Bendire's Thrasher (*Toxostoma bendirei*) Nest and Juvenile Survival in Relation to Vegetation Characteristics in the Southwest United States

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Introduction

Little is known about many desert aridland 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, over grazing and habitat fragmentation (North American Bird Conservation Initiative 2014), but research has yet to confirm these theories. 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.

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a greater diversity of shrub species that also contain large patches of bare ground for foraging (Sutton and Desmond, unpublished).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 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, such as the length of the breeding season, nest initiations dates and number of clutches. 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).

Daily nest survival estimates are the preferred method to assess survival compared to the older method of percent nest success, as 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 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% 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 grater survival pressures than adults. More recently, post-fledging and juvenile survival studies have become possible with improved tracking devices and the post-fledging and juvenile stage has proven to be an important stage 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 became scarce, necessitating some juveniles to make long and risky flights in order to obtain resources requisite for survival. Body condition may also influence the ability of juveniles to make long distance flights (Vitz & Rodewald 2010). 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 such 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 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. Determine juvenile survival and model this in relation to land management and vegetation characteristics.
4. Examine juvenile movement patterns relative to the nest site and adult territory.
5. Examine the influence of interspecific competition on nest survival and juvenile survival and movement patterns.

Study Site

In 2018, research was focused on Hidalgo County (3,446 sq mi) in southwest New Mexico (Figure 1). Previous research and eBird data have shown that this county is a hotspot for breeding Bendire's Thrashers in New Mexico (Bear-Sutton and Desmond, unpublished). Hidalgo County is in the extreme southwestern portion of the state and contains many private ranch lands and public lands that are subject to a variety of land management practices. The main habitat type is desert scrub, with dominant shrubs including honey mesquite (*Prosopis glandulosa*) and creosote bush (*Larrea tridentata*). Many areas contain small stands of soap tree yucca (*Yucca elata*), ocotillo (*Fourquieria splendens*), cholla, and prickly pear intermixed with four-winged saltbush (*Atriplex canescens*), rabbitbush (*Chrysothamnus spp*.), whitethorn acacia (*Vachellia constricta*), and broom snakeweed (*Gutierrezia sarothrea*). Common grasses include dropseed grasses (*Sporobolus* spp.), tobosa (*Pleuraphis mutica*), and grama (*Bouteloua* spp.).

Methods

Field research was initiated in mid-February. 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, breeding territory, and 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, Monitoring, and Survival Covariates

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 wandering an area by foot for up to 30 minutes, listening and watching for mimids, especially singing males or calling pairs, and could be 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 2-3 different 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, 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 known to be 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 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 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 was 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, attached to rebar placed in the ground 10m away or attached 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 have been torn or destroyed, nests missing completely, and presence of fecal droppings left 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).

Competition - In order to assess competition between Bendire's Thrashers 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 mimd species. Two point count transects consisting of two points each, with 400m between the points, 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 of 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 (Bear-Sutton & Desmond unpublished). 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.

Arthropod Sampling and Berry-Producing Shrubs- 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.

Abundance of berry-producing shrubs was estimated using the same two parallel, 100m transects used for sweep- and beat-netting, which were 10m apart. Abundance of berry-producing shrubs was evaluated immediately following arthropod sampling. Observers recorded presence of berry-producing shrubs, species of berry-producing shrubs, and presence or absence of berries on each shrub within 10m of each side and included the 10m between the parallel transects (Vega Rivera et al. 1999).

Juvenile Monitoring and Survival Covariates

<u>Radio-telemetry</u> – Radio transmitters (17x7x4mm, 1.0g, with an estimated 8 week lifespan from Advanced Telemetry Systems, Inc., Isanti, MN, USA) were placed on random 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 body weight of juveniles. Transmitters were placed on nestlings aged 9-10 days old to ensure that they did not fledge prematurely. 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, 0.2g grams). Tarsus and weight measurements were taken to estimate body condition (Donnelly & Sullivan 1998, Vitz & Rodewald 2010) as nestlings often have not developed complete flight feathers.

Once nestlings fledged, they were re-located using handheld telemetry receivers (R-1000, Communications Specialist, Orange, CA) with three-prong yagi antenna. We attempted to locate them every day, 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 (Dittmar et al. 2014, White & Faaborg 2008). Locations were marked with a GPS (~5m accuracy) and status of the fledgling was recorded as alive, deceased, or missing and observers noted if family units were still intact. 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 and the post-dispersal home range, following the definitions by Anders (1998). Attempts were made near the end of each transmitter's life to recapture juveniles and retrieve transmitters using mist nets.

<u>Competition</u> – In order to assess competition between Bendire's Thrasher and Curve-billed Thrasher and other mimids, point counts were conducted at every other juvenile location. These point counts were conducted within 24 hours of relocation of the juvenile to that point, and consisted of a single transect with two point counts, spaced 400 m apart, radiating in a random direction from the known juvenile location. Point-count methods used for juvenile locations were the same as those described above for adult breeding territories (i.e., 3-minute silent count followed by a playback count, etc.).

<u>Arthropod Sampling and Berry-Producing Shrubs</u> – Sweep-netting and beat netting were conducted at every other post-fledging location and a paired-random location 600m away from juvenile relocation sites (Jamison et al. 2002). These samples were collected within 24 hours of each juvenile's relocation. Sweep-netting at juvenile relocations was conducted using the same method as on adult breeding territories as described above (i.e., along two 100m transects, 10m apart, with 100 low and fast sweeps using the figure-eight method between the hours of 10:00 and 16:00, Brust et al. 2009, Whipple et al. 2010). One of the 100m transects started at a known juvenile relocation (or paired-random location), the second was parallel to the first. Transects were placed in a random direction. Beat-netting also occurred at juvenile locations and paired-random locations, similar to the sample method for adult breeding territories described above. All insect samples were sorted to order and counted.

