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Le Conte's Thrasher (*Toxostoma lecontei)*
Occupancy and Distribution:
Barry M. Goldwater Range and Yuma Proving Ground in Southwestern Arizona
Year 2

Scott T. Blackman AZ Game and Fish Dept.
2013

Le Conte's Thrasher (*Toxostoma lecontei)* Occupancy and Distribution: Barry M. Goldwater Range and Yuma Proving Ground in southwestern Arizona Year 2 Report

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RECOMMENDED CITATION

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INTRODUCTION

The Department of Defense (DoD) manages large tracts of Sonoran Desert and correspondingly shares responsibility for conservation in this ecoregion (Marshall et al. 2000). The Barry M. Goldwater Range East and West (BMGR) are jointly managed by the U.S. Air Force and U.S. Marine Corps, respectively, to train military aircrews for air combat missions (BMGR 2012). The Yuma Proving Ground (YPG) is used for testing training equipment and personnel in a desert environment. Natural resource monitoring and management occurring on BMGR and YPG is guided by the Integrated Natural Resources Management Plans (BMGR 2012, USYPG 2012). Information on sensitive, threatened and endangered species that occur on BMGR and YPG is needed to make military planning compatible with sensitive species management.

One such species is the Le Conte's Thrasher [(*Toxostoma lecontei*) (LCTH)], an uncommon resident of sparse landscapes within the San Joaquin Valley, Kern River basin, Owens Valley, Mojave Desert, and the Lower Colorado River Valley subdivision of the Sonoran Desert in the southwestern United States (Sheppard 1996, Corman and Wise-Gervais 2005). This species is listed as a Bird of Conservation Concern by the U.S. Fish and Wildlife Service (USFWS), and as a Wildlife Species of Concern by the Arizona Game and Fish and California Fish and Game Departments (Latta et al. 1999, California Partners in Flight 2006).

Le Conte's Thrashers usually nest from January to June (Sheppard 1970, Sheppard 1996, Corman and Wise-Gervais 2005). Density estimates in California for this species range from 0.2-7.3 pairs/km² (California Partners in Flight 2006); however, population decline is evident in some areas primarily in the San Joaquin Valley (California Partners in Flight 2006, Coachella Multi-species Habitat Conservation Plan 2007). Apparent LCTH population declines in Arizona have also been observed near agriculture, urban and other human developments, particularly in the eastern portion of its range (Corman and Wise-Gervais 2005). The densest concentrations of LCTH in Arizona occur in the Cabeza Prieta National Wildlife Refuge and BMGR (Corman and Wise-Gervais 2005). In order to ensure continued mission success on BMGR and YPG, a thorough understanding of the ecology of LTCH is necessary. Therefore, we designed a study focused on increasing our understanding of the distribution and occupancy status of LCTH on BMGR and YPG in southwest Arizona. This knowledge will allow BMGR and YPG to manage LCTH populations and habitat for long-term sustainability, and will be useful to land managers throughout this species' distribution.

OBJECTIVES

1) Refine the LCTH Prediction of Occurrence (PO) Model by incorporating 2012 LCTH survey results and additional landscape-scale covariates;
2) Survey for the presence of LCTH at different survey locations from year 1 within BMGR and YPG and relate site-specific occupancy to habitat attributes; and
3) Determine Proportion of Area Occupied (PAO) for LCTH on BMGR and YPG.

STUDY AREA

Barry M. Goldwater Range East and West

BMGR is co-managed by the U.S. Air Force and the U.S. Marine Corps. The land-management authority for the eastern 445,154 ha is the 56th Range Management Office (56 RMO) at Luke Air Force Base, Phoenix, AZ. The western portion consists of approximately 242,811 ha and is managed by the Range Management Department at Marine Corps Air Station, Yuma, AZ. The Range occupies portions of Pima, Maricopa and Yuma counties, from the City of Yuma to several miles East of Gila Bend, Arizona, and totals approximately 7,066 km^2 (Figure 1). The Range 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 lands.

Elevations at BMGR range from 61 m at western portions of the Range to 1,128 m in the Sand Tank Mountains at the eastern border (BMGR 2012). Temperatures on BMGR can range from below 0° C to 49° C, with a range-wide average annual rainfall of approximately 12.7 cm (BMGR 2012). The Lower Colorado River subdivision of the Sonoran Desert is the predominating vegetative community on BMGR and is characterized by extremely drought-tolerant plant communities consisting primarily of creosote (*Larrea tridentata*), bursage (*Ambrosia* spp.), paloverde (*Parkinsonia* spp.) and cacti (e.g., *Cylindropuntia* spp. and *Carnegiea gigantea*) (Brown 1994, Marshall et al. 2000). The broad, flat and sparsely vegetated desert plains of BMGR 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. The Arizona Upland Subdivision of the Sonoran Desert occurs on elevated hills and mountain slopes of BMGR East, primarily east of State Route 85. Because LCTH does not inhabit the Upland Subdivision, we do not provide a detailed description of this subdivision.

Yuma Proving Ground

YPG is managed by the U.S. Army. YPG occupies portions of La Paz and Yuma counties near Yuma, Arizona, and totals approximately 345,000 ha (Figure 1). Kofa National Wildlife Refuge and YPG share a 93 km long boundary (USDI 1996). The elevation at YPG ranges 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 prevalent habitat 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. The elevated hills and mountain slopes at YPG are within the Sonoran Desert's Arizona Upland Subdivision, where plants such as beargrass (*Xerophyllum tenax*), cacti and agave (*Agave* spp.) can be found.

