. 2004, Rush and Stutchbury 2008, Streby and Anderson 2013, Raybuck et al. 2020). Predation is the main cause of mortality and fledglings are exposed to multiple predators as they leave the nest site (Suedkamp Wells et al. 2007, Davis and Fisher 2009, Vitz and Rodewald 2011, Raybuck et al. 2020). Survival estimates vary with fledging age and tend to be lowest immediately after fledging and often increase as fledglings grow to adult size and have increased mobility (Jenkins et al. 2016, Naef-Daenzer and Grüebler 2016, Raybuck et al. 2020). Generally, fledglings gradually move away from the nest site over time with studies associating them with dense cover for concealment and food resources (Vega Rivera et al. 1998, Yackel Adams 2001). Depending on habitat type or available resources, fledglings may have to move long distances to seek cover from predators and find food (White and Faaborg 2008, Blackman and Diamond 2015). For

example, some LeConte's Thrasher fledglings exhibited large movements, up to 900-m away from the nest site within the first 1-3 days post-fledging, most likely due to sparse vegetation cover in the Mojave Desert (Blackman and Diamond 2015). To effectively manage for the post-fledging stage, we need to better understand the factors, such as food availability and concealment requirements, that influence movement. Barn Swallow (*Hirundo rustica*) fledglings showed a preference for crop habitats, most likely due to the high availability of insects, compared to several other available habitat types (Boynton et al. 2020). In an Iowa study of Eastern Meadowlarks (*Sternella magna*), fledglings stayed within the same crop fields they hatched from until they became independent from their parents and did not use wooded areas, as croplands seemed to provide sufficient cover from predators and food resources (Guzy and Ribic 2007).

Bendire's Thrashers (*Toxostoma bendirei*) are an arid land obligate passerine experiencing population declines and, as a result, have been listed as a vulnerable species by the IUCN Red List, and a species of conservation concern by federal and state agencies in the southwestern Unites States (IUCN 2021, Sauer et al. 2017, USFWS 2021). Bendire's Thrashers are a secretive and difficult species to detect, therefore, little has been documented regarding their nesting ecology and reproduction. A more complete understanding of stage-specific survival estimates, and habitat use is critical for conservation. Therefore, I sought to examine post-fledging survival, movement, and habitat use of fledgling Bendire's Thrashers, as this has not previously been studied for this species. Specifically, my objectives were to (1) document estimated weekly survival and model this in relation to variables known to influence post-fledgling survival, (2) document movement patterns away from the nest site and (3) examine fledgling habitat use and associated vegetation characteristics. I hypothesized that (1) survival

would increase with age, (2) movement distances would increase with age as fledglings fully develop primary feathers and become capable of flight; and (3) fledglings would seek areas with greater vegetation cover and show a preference for dense vegetation in order to avoid predators.

METHODS

Study Area

Research was conducted within Hidalgo county New Mexico from May – July in 2018 and Hidalgo and Grant counties New Mexico April – June 2019 (Figure 1). Elevation within the study area spanned 1,200-1,400-m and topography included playas or large expanses of dry lake beds that collect rainwater during monsoons but quickly evaporate due to alkali soils (Bolen et al. 1989). The mean daily temperature in 2018 was 25.15°C ± 0.38 (SE) and in 2019 was 16.99°C ± 0.49. The mean daily precipitation in 2018 was 1.04mm ± 0.33 (SE) and in 2019 was 0.32 ± 0.12 (SE) (PRISM Climate Group 2020).

The study area was comprised of several dominant shrubs including soaptree yuccas (*Yucca elata*), honey mesquite (*Prosopis glandulosa*), broom snakeweed (*Gutierrezia sarothrae*), and rabbitbrush (*Chrysothamnus* spp). Less common shrubs and cacti included longleaf ephedra (*Ephedra trifurca*), whitethorn acacia (*Vachellia constricta*), littleleaf sumac (*Rhus microphylla*), graythorn (*Ziziphus obtusifolia*), allthorn (*Koeberlinia spinosa*), wolfberry (*Lycium barbarum*), apache plume (*Fallugia paradoxa*), prickly pear cactus *(Opuntia* spp.), cane cholla (*Cylindropuntia imbricata*), and desert willow (*Chilopsis linearis*). Vegetation in the Chihuahuan Desert is sparse, and adult thrasher territories are composed of distinct stands of shrub and cacti with large areas of bare ground interspersed with patches of tobosa grasses (*Pleuraphis mutica*) as well as giant (*Sporobolus wrightii*) and alkali sacaton (*Sporobolus airoides*) grasses.

Field Methods

Nest Searching and Monitoring. Breeding territories were discovered by area searches supplemented with call playback at known locations for Bendire's Thrashers based on previous research (Sutton 2020) and eBird locations (eBird 2018). Once adults were located, territory mapping followed using the flush-mapping technique (Reed 1985, Sutton 2020) with a handheld GPS (GARMIN 64s; Garmin, Olathe, Kansas - accuracy ~3m). Once territories were delineated, nest searching occurred primarily through parental cues, but also by systematically searching shrubs (Ruehmann et al. 2011). When nests were found they were marked with a GPS location and checked every 2-5 days until fledging or failure following standard nest monitoring protocols (Martin and Geupel 1993). Nests were checked daily as fledging was expected (~15 days since hatching) to ensure capture for transmitter attachment.

