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Research Paper

Post-fledging survival, movement patterns, and habitat associations of Bendire's Thrashers (*Toxostoma bendirei*) in the Chihuahuan Desert

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ABSTRACT. Knowledge gaps about the basic demography of a species facing population declines impede conservation efforts. For many passerine species, the survival rate of the post-fledging stage is unknown but may directly contribute to population trajectories. Bendire's Thrasher (*Toxostoma bendirei*) exhibits steep population declines in the southwestern United States, yet little is known about the basic breeding biology of this species. We examined juvenile Bendire's Thrasher survival during the post-fledging period and movement patterns from the nest site. We attached transmitters to 25 nestlings and tracked 19 fledglings using radio-telemetry. Using the known fate survival method, we modeled fledgling weekly survival in relation to age, time, and body condition, as well as habitat characteristics recorded at tracking locations. The top ranked model indicated that weekly survival increased with age since fledging ($\beta = 0.225$, 95% CI: 0.109, 0.340), and survival was low ($< 50\%$) during the first 10 days post-fledging. Predation pressure on fledglings was strong because they were not capable of flight for the first several days after leaving the nest. Distances moved from the nest increased with fledgling age, and in general, fledglings remained with family units (siblings and adults) on or near the breeding territory until the family unit dispersed. Further investigation into the post-fledging stage, in combination with other life cycle stages, will be critical for future conservation and population growth of Bendire's Thrashers within the Chihuahuan Desert.

Survie après l'envol, tendance de déplacements et préférences en matière d'habitats des Moqueurs de Bendire (*Toxostoma bendirei*) dans le désert de Chihuahua

RÉSUMÉ. Les lacunes quant aux connaissances sur la démographie de base d'une espèce dont la population est en baisse entravent les efforts de conservation. Pour de nombreuses espèces de passereaux, le taux de survie après l'envol n'est pas connu mais peut contribuer directement à la trajectoire de l'état de santé des populations. Le Moqueur de Bendire (*Toxostoma bendirei*) présente une diminution marquée de sa population dans le sud-ouest des États-Unis, mais on sait peu de choses sur la biologie de base de la reproduction de cette espèce. Nous avons examiné la survie des jeunes Moqueurs de Bendire pendant la période qui suit l'envol et leurs déplacements à partir du site de nidification. Nous avons fixé des émetteurs à 25 oisillons et suivi 19 d'entre eux par radiotélémétrie. Au moyen d'un modèle de survie fondé sur le destin connu, nous avons modélisé la survie hebdomadaire des oisillons en fonction de l'âge, du temps et de la condition physique, ainsi que des caractéristiques de l'habitat colligées sur les lieux de suivi. Le meilleur modèle a indiqué que la survie hebdomadaire augmentait avec l'âge depuis l'envol ($\beta = 0,225$, I.C. à 95 % : 0,109, 0,340) et que la survie était faible ($< 50\%$) pendant les 10 premiers jours après l'envol. La pression de prédation sur les oisillons était forte car ces derniers n'étaient pas capables de voler pendant les premiers jours après avoir quitté le nid. Les distances parcourues depuis le nid augmentaient avec l'âge des oisillons et, en général, ceux-ci restaient avec les groupes familiaux (frères, sœurs et parents) sur le territoire de nidification ou à proximité, jusqu'à ce que le groupe familial se disperse. De plus amples recherches sur la période suivant l'envol, en combinaison avec d'autres étapes du cycle annuel, seront essentielles pour favoriser la conservation future et la croissance de la population du Moqueur de Bendire dans le désert de Chihuahua.

Key Words: *habitat associations; juvenile; known fate models; movement; parental care; passerine; RMark*

INTRODUCTION

Demographic studies are essential in the conservation and management of species. Reliable information on multiple life cycle stages, including overall productivity, and juvenile and adult survival is critical to obtain accurate estimates of population abundance (Anders and Marshall 2005). The post-fledging period is the most vulnerable period in the life cycle of a bird, yet for most passerines this life stage is relatively unknown (Cox et al. 2014). Advances in technology have created an opportunity to conduct more detailed studies of passerine survival during post-fledging, which has resulted in more accurate estimates of juvenile songbird survival. Historically, estimates of juvenile survival were

not possible for passerines and were assumed to be half the estimated 0.62 of adult survival (Greenberg 1980, Temple and Cary 1988). However, subsequent studies have shown that post-fledging passerine survival is variable, and is related to individual growth (Vitz and Rodewald 2011, Naef-Daenzer and Gruebler 2016) and movement (Yackel-Adams et al. 2001, Kershner et al. 2004), and available habitat (Jenkins et al. 2016, Jones et al. 2017). A greater understanding of the post-fledging stage will provide valuable information on behavior and habitat characteristics that may influence survival (Anders and Marshall 2005, Streby et al. 2014).

The post-fledging stage is a particularly sensitive time for juvenile birds because they have not yet developed predator avoidance and foraging skills. Many altricial species leave the nest prior to completion of primary feather growth and are unable to fly for the first few days after fledging, which increases their vulnerability to predation (Yackel-Adams et al. 2001, Ausprey and Rodewald 2011, Naef-Daenzer and Gruebler 2016). During this period, adults caring for fledglings have demonstrated different strategies, including brood splitting, which has been observed in Lark Buntings (*Calamospiza melanocorys*) (Yackel-Adams et al. 2001) and Cerulean Warblers (*Setophaga cerulea*) (Raybuck et al. 2020), or keeping the family unit together, as observed in Wood Thrushes (*Hylocichla mustelina*) (Vega Rivera et al. 2000) and LeConte's Thrashers (*Toxostoma lecontei*) (Sheppard 2018). However, some species exhibit plasticity in caring for broods depending on the availability of resources (Yackel-Adams et al. 2001). The length of the post-fledging period also varies among species. For example, in the tropics, adult Western Slaty-Antsrikes (*Thammodon atrinucha*) care for broods for up to 12 weeks post-fledging (Tarwater and Brawn 2010). In contrast, parental care in North American species is generally much shorter (Russell et al. 2004); for example, Gray Catbird (*Dumetella carolinensis*) parents care for broods for only 12–15 days (Zimmerman 1963). These studies indicate that passerines have evolved unique life history strategies during the post-fledging period, and understanding these behaviors is critical to the conservation and management of species of concern.