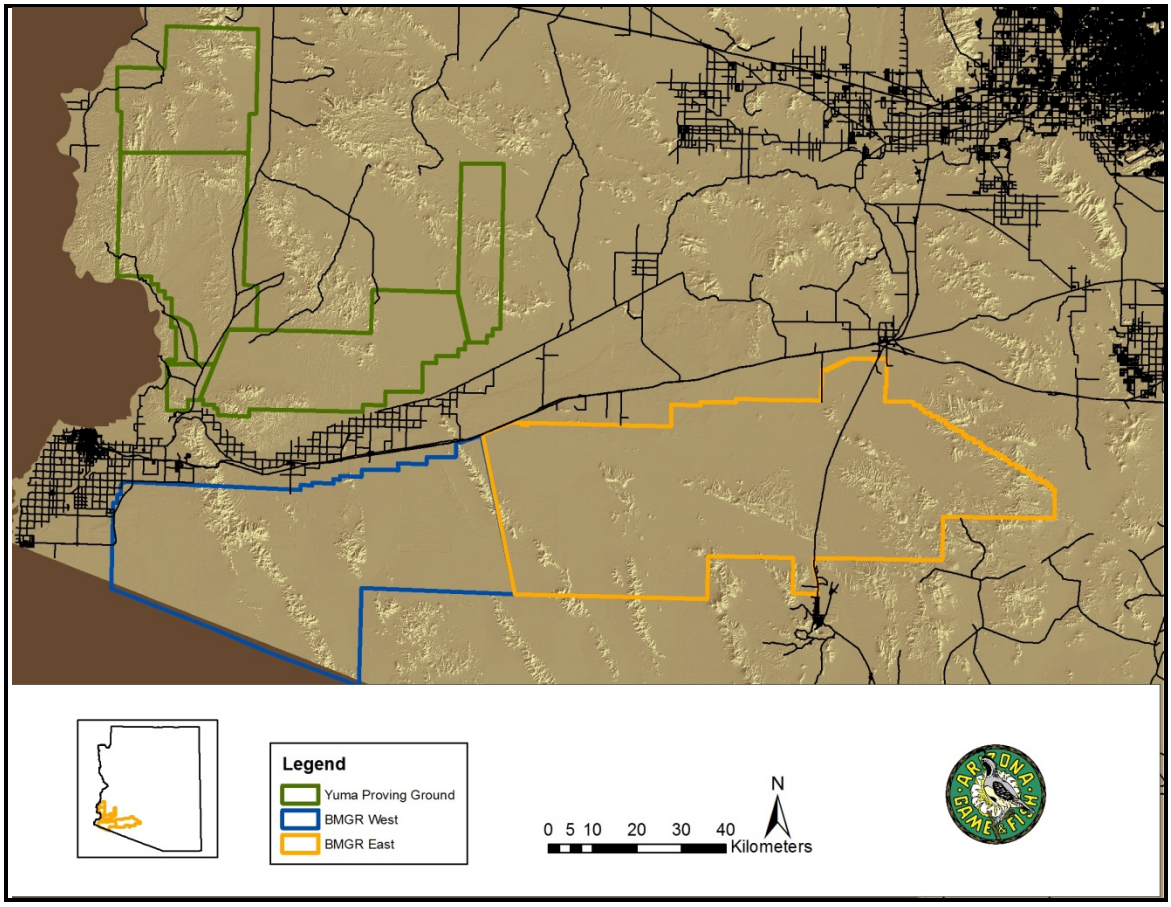

Figure 1. Locations of Le Conte's Thrasher 2012 survey study area at YPG, BMGR East and BMGR West.

METHODS

Sampling Design

We used a Geographic Information System (GIS) model developed in 2010 to predict LCTH occupancy based on habitat suitability of the study region and surrounding areas. Model inputs included vegetative cover (SWReGAP 2007), soil series (NRCS 2008), elevation (LANDFIRE 2010), slope (LANDFIRE 2010), and previous LCTH detection locations (Blackman et al. 2010, 2012). This PO Model produced a 10-category ranking of potential LCTH occurrence throughout the modeled area ranging from category one (least suitable LCTH habitat) to ten (most suitable LCTH habitat). We omitted land areas classified as category 1-5 from field surveys because these areas incorporate large amounts of land cover types known to be unsuitable for LCTH. We used the remaining five categories to create a stratified random sample of 30 points distributed evenly across model categories 6-10 in ArcGIS (ESRI 2012) throughout BMGR East, BMGR West and YPG. Points were distributed at least 3 km apart to ensure independence among LCTH detections. These thirty points represent the center of our survey plots.

Broadcast-response Surveys

Despite inhabiting very sparse landscapes, LCTH can be difficult to detect due to cryptic coloration and secretive behavior. LCTH plumage matches the soil surface, and they typically forage on the ground beneath shrubs and trees unless vocalizing. Research conducted in 2009 and 2011 on BMGR East 2011 on BMGR West and 2011 on YPG used broadcasting to survey for LCTH (Blackman et al., 2010, 2012). This project followed the protocols developed during these 2009 and 2011 LCTH surveys.

Broadcast survey points were spaced 400 m apart along transects projecting out from the center of each of the thirty randomly generated plots. Two observers began at the center of each randomly generated plot and surveyed in opposite directions (e.g., North/South or East/West). Because broadcast points along each transect were spaced at 400 m intervals, both surveyors commenced broadcasting once they had walked 400 m from the original random point (Figure 2). After conducting the first broadcast station, each surveyor then walked 400 m to the next point. Transects included five points along one transect away from the center and five points along a second transect parallel to and 1 km away from the original transect (Figure 2). Upon completion of the first survey transect, each surveyor moved 1 km perpendicular to the first transect line to start the second transect line. The direction that the surveyor chose to begin the second transect was contingent upon the suitability of the landscape to LCTH occurrence. Double counting was eliminated by skipping broadcast points directly adjacent to points where LCTH were detected if detected birds began to follow the observer. Each of the thirty randomly generated plots was surveyed four times throughout the course of the 2012 season.

At each broadcast survey point, surveyors first spent one minute sampling LCTH using visual and auditory sampling for LCTH. At the conclusion of the first minute, each surveyor 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. The observer then broadcast the LCTH vocalizations for another 90 seconds in the direction opposite of the first broadcast direction, followed by 2 minutes of visual and auditory sampling. If no LCTH was detected, total survey time at each point was 8 minutes. If we detected LCTH, the observer stopped the broadcast, spent from 15 to 20 minutes observing the LCTH and recording behavioral data.

We documented the location and tree/shrub species of the perch where each LCTH was first detected. Perch locations were recorded using a hand held Garmin global positioning system (GPS) using the North American Datum (NAD) 83 datum projected in Universal Transverse Mercator (UTM) Zones 11 and 12. We marked perches with flagging tape for future habitat measurements. Surveyors searched for nests for up to 15 minutes at each detection point. All other avian species detections were recorded at each LCTH point along with the distance to each individual of all species according to Buckland et al. (2001).

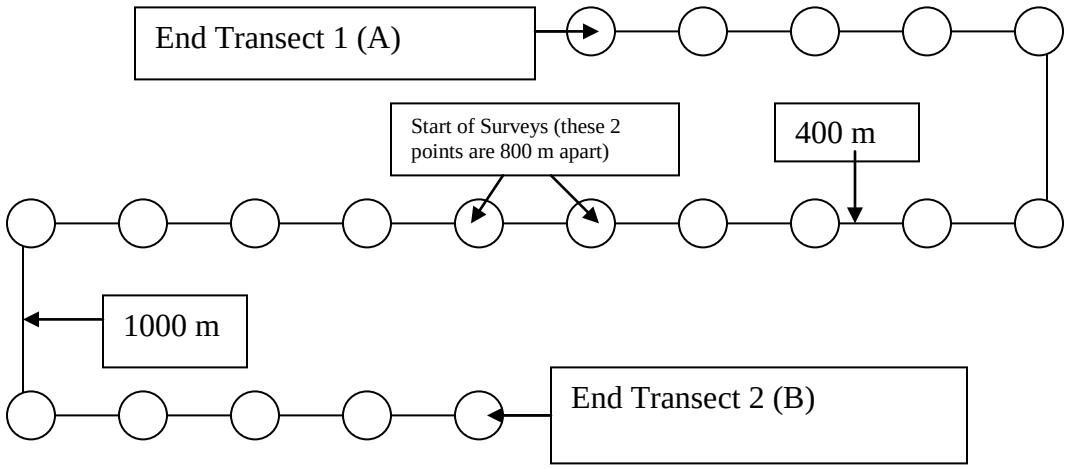

Figure 2. Schematic of parallel transects of call-broadcast survey points conducted by two surveyors walking in opposite directions. The middle 2 points are 800 m apart and are centered about a randomly-generated point. Other points on each transect are 400 m apart. Transects are 1 km apart.

