Bendire's Thrasher Nest and Juvenile Survival in Relation to Vegetation Characteristics in the Southwest United States

Allison Salas, Graduate Research Assistant
Martha Desmond, Regents Professor
Department of Fish, Wildlife and Conservation Ecology
New Mexico State University
Las Cruces, NM 88003

INTRODUCTION

Little is known about many desert arid land birds that reside in the southwestern United States, despite dramatic population declines that have been documented for many of the species in this assemblage (North American Bird Conservation Initiative 2014). One species in particular, the Bendire's Thrasher (*Toxostoma bendirei*), has shown a 90% global population decline in the last 40 years (BirdLife International 2017). According to Breeding Bird Surveys, this species is not being detected at some historical locations of occurrence (Sauer et al. 2017). Because of declining population trends, the Bendire's Thrasher has been listed on the IUCN Red List of Threatened Species as a vulnerable species since 2004 (BirdLife International 2017). The 2014 State of the Birds Report summarizes that the threats to Bendire's Thrasher could include climate change, desertification, overgrazing and habitat fragmentation (North American Bird Conservation Initiative 2014), but research has yet to confirm these theories. A recent report by the Audubon Society predicts that with an increase in 3°C, Bendire's Thrasher will face severe spring heat waves that could potentially decrease nest productivity and delay or change nest initiation dates (Wilsey et al. 2019). Additional potential pressures faced by Bendire's Thrashers include competition with the more common Curve-billed Thrasher (*Toxostoma curvirostre*) and other mimids and delayed breeding due to drought conditions (BirdLife International 2017). In order to properly manage this species, we must first identify key threats.

Habitat generalists in the Mimidae family, such as the Northern Mockingbird (*Mimus polyglottos*) and Crissal Thrasher (*Toxostoma crissale*), have been known to nest in a variety of different substrates in the Chihuahuan Desert. Preferred nest site shrubs were often dense, thus providing better cover, and usually contained spines for additional protection, such as mesquite (*Prosopis* spp.), sumac (*Rhus* spp.), and yuccas (*Yucca* spp.) (Kozma & Mathews, 1997). Curve-billed Thrashers are known to place nests at about 1-2m off the ground and have a preference for yucca species (Fischer 1980). Recent research has documented that Bendire's Thrashers show preferences for breeding territories with taller shrubs (greater than 1.5m) and a greater diversity of shrub species that also contain large patches of bare ground for foraging (Sutton and Desmond, unpublished data). Data collected from 1970 indicates that Bendire's Thrashers may prefer cholla (*Cylindropuntia* spp.) and juniper (*Juniperus* spp.) as nest site substrates. However, this information is anecdotal (Darling, 1970) and may be site specific. To improve management actions for this declining species, we need to better understand its breeding ecology, as the majority of basic breeding parameters for the species are unknown. These breeding parameters include: the length of the breeding season, nest initiation dates and number of clutches within a season.

Daily nest survival estimates are the preferred method to assess survival compared to the older method of percent nest success (apparent nest success). Nest success estimates may be more prone to overestimation since nests that are active longer are more likely to be found. Daily nest survival more accurately estimates true survival based on exposure days (Dinsmore et al. 2002). Average daily nest survival estimates for southwestern thrasher species are mostly unknown. Fischer (1980) determined apparent nest success for Curve-billed and Long-billed Thrashers (*Toxostoma longirostre*) in southern Texas to range from 37-44% and 26-30%, respectively, but daily nest survival was not calculated. A study of breeding biology for Sage Thrashers (*Oreoscoptes montanus*) in southern Idaho showed a 45% apparent nest success rate, but again, daily nest survival was not calculated. Several previous studies have been able to determine solid nest survival estimates for passerines in relation to vegetation characteristics. For example, Kerns et al. (2010) estimated overall nest survival for three grassland species all to be under 20%, with survival positively related to vegetation cover, especially grass density and height.

Post-fledging studies have been historically difficult to pursue, as fledglings are secretive and tracking technology was not previously available. Often, survival estimates of species were roughly based on 25-50% of adult survival, possibly resulting in erroneous estimates (Cox et al. 2014) as fledglings and juveniles face greater survival threats than adults. More recently, post-fledging and juvenile survival studies have become possible with improved tracking devices and these life stages have proven to be an important part of overall avian reproductive success (Streby et al. 2014). While predation is a well-established pressure for passerines (Benson et al. 2010, Segura & Reboreda 2012), several other factors also affect juvenile survival, including food availability (McDermott & Wood 2010). Arthropod abundance and diversity have been closely associated with habitat selection in several avian species. Adult Swainson's Warblers (*Limnothlypis swainsonii*) showed a clear association between occupied sites and abundance and diversity of arthropods (Brown et al. 2011). Post-fledging Wood Thrushes (*Hylocichla mustelina*) also showed a preference for habitat types that contained a higher abundance of insects and berry-producing shrubs (Anders et al. 1998). Fruits may be an important source of carbohydrates, water, vitamins, and minerals for Bendire's Thrasher juveniles (Breitwisch et al. 1984). Native berry-producing shrubs of the Chihuahuan Desert include prickly pear cactus (*Opuntia* spp.), hackberry (*Celtis* spp.), sumac, wolfberry (*Lycium torreyi*), gray thorn (*Ziziphus obtusifolia*), and junipers (Fischer 1980, Hammerquist Wilson & Crawford 1987). Other, less documented factors that influence juvenile survival include severe weather and competition.

Post-fledging movements, including distance and frequency, can be influenced by factors such as vegetation cover, food, and competition. Kershner et al. (2004) measured daily movement of Eastern Meadowlarks (*Strunella magna*) in Illinois and determined that distance traveled increased with age. Some juvenile birds reached distances of close to 13 km away from the nest site. Suedkamp Wells (2008) concluded that large movements by juvenile Eastern Meadowlarks became more frequent as resources become scarce, necessitating some juveniles to make long and risky flights in order to obtain resources requisite for survival. LeConte's Thrasher juveniles were recorded traveling maximum distances over 1500m from nest sites (Blackman & Diamond 2015). Other studies have shown that juveniles occupy non-territorial home ranges and concentrate the majority of their time in one central part of this range before initiating migration (Anders 1998, Eraud et al. 2011, Vormwald et al. 2011). LeConte's Thrasher juveniles concentrated daily activities within 90ha of the average 365ha size home range (Blackman & Diamond 2015).

Identifying key vegetation characteristics associated with each stage of the Bendire's Thrasher's life cycle, common predators of nestlings and juveniles, and if interspecific competition occurs will greatly enhance our fundamental understanding of this species and its interactions with its environment. A better understanding of Bendire's Thrasher breeding ecology, including nest survival, fledging rates, and juvenile movements in relation to vegetation characteristics, will improve our ability to define this species' conservation needs. Because the Bendire's Thrasher is an understudied species, and so many knowledge gaps exist with respect to its breeding biology, this information will be essential for identifying future management actions. Only when the ecology and key demographic parameters, such as juvenile and nest survival rates, are better understood for Bendire's Thrashers can proper conservation efforts be implemented for this species (Cox et al. 2009).

Objectives

1. Determine basic breeding information for Bendire's Thrashers including: nest initiation date, clutch size, incubation time, and length of the nestling period.
2. Determine the daily survival rate of Bendire's Thrasher nests and model this in relation to local and landscape scale variables.
3. Examine juvenile movement patterns relative to the nest site and adult territory.
4. Determine juvenile survival and model this in relation to local and landscape scale vegetation characteristics.
5. Examine the influence of interspecific competition on nest survival and juvenile survival and movement patterns.

STUDY SITE

In 2018, research was focused within Hidalgo County (3,446 mi^2) in southwest New Mexico. In 2019, we expanded the focal area to include parts of Grant County (3,968 mi^2), New Mexico (Figure 1). Previous research and eBird data have shown that this area is a hotspot for breeding Bendire's Thrashers in New Mexico (Sutton and Desmond, unpublished data). Known as the "bootheel", this portion of the state contains many private ranch lands and public lands that are subject to a variety of land management practices. The habitat is desert scrub and gradssland, dominated by honey mesquite (*Prosopis glandulosa*) and creosote bush (*Larrea tridentata*). Many areas contain stands of soap tree yucca (*Yucca elata*), cholla, and prickly pear cactus intermixed with four-winged saltbush (*Atriplex canescens*), rabbitbush (*Chrysothamnus spp*.), whitethorn acacia (*Vachellia constricta*), and broom snakeweed (*Gutierrezia sarothrea*). Common grasses include dropseed (*Sporobolus* spp.), tobosa (*Pleuraphis mutica*), and grama (*Bouteloua* spp.).

METHODS

In 2018, field research was initiated in mid-February and in 2019 field research was initiated in early March. We began by identifying occupied sites, mapping territories, and nest searching. Once nests were found, they were monitored until nest termination or fledging. Radio transmitters were placed on fledglings to monitor movement away from the nest and determine juvenile survival rates. Vegetation data were collected at each nest site, within each breeding territory, and at every other post-fledging location. For post-fledging locations, data were collected at paired random points for comparison. Arthropod sampling and evaluation of abundance of berry-producing shrubs were conducted on all occupied breeding territories and at fledgling locations and paired-random points.

Nest Searching and Monitoring

Nest Searching – Area searches for Bendire's Thrashers took place at previously known locations of breeding pairs, recent eBird sightings, and in suitable habitat. Area searches were conducted between sunrise and 4 hours after sunrise and consisted of an observer, or a group of observers, systematically moving through an area by foot for up to 30 minutes, listening and watching for mimids, especially singing males or calling pairs. Often searches were supplemented with call playback to locate individuals (Ralph 1993, Loffland et al. 2011). Once a singing male was identified, the territory was mapped using the flush-mapping technique (Reed 1985) over a period of 2-3 visits. The flush-mapping technique entails marking each location of a perched male with a GPS. Males were flushed from perched locations occasionally to quicken the mapping process, as some individuals will perch for extended periods of time within the territory (Weins 1969, Reed 1985). During territory mapping, individuals were not flushed if it appeared they were visiting a nest site. During territory mapping, observers also looked for evidence of a female, nest building, or adults incubating eggs or feeding young (Martin & Geupel 1993). If a nest was not located during territory mapping, nest searching continued at each territory every 2-3 days. If a nest could not initially be located based on adult behavioral cues, the territory was systematically searched after territory mapping was completed by checking each suitable nest substrate within the territory (Ruehmann et al. 2011). While examining possible nest shrubs, if it was necessary to gently move vegetation for better viewing, the observer used a stick, rather than their hands, in order to avoid leaving a human scent that may attract predators. When systematically searching shrubs, if a nest was found, the surrounding shrubs were also "searched", as some corvid species may respond to cues from observers finding nests, thus increasing nest predation risk for the found nest (Nichols et al. 1984). Once a nest was located, we quickly examined it to determine nest occupancy and stage (eggs or nestlings) and clutch size. Nests discovered in the building stage were not approached, as many passerines are likely to abandon nests before laying eggs. We marked a location 10 m directly south of the nest using a GPS, and a written description of the nest site was recorded for future nest checks.