Also similar to the above-described methods for adult breeding territories, abundance of berry-producing shrubs was estimated using the same two parallel 100m transects used for sweep-netting and beat-netting at juvenile and paired-random locations.

Vegetation Data Collection
<u>Nest Site</u> – Within 2-5 days of 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, viewed from the top, bottom (when possible) and sides (from each of the cardinal directions) of the nest (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.

Breeding Territories – 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, and Belt Transect 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 plant 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 at 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 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 in gaps, for both plant canopies and basal area. Belt transects were conducted on the same 25m transects. 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). ArcGIS and aerial photos will be used to calculate shrub density for each territory.

Juvenile Locations – Vegetation collection occurred at every other juvenile relocation within 24 hours of re-sighting and at a paired-random location 600m, 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; four transects radiated from the juvenile location or paired-random location in the four cardinal directions. 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). The Gap Intercept method was used to estimate concealment, in the same manner as used for the adult territories. Cover types and shrub density were estimated within the 11.3 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 was taken from the 11.3m end of each transect, facing the central point.

Statistical Analysis

Nest and Juvenile Survival – Preliminary daily nest survival was analyzed using Program MARK (White & Burnham 1999, Rotella et al. 2004). Cumulative nest survival estimates, based on the null model, are calculated by raising the daily survival to the length of the complete nesting cycle, which was 22 days for first nest attempts (Dinsmore et al. 2002). Potential covariates were examined for multicollinearity using Pearson's Correlation before modeling began, and any variables over 0.7 correlation were removed. (Bensons 2009). Covariates include a combination of vegetation characteristics at the nest site and the territory scale, food availability, and presence or absence of Curve-billed Thrashers and other mimids on occupied territories. Description of model covariates for nest survival can be found below (Table 1). Models 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 survival has not yet been analyzed due to insufficient sample sizes based on 2018 data (data from 2019 will hopefully increase our sample size and enable these models to be run in future). Covariates for a priori models to be considered in future analyses of juvenile survival can also be found below (Table 2). Climatic variables that will be used for future analyses of both nest and juvenile survival will include mean daily temperature and bioyear precipitation, defined as the total amount of precipitation (in) recorded in the seven months preceding the breeding season (Rotenberry & Wiens 1991), which will be downloaded from the PRISM database from Oregon State University at a 4km scale. Extreme temperatures and drought (especially in months prior to breeding) are known to affect survival of some avian species (Rotenberry & Wiens 1991, Skagen & Yackel Adams 2012). Temporal variables, such as nest age starting the day the last egg is laid, day of season starting from the date the first nest with eggs was found, and juvenile age starting from fledging date, will also be included in future analysis. 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.

Juvenile Movement and Home Range Analysis – Distances between nest site and relocations and between each relocation were measured using the measuring tool in ArcGIS (Hooge & Eichenlaub 2000). Mean daily distances moved will be calculated in the future. Kernel Density Estimators (KDE) will be used in future analyses, when there are sufficient data available, to estimate home-range use for any juveniles with at least 30 relocation waypoints (Suedkamp Wells et al. 2007, Ciudad et al. 2009, Carneiro et al. 2012).

Juvenile Vegetation Analysis – Vegetation characteristics were compared between juvenile relocations and paired-random sites. In future we will also compare vegetation characteristic at occupied territories and nest-sites with juvenile locations and paired-random points. Juvenile relocations and paired-random sites are currently only compared based on descriptive statistics. In future, a paired t-test will be conducted and, if sample sizes are sufficient, we will model differences between juvenile locations and paired-random sites using logistic regression. Vegetation variables considered thus far 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, field work was concentrated in Hidalgo County, with hotspots northwest of Lordsburg and in the Middle Animas area. Field work 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 27 first nest attempts were found and there were an additional 15 re-nesting attempts (with some pairs initiating 2nd and 3rd clutches). Preliminary analysis was conducted on first nest attempts only. There was high nest failure due to predation (Table 3). The most common nest predators were Chihuahuan Ravens, 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 (juveniles) being missing. Average clutch size was less than three eggs (2.77±0.86) and the number of nestlings and fledglings 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). Nests were found on three different landownerships types through New Mexico, including state, BLM and private land (Appendix A). Overall, nest success was low, but nests had slightly higher success on BLM and private lands compared to state lands (Table 5).

Nest Site Characteristics

Nests were located 1-2m from the ground (mean height (m) of 1.2±0.31), and concealment estimates were high (Table 6). Surprisingly, soaptree yuccas were selected for nesting locations more than expected (Table 6 and Figure 2).

Nest Survival

Nest survival estimates, based on an average complete nesting cycle length of 22 days, was estimated to be 33% for first nest attempts (daily survival rate of 0.951±0.011, 95% CI [0.924, 0.968]). Preliminary models for daily nest survival show that the model including nest shrub species was the highest ranked model with the lowest AIC_c value, followed closely by the null model. However, the model including nest shrub was not strongly supported as the confidence intervals bound zero (95% CI [-1.977, 0.272]), which is in part due to our low sample size with only one year of data (Table 7).

Following the null model, models with only two parameters had the lowest AIC_c values compared to models with more than two parameters, which were not considered supported ($\Delta AIC>2$). We did observe some interesting trends, but will need more data from 2019 to fully examine them. Surprisingly, the third highest ranked model, which included nest height, showed a negative relationship with survival, suggesting that nests lower to the ground have higher survival. Shrub height also showed a negative relationship to nest survival, which may make biological sense, as taller shrubs could act as perches for predators like ravens. Again, more data is needed to effectively evaluate this. A model including an interaction term between nest height, shrub height, and shrub species may have more support than the current models, but we will need a larger sample size to examine this.