Studies have shown substantial variation in fledgling survival among species, often related to measures of vegetation cover that influence a fledgling's ability to avoid predation (Kershner et al. 2004, Rush and Stutchbury 2008, Streby and Anderson 2013, Raybuck et al. 2020). Predation is the main cause of post-fledging mortality (Suedkamp Wells et al. 2007, Davis and Fisher 2009, Vitz and Rodewald 2011, Raybuck et al. 2020). Survival estimates vary with fledgling age; they tend to be lowest immediately after fledging and increase as fledglings become increasingly mobile (Jenkins et al. 2016, Naef-Daenzer and Gruebler 2016, Raybuck et al. 2020, Fischer et al. 2022). Generally, fledglings gradually move away from the nest site and occupy locations with dense cover that provide concealment and food resources (Vega Rivera et al. 2000, Yackel-Adams et al. 2001). Depending on habitat type or available resources, fledglings may stay near the nest site (Young et al. 2019) or move long distances (White and Faaborg 2008, Blackman and Diamond 2015). For example, some LeConte's Thrasher fledglings in the Mojave Desert exhibited large movements, an average of 700 m away from the nest site, likely due to sparse vegetation cover (Blackman and Diamond 2015). To manage for the post-fledging stage, we need to understand the factors that influence movement and how associated vegetation characteristics influence fledgling survival.

Bendire's Thrasher (*Toxostoma bendirei*) is an arid land obligate species that has experienced historical declines. As a result, it has been listed as globally vulnerable by the IUCN (2021), and a species of conservation concern by federal and state agencies in the southwestern United States (Pardieck et al. 2020, USFWS 2021). Bendire's Thrasher is a secretive and difficult species to detect; therefore, its nesting ecology and reproduction remains poorly documented. We examined the post-fledging ecology of Bendire's Thrasher to (1) estimate post-fledging survival and

identify factors that influence this parameter, (2) document movement patterns away from the nest site, and (3) examine vegetation characteristics commonly associated with fledgling locations. We hypothesized that survival and movement distance would increase with age as fledglings fully develop flight feathers and become capable of sustained flight. We further hypothesized that fledglings would use areas with greater and denser vegetation cover due to predator avoidance.

METHODS

Study area

We conducted this study in Hidalgo County, New Mexico from mid-February to July 2018, and Hidalgo and Grant Counties, New Mexico in March–June 2019. We located and monitored birds at four sites within the Chihuahuan Desert of New Mexico near the Lordsburg Playa (32°23'34.3" N 108°58'04.6" W), Middle Animas (31°49'50.9" N 108°47'21.6" W), Hachita (32°00'26.7" N 108°21'27.7" W), and Rodeo (31°50'12.3" N 109°01'52.8" W) (Fig. 1). Elevation within the study area spanned 1200–1400 m, and topography included desert scrub, arroyos, and playas, which are large expanses of dry lake beds that collect rainwater during monsoons, but the water quickly evaporates due to the presence of alkali soils (Bolen et al. 1989, Salas 2021). The study area was composed of several dominant shrubs species, including soap tree yuccas (*Yucca elata*), honey mesquite (*Prosopis glandulosa*), broom snakeweed (*Gutierrezia sarothrae*), and rabbitbrush (*Chrysothamnus* spp.). Less common shrubs and cacti species included longleaf ephedra (*Ephedra trifurca*), whitethorn acacia (*Vachellia constricta*), littleleaf sumac (*Rhus microphylla*), graythorn (*Ziziphus obtusifolia*), allthorn (*Koeberlinia spinosa*), wolfberry (*Lycium barbarum*), apache plume (*Fallugia paradoxa*), prickly pear cactus (*Opuntia* spp.), cane cholla (*Cylindropuntia imbricata*), and desert willow (*Chilopsis linearis*). Vegetation in the Chihuahuan Desert is sparse, and adult thrasher territories are composed of distinct stands of shrub and cacti with large areas of bare ground interspersed with patches of tobosa grass (*Pleuraphis mutica*), as well as giant sacaton (*Sporobolus wrightii*) and alkali sacaton (*Sporobolus airoides*) grasses.