Nest Monitoring – Nests were checked every 2-5 days until close to the fledging date (approximately 9-10 days of age). At this time, nest check frequency increased to every other day. Nest checks occurred an hour after sunrise until 10 am and did not occur after or near dusk, in the presence of predators, or in inclement weather. When an observer was checking a nest, they monitored parental behavior before approaching the nest. While watching with binoculars from a distance of 80m or more (Hammond et al. 2015), observers looked for parental activity, such as visiting the nest shrub, bringing nesting material, bringing food for nestlings, or removing fecal sacs. Only after egg laying, hatching, or fledging were suspected to have occurred, or when no activity was observed and predation, abandonment, or other nest failure was suspected, were nests approached and examined to determine nest stage and number of eggs or nestlings present. A mirror pole was used for nests higher than 2m to check the contents of nests during nest checks. When a nest shrub was approached, the surrounding shrubs were also "searched" to deter avian or other predators from finding the nest (Nichols et al 1984). Observers used different paths to check nests upon each visit so as not to attract predators and to minimize destruction of surrounding vegetation (Martin & Geupel 1993). At each visit, the status of the nest was recorded as active building, laying (female showing signs of laying), incubation (eggs are present), nestling stage (nestlings present), or failure, including apparent causes of failure. For nests in the post-laying stage, the number of eggs, number of nestlings, and estimated age of nestlings were recorded at each visit. Camera traps were used to document failures by predation and assist in monitoring nests with little disturbance, but were not placed in the immediate vicinity of the nest, as this may influence abandonment. Cameras were placed at nests randomly and attached to rebar placed in the ground 10m away or to a fence post (Buckley Luepold et al. 2015, Hammond et al. 2015) and disguised with native shrubs to reduce human scent (Richardson et al. 2009). Evidence of predation included loss of eggs or nestlings from a nest, the bottom and/or sides of the nest were torn or destroyed, the nest was missing in its entirety, and the presence of fecal droppings from rodents in the nest. Evidence of abandonment included inactive nests that still had all or some eggs and/or deceased juveniles still inside the nest (Martin & Geupel 1993).

Nest Survival

Abiotic Predictors - Extreme temperatures and drought (especially in the months prior to breeding) are known to affect survival of some avian species (Rotenberry & Wiens 1991, Skagen & Yackel Adams 2012). We chose to include the Palmer Drought Severity Index (PDSI) to represent the influence of climate on nest survival, as it is an integrated index that incorporates seasonal temperature, precipitation, and evapotranspiration (Brown & Brown 2014). PDSI values were derived from the WestWide Drought tracker via the PRISM data set (Abatzoglou et al. in press).

Temporal Predictors – Temporal variables, including nest age, starting the day the last egg is laid, day of the season starting from the date the first nest with eggs was found, and year were included in the temporal scale. Temporal variables have been shown to be important from previous passerine survival studies (Jehle et al. 2004, Peak & Thompson III 2014), most often because predation pressures and food availability fluctuate throughout the length of the nesting season and among the different nesting stages.

Vegetation Predictors at the Nest Site – Within 2-5 days of the termination of a nest, vegetation characteristics were assessed, including nest shrub species, estimated nest height to the nearest 0.5m, estimated height of the nest shrub to the nearest 0.5m, distance from the nest to the edge of the shrub in cm, and amount of concealment. Concealment was visually estimated from a 1m distance and the nest was viewed from the top, bottom (when possible), and sides (from each of the cardinal directions) (Martin et al. 1997, Jenkins et al. 2016). Concealment was visually estimated with the aid of a 25cm diameter circle, centered on the nest, and rated from 1-8 (0 = 0%, 1 = 1-12.5%, 2 = 12.6-25%, 3 = 26-37.5%, 4 = 37.6-50%, 5 = 51-62.5%, 6 = 62.6-75%, 7 = 76-87.5%, 8 = 87.6-100%, Schill & Yahner 2009). Photographs were taken of each nest site.

<u>Vegetation Predictors within the Breeding Territories</u> – At the territory scale, vegetation characteristics were assessed along six randomly placed 25m transects. Variables measured included the amount and type of cover, shrub density, average height of shrubs, and amount of visual obstruction. Survey techniques used included Point Line Intercept, Gap Intercept, Belt Transect, and Visual Obstruction Reading methods to assess vegetation cover, density, and distribution (Herrick et al. 2005). For the Point Line Intercept method, amount of cover, including plant species (both live and dead), litter, bare ground, or rock were identified at 50cm intervals by dropping a pin flag and recording the cover type that intercepted the transect. Analysis of Point Line Intercept method data converts the number of hits for each cover type out of the total number of possible hits along the transect to calculate percentages of each cover type. The Gap Intercept method was used to estimate the total percentage of both canopy and basal gaps (or the length of the transect not covered by a plant canopy or base) along a transect line. For data collection, canopy was defined as the entire area that the canopy of the plant covers the soil, and basal cover is defined as the entire area that the basal part of the plant covers the soil (Herrick et al. 2005). Canopy and basal gaps were estimated in cm along the 25m transect, but only gaps >20cm were recorded. Analysis for the Gap Intercept method converts recorded distances along the transect out of the entire length of the 25m transect to calculate the percentage of the line that constitutes a gap for both plant canopies and basal area. Belt transects were conducted on the same 25m transects to estimate shrub density. For these transects, all shrubs within 4m of either side of the 25m transect line were identified to species, counted, and the height of each shrub was estimated into three categories (0.1-0.5m, 0.6-2m, and >2m). To estimate visual obstruction, a Robel pole was placed at 5m intervals along each 25m transect and viewed by an observer from 5m away on either side at a height of 1m (Robel 1970). Photographs were taken for each transect at the 0 end facing the opposite end of the transect (Herrick et al. 2005).

<u>Vegetation Predictors within the Landscape Scale</u> – The landscape scale here is defined as an area within a 1km radius of the nest site. Variables for this scale have not yet been analyzed, but descriptions for the variables of consideration can be found in Table 1. Landscape scale variables will be analyzed using the Patch Analyst Extension in ArcMap GIS (Elkie et al. 1999).

<u>Biotic Predictors at the Territory Scale</u> - To assess competition between Bendire's and Curve-Billed Thrashers or other mimids, point counts were conducted from all occupied adult Bendire's Thrasher territories to determine the presence of Curve-Billed Thrashers or other mimid species. Two point count transects consisting of two points each, separated by 400m, were conducted at the farthest ends of each occupied Bendire's Thrasher territory. The first of the two points in each transect occurred at each corner end of the territory. The second point occurred 400m away from the first, in a random direction away from the territory. Point counts were conducted in the morning, within 4

hours of sunrise (Ralph et al. 1997), once during both the incubation and nestling stages at occupied Bendire's Thrasher territories (Gorton 1977, Prescott 1987, Hill & Lein 1989). At each point, observers conducted a 3-minute silent point count and recorded all avian species encountered, as well as a bearing and distance. Following the silent point count, another 3-minute point count was conducted, supplemented with Curve-billed Thrasher playback, during which all mimids encountered were recorded along with a bearing and distance (Sutton & Desmond unpublished data). In order to reduce disturbance on the territory, if Curve-billed Thrashers were detected during the silent point count, playback was not used. If Curve-billed Thrashers were detected by point-counts, then territory mapping of Curve-billed Thrashers was conducted by the flush-mapping technique (Reed 1985). This was done to determine if there were any overlap with the local Bendire's Thrasher territory and, if so, the amount of overlap. If encountered during territory mapping, nest locations of Curve-billed Thrashers were marked using a GPS.

An additional biotic predictor for nest survival is food abundance within occupied territories. Sweep-netting is considered one of the most efficient methods for obtaining relative abundance estimates for the order Orthoptera, the primary insect prey of thrashers (Evans & Baily 1993). Sweep-netting was conducted 3 times on each adult territory, once during the incubation stage and twice during the nestling stage (Sutter & Ritchison 2005, Hickman et al. 2006, Kurschback-Brohl et al. 2010). Sweep-netting occurred along two randomly placed, parallel 100m transects, 10m apart within the occupied breeding territory, with 20 sweeps per 20m broken down into five separate sections swept in succession (Steward et al. 2013) for a total of 100 sweeps per transect (Jamison et al. 2002). Sweeps were low and fast, using the figure-eight method with a standard 38-cm diameter muslin sweep net (Brust et al. 2009). Transects were placed in a random direction, and as recommended by Whipple et al. (2010), sweep-netting samples took place between the hours of 10:00 and 16:00. In addition to sweep-netting, the beat-netting (i.e., beat-sheeting) method was used to collect arthropods from shrubs, as Bendire's Thrashers are known to glean insects from shrubs (England & Laudenslayer 1993). Beat-netting occurred concurrently with sweep-netting. Four samples were taken along each sweep netting transect at four randomly selected shrubs within 10m of the transect (McDermott & Wood 2010). One observer held the beating net (18" diameter net) under the shrub and used an aspirator to collect arthropods while another observer beat 4 branches, with 4 beats each (McDermott & Wood 2010). All collected samples were fumigated with ethyl acetate, placed in freezer bags, labeled, and stored frozen until sorted. Collection method, location, date, time, temperature, and wind speed were recorded for each sampling location (Whipple et al. 2010). All arthropod samples were sorted to order and counted. The abundance of berry-producing shrubs was estimated using the same two parallel, 100m transects used for sweep- and beat-netting. The abundance of berry-producing shrubs was evaluated immediately following arthropod sampling. Observers recorded the presence of berry-producing shrubs, species of berry-producing shrubs, and presence or absence of berries on each shrub within 10m of each transect, including the 10m between the parallel transects (Vega Rivera et al. 1999).

Statistical Analysis - Nest survival model analysis was separated by variables based on three scales; the temporal scale, the nest site scale, and the territory scale. Preliminary daily nest survival estimates were analyzed using Program MARK (White & Burnham 1999, Rotella et al. 2004) through Program R (known as RMark) (Laake 2003). Cumulative nest survival estimates, based on the null (intercept) model, were calculated by raising the daily survival estimates to the power of the length of the complete nesting cycle, which was 22 days for first nest attempts (Dinsmore et al. 2002).

For preliminary analysis of the different scales, all variables were examined for multicollinearity using Pearson's Correlation before model analysis began. For pairs of variables with a correlation $\geq$ 0.7, one variable of the pair was removed from consideration for analysis (Benson 2009). Descriptions of model covariates for nest survival can be found below (Table 1). Models within each scale of nest survival were ranked using AIC_c and analysis output includes ΔAIC_c values and model weights (Burnham and Anderson 2002, Rotella et al. 2004, Benson et al. 2010).

Juvenile Monitoring and Home Range

Radio-telemetry – Radio transmitters (17x7x4mm, 1.0g, with an estimated 8-week lifespan from Advanced Telemetry Systems, Inc., Isanti, MN, USA) were placed on randomly selected nestlings (maximum of 2 per nest and only for nestlings that weighed a minimum of 45g), 1 day prior to fledging (Kershner et al. 2004). Transmitters were attached via the leg-loop harness method (Rappole & Tipton 1991) using stretch magic jewelry chord (0.8mm) that added 0.1g in weight. Total transmitter weight, with harness material and federal bands included, did not exceed 3% of the bodyweight of juveniles. Transmitters were placed on nestlings aged 9-10 days old to ensure that they did not fledge prematurely as a result of a transmitter being attached. Nestlings were removed from the nest and temporarily placed in a holding container with a heat source (when needed) for radio transmitter attachment and banding. All nestlings received a federal aluminum band (USGS size 2 bands, 0.2 grams). Tarsus and weight measurements were taken to estimate body condition (Donnelly & Sullivan 1998, Vitz & Rodewald 2010) as nestlings often had not developed complete flight feathers.

