Department of Defense
Legacy Resource Management Program

PROJECT NUMBER (12-343)

Meta-population dynamics of Le Conte's Thrasher (*Toxostoma lecontei*): a species at risk on three southwestern military installations
Year 3

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AZ Game and Fish Department
2015

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2015

RECOMMENDED CITATION

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.

ACKNOWLEDGMENTS

Funding was provided by the Department of Defense Legacy Resource Management Program, Project #12-343. Special thanks to Casey Allen, Myriam Hanna, Christina Kondrat-Smith, Ronald Mixan, Eduardo Moreno, and Matt Pollock for field support. We thank the representatives of military installations in the Sonoran Desert Conservation Partnership Team for sharing with us their management goals and research ideas. Thanks to John Arnett and Aaron Alvidrez of 56th Range Management Office, Luke Air Force Base, Abigail Rosenberg, Marine Corps Air Station-Yuma, and Daniel Steward, U. S. Army Yuma Proving Ground, for logistic support, land access permits, and editorial review. This project is also indebted to Ray Schweinsburg, Mike Ingraldi, Shawn Lowery and Renée Wilcox for valuable logistical and administrative assistance.

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EXECUTIVE SUMMARY

Natural resource managers need information on sensitive, threatened and endangered species that occur on Department of Defense (DoD) land to ensure military planning is compatible with sensitive species management. One such species is the Le Conte's Thrasher (*Toxostoma lecontei*; LCTH), listed as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service, and as a Species of Greatest Conservation Need by the Arizona Game and Fish (AZGFD) and California Fish and Wildlife Departments. In response to information needs, AZGFD studied the distribution, occupancy status, habitat associations and fledgling movement patterns to increase our knowledge of the ecology and behavior of LCTH in southwestern Arizona.

Because juveniles did not disperse during this study, we used all available telemetry data to summarize post-fledgling movement. Rather than disperse, post-fledglings stayed with adults or within parent territories. Furthermore, we determined that LCTH do not inhabit obvious habitat patch size categories (e.g., 1-10 ha, 11-50 ha) within our study area, but respond to a gradation of habitat. Thus, without readily available habitat patches to stratify surveys, we used surveys in an occupancy format to locate as many nests and juveniles as possible. This allowed us to estimate post-fledgling home range with fixed kernel density estimates to determine minimum habitat patch size requirements. We also used survey data to estimate LCTH occupancy and detectability, and to refine the LCTH Prediction of Occurrence (PO) Model with data from all three years.

The Arizona Game and Fish Department previously developed a protocol, which we followed to survey for LCTH during the breeding season on Barry M. Goldwater Range (2011-2013) and Yuma Proving Ground (2011-2012). Across the three DoD installations, we detected 183, 140, and 186 LCTH in 2011, 2012, and 2013, respectively. As a foundation for models used in estimating LCTH detection and occupancy probabilities, we developed ten *a priori* models based on LCTH biology and life history strategies. This candidate suite of models contained habitat (e.g., total length of wash in plot) and landscape attributes (e.g., NRCS soil association, vegetative association, elevation, and precipitation) potentially associated with LCTH occupancy. The estimated Proportion of Area Occupied by LCTH was 0.78 (SE ±0.04) and the detection probability was 0.54 (SE ±0.06) for all three years (2011-2013) across the study area. The highest ranking occupancy model contained four covariates: Soils281 (Momoli-Denure-Carrizo), Soils282 (Why-Wellton-Gunsight-Growler-Denure), Soils283 (Mohall-Denure-Coolidge), and slope.

Our analysis used model-averaged parameter estimates from the best performing occupancy models as predictive variables in the LCTH PO Model regression equation. This model predicts LCTH distribution using habitat associations in terms of occupancy probabilities. We reclassified the model into three LCTH occupancy probability intervals: low (0-31%), medium (31-61%), and high (61-92%). Overall, the LCTH PO model performed well, as goodness of fit was high ($\chi^2 = 9.578$, $P = 0.296$), and the total number of plots with LCTH detections increased in accordance with respective PO model classes.

Survey data from 2013 was used to locate and monitor all LCTH nests for the telemetry component of our study. We then captured juvenile LCTH and used radio telemetry to determine movement patterns, survivorship and home range size. Because fixed kernel estimates produce a utilization distribution or probability density surface consisting of an individual's likelihood of occurrence, we used this method to estimate juvenile home range and core areas. Fourteen birds were radio-marked, from which three survived until the end of the study period. Mean survival of post-fledgling juveniles was 46.13% (SE ±7.69). Average distance between fledglings and respective nests was 678.94 m (SD ±150.03; median 721.89; range 441.91-825.17). Maximum movement distance between fledglings and respective nests averaged 1732.87 m (SD ±420.05; median 1584; range 1321.77-2353.06). Average home range was 364.61 ha (SD ±224.35; median 235.35; range 222.37-747.47). Average core area was 87.28 ha (SD ±40.88 median 66.18; range 48.3-145.47).

In this study, we increased total survey effort for LCTH, evaluated the movement patterns of LCTH fledglings, estimated LCTH occupancy and detectability and developed a landscape-scale predictive model for LCTH. This was the first radio-telemetry study to examine the survival, movements and home range of post-fledging LCTH. Estimates of occupancy and detection probabilities for LCTH across the three DoD installations and three years allowed us to refine the LCTH PO model, and provide a predictive index of LCTH habitat. These efforts together will aid in the long-term management of this sensitive species on DoD land and surrounding region.

INTRODUCTION

The Department of Defense (DoD) manages 1,032,965 ha of Sonoran Desert and shares responsibility for natural resource conservation in this ecoregion (Marshall et al. 2000). Barry M. Goldwater Range (BMGR) East and West are jointly managed by the U.S. Air Force and U.S. Marine Corps, respectively, to train aircrews for combat missions (BMGR 2012). The Yuma Proving Ground (YPG) is used for testing equipment and personnel in a desert environment (USYPG 2012). Natural resource monitoring and management at BMGR and YPG is directed by Integrated Natural Resources Management Plans (BMGR 2012, USYPG 2012). Natural resource managers require an understanding of the temporal and spatial distribution of species of concern to meet the objectives required by these management plans. One such species is the Le Conte's Thrasher [(*Toxostoma lecontei*) LCTH], listed as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS 2008), and a Species of Greatest Conservation Need by the Arizona Game and Fish (AZGFD; Latta et al. 1999, AGFD 2012) and California Fish and Wildlife Departments (California Partners in Flight 2006, CDFG 2007).

The Le Conte's Thrasher is associated with the Mojave Desert and the Lower Colorado River Valley subdivision of the Sonoran Desert in the southwestern United States and northwestern Mexico (Sheppard 1996, Corman and Wise-Gervais 2005). Population declines of this species appear to be associated with habitat loss and fragmentation, primarily in the San Joaquin Valley of California (California Partners in Flight 2006, Coachella Valley Multiple Species Habitat Conservation Plan 2007), and in Arizona adjacent to agriculture and urban development (Corman and Wise-Gervais 2005). A more thorough understanding of the distribution, occupancy status, habitat associations, and fledgling movement patterns of LCTH will aid in preventing future declines.

Most of our knowledge regarding LCTH population biology originates from an intensive banding study conducted by Sheppard (1996) within the San Joaquin Valley of California. Fletcher (2009) used a multi-model approach to identify important environmental and ecological characteristics of this species in Nevada. Blackman et al. (2010) studied microhabitat characteristics associated with LCTH detection locations in the San Cristobal Valley at BMGR East. Determining the proportion of area occupied for this species was first studied in Arizona by Blackman et al. (2011) and continued in 2012 with the addition of predictive habitat modeling (Blackman et al. 2012). Jongsomjit et al. (2012) also used occupancy and predictive habitat modeling to study LCTH distribution in the Carrizo Plain National Monument, CA. Although much uncertainty remains, these studies have all contributed to our understanding of LCTH across its range in the southwestern U.S.

While the range of this species is known, delineating a finer-scale distribution will facilitate effective management. The occupancy status and habitat associations of LCTH will allow us to determine potential impacts of military training activities on LCTH habitat. Describing LCTH fledgling movement patterns will aid in understanding the overall population distribution and dynamics. This knowledge will allow the DoD to make more informed management decisions and aid in the long-term sustainability of LCTH populations.

Lack of suitable habitat and restricted access inhibited regular access to YPG; thus, our research focused LCTH surveys, nest monitoring, and telemetry in 2013 on BMGR. However, we used survey data from YPG obtained in 2011 and 2012 as part of our occupancy and predictive modeling in 2013.

OBJECTIVES

1) Determine the dispersal patterns of juvenile LCTH.
2) Determine and map the minimum habitat patch size used by nesting LCTH.
3) Provide specific habitat management recommendations that would aid in maintaining the long-term persistence of the LCTH.

When these initial objectives were developed, we made two primary assumptions. First, we assumed LCTH juveniles disperse from the natal territory within the first spring. Second, we assumed LCTH occupy a habitat that consists of spatially isolated suitable patches in a landscape of unsuitable habitat. However, at the conclusion of field data collection in 2013, our research determined that the ecology of LCTH on BMGR violated these assumptions. The first assumption was violated when LCTH juveniles that were marked did not leave the natal territory. The second assumption was violated when we determined that LCTH habitat did not occur in the expected patchy distribution. Although LCTH occurrence is non-uniform, its suitable habitat is continuous throughout the study area. Therefore, we redeveloped these objectives into tasks that determined the distribution, occupancy status, habitat associations and fledgling movement of LCTH. These four tasks provide a thorough investigation of the same root ecology that was intended with the initial objectives without assumption violations. Similarly, these tasks will still help DoD balance mission requirements and LCTH conservation.

TASKS

1) Survey for LCTH on BMGR in 2013;
2) Determine LCTH post-fledging home range and movement patterns;
3) Estimate LCTH occupancy and detectability at BMGR, YPG, and surrounding areas with data from all survey years (2011-2013); and
4) Refine the LCTH habitat associations model [Prediction of Occurrence (PO) Model] developed in 2012 for BMGR, YPG, and surrounding areas by incorporating 2013 LCTH survey results.

STUDY AREA

Barry M. Goldwater Range East and West

The land-management authority for the eastern 445,154 ha of BMGR is the 56th Range Management Office (56 RMO) at Luke Air Force Base, Phoenix, AZ. The western portion of BMGR consists of approximately 242,811 ha and is managed by the Range Management Department at Marine Corps Air Station Yuma in Yuma, AZ. BMGR occupies portions of Pima, Maricopa and Yuma counties, from the City of Yuma to several miles East of Gila Bend, Arizona (Figure 1). BMGR is bounded to the south by Mexico and Cabeza Prieta National Wildlife Refuge, to the north by Interstate-8 and a mix of private and public lands, and to the east by the Tohono O’odham Nation and Bureau of Land Management Sonoran Desert National Monument.

Elevations at BMGR range from 61 m in the west to 1,128 m in the Sand Tank Mountains at the eastern border (BMGR 2012). Temperatures range from below 0° C to 49° C, with a range-wide average annual rainfall of 12.7 cm (BMGR 2012). Our study focused on the broad and flat intermountain valleys characterized by sparse vegetative cover and sandy alluvium. The Lower Colorado River subdivision is the predominant vegetative community on BMGR and is characterized by extremely drought-tolerant plant species consisting primarily of creosote bush (*Larrea tridentata*), bursage (*Ambrosia* spp.), paloverde (*Parkinsonia* spp.), saguaro (*Carnegiea gigantea*) and other cacti (e.g., *Cylindropuntia* spp.; Brown 1994, Marshall et al. 2000). The broad, flat and sparsely vegetated desert plains are dissected by numerous incised washes characterized by vegetation consisting of paloverde, ironwood (*Olneya tesota*), smoketree (*Psorothamnus spinosus*), catclaw acacia (*Acacia greggii*), mesquite (*Prosopis* spp.), ocotillo (*Fouquieria splendens*) and other shrubs. Because LCTH does not occupy the Upland Subdivision, we do not provide a detailed description of this community. The Arizona Upland Subdivision of the Sonoran Desert occurs on elevated hills and mountain slopes of BMGR East, primarily east of State Route 85.

Yuma Proving Ground

YPG is managed by the U.S. Army and totals approximately 345,000 ha. YPG occupies portions of La Paz and Yuma counties near Yuma, Arizona (Figure 1). Kofa National Wildlife Refuge and YPG share a 93 km long boundary (USDI 1996). Elevations at YPG range from sea level to 878 m. The average temperatures on YPG are between 42.7° F (December) and 106.7° C (July), with average annual rainfall of approximately 8.8 cm (WRCC 2013).

The predominant vegetation association at YPG is the Lower Colorado River subdivision of the Sonoran Desert. As with BMGR, the broad, flat plains of YPG are dissected by numerous incised washes and consist of similar vegetation species. The elevated hills and mountain slopes at YPG are within the Sonoran Desert's Arizona Upland Subdivision.