Habitat Data Collection

We collected habitat data for LCTH using the same methodology as 2011 survey sampling (Blackman et al. 2012). For all LCTH perches and confirmed nests, we recorded the location, described the perch or nest substrate, identified the tree or shrub species and estimated the height of the perch and/or nest tree. We identified all trees and shrubs within 10 m of all perches, nests, and locations where LCTH were first detected during surveys. At all locations where we detected LCTH, and at a subset of broadcast stations, we estimated habitat characteristics such as vegetation diversity, proportion of ground cover, percent shrub and tree cover, and the distances to the nearest tree and ephemeral wash. The subset of broadcast stations where habitat data was collected was standardized (i.e. collected at points 2, 6 and 10 for each survey transect) and averaged within each plot. We used Fisher's Least Significant Differences and mixed model Analysis of Variance (ANOVA) to test differences between habitat covariates at LCTH detection locations and at representative broadcast points within each plot (Sokal and Rohlf 2001, Zar 1999). Broadcast point habitat data was pooled within each plot across the three DoD properties.

Occupancy Modeling

We used occupancy modeling (MacKenzie et al. 2002) to estimate the occurrence probability and detectability of LCTH throughout the study area and correlate presence/absence with covariates within an information-theoretic context (Burnham and Anderson 2002). Occupancy modeling uses a PAO framework, an abundance estimation technique that incorporate detection probabilities of each species (Bailey et al. 2004, MacKenzie and Royle 2005, MacKenzie 2006, MacKenzie et al. 2006). If the detection probability for each respective species is not incorporated into occupancy estimates, a naïve count of the area (the number of sites occupied by the species divided by the total number of sites surveyed) will underestimate the actual site occupancy (MacKenzie et al.

2002, MacKenzie et al. 2003, Tyre et al. 2003, MacKenzie and Nichols 2004). PAO estimates are calculated using the likelihood-based approach described by MacKenzie et al. (2002), accounting for individuals present, but undetected during surveys. The inclusion of covariates into occupancy modeling can elucidate the relationship between a LCTH and habitat or landscape components. Parameters estimated 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*. Selection of survey locations did not require the presence of LCTH, however, survey locations were randomly generated within boundaries predicted as highly suitable for LCTH occurrence. Randomization and a lack of specific pre-existing knowledge of LCTH site occupancy eliminated site selection bias (MacKenzie and Royle 2005, Collier et al. 2010).

We developed 12 *a priori* models, based on our understanding of LCTH biology and life history strategies, as a foundation for models used for estimating LCTH detection and occupancy probabilities (MacKenzie et al. 2006). A candidate suite of models contained habitat (e.g., distance to nearest wash and total length of wash in plot) and landscape attributes (e.g., soil association, vegetative association, elevation and precipitation) that LCTH presence was associated with (Table 1). We reduced the number of candidate models by evaluating the influence of survey pass on detection probability while holding occupancy constant [$\psi(.)$ p(time)]. We then used the most parsimonious model of detection probability [$\psi(.)$ p(survey)] to model the influence of habitat covariates on LCTH occupancy (Kroll et al. 2007, Henneman and Andersen 2009, Hansen et al. 2011). We used the software program PRESENCE version 5.8 (Hines 2013) to model the probability of detection and occupancy with habitat and landscape covariates measured at all survey plots across the study areas (detection and non-detection plots). LCTH presence/absence data were analyzed at plot scale to avoid spatial autocorrelation and ensure that the closure assumption was not violated.

Table 1. Candidate set of occupancy models applied to Le Conte's Thrasher habitat 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*(.)	Constant occupancy, constant detection
ψ(.) *p*(Julian)	Constant occupancy, Julian day dependent detection
ψ(.) *p*(t)	Constant occupancy, survey pass dependent detection
ψ(Soil) *p*(t)	Soil class dependent occupancy, time dependent detection
ψ(StreamDist) *p*(t)	Stream Distance dependent occupancy, time dependent detection
ψ(MinTemp) *p*(t)	Minimum temp. dependent occupancy, time dependent detection
ψ(MeanTemp) *p*(t)	Mean temp. dependent occupancy, time dependent detection
ψ(Precip) *p*(t)	Precip. dependent occupancy, time dependent detection
ψ(RDLength) *p*(t)	Road length dependent occupancy, time dependent detection
ψ(Veg) *p*(t)	Veg. dependent occupancy, time dependent detection
ψ(Slope) *p*(t)	Slope dependent occupancy, time dependent detection
ψ(Elev) *p*(t)	Elev. dependent occupancy, time dependent detection

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

Akaike's Information Criterion (AIC) was used to rank the set of considered 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 model. Models within $<2\Delta AIC$ of the highest ranked model were considered to be best supported by the data and competed with the most parsimonious model.

Overdispersion in the data was assessed by testing overall model fit of the global model by completing 10,000 parametric bootstraps and using the Pearson chi-square statistic to obtain the variance inflation factor ($\hat{c}$) (Burnham and Anderson 2002). Model selection uncertainty was accounted for by computing parameter and variance estimates within the most supported models (Burnham and Anderson 2002, Sokal and Rohlf 2001, Zar 1999). The AIC weights were summed across covariates represented in the most competitive models ranking within $<2\Delta AIC$ of the highest ranked model to assess the relative importance of the individual covariates.

Prediction of Occurrence (PO) Model

The LCTH PO model was refined by importing detection results from 2011 and 2012, physical covariates and remotely sensed data from WorldClim (www. worldclim.org) (Table 2). We obtained three climate GIS data layers from the WorldClim dataset with 2.5 arc-minute resolutions (Hijmans et al. 2005). These monthly climate layers included minimum and average temperature (°C), and precipitation (cm). Using the map algebra feature in ArcGIS, we converted these layers to reflect annual patterns and assigned these values to each study plot. Roads and perennial stream layers (Tiger 2012, ASLD 2011) were defined by Euclidian distance (i.e., straight-line distance) and used to create "distance from" variables. Spatial resolution was restricted to 500 m and the length of roads and streams in each plot were extracted with Geospatial Modeling Environment (version 0.7.2.0 RC2; Beyer 2012). We calculated slope using the spatial analyst extension in ArcGIS from the U.S. Geological Survey's 30 m National Elevation Dataset (NED) (Gesch et al. 2002).

We assigned dominant parameters to each study plot using the following datasets: vegetation type (SWReGAP 2007), land cover feature (SWReGAP 2007), and soil order (NRCS 2012). We created Generalized Linear Models (GLM) to determine model fit (Hosmer and Lemeshow 2000) using R statistical software program (version 2.15.1; R Development Core Team 2012). We used AIC to select the best fitting predictive variables (Hosmer and Lemeshow 1989, Burnham and Anderson 2002). To evaluate the power of the regression formula, we graphically modeled GIS data by entering its inverse logit into the ArcGIS raster calculator. This transformation graphically represents the regression output in terms of probability. Spatial resolution with the best fit was selected as each covariate was converted to a 30 m pixel dataset (Fisher and Tate 2006). The resulting layer was reclassified into 3 LCTH detection probability intervals: low detection (20-40%), medium detection (40-60%), and high detection (60-80%). Each detection probability interval contained a 1000 m buffer to prevent spatial autocorrelation (Ord and Getis 1995) within each detection class (i.e., plots were a minimum of 1 km apart).