Transmitter Attachment and Tracking Efforts. Nestlings were captured by hand from the nest and each nestling was banded with a single aluminum USGS federal band (Davis and Fisher 2009). Measurements of weight (g), wing chord length (mm), and tarsus (mm) length were taken for all nestlings. VHF radio transmitters (Model A1055, 17x7x4mm, 1.0g, with an estimated 8-week lifespan – Advanced Telemetry Systems, INC., Isanti, MN, USA) were attached using a leg-loop harness and a single drop of false eyelash glue on a single upper retrice covert feather to ensure attachment (Rappole and Tipton 1991, C. Kondrat-Smith, personal comm.). Total transmitter weight with harness materials and federal bands did not exceed the 3% body weight of fledglings as recommended by the USGS Bird Banding Laboratory. Only one nestling in each nest received a transmitter. Fledglings were tracked a minimum of once per week, however most birds were tracked every 2-4 days using a hand-held receiver (R-1000,

Communication Specialist, Orange, CA) and three-prong element yagi using the homing method (White and Garrot 1990, White and Faaborg 2008, Amelon et al. 2009). Locations of fledglings were marked with a handheld GPS unit (GARMIN 64s; Garmin, Olathe, Kansas - accuracy ~3m) using Universal Transverse Mercator (UTM).

Tracking for individuals began at the nest site or the last known location recorded. Once fledglings were located, I recorded the UTM, and noted the type of shrub or vegetation the fledgling was using, and if it was accompanied by adults or siblings. The range of detection for transmitters was 400-600-m with the hand-held yagi antennae. Searches began from the nest site or last known location. When post-fledglings were not immediately detected I searched an area of ~500m radius from nest site or last known location by foot. If unsuccessful, this was followed by a vehicle search with a magnetic roof-mount dipole (#13861, Advanced Telemetry Systems, INC., Isanti, MN, USA) that covered a ~5-20-km radius from the nest site or last known location. Searching efforts were made for up to two weeks after lost signal for missing fledglings (Vitz and Rodewald 2010).

Collection of Variables. Vegetation variables were collected 1-3 weeks after fledgling use within an 11.3-m radius of the fledgling location along four transects radiating from the central point in each of the four cardinal directions (Martin et al. 1997, Jenkins et al. 2016). Vegetation surveys consisted of the line-point-intercept method, gap intercept method, visual obstruction reading at 0-m, 3-m, and 5-m of the transect and the number of shrubs within each quadrant were tallied by size classes (A = <0.5m, B = 0.5-1.5 m, and C = >1.5 m) and totaled to estimate shrub density (Herrick et al. 2005).

Arthropods were collected within 24 hours of relocating fledglings along two parallel 100-m transects, placed 10-m apart, that radiated from the marked location in the direction of a

random bearing. Sweep-netting occurred by sweeping fast and low once every meter for the length of the transect (Jamison et al. 2002, Brust et al. 2009, Whipple et al. 2010). Beat-netting occurred at four shrubs along each transect by beating four branches on each shrub, four times each (McDermott and Wood 2010). Arthropods were stored in plastic gallon Ziploc bags or 50mL centrifuge tubes frozen until sorting occurred. After the breeding season, arthropods were sorted by order, counted, labeled, and stored in 70% ethyl alcohol at the New Mexico State University main campus (Whipple et al. 2010).

The same data collection methods occurred at a paired-available location 600-m away from each used location, which represented the expected distance post-fledgling could be capable of moving (Blackman and Diamond 2015). Paired-available locations were selected using a random azimuth from the used location (Compton et al. 2002).

Statistical Analysis

Survival. Weekly fledgling survival analysis was calculated using the known-fate model implemented in Program MARK (Pollock et al. 1989, White and Burnham 1999) through the RMark package in R (Laake 2013, R Core Team 2020). Weekly survival estimates were determined for one nestling per nest to avoid non-independence within clutches and was based on maximum likelihood estimation (Wightman 2009). Each individual required a unique capture history based on weekly intervals, coded as either alive, dead, or censored. Models were used to estimate survival and incorporate the influence of covariates, including year, time, body condition index, and habitat variables. The covariate of “body condition index” was calculated as the residual value from a simple linear regression model of tarsus length and body weight of all banded nestlings prior to fledging. A binary covariate was created where calculated residual

values >0 represented a mass greater than expected, or a measure of "good body condition", and a value <0 represented a mass lower than expected, or "poor body condition" (Vitz and Rodewald et al. 2011). The average value was taken for habitat variables across all locations for each individual. All variables were checked with Pearson's test for correlation, and in any pair of correlated variables (> |0.65|) one was removed prior to analysis (Schober et al. 2018).

Post-fledgling survival analysis was exploratory and examined for all fledglings (n=25). I tested 8 *a priori* models (Appendix Table 5) using year, time, and body condition index (Table 1). I also tested 10 *a priori* models (Appendix Table 5) and examined the influence of habitat variables on those that survived long enough to leave the nest shrub (n=19) (Table 1). Models were ranked by Akaike's Information Criterion adjusted for small sample size (AIC_c) and included an intercept-only, or null model, and a global model (or the most complex model) (Burnham and Anderson 2002). Models that were within 2 ΔAIC_c were considered competitive and any model with 95% confidence intervals (CIs) that did not bound 0 was considered to have a strong influence on survival (Burnham and Anderson 2002). Model averaging was conducted in the case of high model uncertainty and calculated parameter estimates included all models within the set (Burnham and Anderson 2002, Anderson 2008, Grueber et al. 2011). The cumulative survival rate, or the probability of surviving until dispersal was calculated by raising the weekly estimate from the intercept-only model to the power of the average age until dispersal (4.3 weeks, or 30 days). The standard error for the cumulative survival estimate was calculated using the Delta Method (Powell 2007). All mean values are reported with ± standard error (Anderson et al. 2001).

Movement. To describe post-fledgling movements, GPS locations were entered into QGIS (QGIS.org 2021) and distances from the nest were measured using the measuring tool.