Future analysis will include more covariates, particularly more vegetation attributes from the territory scale, landscape scale variables, climate variables, temporal variables, and potentially important interaction terms within the models. The influence of the presence of Curve-billed Thrashers at Bendire's Thrasher nest sites has not yet been fully examined. Future analysis will investigate the amount of territory overlap between the two species at sites where Curve-billed Thrashers were recorded as present at occupied Bendire's Thrasher territories. Through anecdotal observations, we did observe a few instances were Bendire's Thrasher territories appeared to be vacated or relocated due to the arrival of Curve-billed Thrashers. Even though it ranked low in the preliminary models, food abundance will also be examined more closely, including further evaluation of the relationships between nest survival and both arthropod abundance and density of berry-producing shrubs.

Juvenile Survival

Of the 27 first nest attempts, only nine nests fledged young. We were able to attach VHF transmitters to nine nestlings from seven of the nine successful nests (Figure 3). Survival models have not yet been analyzed for juvenile survival post-fledging due to low sample size, but covariates for future analysis will include important biological variables at tracked juvenile locations and paired-random locations (Table 2). 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 8). Unfortunately, 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 and their body was not found. 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 and were not capable of complete flight until several days after fledging, making them extremely vulnerable to predation. Overall, mean survival length (in days) was 14 days (14.78 ± 13.02) for all tracked juveniles. Mean survival (ie 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 only four days (4.8 ± 4.37) (Table 8).

Vegetation Data

A summary of vegetation attributes recorded in the field for juvenile and paired-random locations has been calculated for three of the four juveniles that survived more than 20 days (Table 9). The juvenile with the transmitter that malfunctioned and for which there are data gaps was excluded from this analysis. There are strong contrasts between the occupied juvenile locations and the 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 greater percentage of litter, most likely due to increased canopy cover (Figure 4). However, these estimates show large variation among the samples and more data will be needed to confirm these patterns in the data.

Juvenile Movements

Average path length data, or the average distance (in meters) between tracked locations, has been calculated for three of the four juveniles that survived long enough to collect sufficient data (Table 10). Typically, juveniles stayed within adult breeding territories; when relocated, they were often seen with parents and/or siblings, which has also been documented for LeConte's Thrashers (Blackman & Diamond 2015). Juveniles stayed on the territories with the family unit for up to 38 days, and family units left occupied territories together. Juveniles did not expand outside of the known adult breeding territories until at least 15 days post-fledging (Figures 5-7), and juveniles occupied areas similar in size to known adult territories (Table 11).

Discussion

The majority of information available for Bendire's Thrashers is anecdotal, from the early 1900's, 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 nest survival of Bendire's Thrashers. Nesting ecology for Bendire's Thrasher in Hidalgo County 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). Nest success (number of nests that successfully produced fledglings in first nest attempts) for this study was 33% and is also similar to previous studies of nest success of related species, including Curve-billed Thrashers (37%), Long-billed Thrashers (26%), and Crissal Thrashers (48%) (Murphy & Fleischer 1986). Incubation and nestling period lengths are difficult to confidently determine from our dataset as nests were found at different stages and most were predated before a complete period (either incubation or nestling) could occur. Only a single nest was monitored from egg laying to fledging, and both the incubation and nestling stages were recorded at 15 days of length. Future data collection will improve estimates for these nesting stages. 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 discovered nests that were found in a variety of shrub species, mostly soaptree yuccas, but also honey mesquite, graythorn, catclaw acia (*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

Even with a small sample size, daily and overall nest survival estimates are similar to the results from studies of other passerine species (Skagen et al. 2005, Schill & Yahn 2009, Benson et al. 2010), especially other *Toxostoma* species (Brown Thrashers, 0.913 daily nest survival, Conner et al. 2010). The nest survival model results suggest that nest shrub species may be an important variable for nest survival, but with such a small sample size and only one year of analysis, further data collection will be needed to determine if nest height and or nest shrub species and survival have a strong relationship. If there is a relationship, this may suggest that lower nests are better protected from aerial predators, including ravens, or height may advantageous based on plant species. The use of soaptree yuccas, the most commonly used nest shrub, showed a negative trend in survival. This may be partly related to the small size of many soaptree yuccas across the landscape and suggests these shrubs do not adequately protect Bendire's Thrasher nests from predation. Alternative nest shrub species, such as littleleaf sumac, may be more beneficial for nesting. In 2019 we will work hard to increase our sample size of nests to better examine this question and will specifically compare yuccas used as nest sites to other yuccas in the surrounding area.

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 selects for small patches and requires variation in habitat types near the occupied territories (Bear-Sutton & Desmond, unpublished). 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. Land management will be incorporated into future models. Additionally, future models will include temporal variables such as nest age, day of the season, daily temperature, and bioyear precipitation, which have been shown to be important variables in other passerine studies (Schill & Yahner 2009, Benson et al. 2010, Peak & Thompson III 2014). Models presented here are preliminary and limited by our small sample size of active nests (Table 5, Appendix A). In future analyses, we will select a subset of variables most likely to influence nest survival, as sample size will limit the number of variables that can be included in model sets.