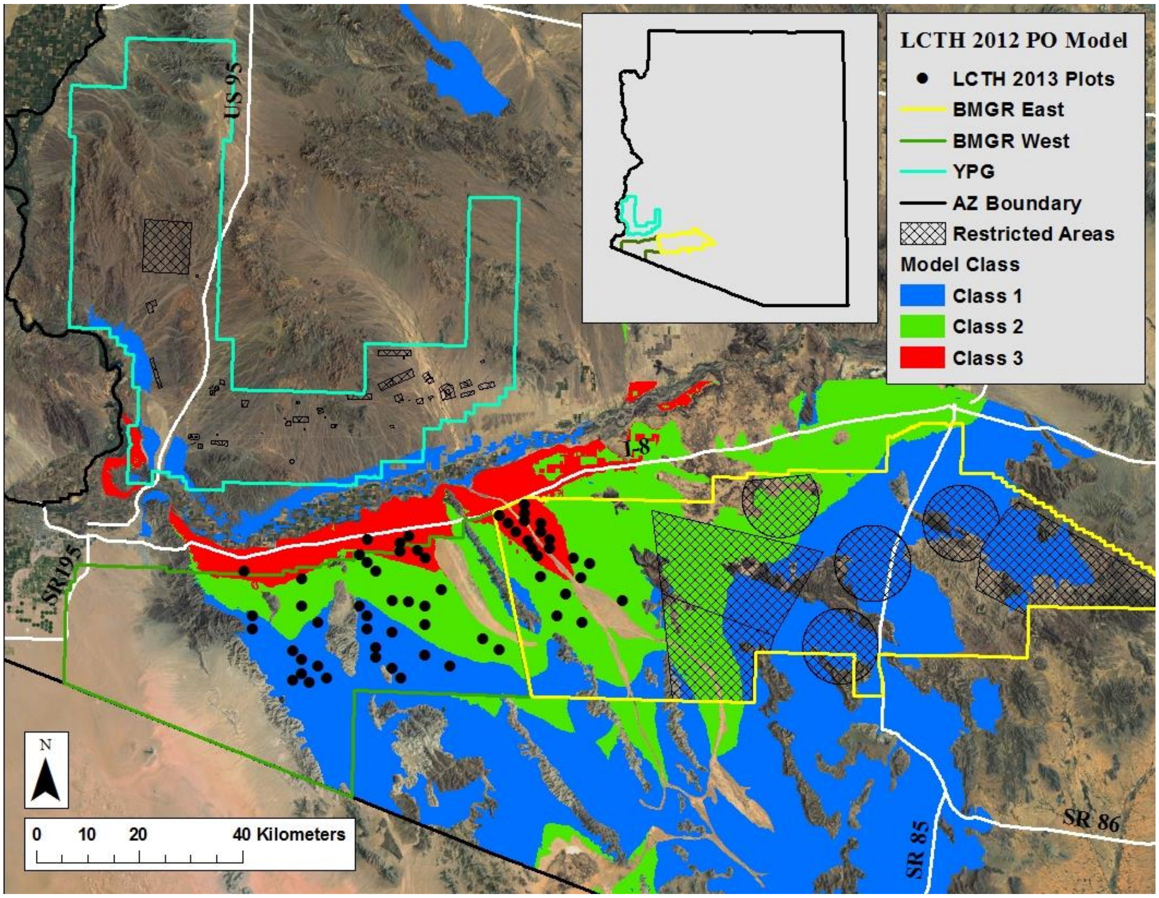

Figure 1. Study area locations at BMGR (East and West) and YPG, and Le Conte's Thrasher Predictive of Occurrence (PO) Model from 2012 depicting low (blue) to high (red) thrasher occupancy probabilities. Points represent plots surveyed for thrashers in 2013.

METHODS

Task 1: Survey for LCTH on BMGR in 2013.

In order to survey for LCTH presence/absence on BMGR, we created a sampling grid and used broadcast calls. As the basis for our survey framework, we used the spatially-explicit model we developed in 2012 (Blackman et al. 2013). This model produced a 3-class ranking of potential LCTH occurrence throughout the study area ranging from class one (least suitable LCTH habitat) to three (most suitable LCTH habitat). Using our model, we created a stratified random sample of 60 plots distributed evenly across the three model classes on BMGR (Figure 1) using ArcGIS (ESRI 2012). Some areas were excluded from surveys (i.e. restricted areas), and areas outside of range boundaries were included to ensure even point distribution within all three model classes. Plots were distributed at least two km apart to ensure independence among LCTH detections and prevent spatial autocorrelation (Ord and Getis 1995).

The Arizona Game and Fish Department previously developed a protocol for previous research (Blackman et al., 2012 and 2013), which we followed in this study to survey for LCTH during the breeding season. Our LCTH surveys at each plot consisted of ten broadcast survey points (Figures 2). Broadcast surveys began at each of the plot locations (point one of each survey) and continued east at 400 m increments along two transects. Transects included five points along one transect and five points along a second transect parallel to and 400 m south of the original transect (Figure 2). To eliminate double-counting LCTH individuals, we skipped broadcast points directly adjacent to points where LCTH were located. We surveyed plots on three occasions between January and April, 2013 along the same transects implemented during the first survey pass.

At each broadcast station, we spent one minute looking and listening for LCTH prior to broadcast calling. At the conclusion of the first minute, we broadcast a recording of LCTH vocalizations for 90 seconds in a direction perpendicular to the transect line, followed by a 2-minute period of observation. We then broadcast the LCTH vocalizations for another 90 seconds in the direction opposite of the first broadcast direction, followed by another 2 minutes of observation. If a LCTH was detected, we stopped the broadcast, spent 15 to 20 minutes observing the LCTH and searching for potential nests, and then moved to the next point. We documented the location with a hand-held GPS using the NAD 83 datum projected in UTM Zones 11 and 12, and identified the tree/shrub species of the perch where each LCTH was first detected.

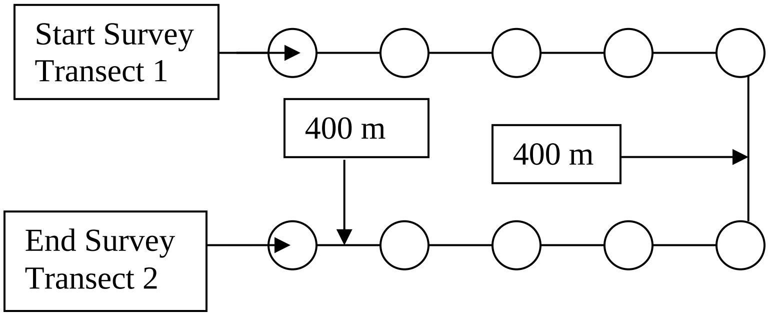

Figure 2. Schematic of parallel transects of call-broadcast survey points conducted by one surveyor. All points on each transect are 400 m apart. Transects are also 400 m apart.

Task 2: Determine LCTH post-fledging home range and movement patterns.

Survey points where we detected LCTH were used as the beginning point for nest searches. Our location efforts also included opportunistic LCTH nest searches as time permitted. If LCTH breeding activity was observed during surveys (e.g., pair courtship, mating or nest building), we inspected suitable nest substrates (e.g., paloverde, mesquite and cholla) for evidence of nesting (e.g., newly constructed or freshly lined nest, presence of eggs or incubating female). Once a nest was located, we monitored it every three to five days to determine nestling ages and to estimate fledging dates.

Our research affixed a radio transmitter to one to two nestlings from each nest two to three days before the projected date of fledging. Transmitters were attached to multiple nestlings from some nests to increase sample sizes (De Solla et al. 1999, Barg et al. 2005, Suedkamp Wells et al. 2008, Vormwald et. al 2011). Transmitters were attached using a leg-loop harness constructed of an elastic cotton–nylon blend material allowing for quick adjustment in the field (Rappole and Tipton 1991). We glued transmitters above the synsacrum, oriented the antenna down the tail, and placed the harness loosely around each leg to allow for the bird's growth. Other researchers have found this attachment method comparatively reliable and safe with other species (Rappole and Tipton 1991). Transmitters were programmed to last 14 weeks and weighed ~3% of bird mass (1.8 g; BD2, Holohil Systems, Carp, Ontario). All birds were banded with a U.S. Geological Survey aluminum band, weighed, measured (tarsus, wing, and bill lengths), and returned to the nest.

Our research tracked radio-marked birds multiple times per day and obtained between one and six locations between 0500 and 1900 using the homing method, which involved tracking individuals until a visual confirmation was obtained (White and Garrott 1990). Locations were collected at least two hours apart to ensure juveniles had sufficient time to move and to prevent autocorrelation of points (Otis and White 1999). We used R-1000 receivers and folding aluminum three-element Yagi antennas (Advanced Telemetry Systems, Isanti, Minnesota). Locations were recorded with a hand-held GPS, and we also recorded juvenile behavior (e.g., foraging, begging, form of locomotion) and presence of conspecifics. If a fledgling was not relocated, we searched the area within a two km radius from the last known location using an all-terrain vehicle, a vehicle equipped for radio telemetry, or on foot. Attempting to determine the cause of all mortalities, we categorized birds as “unknown” if a transmitter was recovered with no signs of predation, the transmitter failed, or was lost.

Our research estimated fledging survival, juvenile movement distances, and home range. To calculate fledging survival, we used the Kaplan-Meier method (Kaplan and Meier 1958) in SPSS v20 (IBM Corp. 2011). To calculate the cumulative survival probability for the study period, we censored birds with unknown fates and omitted juveniles that were depredated before fledging (Berkeley et al. 2007). Using the maximum distance recorded for each fledgling per day, we calculated average distance from nests. Using the total recorded distance moved by fledglings per day, we calculated average successive movements. Home range was defined as the extent of area with a defined probability of occurrence during a specified time period (Kernohan et al. 2001). We considered all post-fledging locations to be a part of their post-fledging home range. For all fledglings with at least 30 telemetry locations, we used the fixed kernel method to estimate juvenile home range and core areas (Seaman et al. 1999). Kernel methods are often preferred over the minimum convex polygon method because the Kernel Density Estimate (KDE) produces a utilization distribution or probability density surface consisting of an individual’s likelihood of occurrence (Kernohan et al. 2001, Laver and Kelly 2009, Keating and Cherry 2009, Kie et al. 2010). Spatial analyses were performed using Geospatial Modeling Environment (GME, version 0.7.2.0 RC2; Beyer 2012) and ArcGIS. We calculated KDE in GME using the least-squares cross-validation smoothing parameter and a cell size of 50. Once the KDE raster was generated for each juvenile, we calculated isopoly contours for the 50%, 90% and 95% intervals. Core areas and home range were defined as the areas bounded by the 50% and 95% contours, respectively.

Task 3. Estimate LCTH occupancy and detectability at BMGR, YPG, and surrounding areas with data from all survey years (2011-2013).

Le Conte’s Thrasher presence/absence data were analyzed using the software program PRESENCE version 5.8 (Hines 2013) at the plot scale to avoid spatial autocorrelation and ensure that the closure assumption was not violated. To estimate the Proportion of Area Occupied (PAO) and detection probability for LCTH, we used occupancy modeling (MacKenzie et al. 2002, MacKenzie 2006, MacKenzie et al. 2006). Within an information-theoretic context, we determined the relationship of presence/absence with habitat and landscape covariates (Burnham and Anderson 2002). We incorporated the presence/absence of LCTH across 60 plots surveyed in 2013, 40 plots surveyed in 2012 and 30 plots surveyed in 2011. These presence/absence data were then used as the basis for the development of occupancy modeling. Parameters estimated included; (Ψ_i) = the probability that a species is present at site *i*, and p_{it} = the probability that a species is detected at site *i* during visit *t*. Based on LCTH biology and ecology, we developed ten *a priori* models. These ten candidate models contained combinations of the following nine covariates (Table 1): total length of wash (ASLD 2011) and roads (Tiger 2010) in plot;

dominate soil (NRCS 2012) and vegetative (SWReGAP 2007) association; average elevation and slope (U.S. Geological Survey, 30 m National Elevation Dataset; Gesch et al. 2002); average minimum and maximum temperature, and average precipitation (WorldClim, 2.5 arc-minute resolution; Hijmans et al. 2005). To estimate the influence of habitat covariates on LCTH occupancy, we used the most parsimonious model of detection probability (Kroll et al. 2007, Henneman and Andersen 2009, Collier et al. 2010, Hansen et al. 2011).

Our research used Akaike's Information Criterion (AIC) to rank all models in order of goodness of fit (MacKenzie and Bailey 2004) and compare AIC weights and ΔAIC to assess model uncertainty (Burnham and Anderson 2002). We ranked all candidate models with respect to AIC values and interpreted the lowest AIC value as the best fit model. Models within $<4\Delta AIC$ of the highest ranked model were considered to be best supported by the data and competed with the most parsimonious model because these models captured >75% of model weight (Burnham et al. 2011).

To test for overdispersion in the data, we assessed Hosmer and Lemeshow goodness of fit of the global model using a bootstrap of 1,000 iterations to obtain the variance inflation factor ($\hat{c}$; Hosmer and Lemeshow 1989, Burnham and Anderson 2002). To account for model selection uncertainty, we computed parameter and variance estimates within the most supported models (Zar 1999, Sokal and Rohlf 2001, Burnham and Anderson 2002). We summed AIC weights across highest ranked models to assess the relative importance of individual covariates.

Table 1. Candidate set of occupancy models applied to Le Conte's Thrasher data gathered during repeated surveys on the DoD lands in southwestern Arizona. Estimated parameters include: Ψ_i = the probability that a species is present at site *i*, and p_{it} = the probability that a species is detected at site *i* during visit *t*.

Occupancy Model	Model Description
ψ(.) *p*(t)	Constant occupancy, survey pass dependent detection
ψ(Soil) *p*(t)	Soil class dependent occupancy, time dependent detection
ψ(StreamLength) *p*(t)	Stream Length dependent occupancy, time dependent detection
ψ(MinTemp) *p*(t)	Minimum temperature dependent occupancy, time dependent detection
ψ(MeanTemp) *p*(t)	Mean temperature dependent occupancy, time dependent detection
ψ(Precip) *p*(t)	Precipitation dependent occupancy, time dependent detection
ψ(RDLength) *p*(t)	Road length dependent occupancy, time dependent detection
ψ(Veg) *p*(t)	Vegetation dependent occupancy, time dependent detection
ψ(Slope) *p*(t)	Slope dependent occupancy, time dependent detection
ψ(Elev) *p*(t)	Elevation dependent occupancy, time dependent detection

All units converted to metric (i.e. cm, m, km and Celsius). Road and Stream length are defined as total length within each LCTH plot.

Task 4. Refine the LCTH habitat associations model [Prediction of Occurrence (PO) Model] developed in 2012 for BMGR, YPG, and surrounding areas by incorporating 2013 LCTH survey results.

To refine the LCTH Prediction of Occurrence (PO), our research used the output from the top performing occupancy models described under task three. We used model-averaged parameter estimates from the best performing occupancy models as the predictive variables in the LCTH PO model regression equation (Hosmer and Lemeshow 1989, Burnham and Anderson 2002). The regression equation defines the mathematical combination of covariates that best predict LCTH occurrence. To evaluate the power of the regression formula, we graphically modeled the inverse logit using ArcGIS raster calculator. This transformation graphically represents the regression output in terms of probability. The initial logistic regression equation was expressed as the logodds that covariates indicate LCTH detection. First, we converted logodds to the probability that covariates would predict an LCTH location by converting logodds of detection to odds of detection by exponentiating (e_{logodds} = odds). Finally, we converted odds of detection to probability of detection (probability = odds/(1+odds). Selecting spatial resolution with the best fit, we converted each covariate to a 30 m pixel dataset (Fisher and Tate 2006). We reclassified the resulting layer into three LCTH occupancy probability intervals: low (0-31%), medium (31-61%), and high (61-92%). To summarize the dominate PO class of each survey plot for each year, we used Zonal Statistics in ArcGIS to validate plot-level occupancy with the model. To assess the accuracy of our model, we used Hosmer and Lemeshow goodness of fit from binomial logistic regression in SPSS v20 (IBM Corp. 2011).