Once nestlings fledged, they were re-located using handheld telemetry receivers (R-1000, Communications Specialist, Orange, CA) with a three-prong yagi antenna. We attempted to locate individuals daily, or every other day, using the homing method (White & Garrot 1990). If individuals could not be found on foot, vehicles were used to cover an area of 5km radius from last known sighting (Vitz & Rodewald 2010). One or more daily locations for each individual were recorded at least 2 hours apart in order to be considered independent of each other (White & Faaborg 2008, Dittmar et al. 2014). Locations were marked with a GPS (~5m accuracy) and the status of the fledgling was recorded as alive, deceased, or missing and observers noted if family units were still intact. Attempts were made to relocate missing juveniles. Tracking efforts for missing individuals ended after a minimum of three tracking attempts were performed on foot or by vehicle without the missing juveniles being located. To avoid attracting predators, observers did not leave a dead-end trail to juveniles while relocating them and flagging was not used to mark juvenile locations. Instead, while relocating juveniles in the field, observers marked locations of juveniles with a GPS and continued walking past juveniles for at least 20m (Jones et al. 2017). Causes of mortality, such as predation, were identified to the observers' best ability. Waypoints collected from juvenile locations were used to estimate the natal home range, defined here as the area occupied by juveniles prior to dispersal (Anders 1998). During this time, juveniles were still depending on parental care from adults. Attempts were made near the end of each transmitter's life to recapture juveniles using mist nests and removing transmitters.

<u>Statistical Analysis</u> - Distances between nest site and juvenile relocations and between each juvenile relocation were measured using the measuring tool in ArcGIS (Hooge & Eichenlaub 2000). Average path length was calculated for all juveniles that lived long enough to track at least two locations (n=19). Average natal home range was calculated, using minimum convex polygons in ArcGIS, for juveniles that lived at least 20 days and were determined to disperse (n=10) (Anders 1998).

Juvenile Survival

<u>Juvenile and Paired-Random Locations</u> – Vegetation collection occurred at every other juvenile relocation within 24 hours of the juvenile having been located and at a paired-random location 600m away, and in a random direction from the actual relocation (Blackman & Diamond 2015, Jones et al. 2017). In the case of mortality, loss of signal, or suspected dispersal, the previously recorded location was used for vegetation data collection (Jenkins et al. 2016). Data collection was similar to that described above for breeding territories. Shorter transects (11.3m long) were used and four transects radiated from the juvenile location or paired-random location in the four cardinal directions (Jenkins et al. 2016). For the Point Line Intercept method, plant species were recorded and cover type was determined at smaller (i.e., 25cm) intervals (Martin et al. 1997, Harrison et al. 2011, Jenkins et al. 2016) to estimate the percent of each cover type. The Gap Intercept method was used to estimate concealment, in the same manner as used for the adult territories. Shrub density was estimated within the 11.3m radius circular plot, divided into 4 quadrants (based on the four cardinal directions), for a total diameter of 22.6m. In each quadrant, shrubs were counted, identified to species, and categorized by height in the same manner as the adult territories (Chalfoun & Martin 2007, Jenkins et al. 2016). To estimate visual obstruction, a Robel pole was placed at 1m, 3m, and 5m distances away from each juvenile location or paired-random point, along each of the four 11.3m transects, and viewed from 4m away from each of the cardinal directions at a height of 1m (Robel 1970, Dieni & Jones 2003). Photographs of each juvenile or paired random location were taken from the 11.3m end of each transect, facing the central point.

<u>Statistical Analysis</u> - Descriptions of variables that will be considered for juvenile survival can be found below (Table 2). As mentioned previously, landscape scale variables have not been evaluated yet but will be analyzed using the Patch Analyst Extension in ArcMap GIS (Elkie et al. 1999).

Vegetation characteristics were compared between juvenile relocations and paired-random sites using descriptive statistics. Because the juvenile vegetation data were not normally distributed, even when transformed, a nonparametric Whittney Mann-U t-test was conducted to test for significance. Vegetation variables considered in this analysis include amount of bare ground (%), amount of canopy cover (%), amount of basal cover (%), amount of litter cover (%), and amount of visual obstruction (%).

RESULTS

Summary of Field Season

In 2018, fieldwork was concentrated in Hidalgo Co., with hotspots northwest of Lordsburg and in the Middle Animas area. Fieldwork was initiated on February 15th, and numerous birds were located in February and March through incidental searching and territory mapping efforts. However, the first nest with eggs was not found until April 4th, much later than we anticipated. The nesting season extended until July 5th, the last day an active nest was recorded during nest monitoring efforts. A total of 30 first nest attempts were found and there were an additional 9 re-nesting attempts (with some pairs initiating 2nd and 3rd clutches). Nest failure was high due to predation (Table 3) and only 12 nests were successful. The average clutch size was less than three eggs (2.77±0.86) and the number of nestlings (2.41±0.72) and fledglings (2.25±0.87) decreased with age of the nest. The average age of nestlings at fledging for the few successful nests was about 13 days (13.3±1.41) (Table 4).

In 2019, fieldwork was initiated on March 6th and efforts were expanded into Grant Co., NM. The nesting season extended to the end of June. A total of 45 first nesting attempts were located with an additional 10 second nesting attempts located. Nest success was higher in 2019, compared to 2018, with 31 of the 45 first nesting attempts being successful. The average clutch size was higher (3.56±0.82) as well as the number of nestlings (3.32±0.93) and fledglings (3.13±0.96) produced per nest (Table 4). On average, nests were initiated 24 days earlier in 2019, compared to 2018 and nests fledged 20 days earlier in 2019 compared to 2018 (Table 4).

In both breeding seasons, the most common nest predators were Chihuahuan Ravens (*Corvus cryptoleucus*) (Image 1), but other documented predators included coyotes (*Canis latrans*), javelina (*Tayassu tajacu*), and rodents. Domestic cattle (*Bos taurus*) were also thought to predate one nest as a video showed them at the nest just prior to the nest contents (nestlings) being documented as missing. Additionally, in both breeding seasons, nests were found on three different land ownerships types throughout New Mexico, including state, BLM, and private land (Appendix A). Overall, nest success was lower in 2018 compared to 2019, and nests had slightly higher success on state and private lands compared to BLM lands (Table 5).

Nest Site Characteristics

Nests were located 1-2m from the ground (mean height of 0.95±0.04(m)), and concealment estimates were high (Table 6). Surprisingly, soaptree yuccas were selected for nesting locations more than expected in both years, with a total of 43 of 75 nests located in soaptree yuccas (Image 2). Nest site vegetation characteristics were similar between both field seasons (Table 6). Anecdotally, nest concealment seemed like an important biological variable for nest sites. Pairs often selected sites for nests with multiple layers of concealment, often within shrubs that had collected Russian Thistle (*Salsola spp.*) over time (Image 3).

Nest Survival

Preliminary models for daily nest survival show that several variables were important at different scales. At the nest site, nest concealment was the only predictor of nest survival that ranked above the null, however other attributes that fall within $\Delta AIC_c \leq 2$ may also contribute to survival (Table 7). Within the occupied territories, vegetation attributes and prey abundance were strongly associated with nest survival; this was particularly true for canopy gaps and arthropod abundance that occurred in all top models (Table 8). However, it is still unclear if this trend was important for nest survival. Unsurprisingly, temporal variables were also shown to be important for nest survival, including the effect of climate and drought, nest age, year, and time, all of which ranked above the null model and had $\Delta AIC_c \leq 2$. However, the 95% CI bound zero, suggesting that the top models within the temporal scale are not statistically significant, probably due to small sample sizes.

Future analysis will include more covariates at the landscape scale, including the effects of vegetation patches and the amount of vegetation edge, which may influence nest survival. Additionally, covariates from each scale will be more closely examined to evaluate importance for consideration in a final model. This model set will include variables from all scales and new combinations of variables that look at interactions between scales. Once a final model set is selected, cumulative nest survival estimates can be analyzed.

The point-count data shows that Curve-billed Thrashers were only detected at 4 occupied Bendire's Thrasher territories in 2018 and 4 occupied territories in 2019. We did observe what appeared to be Curve-billed Thrashers "pushing" Bendire's Thrashers out of one territory in 2018. At this site, a pair of Bendire's Thrashers was present, and then absent as Curve-billed Thrashers became present, however, the Bendire's Thrasher pair never established a nest site. In the preliminary daily nest survival model results at the territory scale, the presence of Curve-billed Thrashers did not rank above the null model. The point-count data also shows that other mimid species were not often detected on territories, except for the Northern Mockingbird, which was often present. Other species of interest, that may also compete with Bendire's Thrashers, especially for nest sites and possibly other resources, include Cactus Wrens, Loggerhead Shrikes, and Western Kingbirds. Some species of special conservation concern often associated with Bendire's Thrasher breeding sites that were detected on point-counts include the Cassin's Sparrow, Lark Bunting, Brewer's Sparrow, and Vesper's Sparrow (Appendix C) (NMACP, 2019).

Preliminary model results showed arthropod abundance (or prey availability) to be important to nest survival. Average arthropod abundance was slightly higher for successful nests than failed nests. Average arthropod abundance was higher overall and for each month of the breeding season in 2019 compared to 2018 (Figure 2). Berry producing shrubs were often found within sampling transects, however, they rarely contained berries during the breeding season.

Juvenile Movements
Average path length data, or the average distance (in meters) between tracked locations, was calculated for all juveniles that survived more than one tracking location (Table 12). The average path length for juvenile Bendire's Thrashers at our study site was 146m (145.55±85.08). The maximum distance recorded was 1205m. Typically, juveniles stayed within adult breeding territories; when relocated, they were often seen with parents and/or siblings, something that has also been documented for LeConte's Thrashers (Blackman & Diamond 2015). Juveniles did not expand outside of the known adult breeding territories until at least 15 days post-fledging (Figures 4-6), and juveniles occupied areas similar to or smaller in size to known adult territories (Table 13). Juveniles stayed on territories with family units for up to 38 days, and anecdotally, it was observed that family units left occupied territories together.

Juvenile Survival
In 2018, we attached transmitters to 9 fledglings, while in 2019, we were able to attach transmitters to 18 nestlings (Image 4), due to the much higher nest success rate. In 2018, of the nine fledglings with transmitters, four survived for five days or less (before disappearing), one survived 12 days, and four survived more than 20 days (Table 10). Overall, mean survival length (in days) was 14 days (14.78±13.02) for all tracked juveniles. Mean survival (i.e., days tracked) for juveniles known to disperse was 27 days (27.25±7.37), and for those that went missing and predation was assumed was less than 5 days (4.8±4.37) (Table 10). In 2019, only 12 juveniles were tracked as 6 were predated before tracking could occur and 6 were known to disperse. Mean survival (i.e., days tracked) for juveniles known to disperse was 29 days (29.33±7.90) (Table 10).

A summary of vegetation attributes recorded in the field for juvenile and paired-random locations was calculated for all juveniles that survived long enough to track one location (Table 11). The data shows differences in average vegetation measurements between occupied juvenile locations and paired-random locations, with juvenile locations having a higher percentage of canopy cover and visual obstruction. As a result, these locations also showed a lower percentage of bare ground and a greater percentage of litter, most likely due to increased canopy cover (Figure 3). The results from the Whitney Mann-U t-test (n=78) shows that most variables (except Basal Cover, p = 0.215) are statistically significantly different between actual locations used by juveniles and paired-random locations (p-values [Canopy Cover = 5.06e-11, Litter Cover = 1.12e-08, Bare ground = 2.48e-08, VOR = 4.483e-08]).

DISCUSSION

The majority of information available for Bendire's Thrashers is anecdotal, from the early 1900s, and was collected from the Sonoran Desert in Arizona. Some information is available more recently from the Mojave Desert in California (England 1998). This study represents the first to examine the nest survival of Bendire's Thrashers. Nesting ecology for Bendire's Thrasher in Hidalgo and Grant Co. is similar to known ecology of related species, such as Curve-billed and Brown Thrashers (*Toxostoma rufum*), with clutch sizes of 3-4 eggs (Murphy & Fleischer 1986), 2-3 nestlings, and 1-3 fledglings (Kozma & Mathews 1997). Apparent nest success (number of nests that successfully produced fledglings in first nest attempts) for this study was 57.3% and is slightly higher than previous studies of nest success for related species, including Curve-billed Thrashers (37%), Long-billed Thrashers (26%), and Crissal Thrashers (48%) (Fischer 1980, Finch 1982). In California, Bendire's Thrashers are known to nest in species of cholla, mesquite, juniper, Joshua tree, and yuccas (England 1998). Bendire's Thrasher nests were previously only known to occur in cholla and juniper species in New Mexico (Darling 1970). Our study documented nests in a variety of shrub species, mostly soaptree yuccas, but also honey mesquite, graythorn, catclaw acacia (*Senegalia greggii*), four-winged saltbush, littleleaf sumac (*Rhus microphylla*), Mormon tea (*Ephedra viridis*) and neatleaf hackberry (*Celtis laevigata*). Specific nest predators were previously not known for Bendire's Thrashers, but as mentioned previously, game cameras placed in the vicinity of nests have documented Chihuahuan Ravens as the most common predator, but also rodents, coyotes, javelina, and cattle have been documented as predators.