Field methods

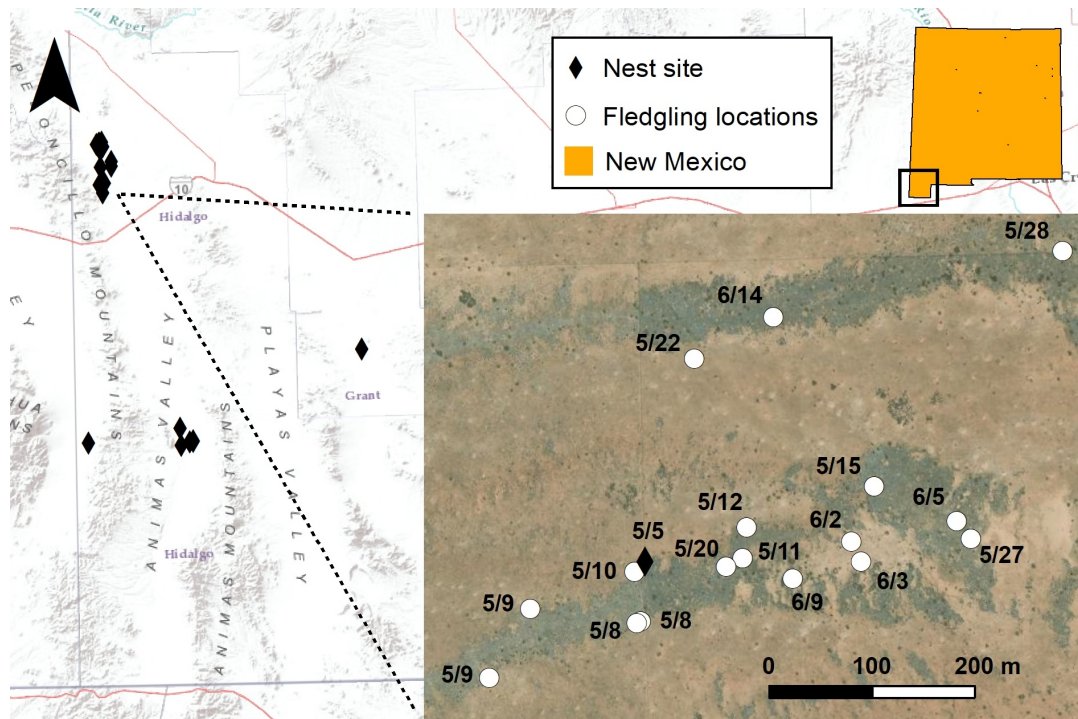
Nest searching and monitoring

We used the area search method supplemented with call playback to locate Bendire's Thrashers and map breeding territories. We conducted searches at known locations based on previous research (Sutton 2020) and eBird sightings (Sullivan et al. 2009). Once we located adults, we mapped territories using the flush-mapping technique (Reed 1985, Sutton 2020) with a handheld GPS (GARMIN 64s; Garmin, Olathe, Kansas, USA; accuracy ~3 m). We conducted nest searching within mapped territories using primarily parental cues, but also systematically searched shrubs (Ruehmann et al. 2011). When we found nests, they were marked with a GPS location and were checked every 2–5 days until fledging or failure, following standard nest monitoring protocols (Martin and Geupel 1993). We checked nests daily when the expected fledging day approached (~15 days from hatching).

Transmitter attachment and tracking efforts

We captured 10- to 12-day old nestlings by hand from the nest and banded each nestling with a single aluminum USGS federal

Fig. 1. Study site locations for fledgling Bendire's Thrashers in Grant and Hidalgo Counties, in the Chihuahuan Desert of New Mexico during 2018 and 2019. The insert represents one nest site with fledgling locations by date, demonstrating juvenile movement with age.



band (Davis and Fisher 2009). We measured the weight (g), wing chord length (mm), and tarsus length (mm) of all nestlings. We attached VHF radio transmitters (Model A1055, 17 x 7 x 4 mm, 1.0 g, with an estimated 8-week lifespan; Advanced Telemetry Systems, INC., Isanti, Minnesota, USA) using a leg-loop harness and a single drop of false eyelash glue on a single upper rectrix covert feather to ensure attachment (Rappole and Tipton 1991, C. Kondrat-Smith, personal communication). Total transmitter weight with harness materials and federal bands averaged 2.6% of the fledglings' body weight. Only one nestling in each nest was given a transmitter. We tracked most fledglings every 2–4 days or at least once per week using a handheld receiver (R-1000, Communication Specialist, Orange, California, USA) and a three-prong element Yagi antennae, and used the homing method (White and Garrot 1990, White and Faaborg 2008, Amelon et al. 2009). We recorded locations of fledglings with a handheld GPS unit using Universal Transverse Mercator (UTM).

Tracking of individuals began at the nest site or the last known location recorded, and once we located fledglings, we recorded the UTM. The range of detection for transmitters was 400–600 m with the handheld Yagi antennae. When we were unable to locate transmitter signals, we searched, by foot, an area of ~500-m radius from the nest site or last known location. If unsuccessful, we conducted a vehicle search with a magnetic roof-mount dipole (#13861, Advanced Telemetry Systems, INC., Isanti, Minnesota, USA). This search covered approximately a 5- to 20-km radius from the nest site or last known location; for fledglings that went missing, searching efforts were made for up to 2 weeks after the signal was lost (Vitz and Rodewald 2011).

Vegetation and arthropod data collection

We collected vegetation data within a 11.3-m radius circle, with the fledgling location as the center point, 1–3 weeks after fledglings left the area. These data were collected along four transects radiating out from the central point, one in each of the four cardinal directions, which divided the plot into four quadrants (Martin et al. 1995, Jenkins et al. 2016). We estimated canopy cover (%) using the line-point intercept method. We used a Robel pole to estimate vertical cover, and collected visual obstruction readings at 0 m, 3 m, and 5 m along the transects. Additionally, we quantified the number of shrubs within each quadrant by size classes (shrub height: A = < 0.5 m, B = 0.5–1.5 m, and C = > 1.5 m) and estimated shrub density based on the number of shrubs per hectare (Herrick et al. 2005). We calculated descriptive statistics of habitat characteristics based on tracking locations of fledglings.

Within 24 hours of relocating fledglings, our team collected arthropods along two parallel 100-m transects, placed 10 m apart, that radiated out from the fledglings' location in the direction of a random bearing. We conducted sweep-netting by sweeping fast and low once every meter for the length of the transect (Jamison et al. 2002, Brust et al. 2009, Whipple et al. 2010). We performed beat-netting at four shrubs along each transect by beating four branches on each shrub, four times each (McDermott and Wood 2010). We stored arthropods in plastic gallon Ziploc bags or 50-mL centrifuge tubes in a freezer until sorting was conducted. After the breeding season, we sorted arthropod samples by order. We counted, labeled, and stored all samples in 70% ethyl alcohol (Whipple et al. 2010) at New Mexico State University.

Statistical analysis

Survival

We constructed a capture history based on weekly intervals, coded as either alive, dead, or censored for each fledgling. We estimated weekly fledgling survival using the known fate model in Program MARK (Pollock et al. 1989, White and Burnham 1999) and the RMark package in R (Laake 2013, R Core Team 2021). We also investigated the influence of covariates, including time, body condition index, age since fledging, and habitat variables on post-fledging survival (Table 1). We calculated the body condition index covariate as the residual value from a simple linear regression model of tarsus length and body weight of all banded nestlings prior to fledging (Pärt 1990). We created a binary covariate where calculated residual values > 0 represented a mass greater than expected, or a measure of “good body condition”, and a value < 0 represented a mass lower than expected, or “poor body condition” (Vitz and Rodewald 2011). We used the mean value of habitat variables across all locations for each fledgling. We used Pearson’s correlation coefficient to check all continuous habitat variables for collinearity, and in any pair of highly correlated variables ($> |0.65|$), we removed one variable prior to analysis.

Table 1. Vegetation and temporal variables measured to examine fledgling survival and habitat use during the 2018–2019 breeding seasons of Bendire’s Thrashers in the Chihuahuan Desert of New Mexico.