RESULTS

Task 1: Survey for LCTH on BMGR in 2013.

Our research detected 186 LCTH at 94 discrete points between January and April 2013 across BMGR (Appendix 1). At BMGR East, we detected LCTH at 61 discrete points in 18 plots (Appendix 1). Of the 39 plots surveyed at BMGR West, we detected LCTH at 67 discrete points within 25 plots (Appendix 1). Additionally, 26 LCTH were observed incidentally between survey points or en route to survey plots during our study. Overall, we detected LCTH in 43 (72%) of the 60 survey plots. In the low, medium and high probability classes, we observed LCTH at 11, 15 and 17 plots from the 2012 PO Model, respectively (Table 2).

Table 2. Number (and percentage) of plots where LCTH were detected during 2013 within three predictive model classes delineated by 2012 PO Model. Each stratum contained 20 plots surveyed in 2013.

	2012 Predictive Model Class		
	(1) Low	**(2) Medium**	**(3) High**
2013 Plots with LCTH Detections	11 (55)	15 (75)	17 (85)
2013 Plots with No LCTH Detections	9 (45)	5 (25)	3 (15)

Task 2: Determine LCTH post-fledging home range and movement patterns.

Our research detected two LCTH simultaneously at 52 discrete points within 31 sample plots. These potential LCTH pairs were used to locate and monitor 23 nests during this study. Of these 23 nests, we banded 18 nestlings from eight nests. These individuals were banded just prior to the expected fledging date (approximately 11-14 days after hatching). The mean brood size was 2.4 (SD ±0.62; median 2.5; range: 1-3). Using a maximum of two nestlings per sample nest, we radio-marked fourteen nestlings (Figure 3).

Our research detected nest depredation at 17 nests. This depredation consisted of: destroyed nests, complete depredation of all nestlings, and depredation of some young (Appendix 2). The remaining nests possibly fledged before we could attach transmitters or failed due to climatic events (e.g., severe dust storms and hard freezes). Eleven of the 14 radio-marked birds were depredated during the survey period; seven as nestlings and four as fledglings. Thus, movement data was obtained for the four fledglings that were depredated during our study, and the three fledglings that survived past our total study tracking duration. Data from five birds were sufficient to calculate home range estimates (≥ 30 telemetry locations; Seaman et al. 1999). In order to produce movement data for first and second clutch fledglings, we captured nestlings at two nests reused for second broods. Immediately after fledging, juveniles exhibited limited flight and used available cover adjacent to washes closest to the nest. Substantial variation in the transmitter range was detected (200–1100 m).

With data for seven LCTH (juveniles that were not depredated in the nest; Figure 4), we calculated survival probabilities, post-fledging home range, and movement patterns. Mean survival of post-fledglings was 46.13% (SE ±7.69) during the first 58 days of the post-fledging period (Table 3). Survival probability was inversely related to fledgling age, as survivorship decreased with greater time spent out of the nest. We mapped the detections of radio-marked birds (Appendices 3-7) and calculated home range (95% fixed kernel contour) and core areas (50% fixed kernel contour).

Average home range (95% fixed kernel estimate) for fledglings was 364.61 ha (SD ±224.35, median 235.35; range 222.37-747.47) with an average perimeter of 8.29 km (SD ±3.05; Table 4). Average core area (50% fixed kernel estimate) for fledglings was 87.28 ha (SD ±40.88, median 66.18; range 48.3-145.47) with an average perimeter of 4.19 km (SD ±1.29; Table 4). Home ranges and core areas overlapped for three birds (radio frequencies 148.2802, 148.0987 and 148.4191; Table 6).

Fledglings made dynamic movements throughout the study period, consisting of large distances away from and returning toward their nest areas (Figure 5). Average distance between fledglings and their nest was 678.94 m (SD ±150.03, median 721.89; range 441.91-825.17; Table 5). Though older fledglings consistently made longer movements (Figure 6), two birds from different nests moved >900 m shortly after fledging. Maximum movement distance between fledglings and respective nests averaged 1732.87 m (SD ±420.05; median 1584.0; range 1321.77-2353.06; Table 5).

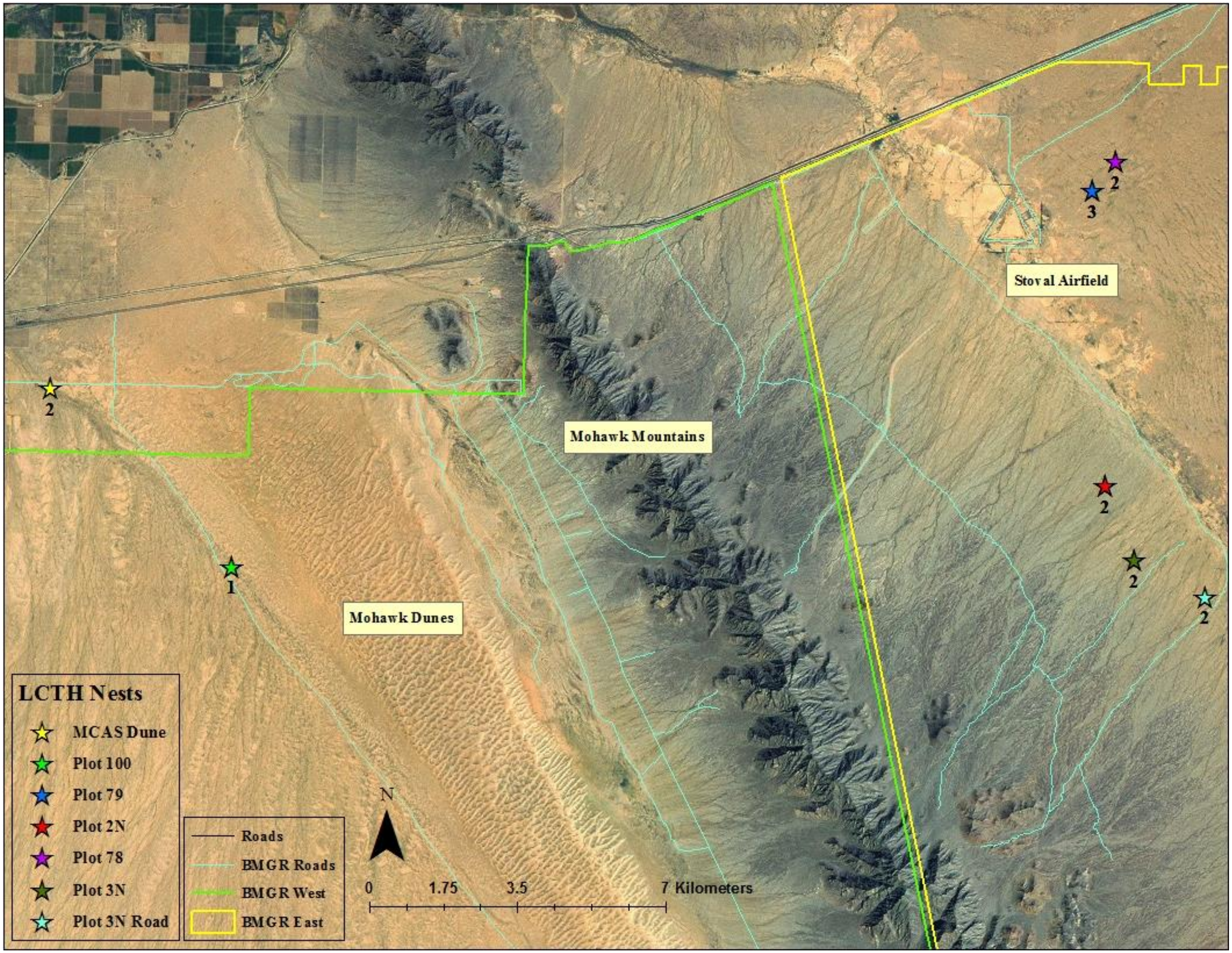

Figure 3. Locations of nest sites where Le Conte's Thrashers were captured and fitted with VHF transmitters in 2013. Numbers signify the quantity of transmitters from each nest.

Table 3. Percent survival estimates with 95% upper and lower confidence intervals for seven juvenile Le Conte's Thrashers during the first 58 days of the post-fledging period, 2013.

Mean				**Median**			
Estimate	Std. Error	Upper 95% CI	Lower 95% CI	Estimate	Std. Error	Upper 95% CI	Lower 95% CI
46.13	7.69	31.05	61.20	58.00	19.69	19.41	96.59

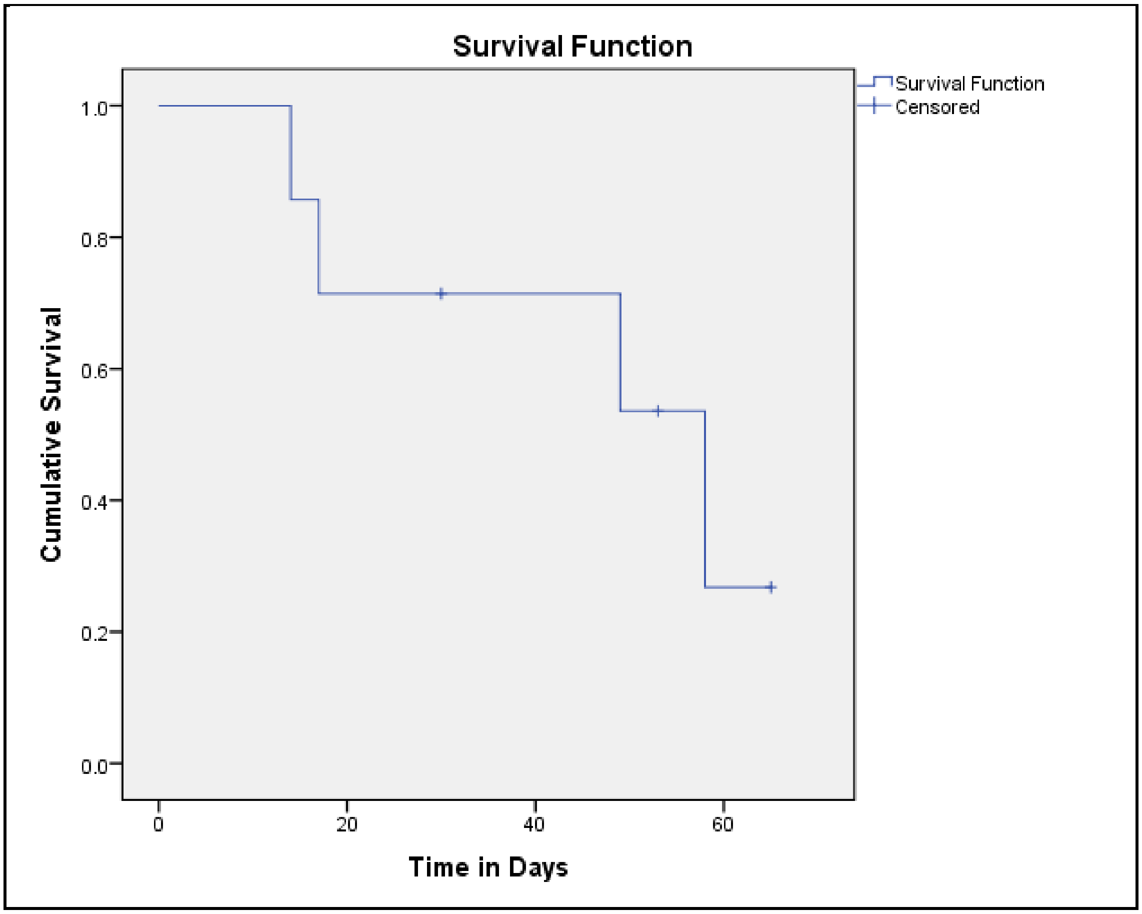

Figure 4. Survival estimates for seven juvenile Le Conte's Thrashers during the first 58 days of the post-fledging period, 2013.

Table 4. Home range (95% fixed kernel contour) and core area (50% fixed kernel contour) of five juvenile Le Conte's Thrashers obtained from 2013 telemetry data.

Plot	**Radio Frequency**	**Home Range (95% Fixed Kernel) (Ha)**	**Home Range Perimeter (Km)**	**Core Area (50% Fixed Kernel) (Ha)**	**Core Perimeter (Km)**
78	148.0987	385.10	7.78	114.02	5.96
79	148.2802	222.37	7.16	48.30	2.92
79	148.4191	747.47	13.64	145.47	4.45
3N	148.2394	235.35	6.05	62.44	2.94
3NRD	148.1800	232.75	6.83	66.18	4.65
Average		364.61 (SD ±224.35)	8.29 (SD ±3.05)	87.28 (SD ±40.88)	4.19 (SD ±1.29)
Median		235.35	7.16	66.18	4.45

Table 5. Movement statistics in relation to nest location for six juvenile Le Conte's Thrashers obtained from 2013 telemetry data.