Nest Survival

Preliminary model results show that variables at multiple scales show importance to nest survival for Bendire's Thrashers. As expected, temporal variables have a strong influence on nest survival. Beta estimates from this preliminary temporal model show a clear negative relationship between survival and day of the season. Nest concealment, arthropod abundance, and foraging space also strongly influence nest survival at our site and the beta estimates show a positive relationship between these variables and survival. But the impact of Curve-billed Thrashers is still not clear for our study site as so few were detected. Currently, variables from each scale are undergoing univariate analysis to determine selection for a final model set. Ecological interactions are often complex and interactions of variables at each scale and their interactions with variables from other scales will need to be evaluated in order to better understand nest survival. Future analysis will include solid nest survival estimates from a final model set of biologically important variables from each scale that interact within and across scales.

Although little is known about Bendire's Thrashers, we do know some habitat characteristics they are selecting for at breeding sites. Habitat features they seek within occupied territories include taller shrubs, more bare ground, and greater canopy cover. On a larger scale, it is also known that habitat heterogeneity is important, as they seem to be an edge-adapted species that select for small patches and requires variation in habitat types near the occupied territories (Sutton & Desmond, unpublished data). Previous passerine nest survival research suggests that fragmentation and patchiness may be detrimental to some small passerine species as it could attract a diversity of predators, thereby acting as an ecological trap (Skagen et al. 2005). Planned future analysis of vegetation attributes at a landscape scale may provide more insight into whether or not Bendire's Thrasher nest survival is influenced by habitat edges or patchiness. In particular, future analyses of nest survival will include variables characterizing the habitat heterogeneity in the landscape surrounding territories, such as mean patch size, patch dominance, patch richness, and edge density. Land ownership and associated management practices, such as development or grazing regimes, may also be influencing nest survival and habitat heterogeneity. In particular, differences in nest success are seen among state, BLM, and private lands, which are likely to experience different management practices. Models presented here are preliminary and future analyses will include variables from across all scales and interactions both within and across scales within a final model set to analyze cumulative nest survival for the Bendire's Thrasher.

Juvenile Movements

We were expecting juveniles to become independent from adults sooner than we observed in the field (Rivera et al. 1998, Streby et al. 2012); juveniles were still being tracked in close proximity to adults and siblings up to 46 days after fledging. Therefore, juvenile movements were not independent and may have been influenced by the movements of the adults. Average path length analysis shows that, as expected, distances traveled by juveniles increased with age, and the maximum recorded distance between two points was 1205m. The results from this study differ from the study by Blackman and Diamond (2015) in which LeConte's Thrasher post-fledgling movement patterns consisted of large daily movements (>600m), with a maximum-recorded movement of 1733m.

Juvenile Survival

Unfortunately, in 2018, we experienced issues with a transmitter for one of the juveniles that lived more than 20 days and there is a large gap in the dataset for that individual. The five juveniles that survived fewer than 20 days but ended up missing (unable to relocate) were considered to be mortalities as they were too young to disperse but they were not recovered. We assumed that a large predator moved them far enough from the last recorded tracking location (i.e., greater than 5km from last known sighting) that we were no longer able to detect them. Juveniles were unable to fly the first 3-5 days post-fledging (i.e., had left the nest but were still flightless) and were not capable of complete flight until several days after fledging, making them extremely vulnerable to predation during this time.

Post-fledging juvenile survival data have not yet been analyzed. Post-fledging survival estimates vary across studies, and juveniles of many species seek greater amounts of cover and abundant or easy to obtain food sources as predation pressures are high (Rivera et al. 1998, Cox et al. 2004). Post-fledging survival is also known to vary with age, as younger birds face higher predation pressures (Anders et al. 1997). Future model analysis will include covariates anticipated to be important for post-fledging survival of Bendire's Thrashers, including vegetation cover, food availability, age of the juvenile, day of the season, competition, and effects of climate using the PDSI.

Basic summary statistics that have been calculated for juvenile locations and paired-random locations show that there are significant differences between used sites and random locations. However, there is large variation among surveyed locations and sample sizes are relatively small. Juveniles were found in locations with higher mean cover and visual obstruction, most likely because association with these vegetation features helps juveniles avoid predation. The mean amount of bare ground was higher for paired-random locations, which may indicate that predation pressures were stronger for post-fledging juveniles, as they were still dependent on adults for food and were seeking areas with more cover than comparatively open foraging spaces.

Conclusion

In summary, because there is such a large information gap regarding basic breeding biology and ecology for Bendire's Thrasher in New Mexico, further investigation into nesting and post-fledging survival is crucial for conservation. An enhanced understanding of what is influencing nest survival for this species will be the basis for conservation efforts in the future. Current potential threats for this species include loss of breeding habitat, possibly due to land management practices and associated increases in shrub density (England 1998), loss of suitable nest shrubs, and competition with Curve-billed Thrashers (Ambrose 1963). This study encompasses data collection for variables most likely to affect nest survival including: vegetation characteristics, food availability, competition with sympatric species, temporal variables, and land management (ownership). Identification of the most pressing threats for this species will help the development of effective management practices for future conservation efforts. While the results presented here describe many important aspects of the breeding biology and ecology of the Bendire's thrasher, more results will be forthcoming in the future as further analyses are performed.

Literature Cited

Abatzoglou, J. T., D. J. McEvoy, and K. T. Redmond, in press, The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales, Bulletin of the American Meteorological Society.

Ambrose, J. E., Jr. 1963. The Breeding Ecology of *Toxostoma curvistre* and *T. bendirei* in the Vicinity of Tucson, Arizona. M. S. Thesis, Univ. Arizona, Tucson, Arizona.

Anders, A. D., D. C. Dearborn, J. Faaborg, and F. R. Thompson III. 1997. Juvenile Survival in a Population of Neotropical Migrant Birds. Conservation Biology, Vol. 11, No. 3, pp. 698-707.

Anders, A. D., J. Faaborg, and F. R. Thompson III. 1998. Post-fledgling Dispersal, Habitat Use, and Home-range Sizes of Juvenile Wood Thrushes. The Auk, Vol. 115, No. 2, pp. 349-358.

Benson, T. J., N. M. Anich, J. D. Brown, and J. C. Bednarz. 2009. Swaison's Warbler Nest-site Selection in Eastern Arkansas. The Condor vol. 111, pp. 694-705.

Benson, T. J., N. M. Anich, J. D. Brown, and J. C. Bednarz. 2010. Habitat and Landscape Effects on Brood Parasitism, Nest Survival, and Fledgling Production in Swainson's Warblers.

BirdLife International. 2017. *Toxostoma bendirei*. (amended version published in 2016) The Red List of Threatened Species 2017: e.T22711108A110276662. http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T22711108A110276662.en. Downloaded on **10 September 2017**.

Blackman, S. T., and J. Diamond. 2015. Meta-population Dynamics of LeConte's Thrasher (*Toxostoma lecontei*): A Species at Risk on Three Southwestern Military Installations. Year 3 Report. Wildlife Contracts Branch, Arizona Game and Fish Department.

Breitwisch, R., P. G. Merrit, and G. H. Whitesides. 1984. Why Do Northern Mockingbirds Feed Fruit to Their Nestlings? The Condor, Vol. 86, No. 3, pp. 281-287.

Brown, C. R., and M .B. Brown. 2014. Breeding Time in Migratory Songbird is Predicted by Drought Severity and Group Size. Ecology, Vol. 95, No. 10, pp. 2736-2744.

Brown, J. D., T. J. Benson, and J. C. Bednarz. 2011. Arthropod Communities Associated with Habitats Occupied by Breeding Swainson's Warblers. The Condor, Vol. 113, No. 4, pp. 890-898.

Brown, W. P., and R. R. Roth. 2004. Juvenile Survival and Recruitment of Wood Thrushes *Hylocichla mustelina* in a Forest Fragment. Journal of Avian Biology, Vol. 35, No. 4, pp. 316-326.

Brust, M. L., W. Hoback, and R. J. Wright. Degree-day Requirements for Eight Economically Important Grasshoppers (Orthoptera: Acrididae) in Nebraska Using Field Data. Entomological Society of American Vol. 38, No. 5, pp. 1521-1526.

Buckley Luepold, S. H., T. P. Hodgman, S. A. McNulty, J. Cohen, and C. R. Foss. 2015. Habitat Selection, Nest Survival, and Nest Predators of Rusty Blackbirds in Northern New England, USA. The Condor, Vol. 117, No. 4, pp. 609-623.

Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multimodel Inference. New York, Springer-Verlag.

Carneiro, A. P. B., J. E. Jiménez, and T. H. White Jr. 2012. Post-fledging Habitat Selection by the Sledner-billed Parakeet (*Enicognathus leptorhychus*) in a Fragmented Agricultural Landscape of Southern Chile. The Condor, Vol. 114, No. 1, pp. 166-172.

Chalfoun, A. D., and T. E. Martin. 2007. Assessments of Habitat Preferences and Quality Depend on Spatial Scale and Metrics of Fitness. Journal of Applied Ecology, Vol. 44, No. 5, pp. 983-992.

Chalfound, A. D., and T. E. Martin. 2009. Habitat Structure Mediates Predation Risk for Sedentary Prey: Experimental Tests of Alternative Hypotheses. Journal of Animal Ecology, Vol. 78, No. 3, pp. 497-503.

Ciudad, C., H. Robles, and E. Matthysen. 2009. Postfledgling Habitat Selection of Juvenile Middle Spotted Woodpeckers: A Multi-Scale Approach. Ecography, Vol. 32, No. 4, pp. 676-682.

Conner, L. M., J. C. Rutledge, and L. L. Smith. 2010. Effects of Mesopredators on Nest Survival of Shrub-nesting Songbirds. The Journal of Wildlife Management, Vol. 74, No. 1, pp. 73-80.

Cottam, G., and J. T. Curtis. 1956. The Use of Distance Measures in Phytosociological Sampling. Ecology, Vol. 37, No. 3, pp. 451-460.

Cox, W. A., F. R. Thompson III, A. S. Cox, and J. Faaborg. 2014. Post-fledging Survival in Passerine Birds and the Value of Post-fledging Studies to Conservation. The Journal of Wildlife Management, Vol. 78, No. 2, pp. 183-193.

Darling, J .L. 1970. New Breeding Records of *Toxostonma curvirostre* and *T. bendirei* in New Mexico. The Condor, Vol. 72, No. 3, pp. 366-367.

Davis, S. K. 2005. Nest-site Selection Patterns and the Influence of Vegetation on Nest Survival of Mixed-Grass Prairie Passerines. The Condor, Vol. 107, No. 3, pp. 605-616.

Devineau, O., W. L. Kendall, P. F. Doherty Jr., T. M. Shenk, G. C. White, P. M. Lukacs, and K. P. Burnham. 2014. Increased Flexibility for Modeling Telemetry and Nest-Survival Data Using the Multistate Framework. Journal of Wildlife Management, Vol. 78, No. 2, pp. 224-230.