Predictor variable	Definition
Time trend	Time trend model, day of the season based on the first nest found
Body condition index	Measure of nestling body condition prior to fledging (“poor”, “good”)
Age since fledging	Age in days since fledging the nest
Shrub cover	Percent shrub cover measured by line-point intercept
Visual obstruction	Percentage of vertical cover determined by Robel pole
Shrub density	Density of shrubs (shrubs/ha) of all height classes
Tall shrubs	Density of shrubs (shrubs/ha) > 1.5 m in height
Shrub height	Average height of all shrubs > 1.5 m in height at location
Arthropod abundance	Average abundance of arthropods collected on locations

We developed eight a priori models using age, time, and body condition index for all radio-marked fledglings ($n = 25$). We also developed an additional eight a priori models and performed a separate analysis to examine the influence of habitat variables on radio-marked fledglings that survived long enough to leave the nest shrub ($n = 19$). We ranked models using Akaike’s Information Criterion adjusted for small sample size (AIC_c) and included a null model and a global model with the additive combination of all variables (Burnham and Anderson 2002). Models that were within two ΔAIC_c were considered competitive (Burnham and Anderson 2002).

Movement

To describe post-fledging movements, we entered GPS locations into QGIS (2021), and measured, in meters, distances from the

nest to each fledgling location using the measuring tool by drawing a straight line between points. We created age classes based on flight capability using the following categories of days since fledging: 1–2, 3–5, 6–10, 11–15, 16–20, and 21–40 (Wightman 2009, Vormwald et al. 2011, Raybuck et al. 2020). We calculated median values and other summary statistics of distance from the nest site to locations for each age class, and reported the results using boxplots. We conducted all analyses in R (R Core Team 2021).

RESULTS

Bendire’s Thrashers left the nest 12–15 days after hatching, 2–5 days before they were capable of flight. We monitored fledgling survival of 25 individuals (7 in 2018; 18 in 2019) and movements of 19 juveniles (7 in 2018; 12 in 2019). In 2018, we suspected that the adults of two clutches had removed the transmitters from the nestlings prior to fledging because the transmitters were not in the nest but the nestlings remained. There was no evidence of transmitters slipping off fledglings once they had fledged. We fitted the transmitters back on those two nestlings. We assumed that six fledglings had been depredated because we were unable to relocate them alive. As a result, no habitat and movement data were collected for those individuals. Fledglings left the nest before complete growth of the primary feathers and were vulnerable to predation during that period. Predators were not identified, but suspected predators included coyotes and raptors, as well as snakes and rodents because several transmitters were recovered from remains of fledglings or were tracked to underground burrows.

Survival

Of the 25 fledglings that had transmitters, nine died within 5 days of fledging, and six died within 20 days of fledging. Of the 15 fledglings that died, five were confirmed to have been depredated based on transmitter recovery, while 10 were assumed to have been depredated because they were too young to fly and could not be relocated. Ten fledglings survived until dispersal (four in 2018; six in 2019), all of which remained with the family unit on the breeding territories for an average of 30 days. There was no evidence of brood splitting during this study.

The top ranked model in the survival analysis of temporal characteristics ($n = 25$) included age of the fledgling, which carried more than 50% of the model weight (Table 2). Weekly survival of fledglings was positively associated with age ($\beta = 0.225$, 95% CI: 0.109, 0.340) (Fig. 2). The top ranked model in the survival analysis of habitat characteristics ($n = 19$) was the null model, which indicated there was no evidence of an influence of habitat variables on post-fledging survival (Table 2).

Movement and habitat

We located and followed 19 fledglings for an average of 14.04 ± 2.61 days (range 1–41). The median distance moved by fledglings from the nest site was 139 m (interquartile range: 234 m). Median distance moved from the nest site varied with age of the fledgling (Fig. 3). During relocation efforts, fledglings were often found motionless and quiet, hiding within vegetation with siblings, and parents would alarm call within 10 m. By days 3–5 after leaving the nest, fledglings would hop from branch to branch in shrubs when we approached. In general, younger birds that

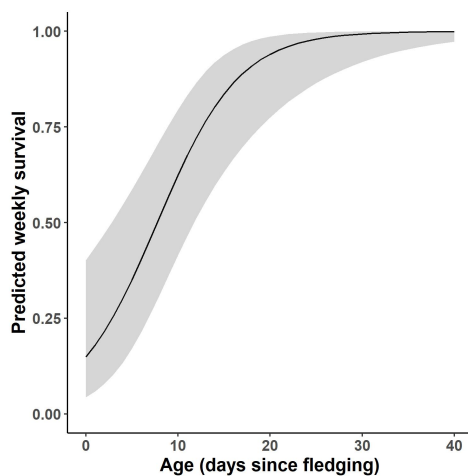
were incapable of flight stayed within 100 m of the nest site, and movement was restricted to running on the ground or short flights. However, once capable of flight, older fledglings were documented moving more than 300 m from the nest site but continued to return to the nest area, as shown in Fig. 1. The most common shrubs used by fledglings on our site were soap tree yucca and honey mesquite.

Table 2. Weekly fledgling survival model selection results for Bendire's Thrasher during the 2018–2019 breeding seasons in the Chihuahuan Desert of New Mexico. Model selection results are presented for temporal characteristics ($n = 25$) and habitat characteristics ($n = 19$). K is the number of parameters in the model, ΔAIC_c is the difference in AIC_c values from the top model, w_i is the model weight, and dev is the model deviance.

Characteristic	Model	K	ΔAIC_c	w_i	dev	
Temporal	S(~Age)	2	0.00	0.53	34.67	
	S(~Age + Index)	3	1.77	0.22	34.57	
	S(~Age + Time)	3	2.16	0.18	34.66	
	S(~Age + Time + Index)	4	3.99	0.07	34.25	
	S(~Null)	1	38.28	0.00	72.29	
	S(~Time)	2	39.16	0.00	71.07	
	S(~Index)	2	39.53	0.00	71.42	
	S(~Time + Index)	3	40.24	0.00	69.97	
	Habitat	S(~Null)	1	0.00	0.35	6.00
		S(~Shrub cover)	2	1.42	0.17	52.45
S(~Arthropod)		2	1.56	0.16	52.59	
S(~VOR)		2	2.11	0.12	53.14	
S(~Shrub cover + Arthropod)		3	3.16	0.07	52.00	
S(~Shrub cover + VOR)		3	3.51	0.06	52.34	
S(~VOR + Arthropod)		3	3.73	0.05	52.34	
S(~Shrub cover + VOR + Arthropod)		4	5.41	0.02	51.99	

†Age = age in days since fledging, Index = body condition index, Time = time in weeks, Canopy cover = percent canopy cover, Arthropod = arthropod abundance, VOR = visual obstruction reading.