Plot	Trans. Number	Num. of Locations	Max. Distance from Nest (m)	Mean Distance from Nest (m)
78	148.0987	57	1518.91	687.48 (SD±471.78)
78	148.9345	19	1408.54	561.15 (SD±408.63)
79	148.2802	58	1321.77	441.91 (SD±264.16)
79	148.4191	33	2145.87	756.30 (SD±664.58)
3N	148.2394	59	1649.08	825.17 (SD±345.07)
3NRD	148.1800	85	2353.06	801.61 (SD±486.46)
Average			**1732.87 (SD±420.05)**	**678.94 (SD±150.03)**
Median			**1584.0**	**721.89**

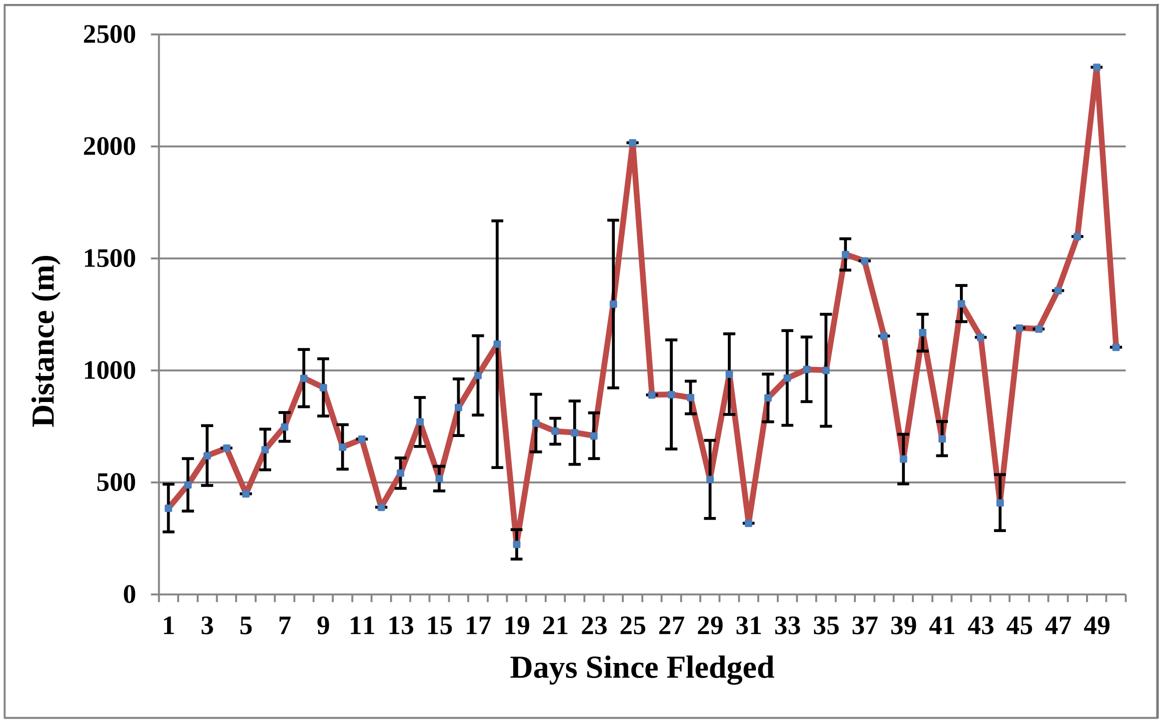

Figure 5. Maximum daily distance from nest during the first 49 days after fledging by seven juvenile Le Conte's Thrashers in southwest Arizona in 2013. Bars represent standard errors.

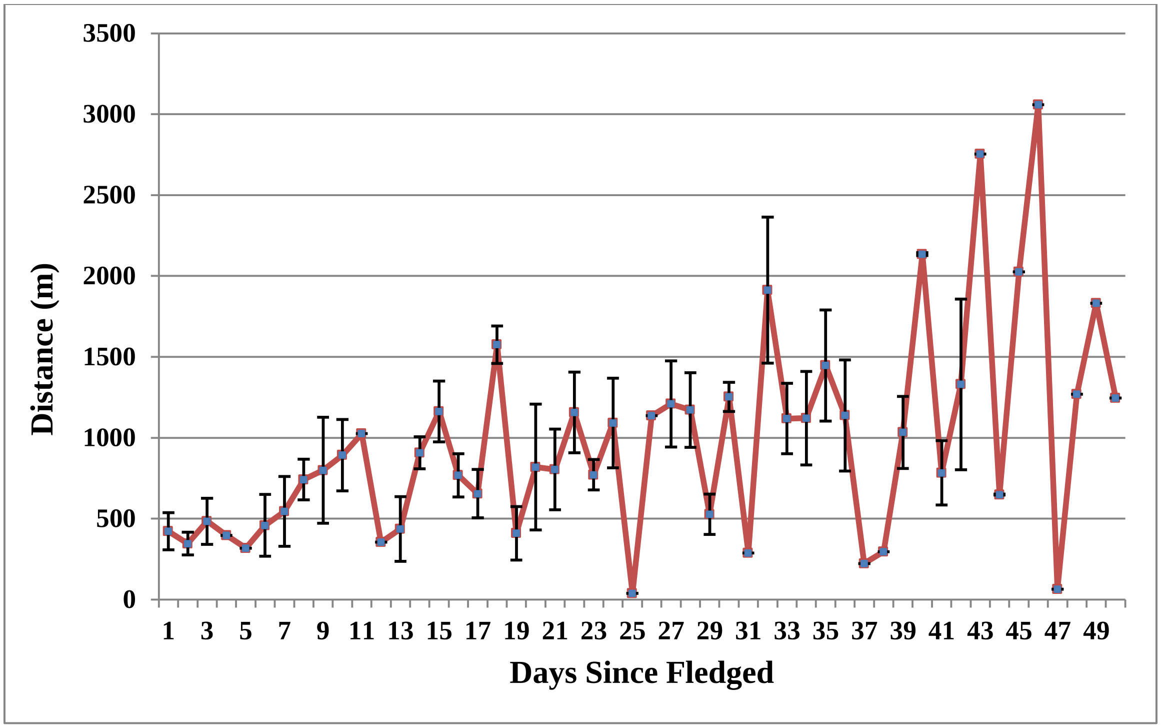

Figure 6. Successive distance moved between daily locations during the first 49 days after fledging by seven juvenile Le Conte's Thrashers in southwest Arizona in 2013. Bars represent standard errors.

Table 6. Amount of overlap of home ranges (95% fixed kernel contour) and core areas (50% fixed kernel contour) area overlap for three juvenile Le Conte's Thrashers. Juveniles from plot 79 are from the same nest but from different clutches (see maps in Appendices 3-5).

LCTH Survey Plot Number	Trans. Number	% Contour	Overlapping Area (Ha)	LCTH Survey Plot Number	Trans. Number	% Contour
79	148.2802	95	**217.95**	79	148.4191	95
79	148.2802	95	**125.44**	79	148.4191	50
79	148.2802	50	**48.30**	79	148.4191	95
79	148.2802	50	**46.89**	79	148.4191	50
78	148.0987	95	**128.81**	79	148.4191	95
78	148.0987	95	**54.76**	79	148.4191	50
78	148.0987	50	**49.11**	79	148.4191	95
78	148.0987	50	**5.43**	79	148.4191	50
78	148.0987	95	**87.38**	79	148.2802	95
78	148.0987	95	**25.91**	79	148.2802	50
78	148.0987	50	**21.10**	79	148.2802	95
78	148.0987	50	**1.70**	79	148.2802	50

Task 3. Estimate LCTH occupancy and detectability at BMGR, YPG, and surrounding areas with data from all survey years (2011-2013).

Using survey data for BMGR (2011-2013) and YPG (2011-2012), we estimated the PAO and detection probability of LCTH. The highest ranking detection model incorporated survey-specific pass as a detection covariate (Table 7). We ran occupancy models using the most supported detection model [p(Survey)] and nine site-specific occupancy covariates (Table 8). The global occupancy model provided adequate fit to the data (GOF: $\chi^2 = 13.1$, $P = 0.68$). Overdispersion was not evident in the global occupancy model ($\hat{c} = 0.83$), however, we used QAIC to adjust model weights and standard errors using a variance inflation factor of one. The estimated PAO by LCTH across the three DoD installations was 0.78 (SE ±0.04) and the naïve abundance estimate was 0.73 for all three years (2011-2013). The detection probability of LCTH across the three DoD installations was 0.54 (SE ±0.06) for all three years (2011-2013).

The highest ranking occupancy model contained four covariates: Soils281 (Momoli-Denure-Carrizo), Soils282 (Why-Wellton-Gunsight-Growler-Denure), Soils283 (Mohall-Denure-Coolidge), and slope. One other model exhibited high model weight and was within <4 ΔAIC of the best performing model (Table 8). The second most supported model contained all covariates used in the highest ranking model and additionally included stream length (Table 8). Soils283 contained the highest parameter importance followed by, in decreasing order of importance, Soils282, Soils281, slope, and stream length (Table 9). Slope was the only covariate with a negative parameter estimate (Table 9). Because stream length exhibited high standard error with respect to its parameter estimate, it was omitted from predictive modeling (Table 9).

Table 7. Detection models for Le Conte's Thrasher at three DoD installations in southwest Arizona. The table includes the Akaike Information Criterion (AIC), log-likelihood (-2logLik), number of parameters (*K*), Akaike difference (ΔAIC), and Akaike weight (*w*).

Model	AIC	-2logLik	*K*	ΔAIC
psi(.),p(Survey)	544.99	534.99	5	46.08
psi(.),p(.)	547.97	543.97	2	49.06

Table 8. Occupancy models for Le Conte's Thrasher at three DoD installations in southwest Arizona. The table includes the quasi-AIC ($QAIC_c$) for overdispersed data and small sample size, log-likelihood (-2logLik), number of parameters (*K*), Akaike difference ($\Delta QAIC_c$), and Akaike weight (*w*).

Model	$QAIC_c$	-2logLik	*K*	$\Delta QAIC_c$	*w*
psi(s282,s283,s281,slope); p(survey)	1665.78	519.63	8	0	0.73
psi(s282,s283,s281,slope,stream); p(survey)	1668.9	518.06	9	3.12	0.15

Table 9. Model averaged estimates and standard errors for parameters included in the best occupancy models. Bold indicates parameters used in LCTH Prediction of Occurrence Model.

Parameter	Estimate	Standard Error
SoilS281 (Momoli-Denure-Carrizo)	**1.819**	**0.978**
SoilS282 (Why-Wellton-Gunsight-Growler-Denure)	**1.588**	**0.435**
SoilS283 (Mohall-Denure-Coolidge)	**2.459**	**1.291**
Slope	**-1.139**	**0.599**
Stream Length	0.013	0.038

Task 4. Refine the LCTH habitat associations model [Prediction of Occurrence (PO) Model] developed in 2012 for BMGR, YPG, and surrounding areas by incorporating 2013 LCTH survey results.

To refine the LCTH PO model, we used model-averaged parameter estimates from the four variables ranked in the best fit model under task three (Table 9). Parameter estimates were used from Soils281, 282, 283, and slope, as all other parameters from top performing models contained high SE (Table 9). Thus, we used the following equation to predict LCTH occurrence:

$$\text{Probability} = \text{Exp}\,((1.819 * [\text{Soils281}]) + (1.588 * [\text{Soils282}]) + (2.459 * [\text{Soils283}]) - (1.139 * [\text{slope}])) / (1 + \text{Exp}\,((1.819 * [\text{Soils281}]) + (1.588 * [\text{Soils282}]) + (2.549 * [\text{Soils283}]) - (1.139 * [\text{slope}])))).$$

Model fit for the data was high ($\chi^2 = 9.578$, $P = 0.296$), and we spatially depicted the raster output of the LCTH PO Model as a color ramp of occupancy probabilities (Figure 7). We then reclassified model output categories into three probability classes and overlaid all survey plots from each year (Figures 8-10). Class 1 (0-31%) contained the most plots without LCTH detections, but contained the lowest number of total plots surveyed from 2011 to 2013 (Table 10, Figures 8-10). Classes 2 (31-61%) and 3 (61-92%) contained more plots with LCTH detections than non-detections for all years (Table 10, Figures 8-10). Totals increased according to respective PO model classes; Class 1 contained the least and Class 3 contained the most plots with LCTH detections (Table 10, Figures 8-10). Percentage of plots with LCTH detections were contained within the range of probabilities for model classes 2 and 3 (Table 10, Figures 8-10).

Table 10. Number of plots of plots where Le Conte's Thrashers were detected within three Prediction of Occurrence 2013 Model Classes. Predictive Model Class ranges represent the probability of LCTH occupancy.

Year	**Predictive Model Class**		
	(1) 0-31%	**(2) 31-61%**	**(3) 61-92%**
2011 Plots with LCTH Detections	1	5	21
2011 Plots with No LCTH Detections	2	8	2
2012 Plots with LCTH Detections	0	2	22
2012 Plots with No LCTH Detections	0	3	2
2013 Plots with LCTH Detections	0	0	43
2013 Plots with No LCTH Detections	0	3	14
% of Plots with LCTH Detections	**33**	**33**	**83**

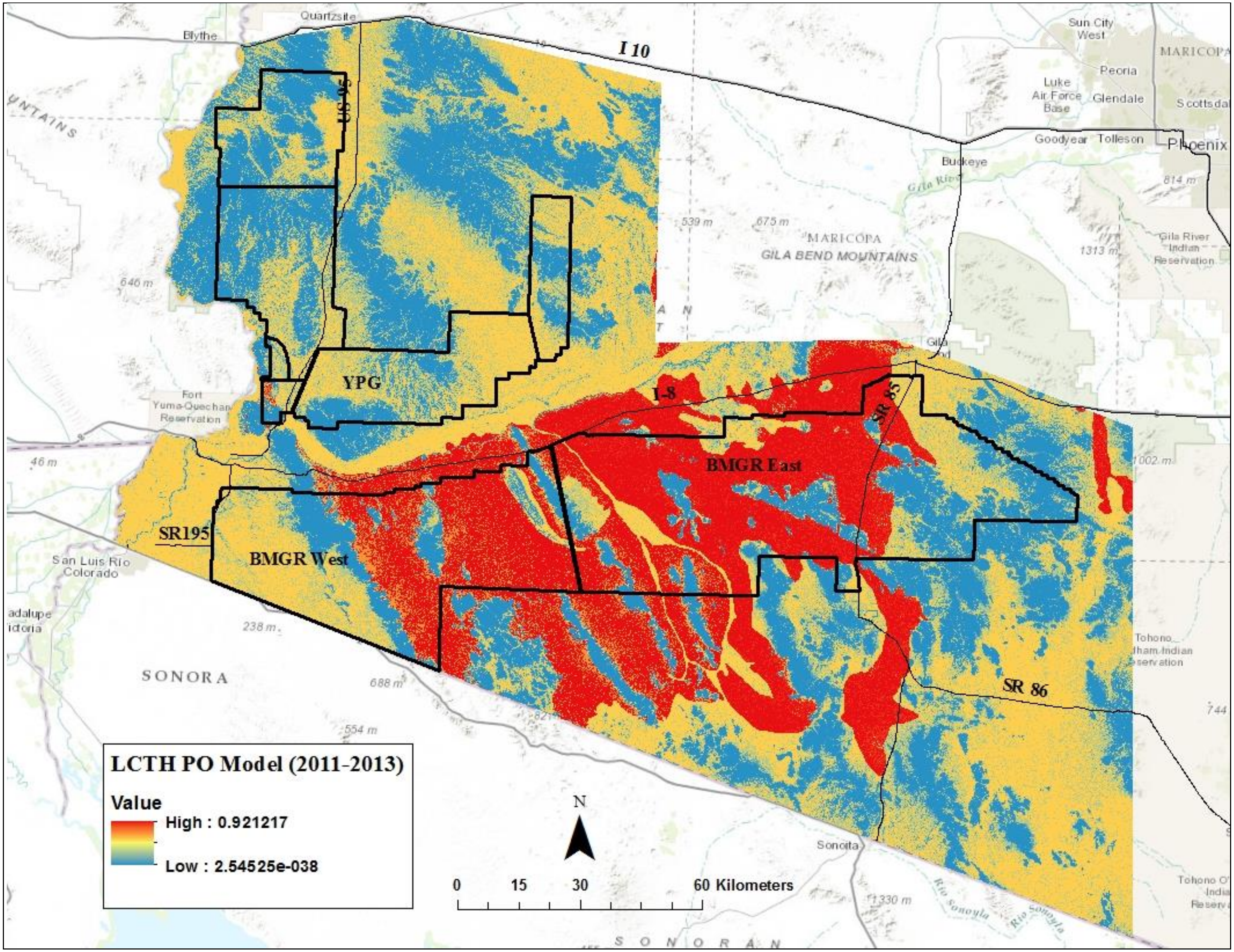

Figure 7. Prediction of Occurrence Model depicting areas with low (blue) to high (red) occupancy probabilities for Le Conte's Thrasher.