Juvenile Survival

Post-fledging juvenile survival data have not yet been analyzed for the 2018 field season. With such a small sample size (n=9), more data will be needed to run the analyses. Post-fledging survival estimates vary across studies, and juveniles of many species seek greater amounts of cover and abundant or easy 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 important for post-fledging survival of Bendire's Thrashers, including vegetation cover, food availability, age of juvenile, day of season, mean temperature, and bioyear precipitation (Table 2).

Vegetation Data

Basic summary statistics that have been calculated for juvenile locations and paired-random locations show that there are differences between used sites and random locations. However, there is large variation among surveyed locations (Figure 4). 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 is higher for paired-random locations, which may indicate that predation pressures are stronger for post-fledging juveniles, as they are still depending on adults for food and are seeking areas with more cover than foraging areas. Future data analyses will include a paired t-test between used and random points, comparison of vegetative characteristics between territories with successful versus unsuccessful nests, and an examination of important habitat characteristics for juveniles that survived compared to those that died during the period they were tracked.

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 up to 38 days after fledging. Therefore, juvenile movements were not independent and may have been influenced by movements of the adults. Average path length analysis shows that, as expected, distances traveled by juveniles increased with age, and the maximum distance between points was 495m. Future analysis may include Kernel Density Estimates for juveniles that survive long enough. These estimates can be used to better understand juvenile movement patterns and home ranges (Suedkamp-Wells et al. 2008). The results from this study differ from the study by Blackman and Diamond (2015) in which LeConte's Thrasher post-fledging movement patterns consisted of large daily movements (>600m), with a maximum-recorded movement of 1733m.

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 on 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 in development of effective management practices. However, we need more data from our planned 2019 field season in order to make solid, statistically supported inferences about the population in New Mexico. A second year of data will be collected in 2019 in Hidalgo County, but data collection will spread from the known hotspots into surrounding patches of desert scrub habitat and will also expand into surrounding counties (i.e., Grant, Luna and Catron). Experience gained in 2018 will aid us greatly in bolstering our nest and juvenile sample sizes during the 2019 field season.

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Figures and Tables

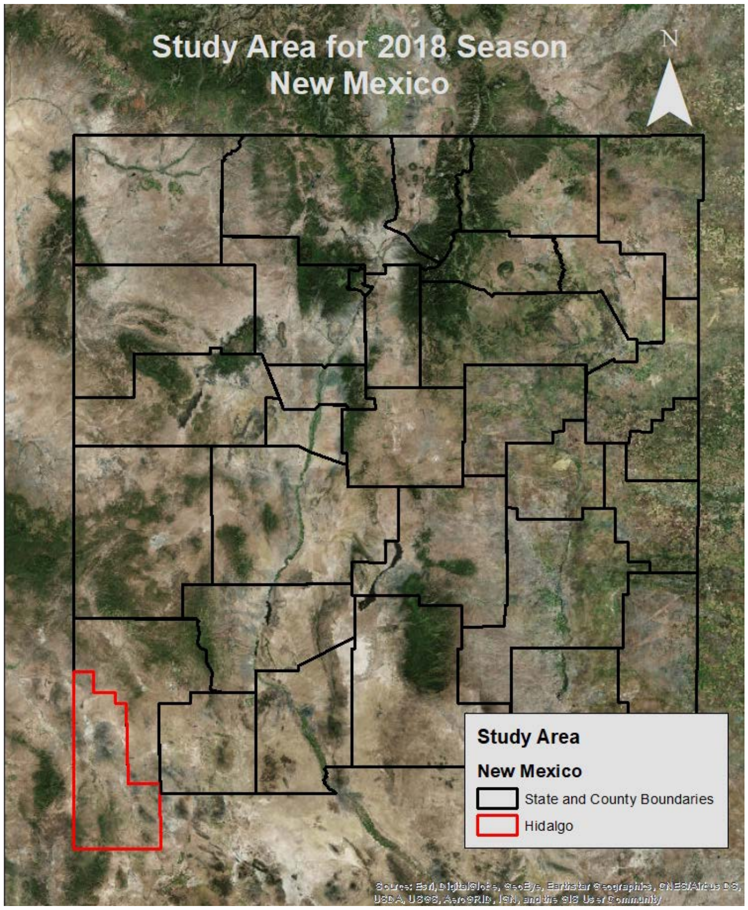

Figure 1. Study site location for the 2018 field season for Bendire's Thrasher surveys in southwestern New Mexico (NM). The red outline indicates the boundary of Hidalgo County, NM where we concentrated our survey efforts in 2018.

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

Scale	Variable	Description
Nest site	***Average Concealment***	Concealment measured from and averaged across each cardinal direction around nest
	Above Concealment	Concealment measured from above 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 nests
	Nest Substrate	Nest shrub species used for nesting is 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	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 structures
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 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 (day1)
	Year	Year (split into two seasons, 2018 and 2019)
	Temperature	Average temperature from February to July from PRISM data
	Bioyear Precipitation	Total precipitation from August through February from PRISM data

Table 2. Description of continuous and categorical variables used to create models for juvenile survival analysis of Bendire's Thrasher in Hidalgo County, New Mexico in 2018.

Scale	Variable	Description
Locations	***Curve-billed Thrasher***	Presence (1) or absence of (0) Curve-billed Thrasher at juvenile locations
	Arthropod Abundance	Average arthropod abundance 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 area around 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	Density of shrubs of all sizes
	Shrub Diversity	Diversity of shrubs calculated using Shannon's Index (H')
	Visual Obstruction (%)	Average visual obstruction in area around juvenile location due to vegetation structures
Landscape	***Mean Patch Size***	Average area (ha) of patches in the 1km buffer around 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	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 (day1)
	Year	Year (split into two seasons, 2018 and 2019)
	Temperature	Average temperature from February to July from PRISM data
	Bioyear Precipitation	Total precipitation from August through February form PRISM data

Table 3. Number of Bendire's Thrasher nests in (2018) Hidalgo County, New Mexico predated by nest stage, including incubation, nestling, and fledgling. Fledgling stage was considered the stage in which juveniles had left the nest, but were not capable of flight. This dataset includes first, second, and third nesting attempts.