Age classes were created based on flight capability and distances from the nest to each tracking location were averaged (n=19) (Wightman 2009, Vormwald et al. 2011, Raybuck et al. 2020).

Habitat Use. I tested 11 *a priori* models (Appendix Table 7) using a conditional logistic regression within the survival package (Therneau 2021) via the "clogit" function in R (R Core Team 2021) for 19 individuals with a total of 73 individual fledgling locations and 73 paired-available locations. A single binary response variable of habitat use was coded as either use or available. Individual locations were grouped by an ID stratum. Variables were tested for correlation using Pearson's correlation test and highly correlated variables (> |0.65|) and in the case of correlation one variable from the pair was removed before analysis (Schober et al. 2018). Models within each scale were ranked by AIC_c value using the information-theoretic approach and models were considered competitive within 2 ΔAIC_c of the top ranked model (Burnham and Anderson 2002).

RESULTS

I found that nestlings left the nest 12-15 days after hatching and parents were often found bringing food to fledglings and alarm calling during observer presence. I was able to attach 25 transmitters to fledglings from unique nests, seven in 2018 and 18 in 2019. The first year, there were two clutches in which adults removed transmitters from nestlings prior to fledging, but there was no evidence of transmitters slipping off fledglings once they had fledged. Six fledglings were assumed to be predated before leaving the nest shrub or before I could confirm they left the nest, and as a result, no habitat data was collected on these individuals. Fledglings left the nest before complete growth of the primary feathers and were vulnerable to predation during this period. Predators were not identified, but suspected predators included coyotes and raptors, as well as snakes or rodents, as several transmitters were recovered with remains of

fledglings or transmitters were tracked to underground burrows. Of the 25 fledglings with transmitters, 9 died within 5 days of fledging, 6 died within 20 days of fledging, and 10 survived till dispersal, four in 2018 and six in 2019, all of which remained on the breeding territories with the family unit for an average of a 30-day period. There was no evidence of brood splitting during this study.

Survival. The weekly survival estimate based on the null model was 0.800 ± 0.05 (95% CIs 0.694-0.876) resulting in a cumulative survival rate of 0.38 ± 0.10 (95% CIs 0.197-0.570) (38% chance of survival) for 4.3 weeks (30 days) post-fledging, based on the average age of dispersing fledglings.

The top model in my survival analysis (n=25) included the variable of year (Table 2) and carried 20% of the model weight. However, all models except for one were considered competitive as they fell within 2 ΔAICc of the top model. The model averaged estimates showed a similar trend in post-fledgling survival between the two years of data collection, although slightly higher in 2018 compared to 2019 (Figure 2), however the 95% confidence intervals bound zero for all variables (Table 4).

The top model in the model set examining the influence of habitat characteristics (n=19) on post-fledgling survival was the null model which carried over 30% of the model weight. Overall, habitat characteristics measured did not appear to have a strong influence on fledgling survival as all models ranked below the null and all of the variables have 95% CIs that bound zero (Table 2).

Movement. I located and followed 19 fledglings for an average of 14.04 ± 2.61 days (range 1-41). The average distance of locations from the nest site varied with age of the post-fledgling (Figure 3). During relocation efforts, fledglings were often found motionless and quiet,

hiding within vegetation with siblings and parents would alarm call within 10-m. By days 3-5 after leaving the nest, fledglings would hop from branch to branch in shrubs when we approached. In general, younger birds incapable of flight stayed with 100-m of the nest site capable of movement by running on the ground or short flights, but once primary feathers completed growth, mobile fledglings could move up to 300-m from the nest site on average and were capable of extended flight. Fledglings gradually increased movement from the nest and, on average, remained on the nest territory for 30 days post-fledging before dispersing from the breeding territory with the family units.

Habitat Use. The average number of locations per individual for habitat data was 4 (3.89 ± 0.54) (range 1 - 10) with an equal number of paired-available locations for a total of 146 locations (73 used and 73 paired-available). The top ranked model in my resource selection function analysis for habitat use was the global model that included all habitat variables. This model carried 100% of the model weight (Table 4). Shrub density negatively influenced site use while all other variables positively affected use, however, average height of tall shrubs and visual obstruction showed 95% confidence intervals bounding zero (Figure 4).

DISCUSSION

Juvenile birds are most vulnerable to mortality immediately after leaving the nest. The length of nestling period has been shown to positively influence survival, however, some species of passerines leave the nest early, appearing to balance a tradeoff between increased growth in nest and vulnerability to predation (Cheng and Martin 2012). Fledgling Bendire's Thrashers had low survival and juveniles were most vulnerable to mortality the first 5 days out of the nest. During this time, fledglings were still not capable of flight and this was the period when most predation occurred. Fledgling movement was mainly contained within the adult breeding territories and

juveniles remained together with adults and siblings as a family unit for 30 days until family units dispersed. While still dependent on adults, juveniles sought cover in vegetation with higher measures of concealment, presumably as a defense against predation.

Survival estimates for fledgling Bendire's Thrashers were low compared to other passerine species; studies have documented survival rates during this sensitive period to range from 19% in Hooded Warblers (*Setophaga citrina*) (Rush and Stutchbury 2008) to 87% for Purple Martins (*Progne subis*) (Tarof et al. 2011). Observed Bendire's Thrasher fledgling survival over the 30-day period was lower than fledgling survival of LeConte's Thrashers over a 58-day period in California (Blackman and Diamond 2015). In New Mexico, adult Bendire's Thrashers established territories on "islands", or patches, of habitat ranging in size from 2 to 9 ha, that were structurally different than surrounding desert. These "habitat islands" may have been easier for predators to search, potentially putting fledgling thrashers at increased risk of predation. Similar to other studies of passerines, fledgling survival increased with age and was not influenced by local vegetation characteristics (Rush and Stutchbury 2008, Jenkins et al. 2016, Naef-Daenzer and Grüebler 2016).