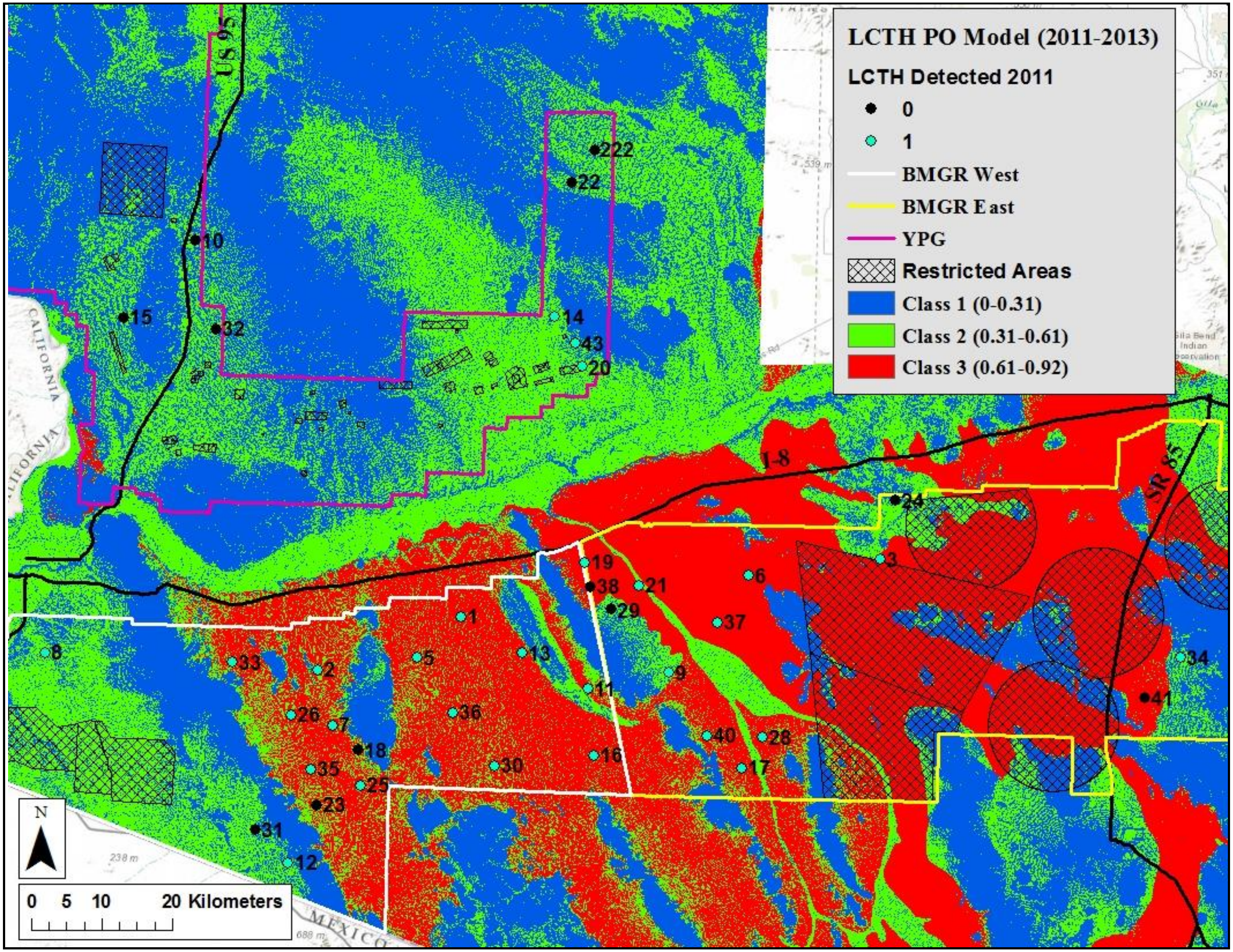

Figure 8. Plots where Le Conte's Thrashers were and were not detected during surveys in 2011 with respect to three Prediction of Occurrence classes (red = high probability to blue = low probability).

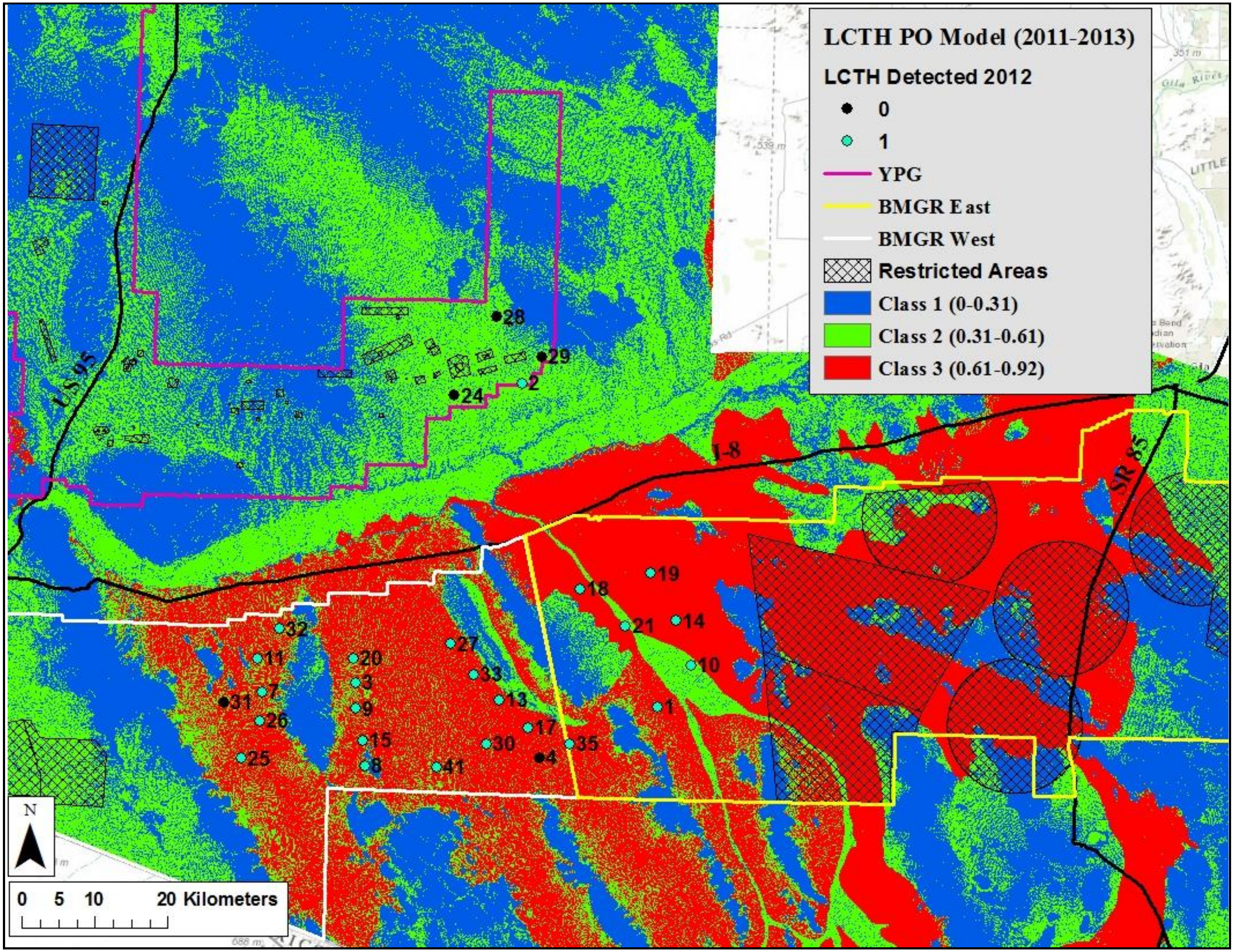

Figure 9. Plots where Le Conte’s Thrashers were and were not detected during surveys in 2012 with respect to three Prediction of Occurrence classes (red = high probability to blue = low probability).

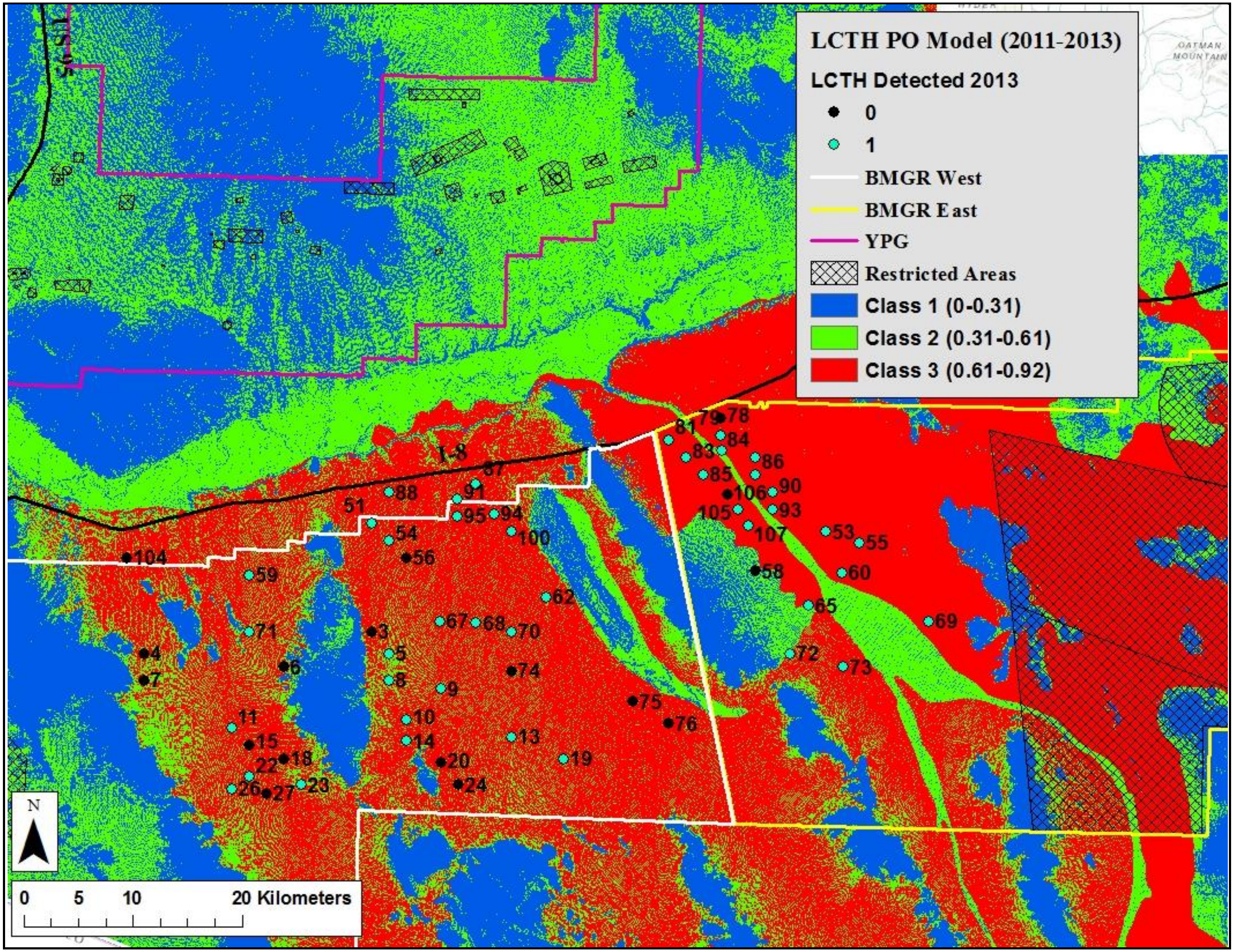

Figure 10. Plots where Le Conte's Thrashers were and were not detected during surveys in 2013 with respect to three Prediction of Occurrence classes (red = high probability to blue = low probability).

DISCUSSION

In this study, our research evaluated the movement patterns and home range size of LCTH fledglings; estimated LCTH occupancy and detectability; and developed a landscape-scale habitat association model for LCTH. This is the first study using radio telemetry to examine the survival, movements, and home range of post-fledging LCTH. We estimated the occupancy and detection probabilities for LCTH across the three DoD installations and three years. Additionally, the refined LCTH PO model provides a predictive index of LCTH habitat. These efforts together will aid in the long-term management of this sensitive species while enabling mission success on DoD lands. Furthermore, these results will assist in conservation planning for this species as project development increases on DoD land and surrounding areas.