Predation events by stage		
Incubation	Nestling	Fledgling
5	13	4

Table 4. Descriptive Statistics for average ($\bar{X}$) clutch size, number of nestlings, number of fledglings per nest and estimated age at fledging for Bendire's Thrashers for the 2018 nesting season in Hidalgo County, New Mexico, with standard deviation (SD) estimates.

	$\bar{X}$	**SD**
Clutch Size	2.77	0.86
Nestlings	1.93	1.17
Fledglings	0.9	1.24
Age At Fledging (n= 9)	13.3	1.41

Table 5. Bendire's Thrasher nest totals by outcome and landownership in Hidalgo County, New Mexico in 2018. Totals include number of nests, including all nesting attempts, with % success rate calculated at the bottom.

	State	**BLM**	**Private**	**Total**
Success	2	4	3	9
Failure	14	7	6	27
Total	16	11	9	36
% Success	12.5%	36.36%	33.33%	25%

Table 6. Summary statistics for nest site characteristics for all nesting attempts by Bendire's Thrashers in 2018 in Hidalgo County, New Mexico, including mean ($\bar{X}$) and standard deviation (SD).

Nest Attempt	**1st**		**2nd**		**3rd**	
Variable	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Shrub Height (m)	2.39	0.84	2.64	1.15	1.89	0
Nest Height (m)	1.02	0.31	1.33	0.59	1.35	0
Distance to Edge (cm)	0.42	0.31	0.49	0.26	0.47	0
Average Concealment (%)	91.67	9.21	90.63	10.02	78.13	0
Above Concealment (%)	89.81	17.70	93.75	6.68	87.50	0
Nest Shrub Species (% in Yucca)	70.37	9.0	75.0	16.4	100	0

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

Table 7. Preliminary Bendire's Thrasher nest survival model selection results from maximum likelihood estimates of the Mayfield model through Program MARK. Results based on 2018 data from Hidalgo County, New Mexico.

Model	AIC_c	ΔAIC_c	w_i	K	Deviance
B0+B1(Yucca)	112.4942	0.000	0.158	2	108.461
Null (B0)	113.0295	0.535	0.121	1	111.018
B0+B1(Nest Height)	114.0839	1.5897	0.072	2	110.051
B0+B1(Distance to Edge)	114.0970	1.6028	0.071	2	110.063
B0+B1(Shrub Density)	114.2501	1.7559	0.066	2	110.217
Bo+B1(Average Concealment)	114.4930	1.9988	0.058	2	110.460
B0+B1(Bare Ground)	114.5150	2.0208	0.057	2	110.482
B0+B1(Shrub Diversity)	114.5808	2.0866	0.056	2	110.548
B0+B1(Average Visual Obstruction)	114.6190	2.1248	0.055	2	110.586
B0+B1(Curve-billed Thrasher)	114.7433	2.2491	0.051	2	110.710
B0+B1(Above Concealment)	114.8695	2.3753	0.048	2	110.836
B0+B1(Arthropod Abundance)	114.8791	2.3849	0.048	2	110.846
B0+B1(Shrub Height)	114.9244	2.4302	0.047	2	110.891
B0+B1(Berry-Producing Shrub Density)	114.9370	2.4428	0.047	2	110.904
B0+B1(Yucca Density)	115.0475	2.5533	0.044	2	111.014
B0+B1(Nest Height)+B2(Distance to Edge)	115.2431	2.7489	0.046	3	109.1751
B0+B1(Above Concealment)+B2(Nest Height)	115.5071	3.0151	0.041	3	109.4397
B0+B1(Average Concealment)+B2(Nest Height)	115.5288	3.0346	0.040	3	109.4614
B0+B1(Average Concealment)+B2(Distance to Edge)	115.6156	3.1214	0.039	3	109.5482
B0+B1(Above Concealment)+B2(Distance to Edge)	115.6463	3.1521	0.038	3	109.5789
B0+B1(Shrub Height)+B2(Distance to Edge)	115.751	3.2568	0.036	3	109.6836
B0+B1(Nest Height)+B2(Shrub Height)	115.7764	3.2822	0.036	3	109.709
B0+B1(Average Concealment)+B2(Above Concealment)	116.2637	3.7695	0.028	3	110.1963
B0+B1(Average Concealment)+B2(Shrub Height)	116.2644	3.7702	0.028	3	110.197
B0+B1(Above Concealment)+B2(Shrub Height)	116.4185	3.9243	0.026	3	110.3511
B0+B1(Above Concealment)+B2(Nest Height)+B3(Distance to Edge)	117.0468	4.5526	0.019	4	108.9342
B0+B1(Average Concealment)+B2(Above Concealment)+B3(Nest Height)	117.5139	5.0197	0.015	4	109.4012
B0+B1(Above Concealment)+B2(Nest Height)+B3(Shrub Height)	117.5394	5.0452	0.015	4	109.4267
B0+B1(Average Concealment)+B2(Above Concealment)+B3(Distance to Edge)	117.6232	5.1290	0.014	4	109.5105

B0+B1(Average Concealment)+B2(Above Concealment)+B3(Shrub Height)	118.3051	5.8109	0.010	4	110.1925

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

Figure 3. Nestling Bendire's Thrasher in Hidalgo County, New Mexico (2018) with VHF transmitter attached just prior to fledging.