Arid land thrashers appear to encounter strong predation pressure and may adapt to this by minimizing the time nestlings stay in the nest (Cheng and Martin 2012, Martin 2015, Lloyd and Martin 2015). This strategy could produce lower quality post-fledglings not capable of escaping predators, resulting in low survival rates (Lloyd and Martin 2015). Median passerine parental care has been reported to be 16 days for north-temperate species (Russell 2000, Tarwater and Brawn 2010), and 77 species exhibit parental care for less than 20 days for fledglings (Russell 2000). Bendire's Thrashers may instead benefit from prolonged parental care after fledging,

which could continue to increase body mass, and reduce movements of fledglings, resulting in improved recruitment (Tarwater and Brawn 2010, López-Idiáquez et al. 2018).

Similar to survival, distances moved by fledglings from the nest site increased with age as young birds grew and become capable of flight. Bendire's Thrasher fledglings remained close to the nest site (~100-m) within the first 5 days of fledging but reached distances up to ~300-m at 20 days post-fledging. Fledglings were observed moving near territory boundaries or outside of the territories around 10-12 days of age. Movements of fledgling Bendire's Thrashers were like those reported for other dependent fledgling thrashers; a median distance of 200-m from the nest site for Brown Thrashers (*Toxostoma rufum*) (Cavitt and Haas 1993) and 300-m from the nest site for Sage Thrashers (*Oreoscoptus montanus*) (Reynolds et al. 1993). Distances moved differed from LeConte's Thrashers within the Mojave Desert, which moved close to 500-m within the first few days post-fledgling and up to 1-km by 30 days post-fledging (Blackman and Diamond 2015). LeConte's Thrasher fledglings made larger movements, but movement patterns were similar to Bendire's Thrashers where fledglings of both species moved away from and back towards the nest site.

Bendire's Thrasher fledglings used vegetation patches that were different from what was available across the landscape and this resulted in the use of patches of habitat surrounded by a more homogenous desert environment that was not utilized by thrashers. Similar to data describing adult breeding territories, my data supports a preference for areas with tall shrubs, greater shrub cover, but also areas of bare ground for foraging (Sutton 2020). Additionally, I observed fledglings to use areas of tall shrubs (>1.5-m in height) and greater shrub cover (both canopy cover and vertical structure), however areas of high shrub density, resulting in less bare ground, were not used. Studies demonstrate that fledglings seek areas with greater cover to avoid

predation (Jones et al. 2017) as well as areas with greater food availability (Boynton et al. 2020) which often are similar to natal habitats (Berkeley et al. 2007, Jenkins et al. 2016). In this study, Bendire's Thrashers show similar selection of habitat in the nesting and post-fledgling stages, largely because they remained on the breeding territories throughout most of the observations. The Chihuahuan Desert is often sparse, consisting of areas of desert grassland lacking shrubs completely, or large expanses of areas where shrubs have grown in homogenously, such as creosote bush (*Larrea tridentata*), due to disturbance (Archer 2010). Future climate projections of increasing temperatures and prolonged drought pose a threat of desertification in the southwest (Archer and Predick 2008) which could degrade large expanses of thrasher habitat.

Species that exhibit movement patterns within the natal areas and require similar habitats types for the nesting and post-fledgling stages may be at higher risk of population declines if those habitat types are lost (Jenkins et al. 2017), therefore, insight into the specific habitat preferences during the post-fledgling stage is important to define. The overlap in habitat use and vegetation characteristics required for the nesting and post-fledgling stage of Bendire's Thrashers indicate that conservation of breeding hotspots are critical for future population growth of this declining species (Jenkins et al. 2017, Jones et al. 2017). Management actions to keep tall vegetation structure while retaining areas of bare ground may be necessary to improve fledgling survival of Bendire's Thrashers within the Chihuahuan Desert (Berkeley et al. 2007, Suedkamp Wells et al. 2007). Low fledgling survival has the potential to bottleneck this already declining global population and therefore further research and conservation efforts are urgently warranted (Jones et al. 2017). A more in-depth understanding of reproductive outputs of Bendire's Thrashers at each life cycle stage, will assist with informed management decision for conservation within the Chihuahuan Desert (Anders and Marshall 2005).