Table 2. GIS layers and descriptions used for Le Conte's Thrasher Prediction of Occurrence Model.

Layer Name	Spatial Resolution	Data Type	Description	Source
Plot_ID	NA	nominal	Year & Plot ID	NA
Area	NA	quantitative	Area of plot	NA
Veg	30 m	categorical	Dominant plot vegetation	SWReGAP 2007
RoadDIST	60 m	Quantitative	Distance from plot center to nearest road	Tiger 2012
StreamDIST	60 m	Quantitative	Distance from plot center to nearest perennial stream	ASLD 2011
MinTemp	775 m	Quantitative	Average minimum temperature x10	Hijmans et al. 2005
MeanTemp	775 m	Quantitative	Average temperature x10	Hijmans et al. 2005
Precipitation	775 m	Quantitative	Average precipitation temperature x10	Hijmans et al. 2005
Landform	30 m	Categorical	Dominant plot landform order	SWReGAP 2007
LengthRoad	500 m	Quantitative	combined length of all road within each plot	NA
LengthStream	500 m	Quantitative	combined length of all perennial stream within each plot	NA
Avg_Slope	30 m	Quantitative	average slope of the plot	LANDFIRE 2012
Avg_Elevation	30 m	Quantitative	average elevation of the plot	LANDFIRE 2012
Soil_Order	30 m	Categorical	Dominant plot soil order	NRCS 2012

RESULTS

Broadcast-response Surveys

We detected 140 LCTH at 80 points within 26 plots between January and April 2012 across the three DoD properties (Table 3). Additionally, we detected three LCTH incidentally while observers walked between survey points or en route to surveys. LCTH breeding was detected within our study area during our surveys. We detected three active LCTH nests, and 48 male-female pairs within 21 plots, potentially consisting of pairs.

Table 3. Number of LCTH detections with respect to plot and timing of survey (AM versus PM).

Survey Pass (AM)	Survey Plots with LCTH Detections	Number of LCTH Detections	Survey Pass (PM)	Survey Plots with LCTH Detections	Number of LCTH Detections
1	21	33	1	18	29
2	14	19	2	8	11
3	10	14	3	7	8
4	14	21	4	3	5

Surveys at YPG

We did not conduct LCTH surveys on the Cibola Arm of YPG as much this region is not suitable LCTH habitat (Blackman et al. 2012). Most of the soil surface within the Cibola Arm is desert pavement, a substrate that is not conducive to LCTH occurrence (Blackman et al. 2010, 2012). Because of restricted access, and that LCTH are not likely to occur in many areas, we conducted relatively few survey plots on YPG (n=3, 10%). LCTH were only detected at one plot (2) south of the Palomas Mountains on the Kofa Arm where the soil surface was predominantly softer sands with relatively less gravel (Appendix 1).

Surveys at BMGR East

Six plots (6 of 30, 23%) were randomly distributed within the San Cristobal Valley, east of the Mohawk Mountains, within BMGR East (Figure 5). We detected LCTH at 37 locations at all six plots located within BMGR East (Appendix 1).

Surveys at BMGR West

Most of our survey plots occurred within BMGR West (20 of 30, 67%). This was due to the amount of area in BMGR West characterized as highly suitable LCTH habitat by the LCTH PO Model (Blackman et al. 2012). Of the 20 plots surveyed at BMGR West, observers detected LCTH at 49 locations within 17 plots (Appendix 1). LCTH were not detected at plots 4, 31, and 36 (Figure 5).

Habitat Assessment

Tree counts and distances to nearest trees and washes to perch LCTH locations were highly variable. The number of trees within 10 m of LCTH perch locations ranged from 0 (n=36), 1 (n=18), 2 (n=13), 3 (n=16), 4 (n=6), and 5 (n=5). In plots where no trees were observed within 10 m of LCTH perch locations (n=36), the distances to the closest tree were 10-50 m (n=7), 50-100m (n=7), and >100 m (n=12). The distances from LCTH perch locations to the nearest wash (of any size) were 0-10 m (n=40), 10-50 m (n=16), 50-100 (n=4) and >100 m (n=32).

We found three active LCTH nests constructed in ironwood (n=1) and mesquite trees (n=2). Other species available for LCTH nest placement included blue and foothills paloverde and crucifixion thorn (*Castela emoryi*). The number of trees within 10 m of LCTH nest locations was 2 (n=1), 3 (n=1), and 4 (n=1). Desert washes (of any size) nearest to the three LCTH nests were 10-50 m (n=1) and >100 m (n=2).

The presence/absence of LCTH was significantly related to distance to tree, forb density, woody composition and litter (Table 4). Standard error graphs are presented in Appendix 2.

Table 4. Results of ANOVA with LCTH habitat covariate F and P-values. Each habitat covariate was assessed using ranked percent cover categories for each location.

Habitat Covariate	F-value	P-value
Sand	2.27	0.1333
Gravel	0.12	0.7347
Tree	**27.66**	**<0.001**
Shrub	2.24	0.1357
Forb	**7.43**	**0.0069**
Woody	**5.03**	**0.0259**
Litter	**16.52**	**<0.001**

Occupancy Estimation

Three detection models were run with constant occupancy: constant occupancy, constant detection [psi(.),p(.)]; constant occupancy, detection modeled as a function of Julian Day [psi(.),p(Julian)]; constant occupancy, detection modeled separately for each survey pass [psi(.),p(Survey)]. The highest ranking model incorporated survey-specific pass as a detection covariate (Table 5).

Table 5. Le Conte's Thrasher detection models. The table includes the Akaike Information Criterion (AIC), log-likelihood (-2logLik), number of parameters (*K*), Akaike difference (ΔAIC), and Akaike weight (*w*).

Model	AIC	*K*	ΔAIC	*w*	-2logLik
psi(.),p(Survey)	295.34	5	0	0.9993	285.34
psi(.),p(.)	310.88	2	15.54	0.0004	306.88
psi(.),p(Julian)	312.09	2	16.75	0.0002	308.09

The estimated PAO by LCTH across the three DoD properties is 0.83 (SE $\pm$0.08) and the naïve abundance estimate is 0.80. The detection probability of LCTH across the three DoD properties is 0.53 (SE $\pm$0.097).

Occupancy was modeled using the most supported detection model [p(Survey)] and 21 site-specific occupancy covariates (Table 6). The global occupancy model provided an adequate fit to the data (GOF: χ^2 = 29.727, P = 0.103) (Table 6). Overdispersion was evident in the global occupancy model ($\sqrt{\hat{c}}$ = 1.43) and the standard errors were adjusted using the variance inflation factor. Given this level of overdispersion, quasi-AIC for overdispersed data was used when comparing occupancy models.