Table 8. Summary statistics for Bendire's Thrasher juvenile survival in Hidalgo County, New Mexico. Includes length of survival in days, including mean ($\bar{X}$) and standard deviation (SD), for all juveniles, those known to survive to dispersal, and those that went missing (i.e., assumed lost to predation, as none of the juveniles were recovered).

	$\bar{X}$	**SD**
All transmitter juveniles	14.78	13.02
Known surviving (n=4)	27.25	7.37
Mortality (n=5)	4.8	4.27

Table 9. Summary statistics of juvenile Bendire's Thrashers in Hidalgo County, New Mexico for comparison of vegetation attributes of known use sites to paired-random locations.

Locations	**Juvenile**		**Paired-Random**	
Vegetation Attributes	$\bar{X}$	**SD**	$\bar{X}$	**SD**
Bare Ground (%)	33.96	25.11	68.80	27.10
Canopy Cover (%)	42.22	18.31	15.03	17.44
Basal Cover (%)	1.49	4.14	2.70	16.44
Litter Cover (%)	57.19	30.06	19.70	22.58
Shrub Density (plants/ha)	2100.16	257.76	2064.22	1700.46
Average Visual Obstruction (%)	19.36	13.83	6.93	8.93

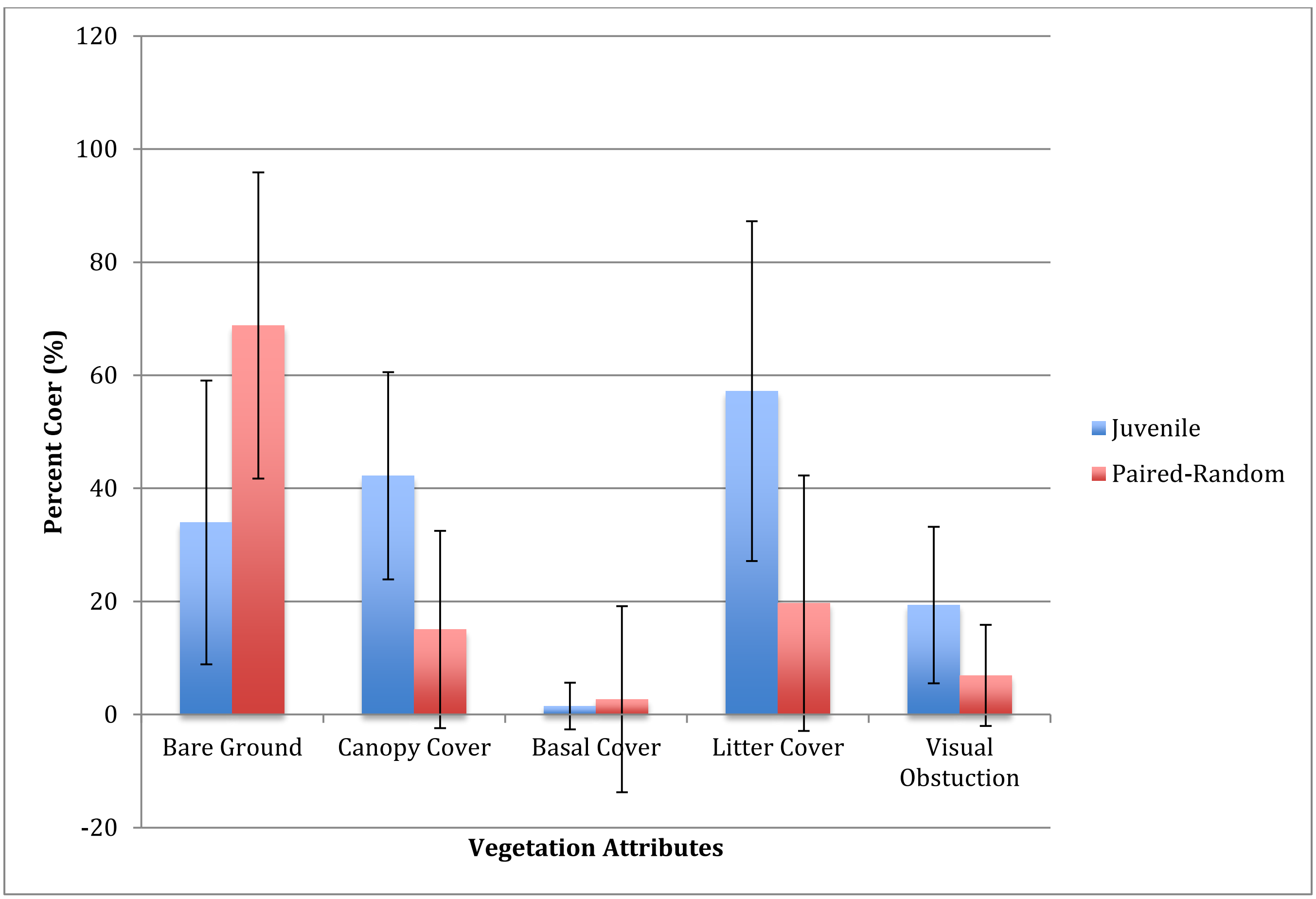

Figure 4. Comparison of vegetation cover attributes of known Bendire's Thrasher juvenile locations to paired-random locations in Hidalgo County, New Mexico in 2018. Graph shows mean ($\bar{X}$) percent cover estimates for juvenile locations (blue) and paired-random sites (red) with standard deviation (black error bars).