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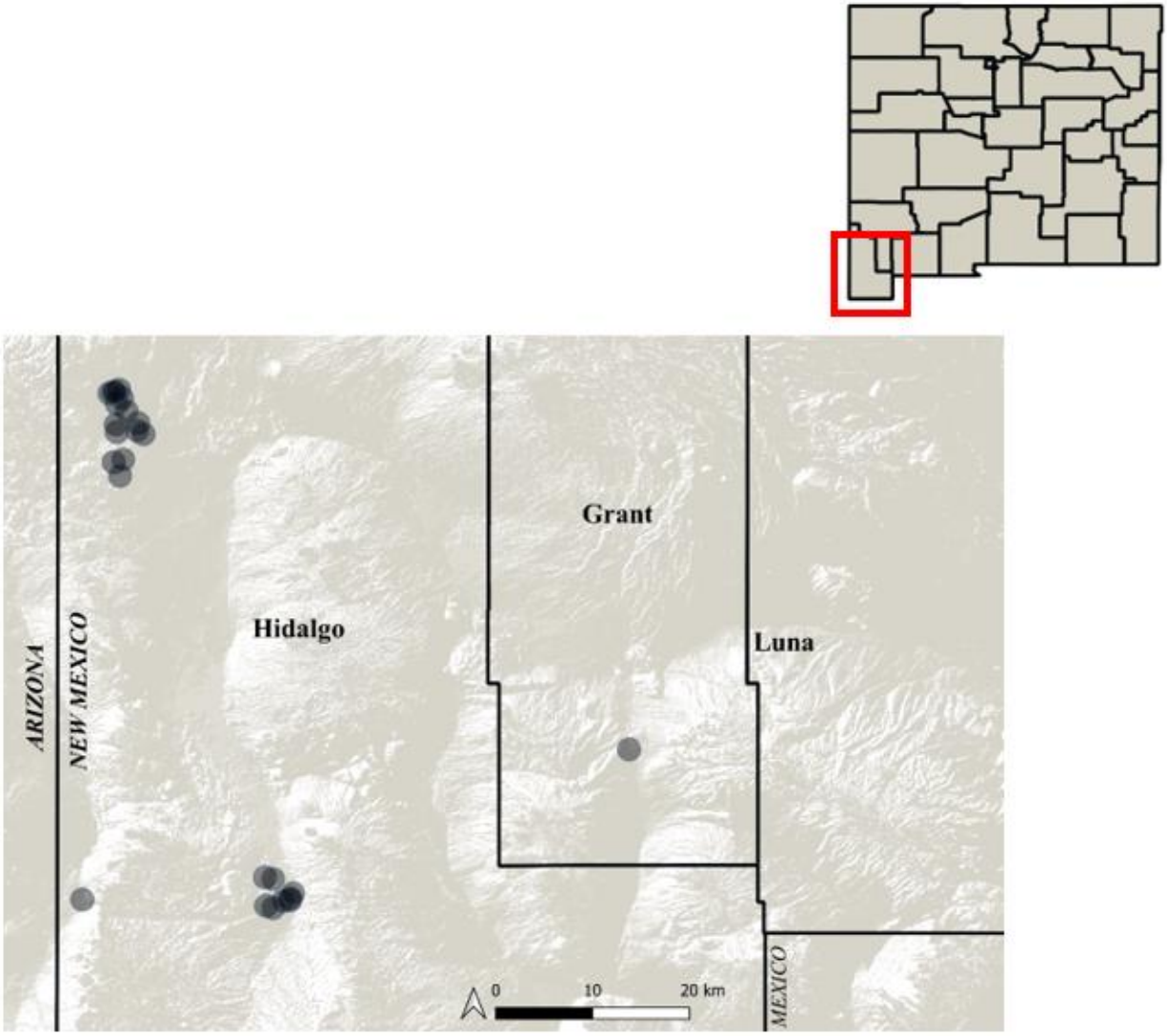

FIGURE 1. Study site locations for post-fledgling Bendire's Thrashers in Grant and Hidalgo Counties, New Mexico in 2018 and 2019. Approximate areas of tracking efforts around nest sites represented in black circles.

TABLE 1. Vegetation and temporal variables measured to examine fledgling survival and habitat use with definitions and model notation for each set of models during the 2018-2019 breeding seasons of Bendire's Thrashers in the Chihuahuan Desert. Each set includes an intercept only model (*null*), or the constant model, a global model (*global*), which is the most complex model, and additive terms.

n	Covariate of Interest	Model Notation	Definition
25	Year*	Year	Day of the season, starts when the first nest is found
	Time Trend	Time	Time trend model, day of the season based on the first nest found
	Body Condition Index*	Index	Measure of nestling body condition prior to fledging
19	Canopy Cover	Can_Cov	Percent canopy cover measured by line-point intercept
	Visual Obstruction	VOR	Percentage of vertical cover determined by Robel Pole
	Density	Density	Density of shrubs (shrubs/ha) of all heights
	Tall Shrubs	Tall_Shrbs	Density of shrubs (shrubs/ha) > 1.5-m in height
	Average Height	Ave_Hgt	Average height of all shrubs >1.5-m in height at location
	Arthropod Abundance	Arthro	Average abundance of arthropod collected on locations

*Categorical variable

TABLE 2. Weekly fledgling survival model selection results of Bendire's Thrashers during the 2018-2019 breeding seasons within the Chihuahuan Desert, adjusted for small sample size.

n	Model	*K*	ΔAIC_c	w_i	*dev*
25	S(~Year)	2	0.00	0.20	41.82
	S(~Null)	*1*	*0.13*	*0.19*	*44.06*
	S(~Year + Index)	3	0.59	0.15	40.24
	S(~Time)	2	1.03	0.12	42.84
	S(~Year + Time)	3	1.30	0.10	40.95
	S(~Index)	2	1.38	0.10	43.19
	S(~Global)	4	1.87	0.08	39.29
	S(~Time + Index)	3	2.09	0.07	41.74
19	*S(~Null)*	*1*	*0.00*	*0.31*	*10.17*
	S(~Can_Cov)	2	1.42	0.15	52.45
	S(~Arthro)	2	1.56	0.14	52.59
	S(~Year)	2	1.94	0.12	9.99
	S(~VOR)	2	2.11	0.11	53.14
	S(~Year + Can_Cov)	3	3.44	0.06	52.28
	S(~Year + Arthro)	3	3.73	0.05	52.57
	S(~Year + VOR)	3	4.13	0.04	52.97
	S(~Year + Can_Cov + VOR)	4	5.33	0.02	52.50
	S(~Global)	5	7.72	0.01	51.97

K = number of parameters in the model
ΔAIC_c = the difference in AIC_c values from the top model
w_i = weight of the model
dev = deviance, or how well the response variable is predicted by a model that includes only the intercept
Null = intercept only model, or constant
Global = most complex model