Dial, R. J., M. D. F. Ellwood, E. C. Turner, and W. A. Foster. 2006. Arthropod Abundance, Canopy Structure, and Microclimate in a Bornean Lowland Tropical Rain Forest. Biotropical, Vol. 38, No. 5, pp. 643-652.

Dittmar, E. M., D. A. Cimprich, J. H. Sperry, and P. J. Weatherhead. 2014. Habitat Selection by Juvenile Black-capped Vireos Following Independence from Parental Care. The Journal of Wildlife Management, Vol. 78, No. 6, pp. 1005-1011.

Dinsmore, S. J., G .C. White, and F. L. Knopf. 2002. Advanced Techniques for Modeling Avian Nest Survival. Ecology, Vol. 83, No.12, pp. 3476-3488.

Donelly, R. E., and K. A. Sullivan. 1998. Foraging Proficiency and Body Condition of Juvenile American Dippers. The Condor, Vol. 100, No. 2, pp. 385-388.

Elkie, P. C., and R. S. Rempel, A. Carr. 1999. Patch analyst user's manual: a tool for quantifying landscape structure. Ontario: Northwest Science & Technology.

England, A. S., and W. F. Laudenslayer Jr. 1993. Bendire's Thrasher (*Toxostoma bendirei*) version 2.0. In The Birds of North America (P.G. Rodewald, editor) Cornell Lab of Ornithology, Ithaca, New York, USA. http://dio.org/10.2173/bna.71

Eraud, C., A. Jacquet, and P. Lagagneux. 2011. Post-Fledging Movements, Home Range, and Survival of Juvenile Eurasian Collared-Doves in Western France. The Condor, Vol. 113, No. 1, pp. 150-158.

Etterson, M .A., L. R. Nagy, T. R. Robinson, and D. H. Johnson. 2007. Partitioning Risk among Different Causes of Nest Failure. The Auk, Vol. 124, No. 2, pp. 432-443.

Evans, E. W., and K. W. Bailey. 1993. Sampling Grasshoppers (Orthoptera: Acrididae) in Utah Grasslands: Pan Trapping versus Sweep Sampling. Journal of the Kansas Entomological Society. Vol. 66, No. 2 pp.214-222.

Finch, D. H. 1982. Rejection of cowbird eggs by Crissal Thrashers. Au, Vol. 99, pp. 719-724.

Fischer, D. H. 1980. Breeding Biology of Curve-Billed Thrasher and Long-Billed Thrashers in Southern Texas. The Condor, Vol. 82, No. 4, pp. 382-397.

Franzerb, K .E., and Zarnoch, S. J. 2011. Factors Affecting Florida Scrub-Jay Nest Survival on Ocala National Forest, Florida. The Journal of Wildlife Management, Vol. 75, No. 5, pp. 1040-1050.

Grant, T. A., T. L. Shaffer, E. M. Madden, and P. J. Peitz. 2005. Time-specific Variation in Passerine Nest Survival: New Insights into Old Questions. The Auk, Vol. 122, No. 2, pp. 661-672.

Gustafsson, L. 1987. Interspecific Competition Lowers Fitness in Collared Flycatchers *Ficedula albicollis*: An Experimental Demonstration. Ecology, Vol. 68, No. 2, pp. 291-296.

Hammerquist Wilson, M., and J. A. Crawford. 1987. Habitat Selection by Texas Bobwhite and Chestnut-bellied Scaled Quail in South Texas. The Journal of Wildlife Management, Vol. 51, No. 3, pp. 575-582.

Hammond, R. L., L. H. Crampton, and J. T. Foster. 2015. Nesting Success of Native and Introduced Forest Birds on the Island of Kaua'i. Journal of Avian Biology, Vol. 46, pp. 001-011.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Volumes I and II, Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, NM.

Hickman, K. R., G. H. Farley, R. Channell, and J. E. Steier. 2006. Effects of Old World Bluestem (*Bothriochloa ischaemum*) on Food Availability and Avian Community Composition within the Mixed-Grass Prairie. The Southwestern Naturalist, Vol. 51, No. 4, pp. 524-530.

Hill, B. G., and M. R. Lein. 1989. Natural and Simulated Encounters between Sympatric Black-Capped Chickadees and Mountain Chickadees. The Auk, Vol. 106, No.4, pp. 645-652.

Hooge, P. N., and B. Eichenlaub. 2000. Animal Movements Extension to ArcView. Version 2.0. USGS, Alaska Science Center, Biological Science Office, Anchorage, USA.

Jacoby, D. M. P., E. J. Brooks, D. P. Croft, and D. W. Sims. (2012). Developing a Deeper Understanding of Animal Movements and Spatial Dynamics through Novel Application of Network Analyses. Methods in Ecology and Evolution, Vol. 3, pp. 574-583.

Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate Biomass: Associations with Lesser Prairie-Chicken Habitat Use and Sand

Sagebrush Density in Southwestern Kansas. Wildlife Society Bulletin (1973-2006), Vol. 30, No. 2, pp. 517-526.

Jehle, G., A. A. Yackel Adams, J. A. Savidge and S. K. Skagen. 2004. A Review of Alternative to the Mayfield Estimator. The Condor, Vol. 106, No. 3, pp. 472-484.

Jenkins, J. M. A., F. R. Thompson, III, and J. Faaborg. 2016. Contrasting Patterns of Nest Survival and Postfledging Survival in Ovenbirds and Acadian Flycatchers in Missouri Forest Fragments. The Condor, Vol. 118, pp. 582-596.

Kerhsner , E. L., J. W. Walk, and R. E. Warner. 2004. Post-fledgling Movement and Survival of Juvenile Eastern Meadowlarks (*Sturnella magna*) in Illinois. The Auk, Vol. 121, No. 4, pp. 1146-1154.

Kerns, C. K., M. R. Ryan, R. K. Murphy, F. R. Thompson III, and C. S. Rubin. 2010. Factors Affecting Songbird Nest Survival in Northern Mixed-Grass Prairie. The Journal of Wildlife Management, Vol. 74, No. 2, pp. 257-264.

King, D. I., R. M. Degraaf, M.L. Smith, and J. P. Buconaccorsi. 2006. Habitat Selection and Habitat-specific Survival of Fledgling Ovenbirds (*Seiurus aurocapilla*). Journal of Zoology (London) Vol. 269, pp. 414-421.

Kozma, J. M, and N. E. Mathews. 1997. Breeding Bird Communities and Nest Plant Selection in Chihuahuan Desert Habitats in South-Central New Mexico. The Wilson Bulletin, Vol. 109, No. 3, pp. 424-436.

Kutschbach-Brohl, L., B. E. Washburn, G. E. Bernhardt, R. B. Chipman, and L. C. Francoeur. 2010. Arthropods of a Semi-Natural Grassland in an Urban Environment: The John F. Kennedy International Airport, New York. Journal of Insect Conservation, Vol. 14, pp. 347-358.

Laake J (2013). "RMark: An R Interface for Analysis of Capture-Recapture Data with MARK." AFSC Processed Rep. 2013-01, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Seattle, WA. http://www.afsc.noaa.gov/Publications/ProcRpt/PR2013-01.pdf.

Lindell, C. A., R. S. O' Connor, and E. B. Cohen. 2011. Nesting Success of Neotropical Thrushes in Coffee and Pasture. The Wilson Journal of Ornithology, Vol. 123, No. 3, pp. 502-507.

Loffland, H. L., R. B. Siegel, and R. L. Wilkerson. 2011. Avian Monitoring Protocol for Sierra Nevada Meadows: A Tool for Assessing the Effects of Meadow Restoration on Birds. Version 1.0. The Institute for Bird Populations, Point Reyes Station, CA

Martin, T. E., C. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. 1997. BBIRD Field Protocol. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana, USA.

McDermott, M. E., and P. B. Wood. 2010. Influence of Cover and Food Resource Variation on Post-Breeding Bird Use of Timber Harvests with Residual Canopy Tree. The Wilson Journal of Ornithology, Vol. 22, No. 3, pp. 545-555.

Murphy, M. T., and R. C. Fleischer. 1986. Body Size, Nest Predation, and Reproductive Patterns in Brown Thrashers and Other Mimids. The Condor, Vol. 88, No. 4, pp. 446-455.

[NMACP] New Mexico Avian Conservation Partners - Species Assessment Scores. 2019.

North American Bird Conservation Initiative (NABCI), US Committee 2014. The State of the Birds 2014 Report. US Department of Interior, Washington DC 16 pages.

Peak, R. G. and F. R. Thompson III. 2014. Seasonal Productivity and Nest Survival of Golden-cheeked Warblers Vary with Forest Type and Edge Density. The Condor, Vol. 116, No. 4, pp. 546-559.

Pons, P. J. M .Bas, R. Prodon, N. Roura-Pascual, and M. Clavero. 2008. Territory Characteristics and Coexistence with Heterospeifics in the Dartford Warbler *Sylvia undata* Across a Habitat Gradient. Behavioral Ecology and Sociobiology, Vol. 62, No. 8, pp. 1217-1228.

Ralph, C. J., J. R. Sauer, and S. Droege. 1995. Monitoring Bird Populations by Point Counts. USDA Forest Service General Technical Report PSW-GTR-149.

Richardson, T. W., T. Gardali, and S. H. Jenkins. 2009. Review and Meta-analysis of Camera Effects on Avian Nest Success. The Journal of Wildlife Management, Vol. 73, No. 2, pp. 287-293.

Ricklefs, R. E. 1965. Brood Reduction in the Curve-billed Thrasher. The Condor, Vol. 67, No. 6, pp. 505-510.

Robel, R. I, J .N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships Between Visual Obstruction Measurements and Weight of Grassland Vegetation. Journal of Range Management 23:295-297.

Rotella, J. J., S. J. Dismore, and T. L. Shaffer. 2004. Modeling Nest Survival Data: A Comparison of Recently Developed Methods that can be Implemented in MARK and SAS. Animal Biodiversity and Conservation, Vol. 27, pp. 187-205.

Rotenberry, J. T. and J. A. Wiens. 1991. Weather and Reproductive Variation in Shrubsteppe Sparrows: A Hierarchical Analysis. Ecology, Vol. 72, No. 4, pp. 1325-1335.

Ruehmann, M., M. J. Desmond, and B. Gould. 2011. Effects of Smooth Brome on Brewer's Sparrow Nest Survival in Sagebrush Steppe. Condor Vol. 113, pp. 419-428

Sauer, J. R., D. K. Niven, J. R. Hines, D. J. Ziolkowski, Jr., K .L. Pardieck, J. E. Fallon, and W. A. Link. 2017. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2050.* Version 2.07.2017 USGS Patuxent Wildlife Research Center, Laurel, MD

Segura, L. N., D. A. Masson, and M. G. Gantchoff. 2012. Mircohabitat Nest Cover Effect on Nest Survival of the Red-crested Cardinal. The Wilson Journal of Ornithology, Vol. 124, No. 3, pp. 506-512.

Schill, K. L., and R. H. Yahner. 2009. Nest-site Selection and Nest Survival of Early Successional Birds in Central Pennsylvania. The Wilson Journal of Ornithology, Vol. 121, No. 3, pp. 476-484.

Schmidt, K. A., S. A. Rush, and R. S. Ostfeld. 2008. Wood Thrush Nest Success and Post-Fledging Survival Across a Temporal Pulse of Small Mammal Abundance in an Oak Forest. Journal of Animal Ecology, Vol. 77, No. 4, pp. 830-837.

Shaffer, T. L. 2004. A Unified Approach to Analyzing Nest Success. The Auk, Vol. 121 No. 2, pp. 526-540.