Table 10. Average path length in meters ($\bar{X}$) for juvenile Bendire's Thrashers in Hidalgo County, New Mexico in 2018 (n=3), 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)
BETH32-04	38	177.59	123.20	5.29	413.89
BETH48-15	26	183.96	138.50	6.28	375.03
BETH21-16	22	258.99	179.58	5.00	495.07

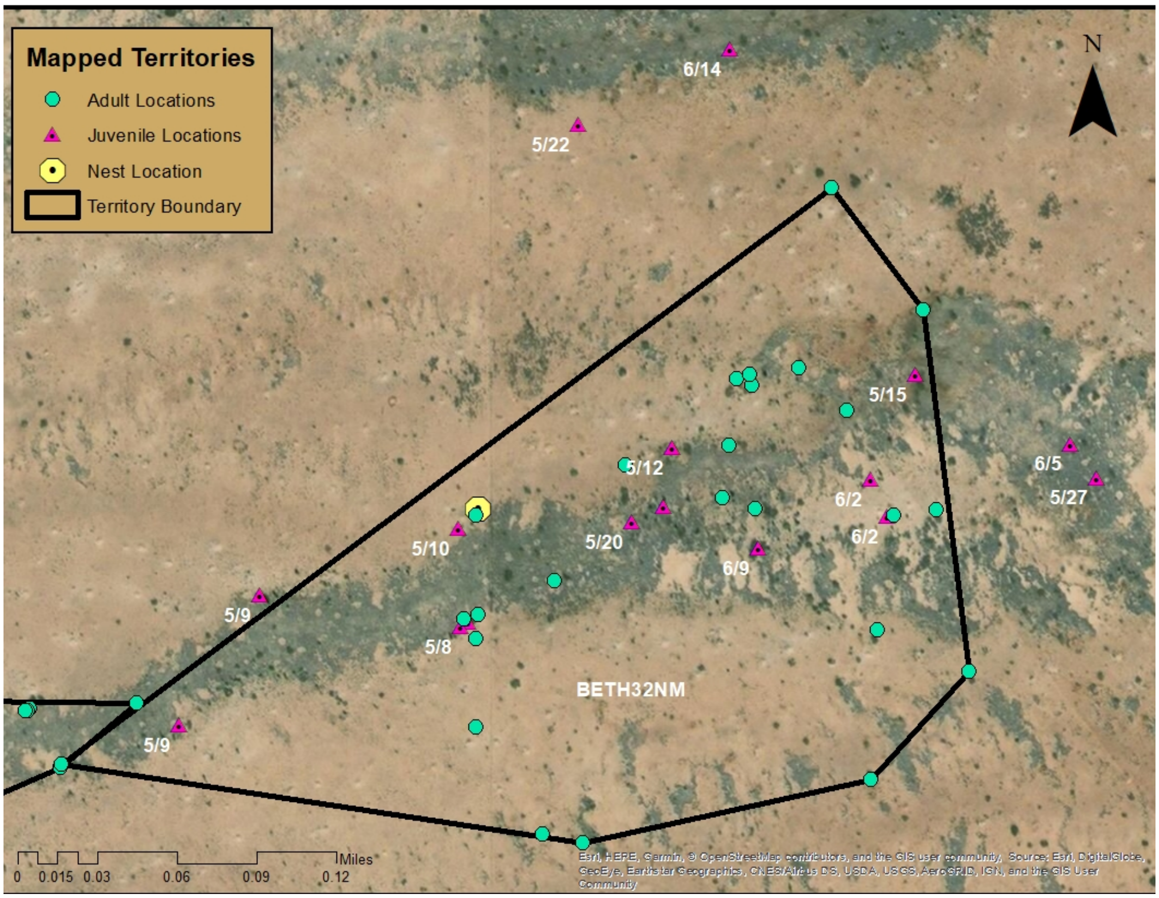

Figure 5. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 5/8) in Hidalgo County, New Mexico in 2018.