TABLE 3. Model averaged parameter estimates of post-fledgling survival of Bendire's Thrashers during the 2018-2019 breeding seasons within the Chihuahan Desert, showing beta (β) coefficient estimates, standard error (SE), and 95% confidence (LCL = lower confidence level, UCL = upper confidence level).

n	Parameter	β	SE	LCL	UCL
25	Year	-1.0288	0.7139	-2.4279	0.3704
	Time	0.1393	0.1330	-0.1214	0.4000
	Index	-0.6825	0.6059	-1.8701	0.5051
19	Year	-0.2786	0.7719	-1.7915	0.1234
	Canopy Cover	-0.3120	0.3709	-1.0389	0.4150
	VOR	0.0455	0.3992	-0.7368	0.8279
	Arthropod Abundance	-0.2760	0.3707	-1.0025	0.4505

TABLE 4. Conditional logistic regression results for habitat use by post-fledgling Bendire's Thrashers during the 2018-2019 breeding season with the Chihuahuan Desert.

Model	***K***	**ΔAIC_c**	**w_i**	***dev***
S(~Global)	5	0.00	1.00	65.45
S(~Can_Cov + Tall_Shrbs)	3	25.98	0.00	95.98
S(~Can_Cov + Tall_Shrbs + Ave_Hgt)	2	26.32	0.00	94.24
S(~Density + VOR)	2	30.51	0.00	100.51
S(~Tall_Shrbs + Ave_Hgt)	2	41.17	0.00	111.17
S(~Tall_Shrbs)	1	42.99	0.00	115.08
S(~Can_Cov + VOR)	2	43.48	0.00	113.48
S(~VOR)	1	49.89	0.00	120.21
S(~Can_Cov)	1	50.15	0.00	122.21
S(~Ave_Hgt)	1	51.63	0.00	123.69
S(~Density)	1	68.97	0.00	141.03

K = number of parameters in the model
ΔAIC_c = the difference in AIC_c values from the top model
w_i = weight of the model
dev = deviance, or how well the response variable is predicted by a model that includes only the intercept
Global = most complex model

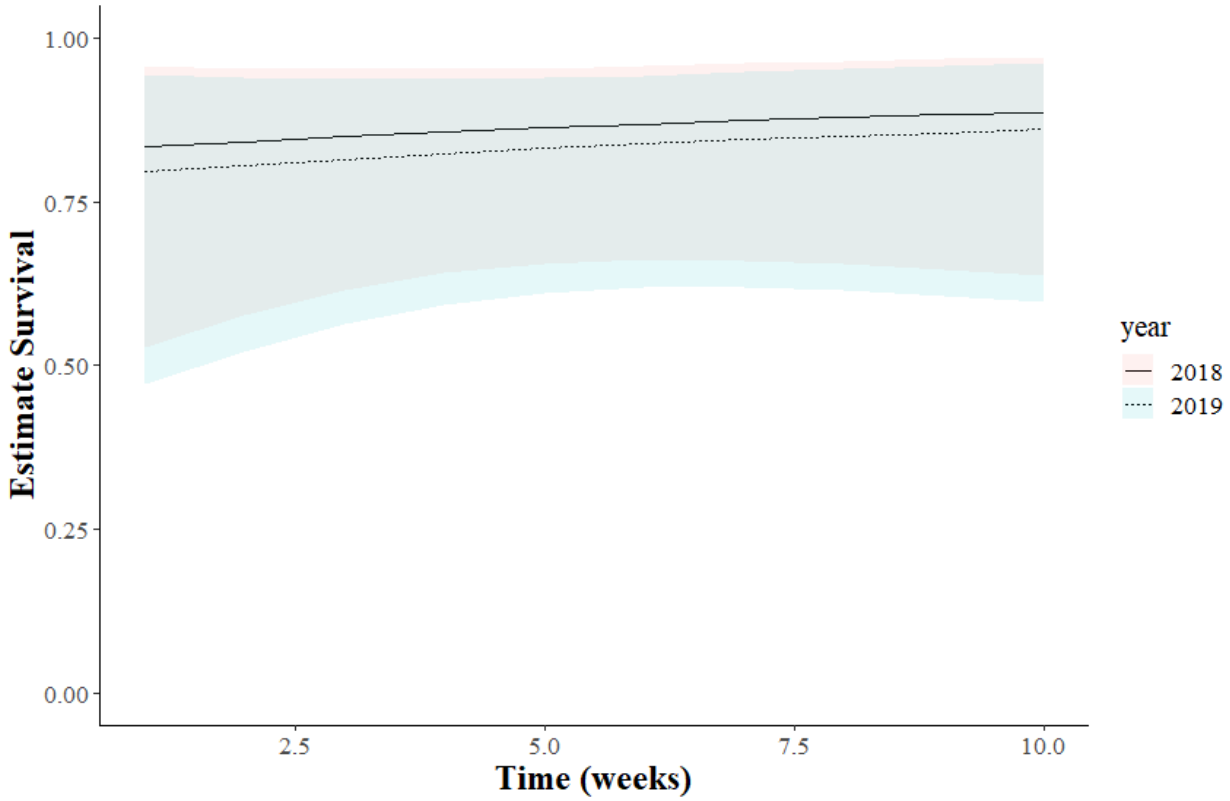

FIGURE 2. Model averaged weekly survival estimates of post-fledglings over time for both years of data collection with 2018 on the top (pink) and 2019 on the bottom (blue) calculated with the average value of body condition index, n=25.