The highest ranking occupancy model contained three covariates: Soils282 (Why-Wellton-Gunsight-Growler-Denure), slope and VegS069 (Lower Colorado River subdivision of the Sonoran Desert) (Table 6). One other model was within <2 Δ*AIC* of the most parsimonious model. This model contained the three covariates used in the highest ranking model and additionally included stream distance. Soils282 contained the highest parameter importance, followed by, in decreasing order of importance, VegS069,

slope and stream distance (Table 7). All covariates in the most parsimonious models, except for slope, contained parameter estimates indicating a positive relationship. We summed the AICw for covariates represented in the most competitive models ranking within <2ΔAIC of the highest ranked model. Model selection uncertainty of the most supported models was fairly low (AICw >0.30) (Table 7). We examined unconditional parameter estimates from covariates included in the best supported models (models within <2 ΔAIC) (Table 7).

Table 6. Comparison of Le Conte's Thrasher occupancy models. The table includes the quasi-AIC (QAIC) for overdispersed data, log-likelihood (logLik), number of parameters (*K*), the small sample QAIC ($QAIC_c$), Akaike difference ($\Delta QAIC_c$), and Akaike weight (*w*).

Model	AIC	logLik	*K*	AIC_c	$QAIC_c$	$\Delta QAIC_c$	*w*
psi(SoilS282 + VegS069 + Slope), p(Survey)	287.92	-136.96	7	289.787	839.121	0.000	0.54
psi(SoilS282 + VegS069 + Slope + StreamDist), p(Survey)	287.71	-135.86	8	290.151	839.810	0.690	0.38

Table 7. Model averaged estimates and standard errors for parameters included in the best fit ($\Delta QAIC_c \leq 2.0$) occupancy models.

Parameter	Estimate	Standard Error
SoilS282	1.957	0.724
VegS069	0.936	0.593
Slope	-0.300	0.201
StreamDist	0.211	0.346

Prediction of Occurrence Model

Figure 3 spatially depicts the raster output of the LCTH PO Model as a color ramp. Class 1 (20-40%) contained the most plots without LCTH detections with respect to the total number of plots surveyed for both years for that class (Table 8). Class 2 (40-60%) contained a lower ratio between LCTH detections and non-detections for 2011 and 2012 (Table 8). All survey plots within Class 3 (60-80%) contained LCTH detections (Table 8). These results are also spatially depicted in figures 4 and 5 for 2011 and 2012 respectively.

Table 8. Number of Le Conte's Thrasher survey sites for three Prediction of Occurrence Model Classes.

Prediction of Occurrence Model Class	2011 Plots with LCTH Detections	2011 Plots with No LCTH Detections	2012 Plots with LCTH Detections	2012 Plots with No LCTH Detections
(1) 20-40%	14	10	10	5
(2) 40-60%	12	2	12	1
(3) 60-80%	2	0	2	0

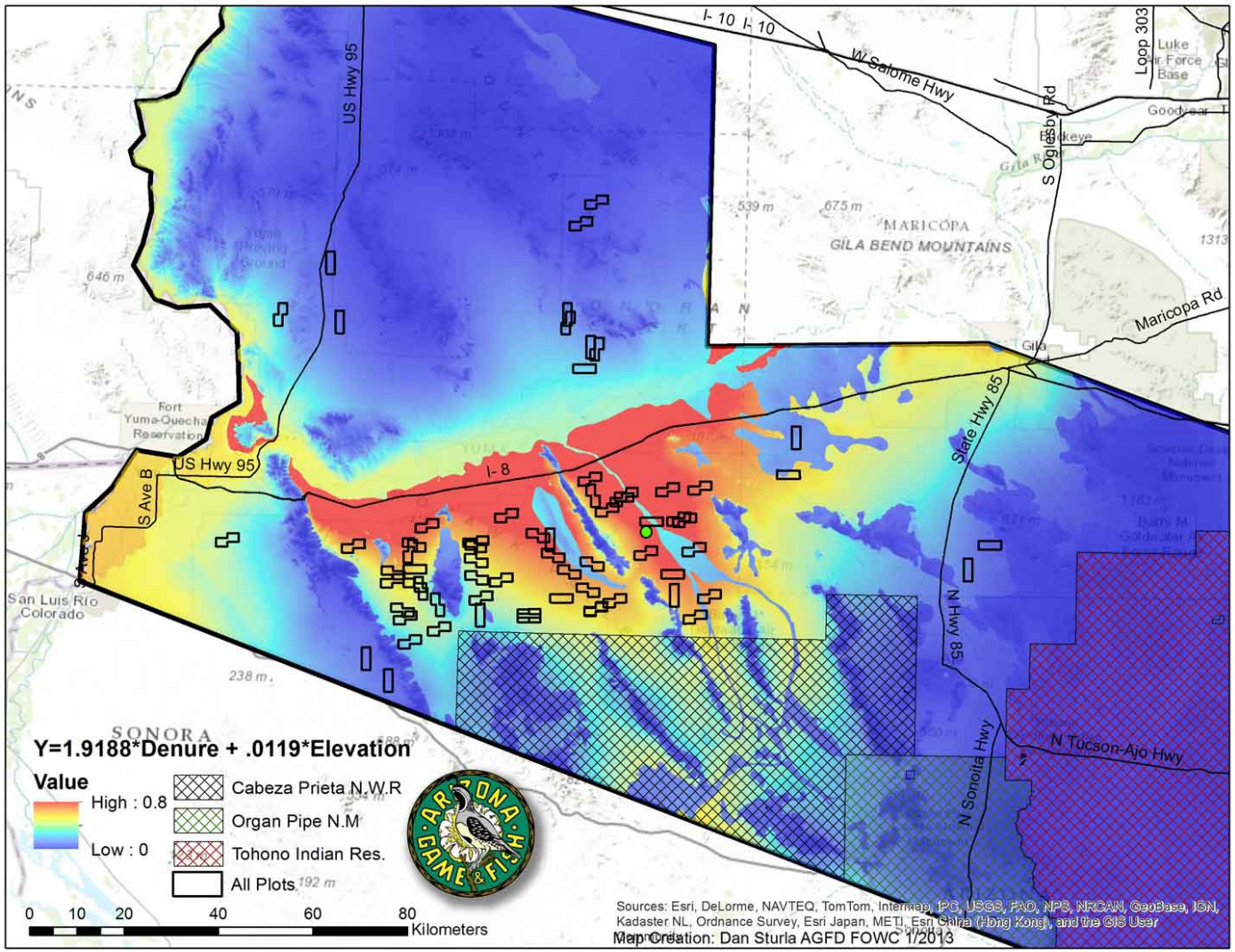

Figure 3. Le Conte's Thrasher Prediction of Occurrence Model; 2011 and 2012 survey plots overlaid.