Fig. 2. Estimated weekly survival as a function of age (days since fledging) for Bendire's Thrasher during the 2018–2019 breeding seasons in the Chihuahuan Desert of New Mexico. Gray shading indicates 95% confidence intervals.



Fledglings were found in areas with an average 38% shrub cover and in shrubs that were taller than 2 m. Fledglings were found in areas with relatively low densities of shrubs compared to the surrounding areas but in areas that had shrubs taller than 1.5 m. Visual obstruction readings, on average, were more than 18% at locations used by fledglings (Table 3).

Fig. 3. Distance (m) fledgling Bendire's Thrashers were located from the nest site by age class (in days) since fledging for the 2018–2019 breeding seasons in the Chihuahuan Desert of New Mexico (n = the number of locations for each age class).

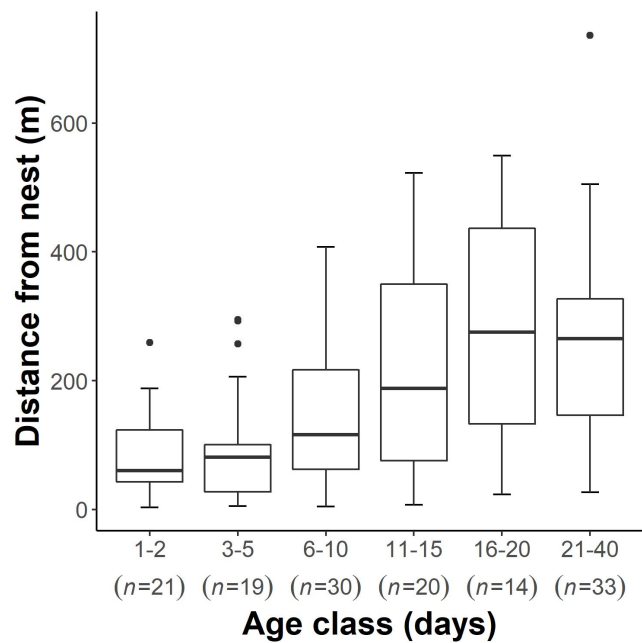


Table 3. Summary statistics for habitat variables from locations used by Bendire's Thrasher fledglings in the Chihuahuan Desert of New Mexico and surrounding area within 600 m of used locations during the 2018–2019 breeding seasons.

Variable	Location	Mean	Standard deviation
Shrub cover	Use	38.12 (%)	18.58
	Surrounding	18.07 (%)	20.06
Shrub density	Use	1113.61 (shrubs/ha)	1759.19
	Surrounding	2173.82 (shrubs/ha)	2235.19
Tall shrubs	Use	132.84 (shrubs/ha)	124.37
	Surrounding	36.81 (shrubs/ha)	55.99
Shrub height	Use	2.14 (m)	0.82
	Surrounding	0.98 (m)	1.71
VOR†	Use	18.38 (%)	13.88
	Surrounding	7.90 (%)	8.22

†VOR = visual obstruction reading.

DISCUSSION

Consistent with our hypothesis, fledgling age influenced both survival and distance moved by young thrashers. Fledglings are most vulnerable to mortality immediately after leaving the nest.

The length of the nestling period has been shown to positively influence survival (Cox et al. 2014). However, some species of passerines leave the nest early, which appears to balance a trade-off between increased growth in the nest and vulnerability to predation (Cheng and Martin 2012). Our findings that juveniles were most vulnerable to mortality the first week out of the nest is consistent with other studies on passerines (Yackel-Adams et al. 2001, King et al. 2006, Berkeley et al. 2007, Rush and Stutchbury 2008, Naef-Daenzer and Gruebler 2016). Bendire Thrasher fledglings were vulnerable during the first 3 days after fledging. During this time, fledglings were still not capable of flight, and this was the period when most predation occurred. Fledgling movement was contained mainly within the adult breeding territories, and juveniles remained together with adults and siblings as a family unit for 30 days until the family units dispersed. While still dependent on adults, juveniles were commonly found in areas with high foliar concealment, presumably as a defense against predation.

Our survival estimate for fledgling Bendire's Thrashers based on the null model was comparable (0.38 for a 30-day period, 95% CI: 0.20, 0.57) to those of other passerine species; studies have documented survival rates during this sensitive period that have ranged from 0.19 in Hooded Warblers (*Setophaga citrina*) (Rush and Stutchbury 2008) to 0.58 for Western Meadowlarks (*Sturnella neglecta*) (Giovanni et al. 2015). Observed Bendire's Thrasher fledgling survival over a 30-day period was lower than fledgling survival of LeConte's Thrashers over a 58-day period in California (Blackman and Diamond 2015). At our study site, adult Bendire's Thrashers established territories on "islands", or patches, of habitat ranging in size from 2 to 90 ha, which were structurally different than the surrounding desert. These "habitat islands" may have been easier for predators to search, which potentially put fledgling thrashers at increased risk of predation. In our study, fledgling survival increased with age, similar to other studies of passerines (Yackel Adams et al. 2006, Jenkins et al. 2016, Hovick et al. 2011). While some studies have also found that survival was not associated with specific vegetation characteristics (Hovick et al. 2011, Fischer et al. 2022), research in more complex habitats has shown that vegetation characteristics influence fledgling survival (King et al. 2006, Moore et al. 2010, Jenkins et al. 2016). Research on another desert passerine, the Gray Vireo (*Vireo vicinior*), also found similar habitat associations for nesting and rearing fledglings, and no association between fledgling survival and measured habitat characteristics (Fischer et al. 2022). There was, however, little variability in habitat structure and composition on our study area, and our sample size was small, which may have limited our statistical power to detect an effect.