Over the course of this study we documented LCTH presence at 509 discrete locations: 183, 140, and 186 in 2011, 2012, and 2013, respectively. Among the three DoD installations, most LCTH were detected at BMGR (East and West) because most surveys (and potential habitat) was on BMGR. Within BMGR, LCTH were not detected at plots close to mountain foothills (i.e., bajadas) or in areas with a gravelly or desert pavement surface. The distribution of LCTH was not uniform across the sampled area and the majority of detections were in areas with non-compacted sand and sparse trees. Thus, LCTH do not inhabit the entire study area despite the appearance of continuous habitat.

For juveniles with transmitters that successfully left the nest (N=7), we estimated survivorship. The probability of a fledgling LCTH surviving to the age of 58 days was 46% during this study (Table 3), which is lower than 67% estimated for 335 color-marked individuals in California (Sheppard 1996). However, Sheppard (1996) also reported that survivorship was much lower (19%) for birds up to 10-12 months old. In general, mortality of juvenile birds is high (Snow 1958, Delius 1965, Smith 1967, Ricklefs 1968, Nolan 1978, Warner et al. 1984, Sullivan 1989, Burton 1990, Magrath 1991, Zann and Runciman 1994, Flint et al. 1995, Anders et al. 1997). Few studies have evaluated post-fledging survival, but estimates have been produced for: Willow Flycatcher (*Empidonax traillii*; 74% over 21 days; Vormwald et. al 2011); Dusky Flycatcher (*Empidonax oberholseri*; 72% over 28 days; Vormwald et. al 2011); Hooded Warbler (*Setophaga citrine*; 19% over 4 weeks; Rush and Stutchbury 2008); Lark Bunting (*Calamospiza melanocorys*) in Colorado (15 to 43% over 21 days; Yackel-Adams et al. 2006); Wood Thrush (*Hylocichla mustelina*) in Missouri (42% over 8 weeks; Anders et al. 1997); Western Bluebird (*Sialia mexicana*; 64% over 20 days; Wightman 2009); Dickcissel (*Spiza americana*) in Missouri (56% over 30 days; Suedkamp Wells et al. 2007); Eastern Meadowlark (*Sturnella magna*) in Illinois (56 to 69% over 13 weeks; Kershner et al. 2004) and in Missouri (0.65 over 30 days; Suedkamp Wells et al. 2007); and Rose-breasted Grosbeak (*Pheucticus ludovicianus*; 62% over 21 days, Moore et al. 2010). Davis and Fisher (2009) reported that 11 of 19 Sprague's Pipits (*Anthus spragueii*) with transmitters died before leaving the nest.

Le Conte's Thrashers inhabit landscapes replete with potential predators such as coyote (*Canis latrans*), fox (*Vulpes* spp.), raptors, loggerhead shrikes (*Lanius ludovicianus*), snakes, and rodents. Fledglings are more vulnerable to predators because of reduced awareness, flight capability, and defensive behaviors (Anders et al. 1997, King et al. 2006, Schmidt et al. 2008). During natal dispersal, young birds must become self-reliant and avoid the perils of obtaining suitable food resources in an unfamiliar environment (Snow 1958; Ricklefs 1968; Nilsson and Smith 1985; Sullivan 1989; Morton 1992; Verhulst 1992; Rohner and Hunter 1996; Anders et al. 1997, 1998). Theoretically, chronically low post-fledgling survival may be detrimental to a species as juvenile to adult recruitment may not offset adult senescence. This scenario is especially important to sensitive species threatened by habitat loss and fragmentation. However, our estimates of LCTH post-fledging survival were comparable with similar studies conducted on other species suggesting juvenile survival is generally low. Furthermore, we observed several pairs produce multiple clutches, which has been previously described (Sheppard 1996). This life history strategy can help alleviate the pressures of low juvenile survivorship on population viability.

Similar to other post-fledging studies, distance moved from the nest (Figure 5) and from previous locations (Figure 6) during our study increased with age as young became more mobile and independent (Yackel-Adams et al. 2001, Cohen and Lindell 2004, Kershner et al. 2004, Berkeley et al. 2007, Guzy and Ribic 2007, Rush and Stutchbury 2008, Suedkamp Wells et al. 2008, White and Faaborg 2008, Wightman 2009, Vitz and Rodewald 2010, Vormwald et al. 2011). Though young LCTH have limited flight abilities (Sheppard 1996), we observed dynamic movements that oscillated far from and returning to the nest (Figure 5). Juveniles from two separate nests exhibited extraordinary movements shortly after leaving the nest in response to predators. One fledgling moved over 900 m at Day 1 post-fledging, and another moved approximately the same distance at Day 3 to avoid a predator. LCTH are flightless upon fledging, but have terrestrial mobility (Sheppard 1996). Such movements may be attributed to the large size of this species compared to other songbirds, predator avoidance, and the sparsely vegetated landscape easing mobility. The paucity of cover may facilitate increased mobility, but undoubtedly also increases LCTH foraging distances and vulnerability to predators.

‘Natal dispersal’ is defined as the movement from nest site to the first breeding area, and ‘post-fledging dispersal’ is the movement of an independent juvenile from the natal area (Anders et al. 1998, Suedkamp Wells et al. 2007, White and Faaborg 2008). Post-fledging dispersal has been reported to be ~300 m for similar-sized species (Cohen and Lindell 2004, White and Faaborg 2008). Sheppard (1996) reported an average distance of 395 m from LCTH nests when leaving the natal territory at 30 days old (N = 23) and subsequent dispersal was rapid and in a random direction from the nest during midsummer (mean = 1,200 m; SD 511, N = 33; maximum 2,500 m). We observed longer post-fledging movements than reported for other species and for LCTH in California. Around 30 days old (approx. fledge day 15) LCTH in our study had approached an average distance from the nest of one km, and surpassed that distance a few days later. However, at least one adult usually remained near each fledgling throughout the course of the study period, even if another clutch had been initiated, and fledglings returned to the nest area. Thus, juvenile dispersal did not occur throughout the duration of this study as post-fledglings remained near adults and within natal territories. Most post-fledging research has been conducted on migratory species. LCTH are non-migratory and have an extended breeding season, which may explain delayed onset of post-fledging independence. Juvenile thrashers have more time to establish territories of their own without the pressures of migration experienced by species in other studies. Additionally, the desert environment characterizing LCTH habitat contains sparse cover, extreme temperatures, and abundant predators that may necessitate greater movement and a larger home range than other species in more hospitable regions.

Other studies have reported that home range estimates based on post-breeding movements are substantially larger than breeding territories (Anders et al. 1998, Cardinal 2005, Vitz and Rodewald 2010, Vormwald et al. 2011). In our study, average post-fledging core area (87.28 ±40.88 ha) and natal home range (364.61 ±224.35 ha) used by LCTH were larger than estimates of 40-100 ha aggregate over multiple years, and ≤20 ha during summer and early fall in California (Sheppard 1996). This disparity may be due to differences in data collection (band-resight in California and radio telemetry in the present study); abiotic and biotic differences between California and Arizona; and home range estimation techniques. All LCTH post-fledgling home ranges in this study overlapped with adjacent territories. The densest concentrations of LCTH in Arizona occur in the Cabeza Prieta National Wildlife Refuge and BMGR (Corman and Wise-Gervais 2005). This probably indicates that conspecific tolerance is higher in this species than in others, and would explain the high frequency of home range overlap observed in this study.

As in other post-fledging studies, our results of high juvenile mortality should encourage the consideration of the post-fledging movement period in population estimates, especially for species with declining populations. Despite this portion of our study being conducted in a single breeding season and containing a small sample size, our results provide an understanding of survival, movement, and home range size of LCTH during post-fledging movement. These data will assist land managers in reserving habitat for sensitive species and ensure military planning compatibility for this species. However, studies of longer duration are needed to more completely understand this life-cycle stage. Ideally, post-fledging survival and spatial use should be studied for any sensitive species over multiple years for more thorough estimates to be incorporated into population stability calculations (Rush and Stutchbury 2008, Suedkamp Wells et al. 2007). While the survival, movement and home range of post-fledgling LCTH provide us with fine-scale detail, occupancy and detection probabilities allow us to estimate habitat use associations.

Without a variety of habitat patch sizes to stratify our surveys at fine scales, we used landscape-scale survey data to estimate LCTH occupancy and detectability across all survey years. The estimated occupancy and detection probabilities for LCTH within the study area for all three years (2011-2013) was 0.78 (SE ±0.04) and 0.54 (SE ±0.06), respectively. These values are higher than results from California reporting occupancy and detection probabilities of 0.33 (0.09 ±SE) and 0.57, respectively (Jongsomjit et al. 2012). Modeling LCTH within the occupancy framework produced a moderately high detection probability indicating imperfect detection (i.e., <1). This demonstrates that LCTH individuals will likely be missed while surveying, particularly late during the breeding season. Blackman et al. 2013 reported that LCTH detection decreased later in the breeding season, which helps explain the low LCTH detection probability relative to PAO. Thus, it is important to incorporate the detection probability into LCTH population estimation. Additionally, PAO estimates were higher than naïve occupancy estimates and emphasize that occupancy estimates will be negatively biased when detection probabilities are not incorporated. We determined that LCTH have a high probability of occupancy throughout our study area; however, this value estimates potential occupancy in highly suitable and unfragmented habitat. Habitat loss has contributed to LCTH population decline in other portions of its distribution (Corman and Wise-Gervais 2005), and these areas would likely contain a lower occupancy probability. Thus, our estimates of detection and occupancy probabilities in high quality habitat can provide a benchmark for future studies of this species in disturbed areas of its range.

Covariates in the highest ranked models contained parameter estimates indicating a positive relationship [Soils281 (Momoli-Denure-Carrizo), Soils282 (Why-Wellton-Gunsight-Growler-Denure), Soils283 (Mohall-Denure-Coolidge), and stream length] except for slope (Table 9). Thus, our model indicates LCTH respond negatively to increasing slope. Our model supports previous findings that LCTH are less likely to be found as slope increases in proximity to desert mountain ranges (Fletcher 2009, Blackman et al. 2012). Increasing slope is likely an environmental driver of higher tree density and gravel content, landscape characteristics to which LCTH select against (Blackman et al. 2012).

Our model indicates that LCTH respond positively to Soils281 (Momoli-Denure-Carrizo), Soils282 (Why-Wellton-Gunsight-Growler-Denure), and Soils283 (Mohall-Denure-Coolidge); (Table 9); these soil types consist of sandy alluvium conducive to LCTH foraging as this species usually locates food by digging and scraping soft soil and leaf litter (Sheppard 1996). These soil types are also characterized by sparse vegetation. LCTH require the presence of trees or similar substrata (e.g., large shrubs, abandoned buildings and cars) for nesting (Sheppard 1996, Blackman et al. 2012). Thus, trees are important components in LCTH habitat, but a threshold density may exist where too many trees inhibit site selection.

Blackman et al. (2012) reported that LCTH occurrence is positively associated with the presence of washes, which is consistent with the results of this study (Table 9). Our model results indicate that LCTH respond positively to total length of streams (Table 9). Washes are likely important to LCTH habitat selection as they provide movement corridors, foraging habitat, predator avoidance, and nesting. However, the total length of stream parameter estimate was ranked low in our model and contained high standard error. This model selection uncertainty may result from the high number of washes in LCTH habitat. Thus, it is difficult to determine the importance of washes to LCTH in the context of landscape-scale modeling as the quantity of washes are likely similar between locations where LCTH were and were not detected. LCTH may also respond to a threshold value of total nearby wash length, and the size of the washes that may be too large or too small for LCTH selection. These models provide us with a correlation between LCTH presence/absence and habitat variables and indicate that LCTH are more likely to be found in flat areas consisting of sandy terrain with sparse vegetation and the presence of washes. However, these covariates are broad-scale, probably only generally influence LCTH occupancy, and are most useful for predicting LCTH habitat when combined.

Due to the lack of existing habitat patch sizes to stratify LCTH surveys at a fine scale, we used landscape-scale estimates derived from the occupancy model to refine our spatially explicit LCTH PO model. The revised LCTH PO model provides an index of potential LCTH habitat across the three DoD managed installations and surrounding region. The revised model uses more survey data and better interpolates the probability of LCTH occurrence across the study area. This is evident when comparing Tables 2 and 10, as the 2012 model over-predicted low and medium quality LCTH habitat. It is also evident that the 2012 model under-predicted high probability habitat when comparing the area of Class 3 in Figure 1 to the area in Figures 7-10. Intuitively, high probability LCTH habitat extends longitudinally through the wide desert valleys in the study area (e.g., San Cristobal and Mohawk Valleys) and habitat quality decreases laterally toward mountain foothills. This pattern is well represented by the revised 2013 PO model. Despite greater accuracy of the 2013 model, LCTH were not detected at all survey locations where the landscape appeared suitable and were predicted as moderate to high probability habitat by the PO model (Table 10; Figures 8-10). This may be explained by the fact that LCTH are uncommon despite containing a fairly high PAO, and do not occupy all suitable habitat. This may also be attributed to the reclassification of the PO model into three categories, which confines the LCTH occupancy probabilities to discrete categories rather than expressed as a continuum. However, model classes 2 and 3 contained proportions of plots with LCTH detections within the range of occupancy probabilities predicted by the PO model (Table 10). Class 1 contained a greater proportion of plots with LCTH detections than its respective range of occupancy probabilities. This can likely be attributed to small sample size. Thus, although the model generally predicts the occurrence of LCTH well, it is still a coarse-scale model that suffers from errors of commission and omission (i.e. over and under-predicts occupancy probabilities in some areas).

Long-term research is critical for separating natural from anthropogenic fluctuations in wildlife populations and occupancy modeling can provide a reliable alternative to more costly and labor intensive methods for estimating abundance. This was the third year of a large-scale study to model the occupancy and detection probabilities of LCTH within three military installations in southwestern Arizona. Survey data from 2011, 2012 and 2013 were used to refine the LCTH PO model. It is possible to extrapolate these results to evaluate the potential impact of urbanization, technology development (e.g., solar and wind energy projects) and agricultural footprints. Our study areas were either undeveloped or within restricted access sites on DoD lands; however, the model can be geospatially overlaid onto maps of surrounding areas. The true value of the PO Model is as a conservation tool incorporating class-level predictions into a spatially-explicit database. This will provide land managers with maps that estimate priority LCTH habitat in proposed footprints for military activities or development (e.g., alternative energy construction areas). Furthermore, these predictive maps can be combined with LCTH home range and movement data to estimate potential impacts at a finer scale. For example, once an area is slated for disturbance (e.g., development or military training), surveys for LCTH can be guided by the PO Model for the area. Survey results can be compared to movement and home range data to estimate how many birds and how much habitat will be displaced. These efforts together will aid in the long-term management of sensitive species while facilitating mission success.