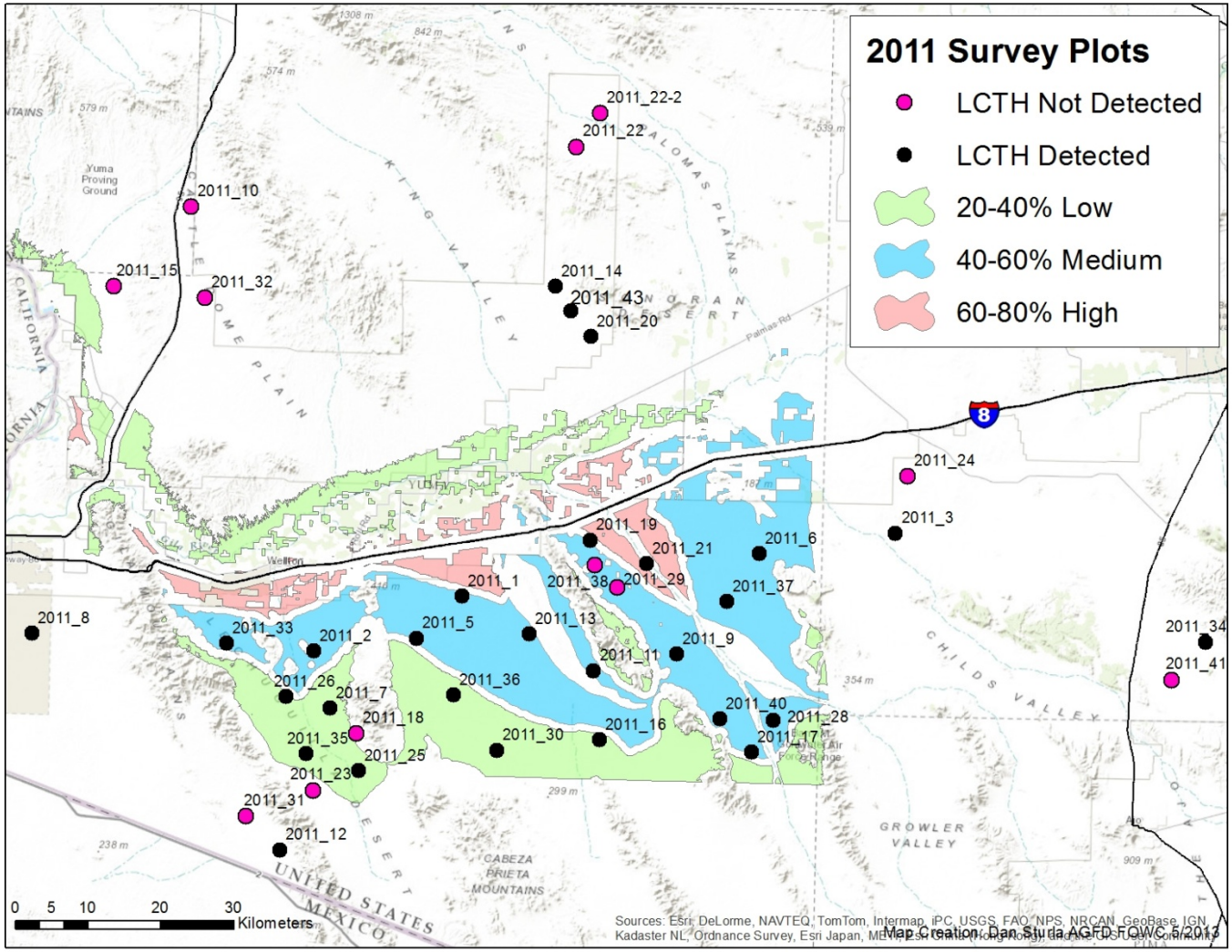

Figure 4. Plots where Le Conte's Thrashers were and were not detected during surveys at YPG, BMGR East, and BMGR West during 2011 with respect to three Prediction of Occurrence classes.

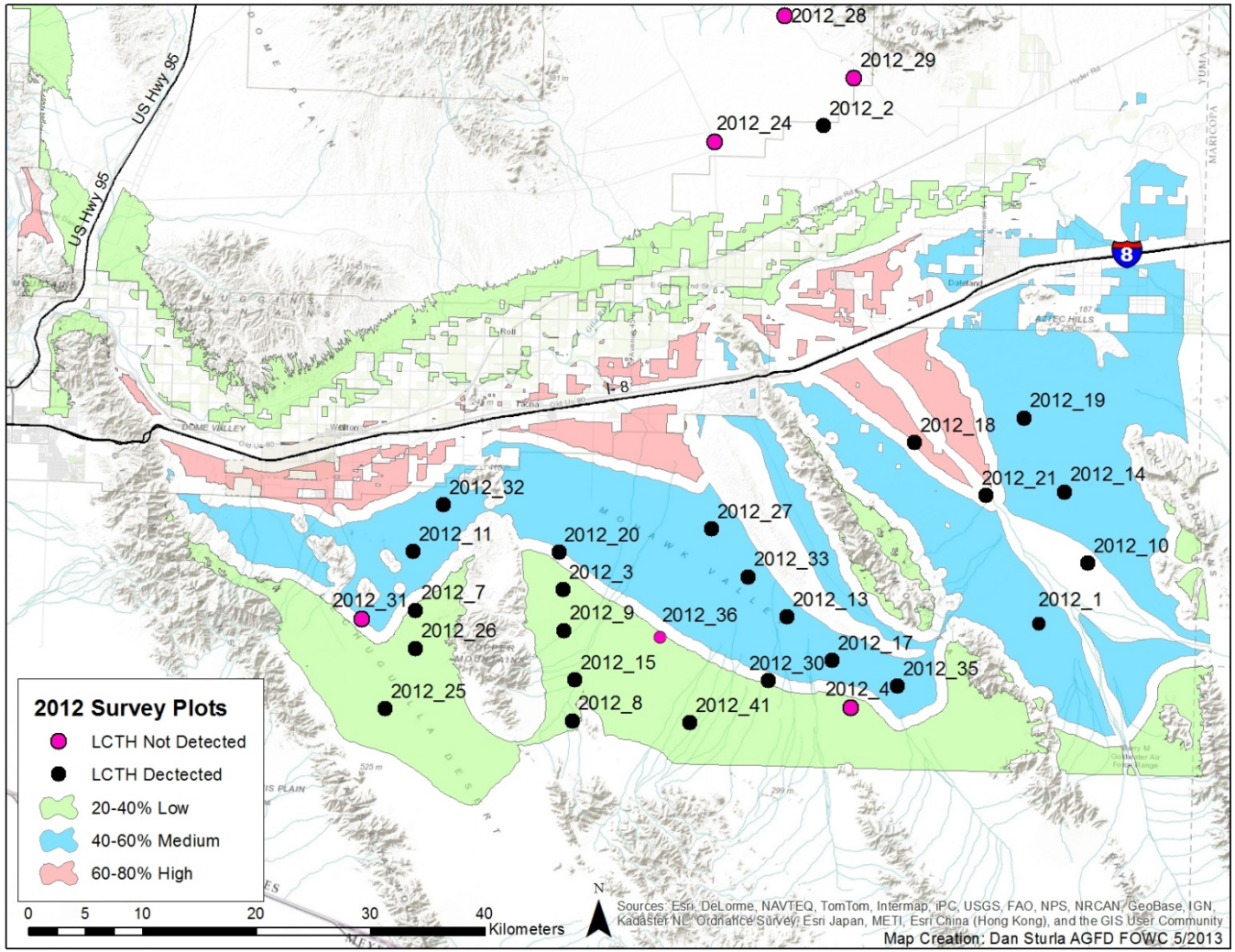

Figure 5. Plots where Le Conte's Thrashers were and were not detected during surveys at YPG, BMGR East, and BMGR West during 2012 with respect to three Prediction of Occurrence classes

DISCUSSION

Across the three DoD study areas, we detected 183 and 140 LCTH in year 1 and year 2, respectively. Similar to the results of year 1, this study demonstrated that LCTH were not detected at all survey locations where the landscape appeared suitable and were predicted as habitat by the PO model. The distribution of LCTH was not uniform across the sampled area and the majority of detections were in areas with soft sand and sparse trees. Among the three DoD properties, most LCTH were detected at BMGR (East and West), in part because most survey plots were located at BMGR.