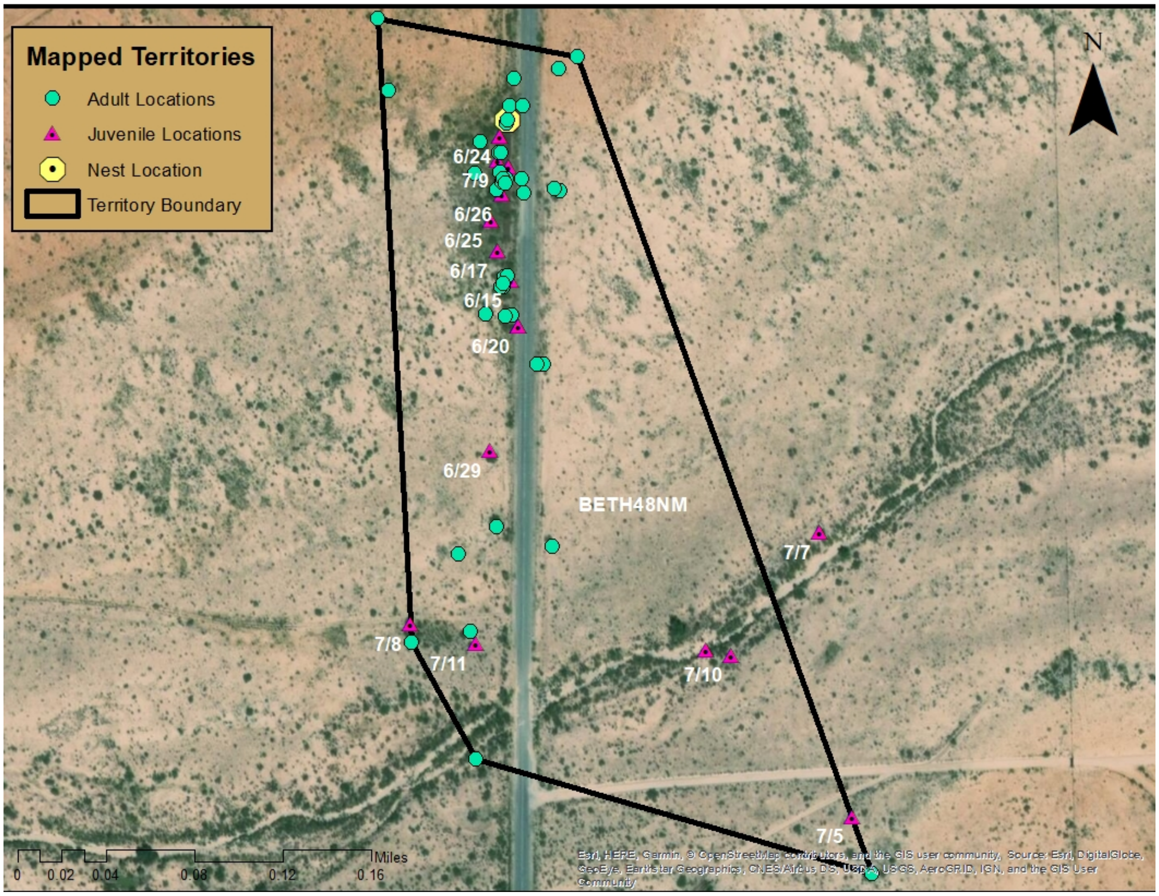

Figure 6. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 6/15) in Hidalgo County, New Mexico in 2018.

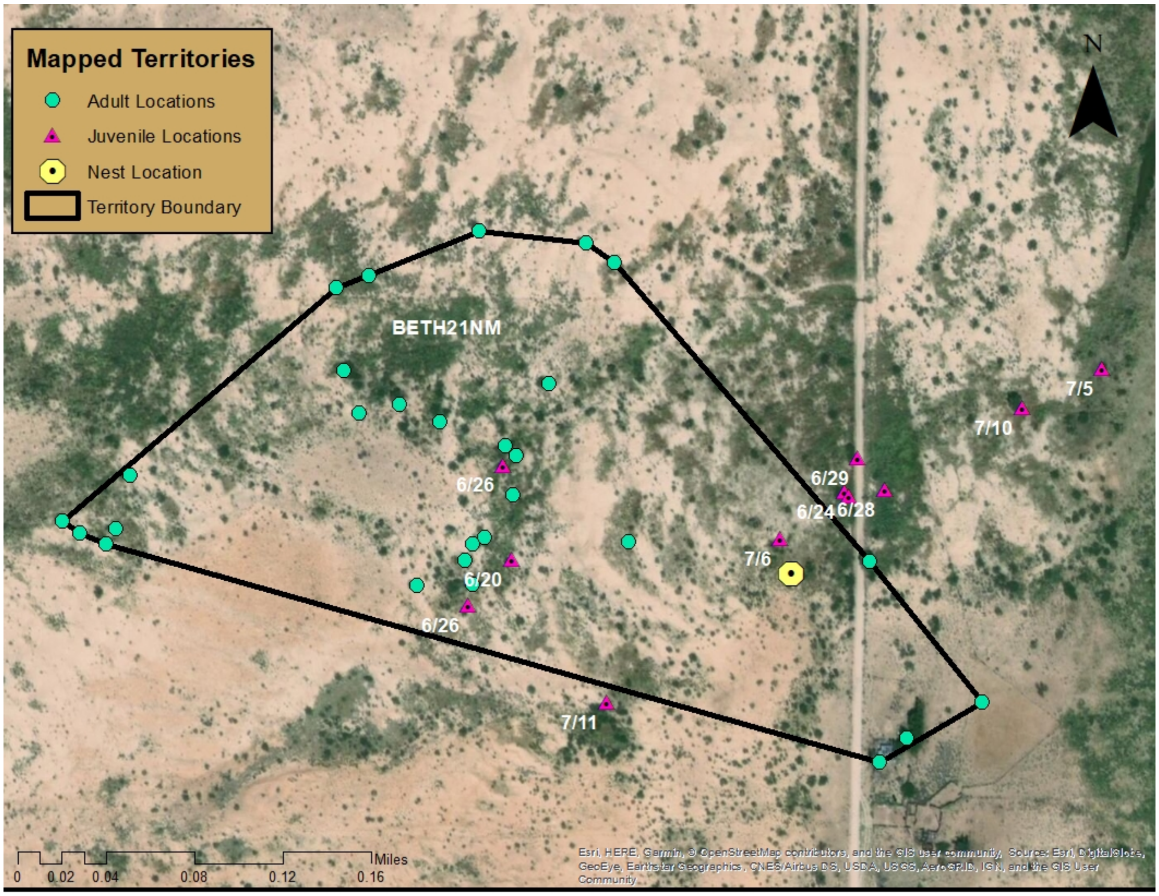

Figure 7. Mapped adult Bendire's Thrasher territory with nest and juvenile locations plotted with dates of juvenile locations (fledged 6/20) in Hidalgo County, New Mexico in 2018.

Table 11. Average territory sizes for occupied adult and juvenile Bendire's Thrasher territories in Hidalgo County, New Mexico in 2018 for juveniles that survived long enough to collect sufficient data (at least 30 locations, n=3).

Territory Size	$\bar{X}$(ha)	SD	Minimum (ha)	Maximum (ha)
Adult	8.14	1.54	2.09	43.45
Juvenile	9.13	1.60	5.93	10.93