Skagen, S. K., A. A. Yackel Adams, and R. D. Adams. 2005. Nest Survival Relative to Patch Size in a Highly Fragmented Shortgrass Prairie Landscape. The Wilson Bulletin, Vol. 117, No. 1, pp. 23-34.

Skagen, S. S., and A. A. Yackel Adams. 2012. Weather Effects on Avian Breeding Performance and Implications of Climate Change. Ecological Applications, Vol. 22, No. 4, pp. 1131-1145.

Steele, C. M., B. T. Bestelmeyer, L. M. Burkett, P. L. Smith, S. Yanoff. 2012. Spatially Explicit Representation of State-and-Transition Models. Rangeland Ecology & Management Vol. 65, Issue 3, pp. 213-222.

Streby, H. M., J. M. Refsnider, and D. E. Anderson. 2014. Redefining Reproductive Success in Songbirds Moving Beyond the Nest Success Paradigm. The Auk, Vol. 131, No. 4, pp. 718-726.

Streby, H. M., & D. E. Anderson. 2013. Survival of Fledgling Ovenbirds: Influences of Habitat Characteristics at Multiple Spatial Scales. The Condor, Vol. 115, No. 2, pp. 403-410.

Sullivan, K. 1989. Predation and Starvation: Age-specific Mortality in Juvenile Juncos (*Junco phaenotus*). Journal of Animal Ecology, Vol. 58, No. 1, pp. 275-286.

Suedkamp Wells, K. M., M. R. Ryan, J. J. Millspaugh, F. R. Thompson III, and M. W. Hubbard. 2007. Survival of Post-fledging Grassland Birds in Missouri. The Condor, Vol. 109, No. 4, pp. 781-794.

Suedkamp Wells, K. M., J. J. Millspaugh, M. R., Ryan, and M. W. Hubbard. 2008. Factors Affecting Home Range Size and Movements of Post-fledging Grassland Birds. The Wilson Journal of Ornithology, Vol. 120, No. 1, pp. 120-130.

Tinbergen, J. M., and M. C. Boerlijst. 1990. Nestling Weight and Survival in Individual Great Tits (*Parus major*). Journal of Animal Ecology, Vol. 59, No. 3, pp. 1113-1127.

Twedt, D. J., R. R. Wilson, J. L. Henne-Kerr, and R. B. Hamilton. 2001. Nest Survival of Forest Birds in the Mississippi Alluvial Valley. The Journal of Wildlife Management, Vol. 65, No. 3, pp. 450-460.

Vega Rivera, J. H. J. H. Rappole, W. J. McShae, and C. A. Haas. Wood Thrush Postfledging Movements and Habitat Use in Northern Virginia. The Condor, Vol. 100, No. 1, pp. 69-78.

Vitz, A. C., and A. D. Rodewald. 2010. Movements of Fledgling Ovenbirds and Worm-eating Warblers Within and Beyond the Natal Home Range. The Auk, Vol. 127, No. 2, pp. 362-371.

Vormwald, L. M., M. L. Morrison, H. A. Mathewson, M. C. Cocimano, and B. A. Collier. 2011. Survival and Movements of Fledgling Willow and Dusky Flycatchers. The Condor, Vol. 113, No. 4, pp. 834-842.

Whipple, S. D., M. L. Brust, W. W. Hoback, and K. M. Farnsworth-Hoback. 2010. Sweep-Sampling Capture Rates for Rangeland Grasshoppers (Orthoptera: Acrididae) Vary During Morning Hours. Journal of Orthoptera Research, Vol. 19, No. 1, pp.75-80.

White, J. D., and J. Faaborg. 2008. Post-fledgling Movement and Spatial Habitat-Use Patterns of Juveniles Swainson’s Thrushes. The Wilson Journal of Ornithology, Vol. 120, No. 1, pp. 62-73.

White, G. C., and R. A. Garrott. 1990. Analysis of Wildlife Radio-tracking Data. Academic, San Diego, California, USA.

Wisley, C., B Bateman, L. Taylor, JX Wu, G. LeBaron, R. Shepard, C. Koseff, S. Friedman, R. Stone. Survival by Degrees: 389 Bird Species on the Brink, National Audubon Society: New York.

Yackel, A. A., S. K. Skagen, and J. A. Savidge. 2006. Modeling Post-fledgling Survival of Lark Buntings in Response to Ecological and Biological Factors. Ecology, Vol. 87, No. 1, pp. 178-188.

Figures and Tables

Figure 1. Study site location for the 2018 and 2019 field seasons for Bendire's Thrasher surveys in southwestern New Mexico (NM). The red outline indicates the boundary of Hidalgo and Grant Counties, NM where we concentrated our efforts. The black circles indicate nesting locations of clusters of birds, or "hotspots" for breeding Bendire's Thrashers.

Table 1. Description of continuous and categorical nest site variables used to create models for daily nest survival of Bendire's Thrasher in Hidalgo and Grant County, New Mexico in 2018 and 2019.

Scale	Variable	Description
Nest site	Average Concealment	Concealment measured from and averaged across each cardinal direction around the nest
	Above Concealment	Concealment measured from above the nest
	Nest Height	Height (m) from the ground to the bottom of the nest cup
	Shrub Height	Height (m) from the ground to the top of the nest shrub
	Distance to Edge	Distance (cm) from nest edge to the end of the longest branch that supports the nest
	Nest Substrate	Nest shrub species used for nesting are yucca (1) or non-yucca shrub (0)
Territory	Curve-billed Thrasher	Presence (1) or absence of (0) Curve-billed Thrasher on occupied territories
	Arthropod Abundance	Average arthropod abundance for a territory collected from transects within the territory
	Berry-Producing Shrubs	Number of berry-producing shrubs (BPS) counted on transects within the territory
	Canopy Cover (%)	Percent of vegetation canopy cover
	Bare Ground (%)	Percent of territory that is bare ground
	Basal Cover (%)	Percent of vegetation basal cover
	Litter Cover (%)	Percent of litter cover
	Canopy Gap (%)	Percent of canopy gaps between vegetation
	Basal Gap (%)	Percent of basal gaps between vegetation
	Shrub Density	The density of shrubs of all sizes
	Shrub Diversity	Diversity of shrubs calculated using Shannon's Index
	Visual Obstruction (%)	Average visual obstruction within territory due to vegetation structure
Landscape	Mean Patch Size	Average area (ha) of patches in the 1km buffer around territories
	Patch Dominance	A measure of how much one or a few patch types dominate the landscape
	Patch Richness	Number of different patch types
	Edge Density	Amount of edge relative to the landscape area
	Land Ownership	Designated owner of land: State, BLM or private
Temporal	Nest Age	Age of nest from the start of incubation date, or last day an egg was laid until failure or fledging
	Nestling Age	Age of nestling from hatching date until failure or fledging
	Day of Season	Numerical date from start of the nesting season (day 1), or the day the first active nest was discovered
	Year	Year (split into two seasons, 2018 and 2019)
	Palmer Drought Severity Index (PDSI)	An integrated index comprised of precipitation, temperature, and evapotranspiration data

Table 2. Description of continuous and categorical variables under consideration to create models for juvenile survival analysis of Bendire's Thrasher in Hidalgo and Grant County, New Mexico in 2018 and 2019. These variables will be based on individual locations.

Scale	Variable	Description
Locations	Curve-billed Thrasher	Presence (1) or absence of (0) Curve-billed Thrasher at juvenile locations
	Arthropod Abundance	Average arthropod abundance per sampling event for all juvenile locations collected along designated transects centered on juvenile locations.
	Berry-Producing Shrubs	Number of berry-producing shrubs (BPS) counted on designated transects centered on juvenile locations
	Canopy Cover (%)	Percent of vegetation canopy cover
	Bare Ground (%)	Percent of the area around a juvenile location that is bare ground
	Basal Cover (%)	Percent of vegetation basal cover
	Litter Cover (%)	Percent of litter cover
	Canopy Gap (%)	Percent of canopy gaps between vegetation
	Basal Gap (%)	Percent of basal gaps between vegetation
	Shrub Density	The density of shrubs of all sizes
	Shrub Diversity	Diversity of shrubs calculated using Shannon's Index (H')
	Visual Obstruction (%)	Average visual obstruction in the area around juvenile location due to vegetation structure
Landscape	Mean Patch Size	Average area (ha) of patches in the 1km buffer around a juvenile location
	Patch Dominance	The measure of how much one or a few patch types dominate the landscape
	Patch Richness	Number of different patch types
	Edge Density	Amount of edge relative to the landscape area
	Average Path Length	The distance measured (m) between known tracking locations
	Number of Movements	Number of movements or tracking locations
Temporal	Juvenile Age	Number of days known to be alive from fledging date
	Day of Season	Numerical date from start of the nesting season (day 1), or the day the first active nest was discovered
	Year	Year (split into two seasons, 2018 and 2019)
	Palmer Drought Severity Index (PDSI)	An integrated index comprised of precipitation, temperature, and evapotranspiration data.

Table 3. The number of Bendire's Thrasher nests in Hidalgo and Grant County, New Mexico during the 2018 and 2019 nesting seasons. Predated by nest stage, including the incubation, nestling, and fledgling stages. The fledgling stage was considered the stage in which juveniles had left the nest, but were not capable of flight. This dataset includes only first nesting attempts.

Predation events by nest stage			
	Incubation	**Nestling**	**Fledgling**
2018	5	13	4
2019	7	6	1

Table 4. Descriptive statistics for average ($\bar{X}$)clutch size, number of nestlings, number of fledglings per nest, and estimated age at fledging for all first nesting attempts of Bendire's Thrashers for the 2018 (n=30) and 2019 (n=45) nesting seasons in Hidalgo and Grant County, New Mexico, with standard deviation (SD) estimates.

Breeding Biology				
	2018		**2019**	
	$\bar{X}$	SD	$\bar{X}$	SD
Clutch Size	2.77	0.86	3.56	0.82
Nestlings	1.93	1.17	3.32	0.93
Fledglings	0.9	1.24	3.13	0.96
Incubation Period (days)	12.31	0.74	13.1	1.79
Nestling Period (days)	15.42	2.39	15.23	1.67
Est. Initiation Date	4/28/18	17.50	4/4/19	12.55
Fledging Date	5/20/18	16.65	5/1/19	14.89

Table 5. Bendire's Thrasher nest totals by outcome and landownership in Hidalgo and Grant County, New Mexico in 2018 and 2019. Totals include the number of first nesting attempts for each nesting season (n=75).

	State	**BLM**	**Private**	**Total**
Success	16	14	13	43
Failure	7	19	6	32
Total	23	33	19	75
Nest Success	69.57%	42.42%	68.42%	57.33%

Table 6. Summary statistics for nest site characteristics for first nesting attempts by Bendire's Thrashers in 2018 (n=30), 2019 (n=45), and both years combined in Hidalgo and Grant Counties, New Mexico, including mean ($\bar{X}$)and standard deviation (SD).

Vegetation Variable	**2018**		**2019**		**2018 -2019**	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Shrub Height (m)	2.35	0.82	2.53	0.93	2.46	0.10
Nest Height (m)	1.01	0.31	0.91	0.36	0.95	0.04
Distance to Edge (cm)	0.43	0.30	0.42	0.17	0.43	0.03
Average Concealment (%)	92.40	9.02	91.76	8.36	91.39	1.15

Image 1. Evidence of nest predation by Chihuahuan Raven on nest BETH25NM18 captured with Reconyx trail camera during the 2018 breeding season. Photo triggered by motion showed the predator entering the nest site.

Image 2. Typical nest placement by Bendire's Thrasher in Hidalgo County, New Mexico in 2018 within a soaptree yucca (*Yucca elata*)

Image 3. Bendire's Thrasher nest site within a Honey Mesquite (*Prosopis glandulosa*), benefiting from the additional concealment of Russian Thistle (*Salsola spp.*) that had been caught in nest shrub and built up over time.