Although the area sampled around detection locations was small compared to LCTH home ranges, inferences can be made at a larger scale. Analysis of 2012 habitat data revealed that sand, gravel and shrub cover were not significant to LCTH occurrence (Table 4). Tree, forb, woody debris and litter cover produced significant P-values (<0.05) and high F-scores highlighting a relationship between LCTH occurrence and these covariates (Table 4). LCTH are unlikely to be detected near mountains where the soil surface has a relatively high amount of gravel and tree densities are greater (Blackman et al. 2010). We anticipated that gravel composition would have a negative influence on LCTH occurrence (i.e., increases in percent gravel composition were inversely proportional to LCTH occurrence). In 2011, gravel composition was the highest ranked individual covariate model, and contained a parameter estimate indicating a negative relationship (Blackman et al. 2012). Surprisingly, ANOVA failed to demonstrate a relationship between LCTH occurrence and sand and gravel composition (Table 4). This may be due to the general lack of gravel within 2012 survey plots and that woody debris, litter and forb cover superseded sand cover when those covariates were documented.

We found a significant positive relationship between LCTH occurrence and total tree cover (Table 4). This is not surprising as several tree species are important to LCTH nesting, including crucifixion thorn and mesquite hummocks (clusters of mesquite tree ‘islands’ within a sparsely vegetated landscape). Other studies have documented nesting in large shrubs (e.g., creosote) and even abandoned buildings and vehicles (Sheppard 1970). LCTH nest-site selection may be more influenced by vegetation structure than plant taxonomy.

We detected fewer LCTH in year 2 than in year 1; however, fewer survey plots were visited in year 2, but contained an additional survey pass. In year 1, the PAO by LCTH was 0.76 (SE $\pm$0.08) and the model-averaged detection probability was 0.64 (SE $\pm$0.09). These values are consistent with year 2, with a PAO of 0.83 (SE $\pm$0.08), and a detection probability of 0.53 (SE $\pm$0.097). A lower detection probability for LCTH during year 2 may be attributed to the addition of a fourth survey pass. LCTH become less conspicuous later in the breeding season, when the home range of breeding pairs decreases and birds become less vocal. Additionally, partitioning the surveys into early (AM) and late (PM) timeframes had relatively little impact on detecting LCTH until the fourth survey pass (Table 3). Although detections were higher for AM passes, it appears most important to conduct LCTH surveys early in the day later in the breeding season.

Modeling LCTH within the occupancy framework produced a moderately high detection probability, but still demonstrated imperfect detection (i.e., <1). The most supported detection model varied by survey pass and was used in subsequent occupancy models (Table 6). No single point within the 26 plots where LCTH were detected was occupied by LCTH during all four survey passes. Only one point within all 26 survey plots produced LCTH detections on the first three passes (BMGR-E plot 1, point 4). LCTH were detected at only one plot (plot 21) during all four survey passes. LCTH were detected on three plots during the first three survey passes, but not on the fourth pass. We detected LCTH during three of four passes at nine plots. Eight plots contained detections on two survey passes. Six plots contained LCTH on only one survey pass, and six plots had no LCTH detections. This demonstrates the general difficulty in detecting LCTH, particularly late during the breeding season. These detection results with respect to survey pass help explain the moderate LCTH detection probability relative to LCTH PAO, and highlight the significance of its incorporation into 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.

Our model corroborates that LCTH select Why-Wellton-Gunsight-Growler-Denure soils, Lower Colorado River subdivision of the Sonoran Desert vegetation association and proximity to washes. However, these covariates are widespread throughout LCTH habitat and are most useful for predicting LCTH habitat when combined. Furthermore, our model indicates LCTH respond negatively to increasing slope. Thus, LCTH are less likely to be found as slope increases in proximity to desert mountain ranges. Correspondingly, gravel content and tree density also increase with slope, landscape characteristics to which LCTH do not select for. Our models also indicate that LCTH respond positively to the proximity of washes. LCTH use washes as movement corridors, for foraging, and predator avoidance. However, model selection may also result from the high number of washes in LCTH habitat.

The Distance to Road covariate consistently had large standard errors relative to parameter estimates. When included in occupancy models, the Distance to Road covariate inflated standard errors of other covariates. In some cases, inclusion of Distance to Road caused parameter estimates to change sign from + to -. Collinearity may explain why the Distance to Road covariate affected occupancy modeling; thus, we omitted it from further occupancy analyses, but included Length of Roads within each plot. Our occupancy models determined that the length of Roads within LCTH survey plots is negatively related to LCTH occupancy. These results suggest that LCTH select areas with low densities of unpaved roads. Thus, increases in unpaved road density may be detrimental to LCTH occurrence. Potential LCTH sensitivity to roads is also a concern for lands with Off-Highway Vehicle (OHV) use, especially in the context of illegally created ‘wildcat’ roads.

The revised LCTH PO model provides a more accurate portrayal of LCTH habitat and occurrence than the previous version produced in year 1 (Blackman et al. 2012). Data

from 2011 and 2012 validate the refined PO model, as the numbers of plots with and without LCTH detections correspond to the respective detection probability classes (Table 8, Figures 4 and 5). Class 3 contained the highest potential for LCTH detection (60-80%) and all plots contained within this class produced LCTH detections (Table 8, Figures 4 and 5); however, the total number of survey plots was small. Plots in Class 2 (40-60%) produced more LCTH detections than non-detections and Class 1 (20-40%), contained the most plots without LCTH detections (Figures 4 and 5, Table 8). Classes 1-3 of the PO Model can be combined with other GIS layers, providing land managers with accurate maps of areas where LCTH are most likely to occur within their jurisdiction. This is a powerful conservation tool for identifying priority LCTH habitat within military activity areas or development footprints (e.g., alternative energy construction areas).

Long-term research is critical for distinguishing natural and anthropogenic causes of fluctuations in wildlife populations. Occupancy modeling can provide a reliable alternative to more costly and labor intensive methods of estimating abundance. High occupancy rates through time at repeated survey locations can indicate a relatively healthy population. However occupancy modeling is not in itself an exclusive monitoring technique for determining whether an LCTH population is self-sustaining. In 2013, we will use the revised LCTH PO model to guide surveys in the three different LCTH PAO categories. This occurrence data will be used to further refine the LCTH PO model and guide nest monitoring efforts. Nests will be monitored until LCTH juveniles are old enough to capture and attach radio-transmitters to obtain juvenile movement and home range data.

MANAGEMENT AND RESEARCH PRIORITIES

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 surrounding these DoD properties is developed for agriculture, alternative energy (solar), and urban expansion. The U.S. Census Bureau projects that Arizona will add 5.6 million people by 2025, making it the 10th most populated state in the country and ranking in the top five fastest-growing states (US Census Bureau 1997).