Members of the thrasher genus that occupy arid lands appear to encounter strong predation pressure and may adapt to it by minimizing the time nestlings stay in the nest but increasing the length of parental care (Cheng and Martin 2012, Lloyd and Martin 2015, Martin 2015). This strategy may increase the likelihood of individual nestling survival. However, fledglings not capable of flight are at increased risk of predation (Lloyd and Martin 2015). The median duration of passerine parental care has been reported to be 16 days for 126 north-temperate species (Russell 2000), and 77 species exhibit parental care for less than 20 days (Russell 2000). Bendire's Thrashers may benefit from prolonged parental care after fledging, which could lead to

increased body mass, and reduced fledgling movements, and thus, higher recruitment (Tarwater and Brawn 2010, Vitz and Rodewald 2011, López-Idiáquez et al. 2018, Fischer et al. 2022).

Similar to survival, distances moved from the nest site increased with age as young birds grew and became capable of flight. Bendire's Thrasher fledglings remained close to the nest site (~100 m) within the first 5 days of fledging but reached distances up to ~300 m at 20 days post-fledging. Fledglings did not move consistently away from the nest; they often returned to locations close to the nest site but gradually increased the distance from the nest. Fledglings were observed moving near territory boundaries or slightly outside the territories at around 10–12 days post-fledging. Movements of fledgling Bendire's Thrashers were similar to those reported for other fledgling thrashers: a median distance of 200 m from the nest site for Brown Thrashers (*Toxostoma rufum*) (Cavitt and Haas 1993) and 300 m for Sage Thrashers (*Oreoscoptes montanus*) (Reynolds et al. 2020). Distances moved differed from those of LeConte's Thrashers within the Mojave Desert: the median distance moved by LeConte's Thrasher fledglings was 721 m within 50 days of leaving the nest site (Blackman and Diamond 2015). LeConte's Thrasher fledglings moved farther from the nest than did Bendire's Thrasher fledglings, but movement patterns were similar to those of Bendire's Thrashers: fledglings of both species moved away from and back toward the nest site. The vegetation of the Chihuahuan Desert is often sparse, consisting of areas of desert grassland that lack shrubs or have low shrub density, primarily soap tree yucca. However, many areas have transitioned into large expanses of shrub-dominated sites, with homogeneous stands of low-stature shrubs such as creosote bush (*Larrea tridentata*), due to desertification (Archer 2010). Bendire's Thrasher fledglings were not observed using these desertified areas. Movement of Bendire's Thrashers may have been limited based on the availability of shrubs within the island-like stands of vegetation that are present at our study site.

Climate projections of increasing temperatures and prolonged drought pose a threat of increased desertification in the southwestern United States (Archer and Predick 2008), which could further degrade large expanses of thrasher habitat. Our research suggests that the post-fledging survival of Bendire's Thrashers in the Chihuahuan Desert is comparable to that of other passerines. However, a more in-depth understanding of reproductive outputs of Bendire's Thrashers at each life cycle stage will inform management decisions regarding conservation within the Chihuahuan Desert.

Author Contributions:

MJD and AJS conceived the idea and research goals, AJS and FA curated data, and AJS and FA analyzed the data, MJD acquired financial support, AJS collected data and conducted research, AJS, MJD, and FA developed methodology, MJD and FA provided project supervision, AJS wrote the original draft, and AJS, MJD, and FA participated in the visualization of the published work and reviewed and edited the manuscript.

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LITERATURE CITED

- Amelon S. K., D. C. Dalton, J. J. Millspaugh, and S. A. Wolf. 2009. Radiotelemetry: techniques and analysis. Pages 57-77 in T. H. Kunz and S. Parsons, editors. Ecological and Behavioral Methods for the Study of Bats. Johns Hopkins University Press, Baltimore, Maryland, USA.
- Anders, A. D., and M. R. Marshall. 2005. Increasing the accuracy of productivity and survival estimates of assessing landbird population status. *Conservation Biology* 19(1):66-74. <https://doi.org/10.1111/j.1523-1739.2005.00543.x>
- Archer, S. R. 2010. Rangeland conservation and shrub encroachment: new perspectives on an old problem. Pages 53-97 in J. T. D. Toit, R. Kock, and J. C. Deutsch, editors. Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems. John Wiley and Sons Ltd, Chichester, UK.
- Archer, S. R., and K. I. Predick. 2008. Climate change and ecosystems of the southwestern United States. *Rangelands* 30(3):23-28. [https://doi.org/10.2111/1551-501X\(2008\)30\[23:CCAEO\]2.0.CO;2](https://doi.org/10.2111/1551-501X(2008)30[23:CCAEO]2.0.CO;2)
- Ausprey, I. J., and A. D. Rodewald. 2011. Post-fledgling survivorship and habitat selection across a rural-to-urban landscape gradient. *Auk* 128(2):293-302. <https://doi.org/10.1525/auk.2011.10158>
- Berkeley, L. I., J. P. McCarty, and L. LaReesa Wolfenbarger. 2007. Postfledging survival and movement in Dickcissels (*Spiza americana*): implications for habitat management and conservation. *Auk* 124(2):396-409. <https://doi.org/10.1093/auk/124.2.396>
- Blackman, S. T., and J. Diamond. 2015. Meta-population dynamics of Le Conte's Thrasher (*Toxostoma lecontei*): a species at risk on three southwestern military installations. Year 3 report. Wildlife Contracts Branch, Arizona Game and Fish Department.
- Bolen, E. G., L. M. Smith, and H. L. Schramm, Jr. 1989. Playas lakes: prairie wetlands of the Southern High Plains. *BioScience* 39(9):615-623. <https://doi.org/10.2307/1311091>
- Brust, M. L., W. Hoback, and R. J. Wright. 2009. Degree-day requirements for eight economically important grasshoppers (Orthoptera: Acrididae) in Nebraska using field data. *Environmental Entomology* 38(5):1521-1526. <https://doi.org/10.1603/022.038.0521>
- Burnham, K. P., and D. R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Second edition. Springer-Verlag, New York, USA.
- Cavitt, J. F., and C. A. Haas. 1993. Brown Thrasher (*Toxostoma rufum*). In A. F. Poole, editor. Birds of the world. Cornell Lab of Ornithology, Ithaca, New York, USA.
- Cheng, Y., and T. E. Martin. 2012. Nest predation risk and growth strategies of passerine species: grow fast or develop traits to escape risk? *American Naturalist* 180(3):258-295. <https://doi.org/10.1086/667214>
- Cox, W. A., F. R. Thompson III, A. S. Cox, and J. Faaborg. 2014. Post-fledgling survival in passerine birds and the value of post-fledgling studies to conservation. *Journal of Wildlife Management* 78(2):183-193. <https://doi.org/10.1002/jwmg.670>
- Davis, S. K., and R. J. Fisher. 2009. Post-fledging movements of Sprague's Pipet. *Wilson Journal of Ornithology* 121(1):198-202. <https://doi.org/10.1676/08-025.1>
- Fischer, S. E., K. Granillo, and H. M. Streby. 2022. Post-fledging survival, movements, and habitat associations of Gray Vireos in New Mexico. *Avian Conservation and Ecology* 17(1):13. <https://doi.org/10.5751/ACE-02053-170113>
- Giovanni, M. D., L. A. Powell, and W. H. Schacht. 2015. Habitat preference and survival for Western Meadowlarks (*Sturnella neglecta*) fledglings in a contiguous prairie system. *Wilson Journal of Ornithology* 127(2):200-211. <https://doi.org/10.1676/wils-127-02-200-211.1>
- Greenberg, R. 1980. Demographic aspects of long-distance migration. Pages 493-504 in A. Keast and E. S. Morton, editors. Migrant birds in the Neotropics: ecology, behavior, distribution, and conservation. Smithsonian Institution Press, Washington, D. C., USA.
- Herrick, J. E., J. W. van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford, et al. 2005. Monitoring manual for grassland, shrubland, and savanna ecosystems. Volume I: quick Start. U.S. Department of Agriculture, ARS Jornada Experimental Range, Las Cruces, New Mexico, USA.
- Hovick, T. J., J. R. Miller, R. R. Koford, D. M. Engle, and D. M. Debinski. 2011. Postfledging survival of Grasshopper Sparrows in grasslands managed with fire and grazing. *Condor* 113(2):429-437. <https://doi.org/10.1525/cond.2011.100135>
- International Union for Conservation of Nature (IUCN). 2021. The IUCN Red List of threatened species. Version 2021-1. <https://www.iucnredlist.org>
- 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* 30(2):517-526.
- Jenkins, J. M. A., F. R. Thompson III, and J. Faaborg. 2016. Contrasting patterns of nest survival and postfledgling survival in Ovenbirds and Acadian Flycatchers in Missouri forest fragments. *Condor* 118(3):582-596. <https://doi.org/10.1650/CONDOR-16-30.1>