Table 7. Preliminary Bendire's Thrasher nest survival model selection results from the nest site scale only, based on 2018 and 2019 data from Hidalgo and Grant County, New Mexico. DTE = Distance to Edge

Model	**AIC_c**	**ΔAIC_c**	**w_i**	**K**	**Deviance**
Average Concealment	216.10	0.00	0.17	2	212.00
Null	216.49	0.40	0.14	1	214.40
DTE	216.68	0.58	0.13	2	214.66
Average Concealment + DTE	216.77	0.67	0.12	3	210.74
Nest Height	217.06	0.96	0.11	2	213.04
Shrub Height	217.84	1.74	0.07	2	213.83
Shrub Species	217.95	1.85	0.07	2	213.94
Nest Height + Average Concealment + DTE	218.21	2.11	0.06	4	210.17

K = number of parameters per model
AIC_c = Akiake's Information Criteria corrected for small sample size
w_i = weight of AIC_c

Table 8. Preliminary Bendire's Thrasher nest survival model selection results from the territory scale only, based on 2018 and 2019 data from Hidalgo and Grant County, New Mexico.

Model	**AIC_c**	**ΔAIC_c**	**w_i**	**K**	**Deviance**
Canopy Gaps + Arthropod Abundance	214.67	0.00	0.20	3	208.64
Canopy Gaps + Tall Shrubs + Average Shrub Height + Arthropod Abundance	215.91	1.24	0.11	5	205.85
Canopy Gaps + Tall Shrubs + Arthropod Abundance	216.21	1.54	0.09	4	208.17
Arthropod Abundance	216.38	1.71	0.09	2	212.37
Null	216.49	1.82	0.08	1	214.48
Average Shrub Height	216.92	2.25	0.07	2	212.91

K = number of parameters per model
AIC_c = Akiake's Information Criteria corrected for small sample size
w_i = weight of AIC_c

Table 9. Preliminary Bendire's Thrasher nest survival model selection results from the temporal scale only, based on 2018 and 2019 data from Hidalgo and Grant County, New Mexico.

Model	**AIC_c**	**ΔAIC_c**	**w_i**	**K**	**Deviance**
Nest Age + PDSI	212.28	0.00	0.14	3	206.26
Year + Time	212.59	0.31	0.12	3	206.57
Year + Nest Age	212.78	0.49	0.11	3	206.75
Year + Nest Age + PDSI	212.01	0.72	0.10	4	204.97
PDSI	213.13	0.85	0.09	2	209.12
Nest Age	213.14	0.85	0.09	2	209.13
Time	213.17	0.89	0.09	2	209.16
Year + PDSI	213.62	1.33	0.07	2	207.60
Year	213.88	1.60	0.06	2	209.87
Global	214.50	2.21	0.05	5	204.44
Time + Nest Age	214.82	2.53	0.04	3	208.80
Null	216.49	4.20	0.02	1	214.48

K = number of parameters per model
AIC_c = Akiake's Information Criteria corrected for small sample size
w_i = weight of AIC_c

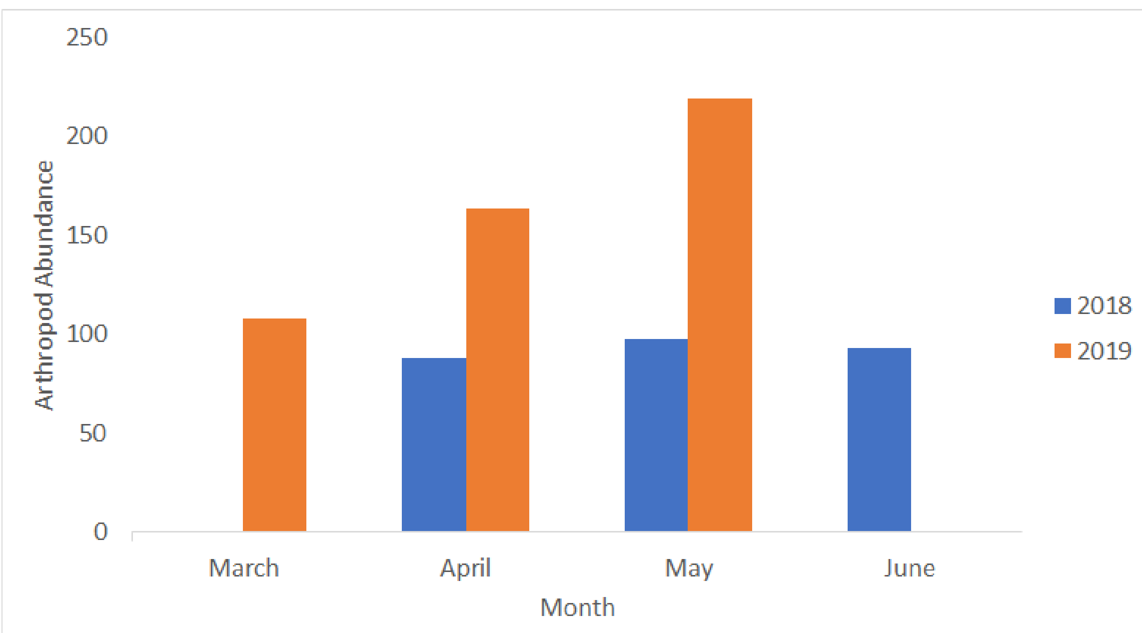

Figure 2. Comparison of average arthropod abundance collected on occupied territories with active nests during the breeding season for 2018 (March n=0, April n=9, May n=18, June n=3) and 2019 (March n=2, April=31, May=12, June=0) in Hidalgo and Grant Counties, NM.

Image 4. Nestling Bendire's Thrasher in Hidalgo County, New Mexico (2018) with VHF transmitter attached just prior to fledging.

Table 10. Summary statistics for Bendire's Thrasher juvenile survival in Hidalgo and Grant Counties, New Mexico for both the 2018 and 2019 field seasons. Includes length of survival in days, including mean ($\bar{X}$) and standard deviation (SD), for all juveniles, those known to survive to dispersal (known surviving), and those that went missing, or were assumed lost to predation (mortality), as none of the juveniles were recovered.

Juvenile Survival (Days) 2018-2019		
	$\bar{X}$	SD
All transmitter juveniles (n=27)	14.04	13.58
Known surviving (n=10)	29.7	7.15
Mortality (n=17)	4.82	5.22

Table 11. Summary statistics of juvenile Bendire's Thrashers in Hidalgo and Grant Counties, New Mexico comparing vegetation attributes of known use sites to paired-random locations, for both 2018 and 2019.
BG = Bare Ground, CC = Canopy Cover, BC = Basal Cover, LC = Litter Cover, SD = Shrub Density, VOR = Visual Obstruction Reading

Vegetation Associations for Juvenile Survival								
	2018 (n=36)				**2019 (n=42)**			
	Juvenile		*Paired-Random*		*Juvenile*		*Paired-Random*	
Vegetation Attributes	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
BG (%)	33.96	25.11	68.80	27.10	59.51	3.28	74.37	3.70
CC (%)	42.22	18.31	15.03	17.44	35.66	3.30	20.95	3.41
BC (%)	1.49	4.14	2.70	16.44	0.63	0.23	1.28	0.45
LC (%)	57.19	30.06	19.70	22.58	51.71	3.81	33.90	4.40
VOR (%)	19.36	13.83	6.93	8.93	16.49	1.95	8.80	1.35
SD (plants/ha)	2100.16	257.76	2064.22	1700.46	2070.46	216.93	1514.88	293.83

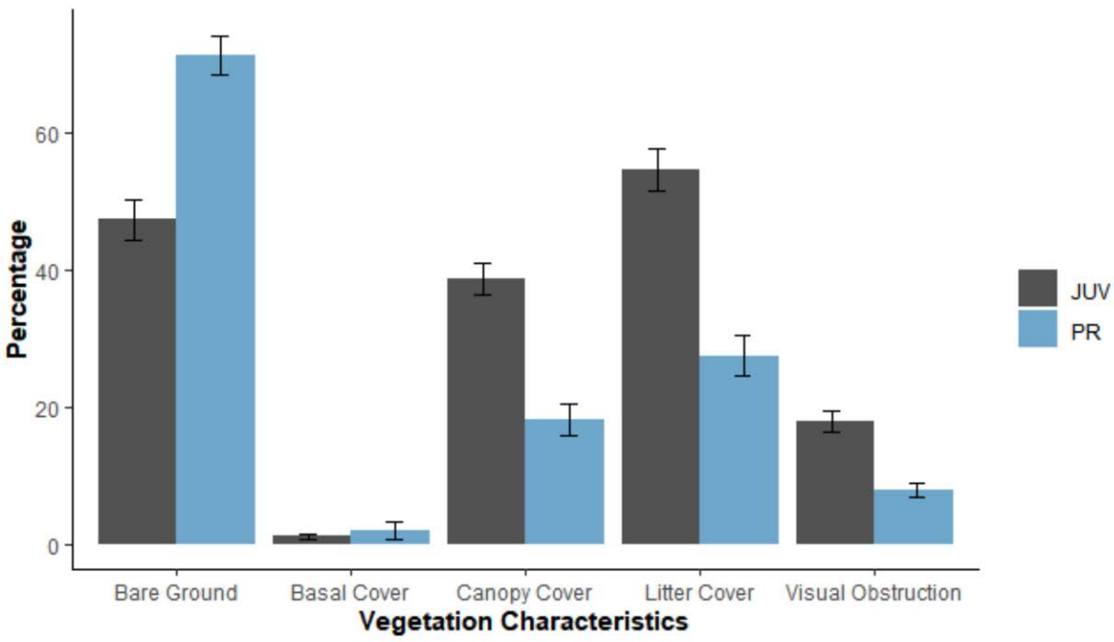

Figure 3. Comparison of vegetation cover attributes of known Bendire's Thrasher juvenile locations to paired-random locations in Hidalgo and Grant Counties, New Mexico for both the 2018 and 2019 field seasons. Graph shows mean $\bar{X}$percent cover estimates for juvenile locations (gray) and paired-random sites (blue) with standard deviation (black error bars; n=78).

Table 12. Average path length in meters ($\bar{X}$) for juvenile Bendire's Thrashers in Hidalgo County, New Mexico in 2018 (n=7) and 2019 (n=12), with standard deviation (SD), minimum, and maximum distances recorded in meters. Days alive is the length of time they were known to be alive before they either left the study site or the season ended (end of transmitter life or dispersal from territory).

Juvenile ID	**Days Alive**	$\bar{X}$	**SD**	**Minimum (m)**	**Maximum (m)**
		- - - 2018 - - -			
BETH 32-04	38	177.59	123.20	5.29	413.89
BETH 14-07	11	114.18	150.90	0.32	375.53
BETH 14-08	5	28.99	37.85	1.19	99.83
BETH 38-09	3	302.62	181.86	174.02	431.23
*BETH 36-11**	29	198.65	308.45	2.36	718.78
BETH 46-12	2	-	-	194.36	194.36
BETH 46-13	2	-	-	28.20	28.20
BETH 48-15	26	183.96	138.50	6.28	375.03
BETH 21-16	22	258.99	179.58	5.00	495.07
		- - - 2019 - - -			
BETH 18-20	33	158.90	134.57	7.48	368.95
BETH 44-24	0	-	-	-	-
BETH 20-25	0	-	-	-	-
BETH 06-28	0	-	-	-	-
BETH 10-33	15	100.86	96.48	16.65	275.98
BETH 24-35	19	165.29	155.36	5.31	387.16
BETH 05-39	28	99.91	190.03	3.35	528.93
BETH 51-42	10	48.35	34.12	14.48	82.72
BETH 36-45	35	316.14	377.81	1.68	1205.00
BETH 31-47	46	167.31	89.04	71.33	344.29
BETH 39-49	23	190.06	153.69	1.18	398.46
BETH 30-50	9	56.04	29.16	29.74	87.04
BETH 02-51	0	-	-	-	-
BETH 53-55	16	73.32	47.28	20.43	129.74
BETH 57-57	4	56.98	20.11	42.76	71.96
BETH 11-59	9	67.23	70.28	6.91	144.41
BETH 55-64	1	-	-	102.13	102.13
*BETH 04-67***	2	-	-	-	-

*Transmitter signal was lost for this individual for 10 days.