The DoD within southern Arizona, along with the U.S. Fish and Wildlife Service, AZ Game and Fish Department, 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 management recommendations for the species of concern on DoD properties in southwestern Arizona. This study addressed the following recommended management and research priorities for LCTH made by the DoD Species-at-Risk project:

- Collect data on LCTH to evaluate this species' distribution in relation to military training activities and potential threats. This study collected the second season of

LCTH occupancy modeling data used to predict occurrence patterns (incorporating a detection probability) and continued research that can be used as a comparison with future surveys.

- 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. An objective of this study was to describe essential habitat components for LCTH; areas containing litter, woody debris, trees and shrub cover were significant to LCTH. Sand, gravel and shrub cover performed poorly in Analysis of Variance where there was not a significant relationship with LCTH occurrence.

- Concentrate training and development activities away from areas with current or historic records of LCTH. In addition, 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. This study used 2011 and 2012 survey data to improve the LCTH PO model that highlights areas potentially suitable to LCTH occurrence. These areas can be more easily predicted across this species distribution and particularly where potential military training-related impacts are planned.

- 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; OHV traffic in this area is difficult to manage.

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 US 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. However, the vast area that exists within this region probably acts as a buffer to directly impacting LCTH population viability.

- Compare the habitat that LCTH are using versus what is available to them. This can be accomplished by measuring habitat variables at plots within LCTH territories in conjunction with measuring habitat variables at random plots.

- Other potential disturbances to LCTH are expected to increase including urban and agricultural development, wind and solar power. In the face of these potential threats, it is important to investigate the thresholds to which LCTH respond negatively to these disturbances.

- Initiate or continue monitoring the expansion of invasive plant species; evaluate effects of invasive species on LCTH populations in US and Mexico.

- Develop and implement integrated management strategies to reduce wildfire fuel loads and further spread of invasive species.

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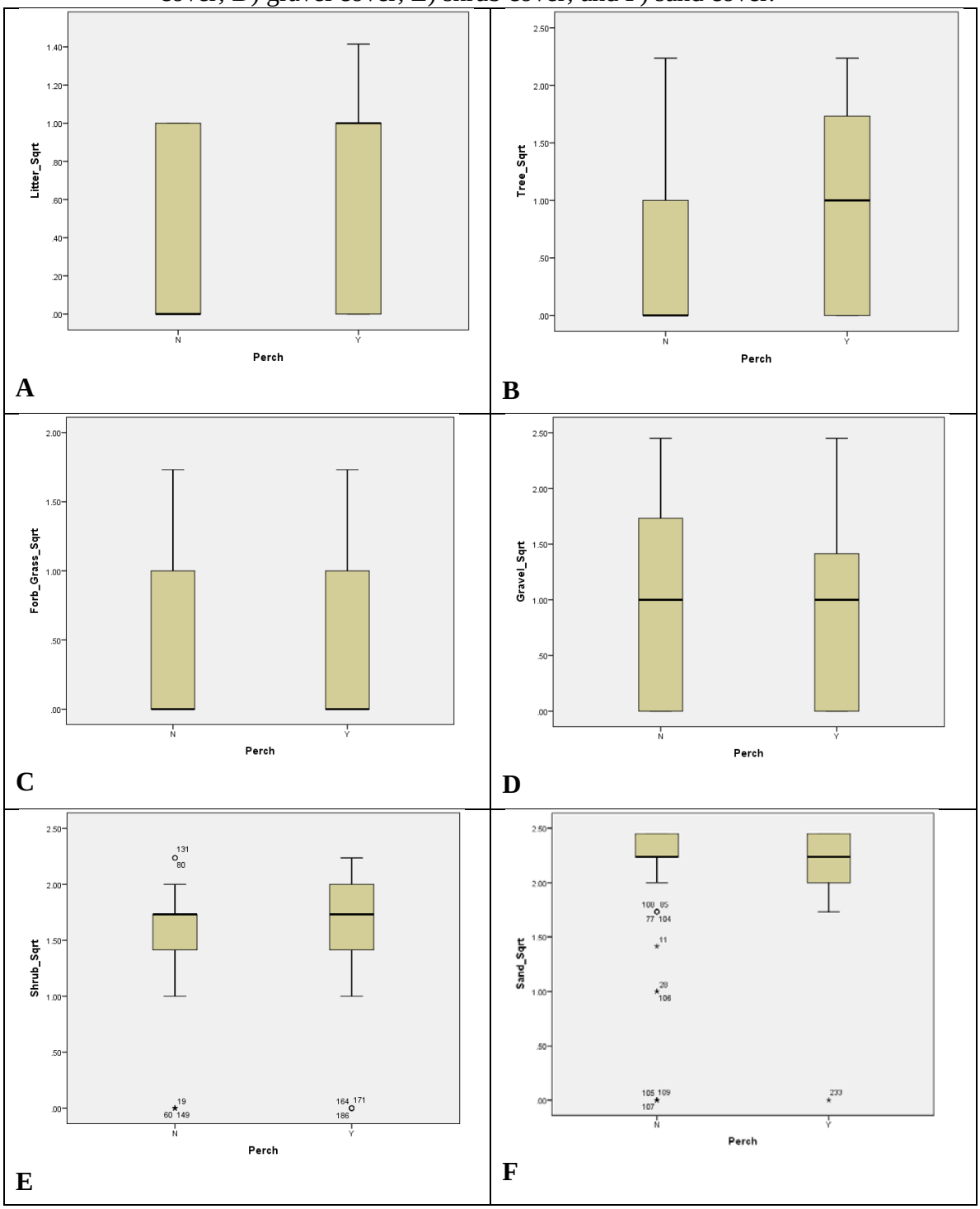
Appendix 1. Randomly generated centers of Le Conte's Thrasher 2012 survey plots with respective numbers of LCTH detections.

Plot ID	Range	LCTH Detection Locations	Easting (NAD 83)	Northing (NAD 83)
1	BMGRE	11	266779	3602204
2	YPG	6	248137	3646708
3	MCAS	1	225254	3605589
4	MCAS	0	250538	3595250
7	MCAS	8	775951	3603928
8	MCAS	5	226567	3594091
9	MCAS	8	225330	3601987
10	BMGRE	1	271326	3607907
11	MCAS	6	775082	3608551
13	MCAS	5	244945	3603195
14	BMGRE	12	269285	3614093
15	MCAS	6	226277	3597625
17	MCAS	6	248879	3599365
18	BMGRE	2	256072	3618466
19	BMGRE	20	265724	3620611
20	MCAS	2	224900	3608864
21	BMGRE	17	262371	3613335
24	YPG	0	238864	3645067
25	MCAS	4	773592	3594673
26	MCAS	6	212133	3600342
27	MCAS	3	238277	3610878
28	YPG	0	244691	3655855
29	YPG	0	250810	3650351
30	MCAS	6	243213	3597130
31	MCAS	0	770769	3602256
32	MCAS	1	777802	3612752
33	MCAS	0	241535	3606689
35	MCAS	2	254617	3597129
36	MCAS	1	230508	3601506
41	MCAS	1	236413	3593932

Appendix 2. Standard error of habitat covariates assessed with ANOVA with respect to LCTH perch or non-perch: A) litter cover; B) tree cover; C) forb and grass cover; D) gravel cover; E) shrub cover; and F) sand cover.