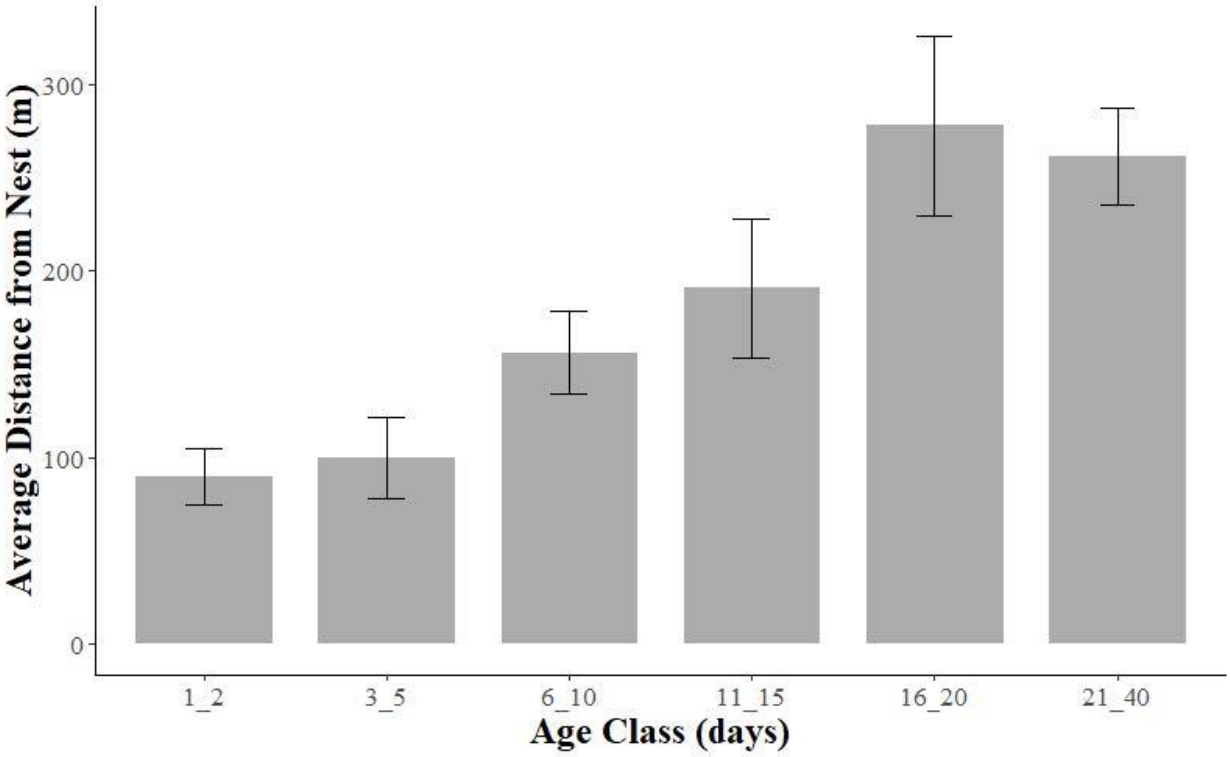

FIGURE 3. Average distance (m) post-fledgling Bendire's Thrashers were located from the nest site by age class (in days) since fledgling for the 2018-2019 breeding seasons in New Mexico, n=19.