- Jones, T. M., J. D. Brawn, and M. P. Ward. 2017. Post-fledgling habitat use in the Dickcissel. *Condor* 119(3):497-504. <https://doi.org/10.1650/CONDOR-17-21.1>
- Kershner, E. L., J. W. Walk, and R. E. Warner. 2004. Postfledging movements and survival of juvenile Eastern Meadowlarks (*Sturnella magna*) in Illinois. *Auk* 121(4):1146-1156.
- King, D. I., R. M. Degraaf, M.-L. Smith, and J. P. Buonaccorsi. 2006. Habitat selection and habitat-specific survival of fledgling Ovenbirds (*Seiurus aurocapilla*). *Journal of Zoology* 269(4):414-421. <https://doi.org/10.1111/j.1469-7998.2006.00158.x>
- Laake, J. 2013. Rmark: an R interface for analysis of capture-recapture data with MARK. AFSC Processed Report 2013-01, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington, USA.
- Lloyd, P., and T. E. Martin. 2015. Fledgling survival increased with development time and adult survival across north and south temperate zones. *Ibis* 158(1):135-143. <https://doi.org/10.1111/ibi.12325>
- López-Idiáquez, D., P. Vergara, J. A. Fargallo, and J. Martínez-Padilla. 2018. Providing longer post-fledgling periods increased offspring survival at the expense of future fecundity. *PLoS ONE* 13:e0203152. <https://doi.org/10.1371/journal.pone.0203152>
- Martin, T. E. 2015. Age-related mortality explains life history strategies of temperate and tropical songbirds. *Science* 349(6251):966-970. <https://doi.org/10.1126/science.aad1173>
- Martin, T. E., J. Clobert, and D. R. Anderson. 1995. Return rates in studies of life history evolution: Are biases large? *Journal of Applied Statistics* 22(5-6):863-875. <https://doi.org/10.1080/02664769524676>
- Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. *Journal of Field Ornithology* 64(4):507-519.
- 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 trees. *Wilson Journal of Ornithology* 122(3):545-555. <https://doi.org/10.1676/09-050.1>
- Moore, L. C., B. J. M. Stuchbury, D. M. Burke, and K. A. Elliott. 2010. Effects of forest management on postfledging survival of Rose-breasted Grosbeaks (*Pheucticus ludovicianus*). *Auk* 127(1):185-194. <https://doi.org/10.1525/auk.2009.09134>
- Naef-Daenzer, B., and M. U. Grüebler. 2016. Post-fledgling survival of altricial birds: ecological determinants and adaptation. *Journal of Field Ornithology* 87(3):227-250. <https://doi.org/10.1111/jfo.12157>
- Pardieck, K. L., D. J. Ziolkowski, Jr., M. Lutmerding, V. I. Ponte, and M. A. R. Hudson. 2020. North American Breeding Bird Survey dataset 1996-2019. U.S. Geological Survey. <https://doi.org/10.5066/P9J6QUF6>
- Pärt, T. 1990. Natal dispersal in the Collard Flycatcher: possible causes and reproductive consequences. *Scandinavian Journal of Ornithology* 21(2):83-88. <https://doi.org/10.2307/3676802>
- Pollock, K. H., S. R. Winterstein, and M. J. Conroy. 1989. Estimation and analysis of survival distributions for radio-tagged animals. *Biometrics* 45(1):99-109. <https://doi.org/10.2307/2532037>
- QGIS Development Team. 2021. QGIS Geographical Information System. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org>
- R Core Team. 2021. R: a language and environment for statistical computing. R Foundation for Statistical Computing, version 4.1.2, Vienna, Austria. <https://www.R-projects.org/>
- Rappole, J. H., and A. R. Tipton. 1991. New harness design for attachment of radio transmitters to small passerines. *Journal of Field Ornithology* 62(3):335-337.
- Raybuck, D. W., J. L. Larkin, S. H. Stoleson, and T. J. Boves. 2020. Radio-tracking reveals insight into survival and dynamic habitat selection of fledgling Cerulean Warblers. *Condor* 122(1):1-15. <https://doi.org/10.1093/condor/duz063>
- Reed, J. M. 1985. A comparison of the "flush" and spot-map methods for estimating the size of Vesper Sparrow territories. *Association of Field Ornithologists* 56(2):131-137.
- Reynolds, T. D., T. D. Rich, and D. A. Stephens. 2020. Sage Thrasher (*Oreoscoptes montanus*). In A. F. Poole and F. B. Gill, editors. *Birds of the world*. Cornell Lab of Ornithology, Ithaca, New York, USA. <https://doi.org/10.2173/bow.sagthr.01>
- Ruehmann, M. B., M. J. Desmond, and W. R. Gould. 2011. Effects of smooth brome on Brewer's Sparrow nest survival in sagebrush steppe. *Condor* 113(2):419-428. <https://doi.org/10.1525/cond.2011.100022>
- Rush, S. A., and B. J. M. Stutchbury. 2008. Survival of fledgling Hooded Warblers (*Wilsonia citrina*) in small and large forest fragments. *Auk* 125(1):183-191. <https://doi.org/10.1525/auk.2008.125.1.183>
- Russell, E. M. 2000. Avian life histories: Is extended parental care the southern secret? *Emu* 100(5):377-399. <https://doi.org/10.1071/MU0005S>
- Russell, E. M., Y. Yom-Tov, and E. Geffen. 2004. Extended parental care and delayed dispersal: northern, tropical, and southern passerines compared. *Behavioral Ecology* 15(5):831-838. <https://doi.org/10.1093/beheco/arh088>
- Salas, A. J. 2021. Nest survival and post-fledging survival, movement, and habitat use of Bendire's Thrashers (*Toxostoma bendirei*) in the Chihuahuan Desert. Thesis. New Mexico State University, Las Cruces, New Mexico, USA.
- Sheppard, J. M. 2018. Studies in western birds. Volume 2. The biology of a desert apparition: LeConte's Thrasher (*Toxostoma lecontei*). *Western Field Ornithologists*.
- Streby, H. M., and D. E. Andersen. 2013. Survival of fledgling Ovenbirds: influences of habitat characteristics at multiple spatial scales. *Condor* 115(2):403-410. <https://doi.org/10.1525/cond.2013.110178>
- Streby, H. M., J. M. Refsnider, and D. E. Andersen. 2014. Redefining reproductive success in songbirds: moving beyond the nest success paradigm. *Auk* 131(4):718-726. <https://doi.org/10.1642/AUK-14-69.1>