MANAGEMENT AND RESEARCH RECCOMMENDATIONS

Within BMGR and YPG are large expanses of relatively undisturbed Sonoran Desert. The importance of these un-fragmented areas to LCTH and many other lowland desert species will continue to increase as the landscape adjacent to DoD installations is developed for agriculture, alternative energy (solar), and urban expansion. The U.S. Census Bureau projected that Arizona would add 3.3 million people by 2030, making it the 10th most populated state in the country and ranking in the top five fastest-growing states (US Census Bureau 2005). Thus, it is highly important to understand population demographics, movement, and territory size of species of concern. In this study, we used three years of consecutive survey data to estimate detectability and occupancy of LCTH. Furthermore, we predicted the spatial occupancy of LCTH in part of southwestern Arizona based on important soil classifications and slope. We also provided important LCTH movement and home range statistics, and recommend that:

- Average distance between fledglings and respective nests was 678.94 m (SD ±150.03; median 721.89; range 441.91-825.17). Maximum movement distance between fledglings and respective nests averaged 1732.87 m (SD ±420.05; median 1584; range 1321.77-2353.06). Although LCTH did not disperse during the course of our study, we found that LCTH make long and dynamic movements from an early age, and we expect that juvenile dispersal movements would be longer than those reported in this study. Thus, we recommend incorporating these movement distances into dispersal corridor design between disturbed areas of suitable habitat. Although the average maximum movement distance between fledglings and nests was below 2 km, we recommend maintaining a buffer of 2.5 km between suitable habitat patches.

- Average home range was 364.61 ha (SD ±224.35; median 235.35; range 222.37-747.47). Average core area was 87.28 ha (SD ±40.88 median 66.18; range 48.3-145.47). Our data reveals this species maintains larger territories and uses more space during the post-fledging period than previously reported. These data should be used for planning the size and location of development in LCTH habitat and factor in the conservation of remaining habitat patches and corridors. Thus, we recommend that suitable habitat patches of 750 ha be maintained as this was the largest LCTH home range documented during this study. This information is important to DoD and other land managers with development projects containing the potential to disturb LCTH habitat.

In southern Arizona, the DoD, USFWS, AZGFD, Bureau of Land Management, National Park Service, Bat Conservation International and Sonoran Joint Venture, are partners in the Sonoran Desert Conservation Partnership Team. In 2007, this team produced DoD Legacy Species-at-Risk documents that synthesized the ecology and made management recommendations for species of concern, including LCTH, on DoD installations in southwestern Arizona. During this three-year study, we addressed the team's management and research priorities as follows:

- *Collect data on LCTH distribution in order to evaluate this species' distribution in relation to military training activities and potential threats. Concentrate training and development activities away from areas with current or historic records of LCTH.* We collected distribution data during three consecutive seasons at discrete plots. This data provides detailed LCTH locations throughout the study area that can be used to plan military training and infrastructure development in accordance with managing for this species. We recommend that development of temporary and permanent infrastructure be located away from known LCTH locations with buffers defined by home range and core area sizes in the above mentioned recommendations.

- *Model occupancy and detection covariates as they relate to LCTH in order to develop a better understanding of their distribution and support development of appropriate management actions. Evaluate potential impacts to the local viability of thrashers, including habitat loss and fragmentation, when developing new training areas. This approach should reduce disturbance to important areas for LCTH and other species while reducing overall fragmentation of wildlife habitat.* Our models determined that LCTH occupancy is related to soil, slope, and washes, and were used to generate a predictive model of occupancy probabilities. We recommend that the revised PO model be used as a benchmark in GIS for future surveys, and can be used as a regional spatial tool for land managers to evaluate how a proposed project may affect LCTH.

- *Create or maintain OHV closure to LCTH breeding areas. The borderlands region of the U.S. experiences a multitude of OHV disturbance from illegal activity and border patrols.* LCTH surveyors noted that OHV footprints were ubiquitous throughout the study area. We acknowledge that this type of disturbance is difficult to police but we recommend that all possible attempts be made to do so.

The following research priorities would address knowledge gaps with respect to LCTH ecology and would improve our ability to proactively manage its habitat:

- Evaluate disturbance threshold of OHV to LCTH populations in the U.S. and Mexico. Unfortunately, OHV use in the borderlands is omnipresent and difficult to study. OHV use from illegal borderland activity and the border patrol agents that police this activity will persist indefinitely. The vast area that exists within this region probably acts as a buffer to directly impacting LCTH population viability; however, we recommend designing a study to test the impacts of roads on LCTH population demographics, viability and habitat.

- Compare the habitat that LCTH are using versus what is available to them. This can be accomplished by measuring habitat variables at plots used by LCTH and compared to measured habitat variables at random plots (available to but not necessarily used by LCTH). Use plots were measured in a study conducted in 2009 on BMGR East, but the sample size was small and random plots were not measured (Blackman et al. 2010).

- Other potential disturbances to LCTH are expected to increase including urban expansion, agriculture and alternative energy (e.g., solar power). In the face of these threats, it is important to investigate the thresholds to which LCTH respond negatively to these disturbances both on and off DoD lands.

- Continue monitoring the expansion of invasive plant species. Continue integrated strategies to reduce wildfire fuel loads and further spread of invasive species. Evaluate effects of invasive species and management practices on LCTH populations in the U.S. and Mexico.

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Appendix 1. Location and number of Le Conte's Thrashers detected at plots surveyed in 2013.

Plot ID	Range	LCTH Detection Locations	Easting (NAD 83)	Northing (NAD 83)
3	MCAS	0	222600	3607400
4	MCAS	0	201800	3605400
5	MCAS	2	224200	3605400
6	MCAS	0	214600	3604200
7	MCAS	0	201800	3603000
8	MCAS	1	224200	3603000
9	MCAS	4	229000	3602200
10	MCAS	5	225800	3599400
11	MCAS	1	209800	3598600
13	MCAS	4	235400	3597800
14	MCAS	1	225800	3597400
15	MCAS	0	211400	3597000
18	MCAS	0	214600	3595800
19	MCAS	11	240200	3595800
20	MCAS	0	229000	3595400
22	MCAS	3	211400	3594200
23	MCAS	4	216200	3593400
24	MCAS	0	230600	3593400
26	MCAS	6	209800	3593000
27	MCAS	0	213000	3592600
51	MCAS	3	222600	3617400
53	BMGRE	5	264200	3616600
54	MCAS	1	224200	3615800
55	BMGRE	5	267300	3615600
56	MCAS	0	225800	3614200
58	BMGRE	0	257800	3613000
59	MCAS	8	211400	3612600
60	BMGRE	7	265700	3612800
62	MCAS	3	238600	3610600
65	BMGRE	3	262600	3609800
67	MCAS	6	228900	3608400
68	MCAS	2	232200	3608200
69	BMGRE	3	273700	3608400
70	MCAS	3	235400	3607400
71	MCAS	1	211400	3607400
72	BMGRE	1	261000	3605400
73	BMGRE	5	265800	3604200
74	MCAS	0	235400	3603800
75	MCAS	0	246600	3601000
76	MCAS	0	249800	3599000
78	BMGRE	0	254600	3627000

Appendix 1 continued. Location and number of Le Conte's Thrashers detected at plots surveyed in 2013.

Plot ID	Range	LCTH Detection Locations	Easting (NAD 83)	Northing (NAD 83)
79	BMGRE	2	254600	3625400
81	BMGRE	8	249800	3625000
83	BMGRE	7	251400	3623400
84	BMGRE	9	257800	3623400
85	BMGRE	4	253000	3621800
86	BMGRE	2	257800	3621800
87	MCAS	2	232200	3621000
88	MCAS	2	224200	3620200
90	BMGRE	2	259400	3620200
91	MCAS	8	230500	3619600
93	BMGRE	6	259400	3618600
94	MCAS	6	233800	3618200
95	MCAS	9	230500	3618000
100	MCAS	4	235400	3616600
104	MCAS	0	200200	3614200
N1	BMGRE	0	255200	3620000
N2	BMGRE	1	256200	3618600
N3	BMGRE	13	257100	3617100
N4	BMGRE	3	254700	3624000

Appendix 2. Monitoring data for Le Conte's Thrasher nests during 2013.

Plot ID	Area/Valley	Model Class Occupancy Probability	UTMmE (NAD 83)	UTMmN (NAD 83)	Nest DiscoveryDate	Nest Substrate[1]	LCTH Notes
N3-RD	BMGRE	HIGH	258541	3615935	3/26/2013	PAFL	2 transmitters; 2 banded; 1 predated
N2	BMGRE	HIGH	256193	3618557	3/4/2013	CYBI	3 chicks; 2 transmitters; both predated
N3	BMGRE	HIGH	257867	3617075	2/13/2013	OLTE	3 Chicks; fledged or predated
N3	BMGRE	HIGH	258038	3616412	5/22/2013	OLTE	First found as old nest; then newly lined on 5/30/13; then 2 Eggs next day; 6/4/13 destroyed
Crucifix	MCAS	HIGH	231298	3620859	4/2/2013	CAHO	2 Eggs; 2 banded; transmitters; 2 predated
N3	BMGRE	HIGH	256864	3616792	3/26/2013	PAFL	2 transmitters/banded; 2 predated
10	MCAS	MEDIUM	226116	3599043	2/28/2013	CYBI	Possible; LCTH pair didn't go to nest
13 INC	MCAS	MEDIUM	235464	3598306	3/13/2013	OLTE	3 eggs; 2 chicks; possible predated
19	MCAS	MEDIUM	241252	3595306	3/13/2013	PAMI	1 young/2 eggs; predated
74 INC	MCAS	HIGH	236370	3600422	2/26/2013	OLTE	1-2 chicks/predated
78	BMGRE	HIGH	256433	3626200	4/17/2013	PRVE	3 chicks; 3 banded/ 2 transmitters; 1 predated
79	BMGRE	HIGH	255878	3625574	3/6/2013	PRVE	1 chick/1 egg; transmitter and band
79	BMGRE	HIGH	255878	3625574	4/16/2013	PRVE	3 banded/ 2 Transmitters; 1 predated with transmitter and band
81	MCAS	MEDIUM	225515	3602965	3/11/2013	CYBI	2 eggs; predated
81	BMGRE	HIGH	250203	3624601	2/14/2013	OLTE	3 chicks; predated
85	BMGRE	HIGH	250203	3624601	3/27/2013	OLTE	Probable second attempt w/in area of first nest
88	MCAS	HIGH	225849	3619699	2/26/2013	CYBI	3 chicks; 2 confirmed as fledged
88	MCAS	HIGH	224536	3619824	2/27/2013	PAFL	3 eggs; predated
93	BMGRE	HIGH	261111	3618551	3/5/2013	PAFL	Renest; 3 eggs; predated

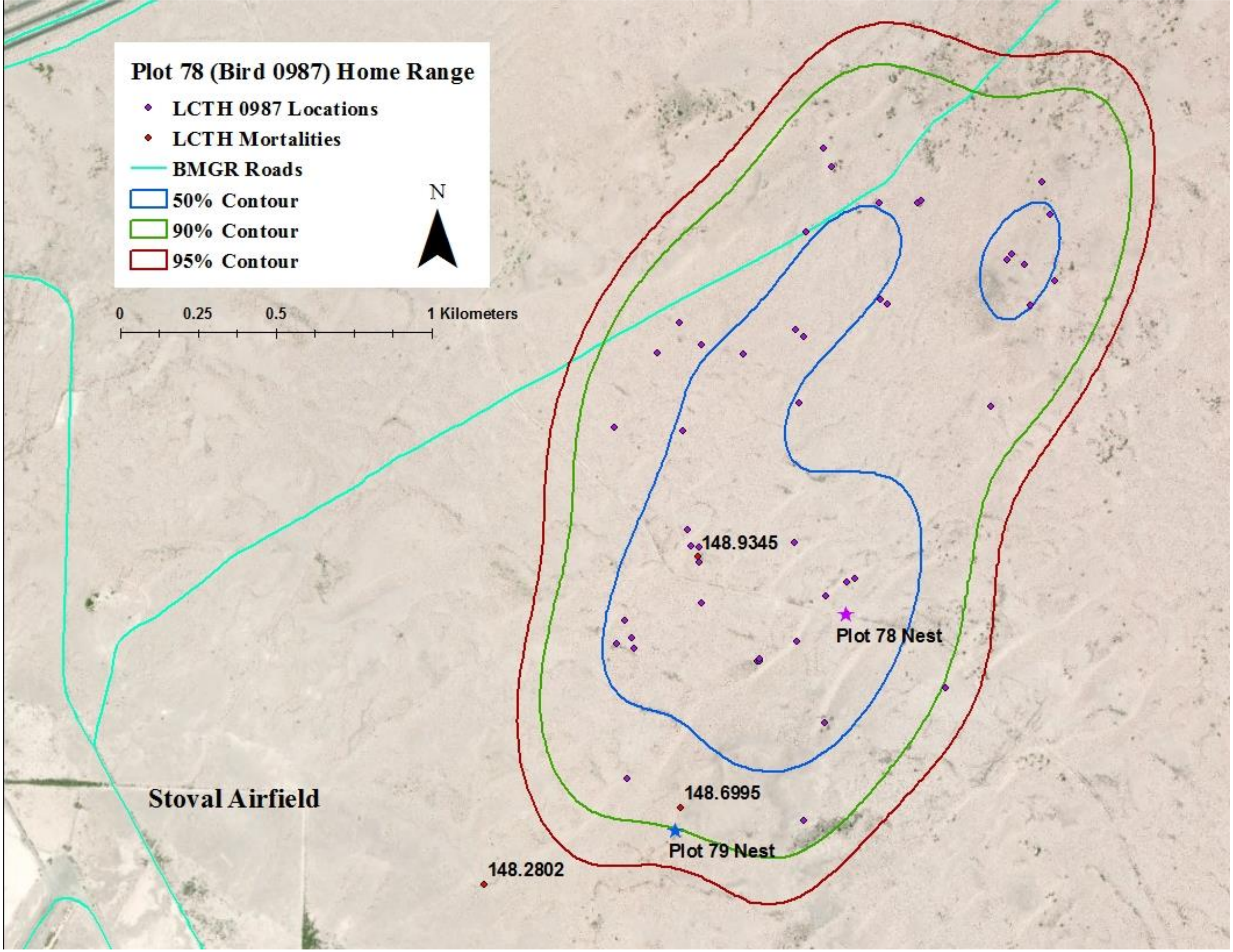
[1] Nest substrate abbreviations: blue paloverde (PAFL, *Parkinsonia floridum*); ironwood (OLTE, *Olneya tesota*); crucifixion thorn (*Canotia holacantha*); yellow paloverde (PAMI, *Parkinsonia microphyllum*); mesquite (PRVE, *Prosopis velutina*); teddy bear cholla (CYBI, *Cylindropuntia bigelovii*).