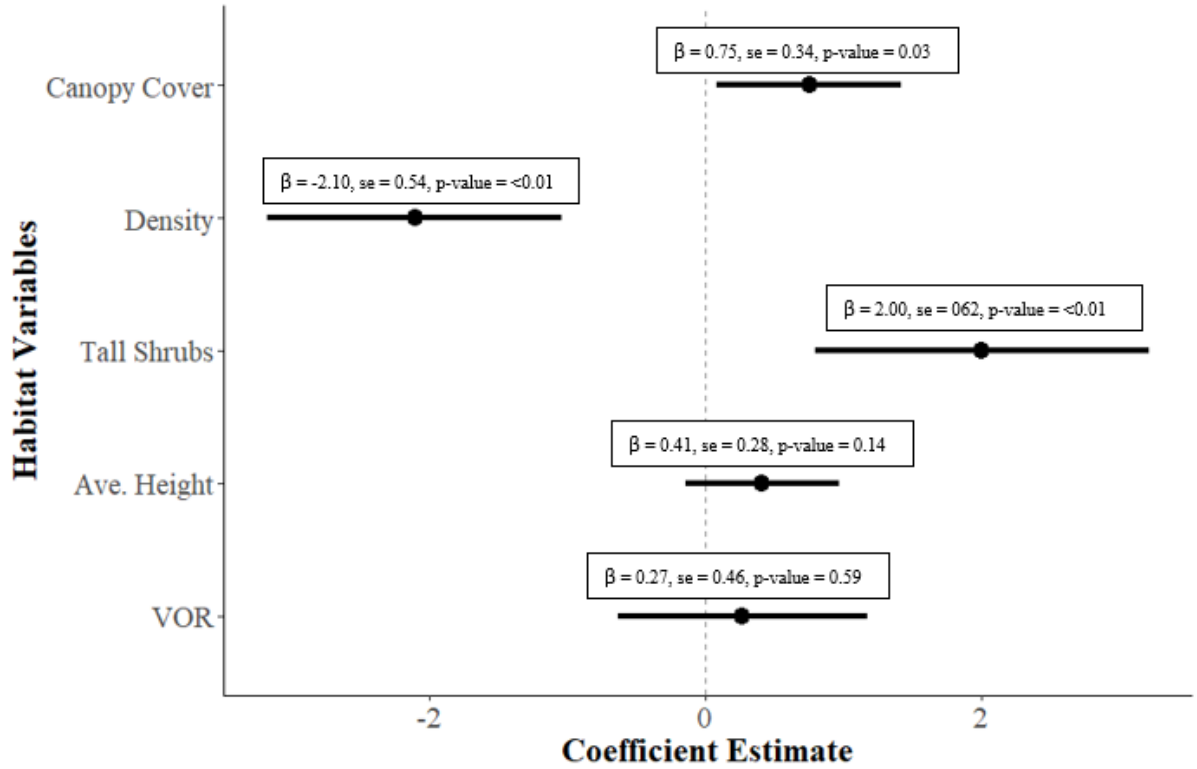

FIGURE 4. Beta (β) coefficient values for habitat variables based on the top model (global model) from the conditional logistic regression analysis of habitat use for post-fledgling Bendire's Thrashers during the 2018-2019 breeding seasons within the Chihuahuan Desert, presented with standard error (se), p-value, and 95% confidence intervals are presented by black lines.

APPENDIX

TABLE 5. Sets of a priori models for survival analysis of post-fledglings during the 2018-2019 breeding seasons of Bendire's Thrashers in the Chihuahuan Desert.

Set	#	Model	Variables
Full	1	Null	~1
	2	Year	~Year
	3	Time	~Time
	4	Body Condition Index	~Index
	5	Year and Time	~Year + Time
	6	Year and Index	~Year + Index
	7	Time and Index	~Time + Index
	8	Global	~Year + Time + Index
Reduced	1	Null	~1
	2	Year	~Year
	3	Canopy Cover	~CC
	4	Visual Obstruction Reading	~VOR
	5	Arthropod Abundance	~Arthro
	6	Year and Canopy Cover	~Year + CC
	7	Year and Visual Obstruction Reading	~Year + VOR
	8	Year and Arthropod Abundance	~Year + Arthro
	9	Year and Canopy Cover and Visual Obstruction Reading	~Year + CC + VOR
	10	Global	~Year + CC + VOR + Arthro

TABLE 6. Model averaged weekly survival estimates for Bendire's Thrasher post-fledglings during the 2018-2019 breeding seasons within the Chihuahuan Desert, showing survival estimates, standard error (SE), and 95% confidence (LCL = lower confidence level, UCL = upper confidence level).

Year	Week	Estimate	SE	LCL	UCL
2018	1	0.834	0.106	0.526	0.957
	2	0.842	0.092	0.577	0.954
	3	0.850	0.082	0.615	0.952
	4	0.857	0.076	0.641	0.952
	5	0.863	0.072	0.656	0.954
	6	0.869	0.071	0.662	0.957
	7	0.874	0.071	0.661	0.961
	8	0.879	0.073	0.655	0.965
	9	0.883	0.075	0.647	0.969
	10	0.887	0.076	0.639	0.972
2019	1	0.827	0.088	0.589	0.941
	2	0.797	0.122	0.472	0.945
	3	0.806	0.107	0.523	0.941
	4	0.815	0.095	0.563	0.938
	5	0.824	0.087	0.592	0.938
	6	0.831	0.082	0.610	0.939
	7	0.838	0.080	0.619	0.943
	8	0.845	0.081	0.619	0.946
	9	0.850	0.083	0.614	0.953
	10	0.856	0.085	0.606	0.958

TABLE 7. Set of *a priori* models for habitat use analysis of post-fledgling Bendire's Thrashers during the 2018-2019 breeding seasons within the Chihuahuan Desert, where k is the number of parameters.

#	Model	k
1	~Can_Cov	1
2	~Density	1
3	~Tall_Shrbs	1
4	~Ave_Hgt	1
5	~VOR	1
6	~Can_Cov + TallShrbs	2
7	~Can_Cov + VOR	2
8	~Density + VOR	2
9	~Tall_Shrbs + Ave_Hgt	2
10	~Can_Cov + Tall_Shrbs + Ave_Hgt	3
11	~Can_Cov + Density + Tall_Shrbs + Ave_Hgt + VOR	5

TABLE 8. Parameter estimates for each model of the conditional logistic regression for habitat use of Bendire's Thrasher post-fledglings for the breeding seasons of 2018-2019 within the Chihuahan Desert, showing beta (β) coefficient estimates, standard error (SE), and 95% confidence (LCL = lower confidence level, UCL = upper confidence level).

Model	Parameter	β	SE	LCL	UCL
1	Can_Cov	1.15	0.23	0.69	1.61
2	Density	-0.94	0.28	-1.48	-0.40
3	Tall_Shrbs	1.66	0.34	1.01	2.32
4	Ave_Hgt	1.34	0.27	0.81	1.87
5	VOR	1.33	0.28	0.78	1.88
6	Can_Cov	0.92	0.24	0.46	1.38
	Tall_Shrbs	1.48	0.36	0.78	2.18
7	Can_Cov	0.72	0.27	0.19	1.25
	VOR	0.84	0.31	0.23	1.45
8	Density	-1.32	0.36	-2.03	-0.61
	VOR	1.67	0.35	0.99	2.34
9	Tall_Shrbs	1.17	0.40	0.39	1.94
	Ave_Hgt	0.61	0.36	-0.05	1.26
10	Can_Cov	0.90	0.27	0.43	1.37
	Tall_Shrbs	1.19	0.81	0.40	1.99
	Ave_Hgt	0.35	1.87	-0.23	0.94
11	Can_Cov	0.75	0.34	0.08	1.42
	Density	-2.10	0.54	-3.16	-1.04
	Tall_Shrbs	2.00	0.62	0.80	3.21
	Ave_Hgt	0.41	0.28	-0.15	0.97
	VOR	0.27	0.46	-0.63	1.17