**No location data was collected for this individual as the transmitter was found without the body at the first tracking attempt. This individual could have lived to be up to two days old.

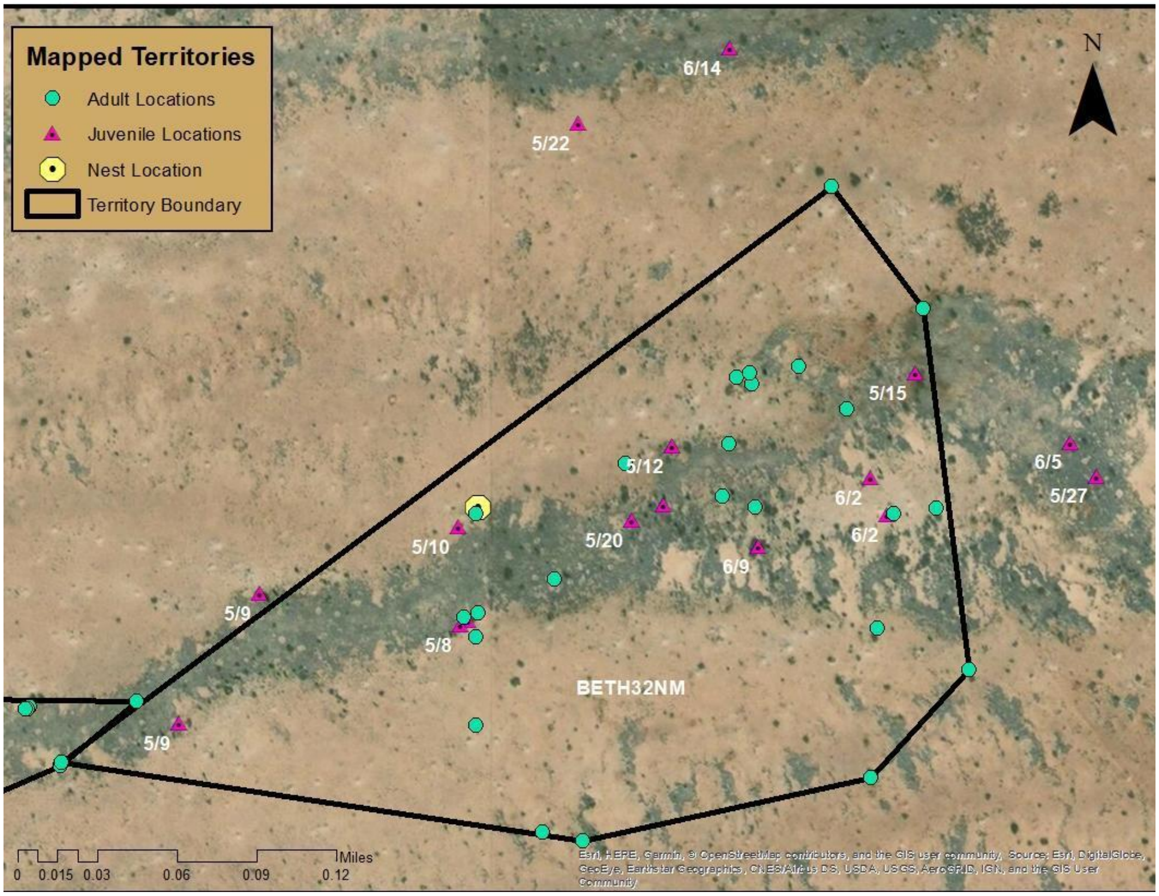

Figure 4. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 8 May 2018) in Hidalgo County, New Mexico in 2018.

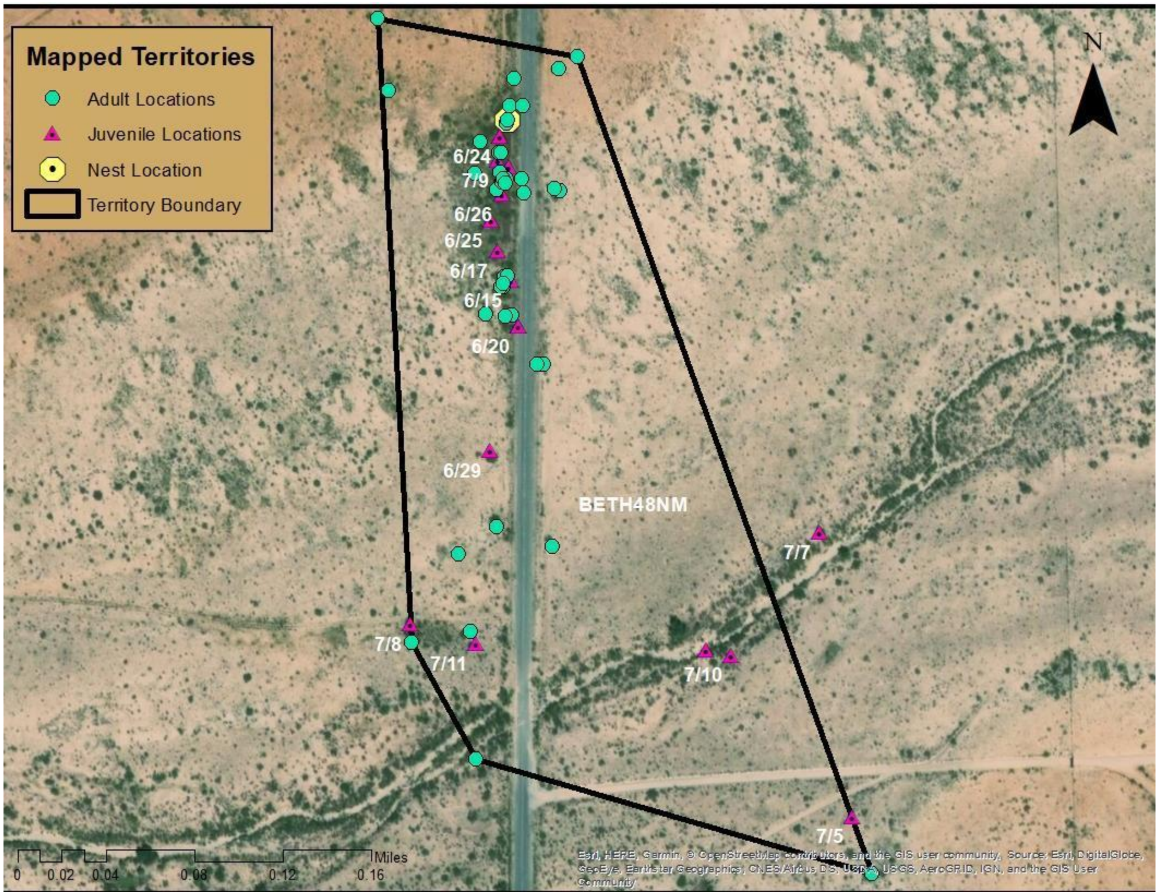

Figure 5. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 15 June 2018) in Hidalgo County, New Mexico in 2018.

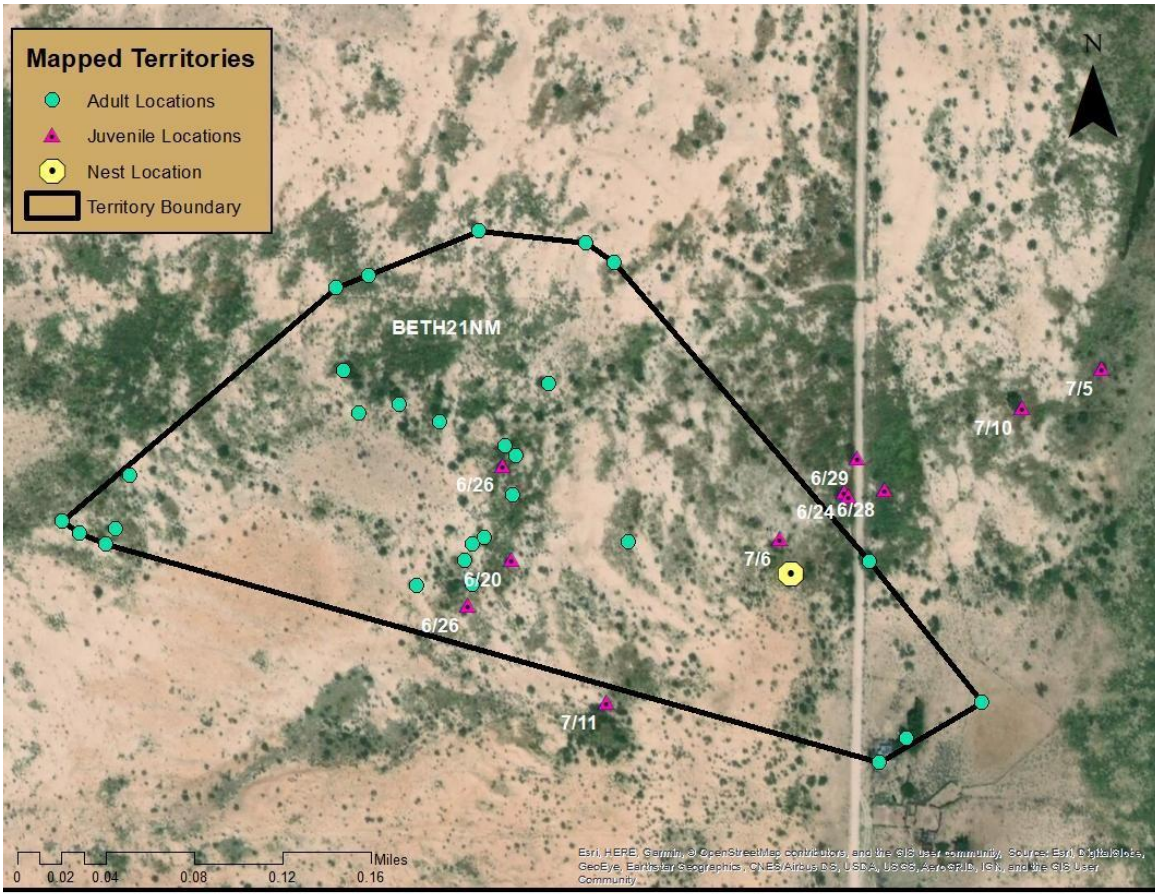

Figure 6. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 20 June 2018) in Hidalgo County, New Mexico in 2018.

Table 13. Average territory sizes for occupied adult Bendire's Thrashers and natal home range sizes of juvenile Bendire's Thrashers in Hidalgo and Grant County, New Mexico in 2018 and 2019. Natal home ranges were calculated for juveniles that survived long enough to collect sufficient data (i.e., juveniles survived for at least 20 days).

Territory Size	$\bar{X}$ **(ha)**	**SD**	**Minimum (ha)**	**Maximum (ha)**
		- - - 2018 - - -		
Adult (n=30)	8.14	1.54	2.09	43.45
Juvenile (n=4)	8.43	2.66	5.93	10.80
		- - - 2019 - -		
Adult (n=45)	8.49	6.42	0.01	28.80
Juvenile (n=6)	4.74	3.81	1.60	11.06