Appendix 2 continued. Monitoring data for Le Conte's Thrasher nests during 2013.

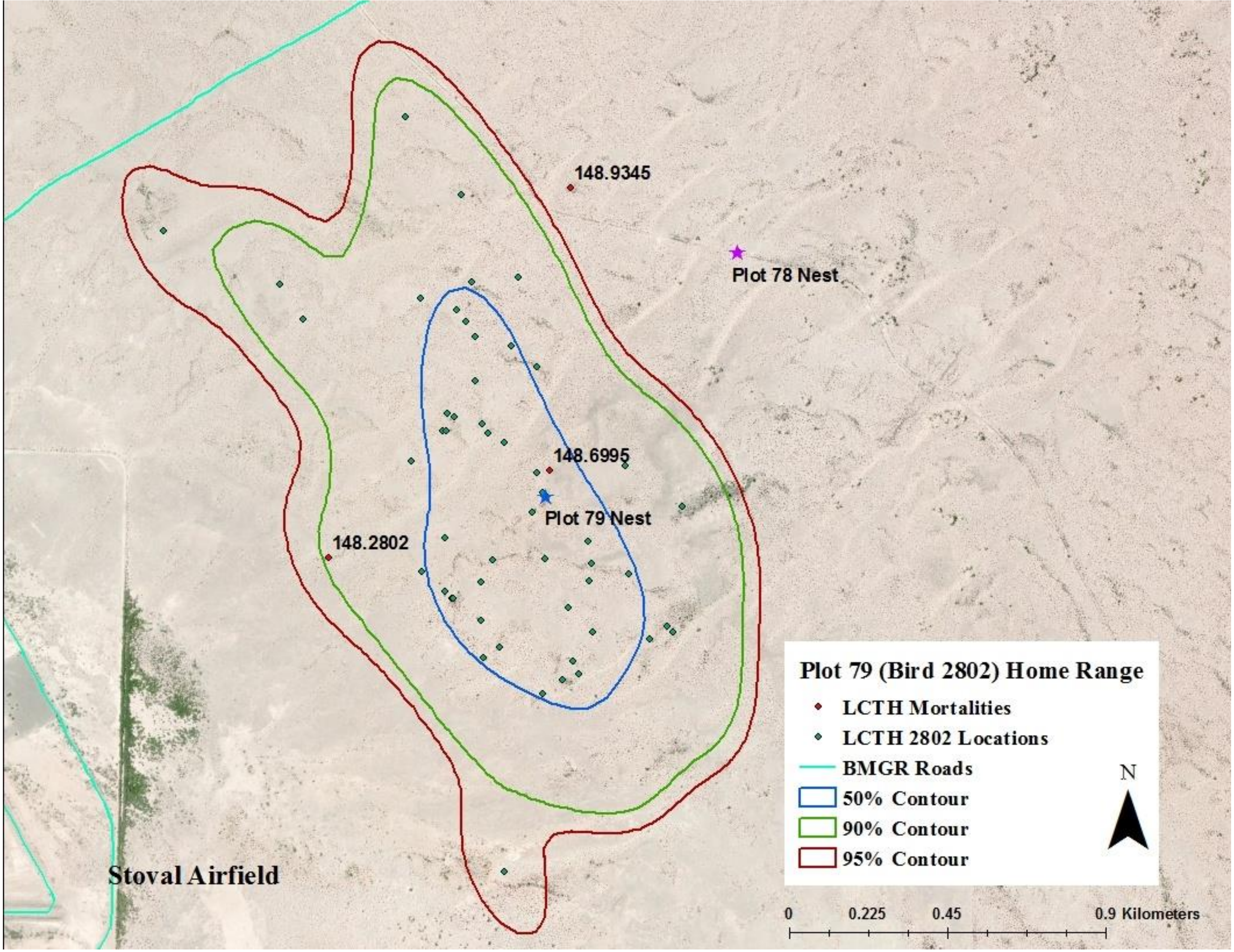
Plot ID	Area/Valley	Strata	UTMmE (NAD 83)	UTMmN (NAD 83)	Nest Detection Date	Nest Veg	LCTH Notes
93	BMGRE	HIGH	261198	3618450	3/26/2013	PRVE	SE of old nest; 3 chicks; predated
100	BMGRE	HIGH	235662	3616534	4/17/2013	CAHO	4 eggs; predated
100	MCAS	HIGH	235596	3616637	2/26/2013	CYBI	3 chicks/transmitters and bands/predated
100	MCAS	HIGH	236263	3615882	2/26/2013	CAHO	1 egg 1 chick, predated

[1] Nest substrate abbreviations: blue paloverde (PAFL, *Parkinsonia floridum*); ironwood (OLTE, *Olneya tesota*); crucifixion thorn (*Canotia holacantha*); yellow paloverde (PAMI, *Parkinsonia microphyllum*); mesquite (PRVE, *Prosopis velutina*); teddy bear cholla (CYBI, *Cylindropuntia bigelovii*).

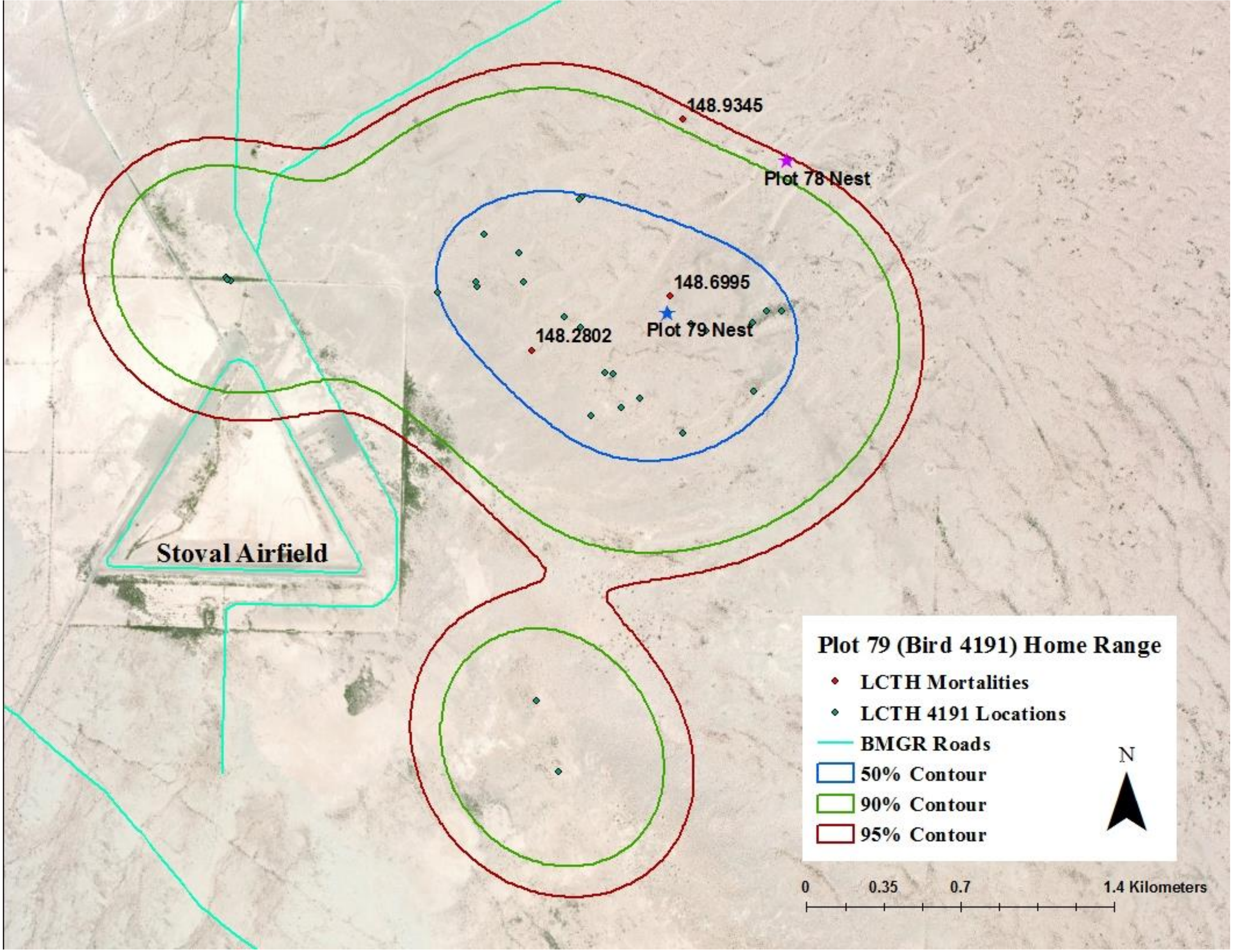
Appendix 3. Fixed kernel density of Le Conte's Thrasher territory Plot 78 (transmitter number 148.0987) depicting 50% (core area), 90% and 95 % contours.



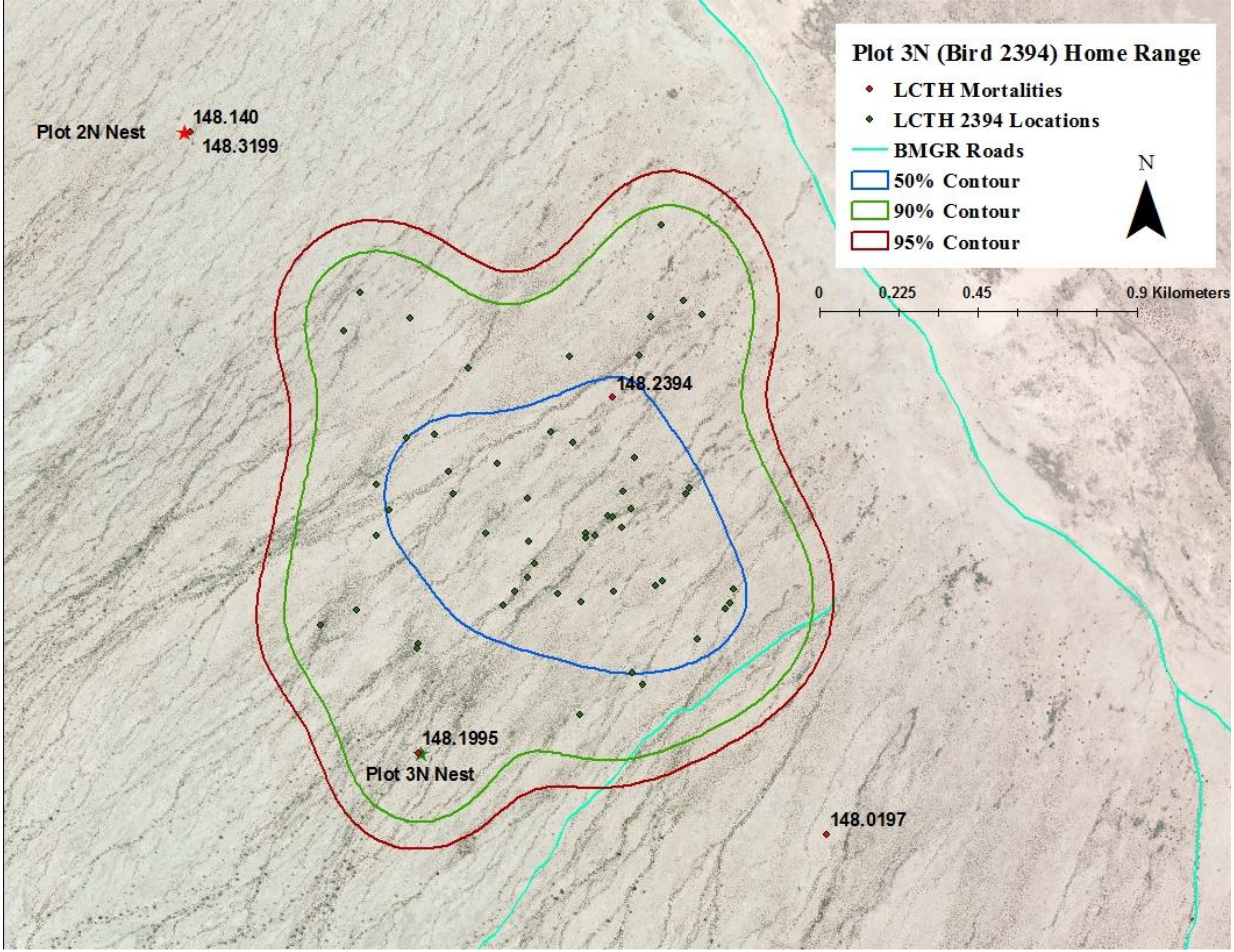
Appendix 4. Fixed kernel density of Le Conte's Thrasher territory Plot 79 (transmitter number 148.2802) depicting 50% (core area), 90% and 95 % contours.



Appendix 5. Fixed kernel density of Le Conte's Thrasher territory Plot 78 (transmitter number 148.4191) depicting 50% (core area), 90% and 95 % contours.



Appendix 6. Fixed kernel density of Le Conte's Thrasher territory Plot 3N (transmitter number 148.2394) depicting 50% (core area), 90% and 95 % contours.



Appendix 7. Fixed kernel density of Le Conte's Thrasher territory Plot 3NRD (transmitter number 148.1800) depicting 50% (core area), 90% and 95 % contours.