- Suedkamp Wells, K. M., M. R. Ryan, J. J. Millsbaugh, F. R. Thompson, III, and M. W. Hubbard. 2007. Survival of postfledging grassland birds in Missouri. *Condor* 109(4):781-794. <https://doi.org/10.1093/condor/109.4.781>
- Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. *Biological Conservation* 142 (10):2282-2292. <https://doi.org/10.1016/j.biocon.2009.05.006>
- Sutton, C. T. 2020. Breeding habitat requirements and territory size of Bendire's Thrashers (*Toxostoma bendirei*) in the southwestern U.S. Thesis. New Mexico State University, Las Cruces, New Mexico, USA.
- Tarwater, C. R., and J. D. Brawn. 2010. The post-fledgling period in a tropical bird: patterns of parental care and survival. *Journal of Avian Biology* 41:479-487. <https://doi.org/10.1111/j.1600-048X.2010.05006.x>
- Temple, S. A., and J. R. Cary. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology* 2(4):340-347. <https://doi.org/10.1111/j.1523-1739.1988.tb00198.x>
- United States Fish and Wildlife Service (USFWS). 2021. Birds of conservation concern 2021. U.S. Fish and Wildlife Service, Falls Church, Virginia, USA. <https://www.fws.gov/media/birds-conservation-concern-2021>
- Vega Rivera, J. H., C. A. Haas, J. H. Rappole, and W. J. McShea. 2000. Parental care of fledgling Wood Thrushes. *Wilson Bulletin* 112(2):233-237. [https://doi.org/10.1676/0043-5643\(2000\)112\[0233:PCOFWT\]2.0.CO;2](https://doi.org/10.1676/0043-5643(2000)112[0233:PCOFWT]2.0.CO;2)
- Vitz, A. C., and A. D. Rodewald. 2011. Influence of condition and habitat use of survival of post-fledgling songbirds. *Condor* 113(2):400-411. <https://doi.org/10.1525/cond.2011.100023>
- 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. *Condor* 113(4):834-842. <https://doi.org/10.1525/cond.2011.110009>
- 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* 19(1):75-80. <https://doi.org/10.1665/034.019.0113>
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46: S120-S139. <https://doi.org/10.1080/00063659909477239>
- White, J. D., and J. Faaborg. 2008. Post-fledgling movement and spatial habitat-use patterns of juvenile Swainson's Thrushes. *Wilson Journal of Ornithological Society* 120(1):62-73. <https://doi.org/10.1676/06-142.1>
- White, G. C., and R. A. Garrot. 1990. Analysis of wildlife radio-tracking data. Academic, San Diego, California, USA.
- Wightman, C. A. 2009. Survival and movement of fledgling Western Bluebirds. *Southwest Naturalist* 54:248-252. <https://doi.org/10.1894/MH-33.1>
- Yackel-Adams, A. A., S. K. Skagen, and R. D. Adams. 2001. Movements and survival of Lark Bunting fledglings. *Condor* 103 (3):643-647. <https://doi.org/10.1093/condor/103.3.643>
- Yackel-Adams, 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* 87(1):178-188. <https://doi.org/10.1890/04-1922>
- Young, A. C., W. Cox, J. P. McCarty, and L. Wolfenbarger. 2019. Postfledgling habitat selection and survival of Henslow's Sparrow: management implications for a critical life stage. *Avian Conservation and Ecology* 14(2):10. <https://doi.org/10.5751/ACE-01418-140210>
- Zimmerman, J. L. 1963. A nesting study of the Catbird in southern Michigan. *Jack Pine Warbler* 41:142-164.

