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Le Conte's Thrasher (*Toxostoma lecontei)*
Occupancy and Prediction of Occurrence Modeling: Barry M. Goldwater Range and Yuma Proving Ground in Southwestern Arizona

Scott T. Blackman AZ Game and Fish Dept.
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Le Conte's Thrasher (*Toxostoma lecontei)* Occupancy and Prediction of Occurrence Modeling: Barry M. Goldwater Range and Yuma Proving Ground in Southwestern Arizona

Scott Blackman, Dan Sturla, Joel Diamond, PhD and David Grandmaison

Scott Blackman (Sblackman@azgfd.gov), Daniel Sturla DSturla@azgfd.gov), Joel Diamond, PhD. (JDiamond@azgfd.gov), Arizona Game and Fish Department, 5000 W. Carefree Highway, Phoenix, AZ 85086.

The Le Conte's Thrasher (*Toxostoma lecontei*) is an uncommon permanent resident of deserts in the southwestern United States. This species is listed as a Bird of Conservation Concern by the US Fish and Wildlife Service and as a Wildlife Species of Concern by the Arizona and California Game and Fish Departments. In Arizona, one of the densest concentrations of Le Conte's Thrasher occurs on the Barry M. Goldwater Range (BMGR). Information on sensitive, threatened and endangered species that potentially occur on Department of Defense (DoD) lands is needed to make military planning compatible with sensitive species management.

The goals of this project were to generate a Prediction of Occurrence model using survey data for Le Conte's Thrashers obtained within an occupancy modeling framework on BMGR and Yuma Proving Ground (YPG) in southwestern Arizona during the breeding season (January-June) 2011 and 2012. A total of 70 survey plots were randomly generated throughout the study site and were surveyed with three (2011) and four (2012) survey passes. Across the three DoD properties, we detected 323 Le Conte's Thrasher at 187 points within 54 plots. The estimated proportion of area occupied (PAO) by Le Conte's Thrasher across the three DoD properties was 0.76 (SE $\pm$0.08) and 0.83 (SE $\pm$0.08) in 2011 and 2012, respectively. The probability of detection for Le Conte's Thrasher across the study area was 0.64 (SE $\pm$0.09) and 0.53 (SE $\pm$0.097) in 2011 and 2012, respectively.

The Le Conte's Thrasher (*Toxostoma lecontei*) is an uncommon permanent resident of deserts within the southwestern United States and northwestern Mexico (Sheppard 1996, Corman and Wise-Gervais 2005). This species is listed as a Bird of Conservation Concern by the US Fish and Wildlife Service and as a Wildlife Species of Concern by the Arizona and California Game and Fish Departments (Latta et al. 1999, California Partners in Flight 2006). In Arizona, the densest concentrations of Le Conte's Thrasher occur on Cabeza Prieta National Wildlife Refuge and the Barry M. Goldwater Range (BMGR) (Corman and Wise-Gervais 2005). Populations have declined in some areas of California (e.g., San Joaquin Valley) (California Partners in Flight 2006, Coachella Multi-species Habitat Conservation Plan 2007) and in Arizona where agriculture and urban development have expanded.

The Department of Defense (DoD) manages many acres of Sonoran Desert and is important to conservation of this eco-region (Marshall et al. 2000, Villarreal et al. 2011). Information on sensitive, threatened and endangered species that potentially occur on BMGR and Yuma Proving Ground (YPG) is needed to make military planning compatible with sensitive species management.

The proportion of area occupied (PAO) is a superior alternative to abundance estimation in wildlife monitoring programs because PAO metrics incorporate the detection probability of each species (Bailey et al. 2004, MacKenzie and Royle 2005). If the detection probability for a 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, MacKenzie et al. 2006). PAO estimates are calculated using the likelihood-based approach described by MacKenzie et al. (2002) that accounts for species or individuals present but undetected during surveys. The goals of this project were to generate a Prediction of Occurrence Model (PO) using the PAO of Le Conte's Thrasher on BMGR and YPG in southwestern Arizona during the 2011-2012 breeding season (January-June).

Study Site

Barry M. Goldwater Range East and West

BMGR is co-managed by the U.S. Air Force and the U.S. Marine Corps. 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 properties, and to the east by the Tohono O'odham Nation and Bureau of Land Management lands. Elevations at BMGR range from 200 ft at western portions of the Range to 3,700 ft in the Sand Tank Mountains at the eastern border (BMGR 2012). Temperatures on BMGR can range from below 0° C (rare) to 49° C, with a range-wide average annual rainfall of approximately 5 inches (BMGR 2012).

The Lower Colorado River subdivision of the Sonoran Desert is the predominating vegetative community and is characterized by drought-tolerant plant species, such as 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 incised washes characterized by 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 Le Conte's Thrashers do 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 3,450 km² (Figure 1). Kofa National Wildlife Refuge and YPG share a 58-mile long boundary (USDI 1996). The elevation at YPG ranges from sea level to 878m. Average temperatures range from 16° C (December) to 30° C (July), with average annual rainfall of approximately 8.8 cm (WRCC 2013).

The prevalent vegetative community on YPG is the Lower Colorado River subdivision of the Sonoran Desert (described above). As at 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.

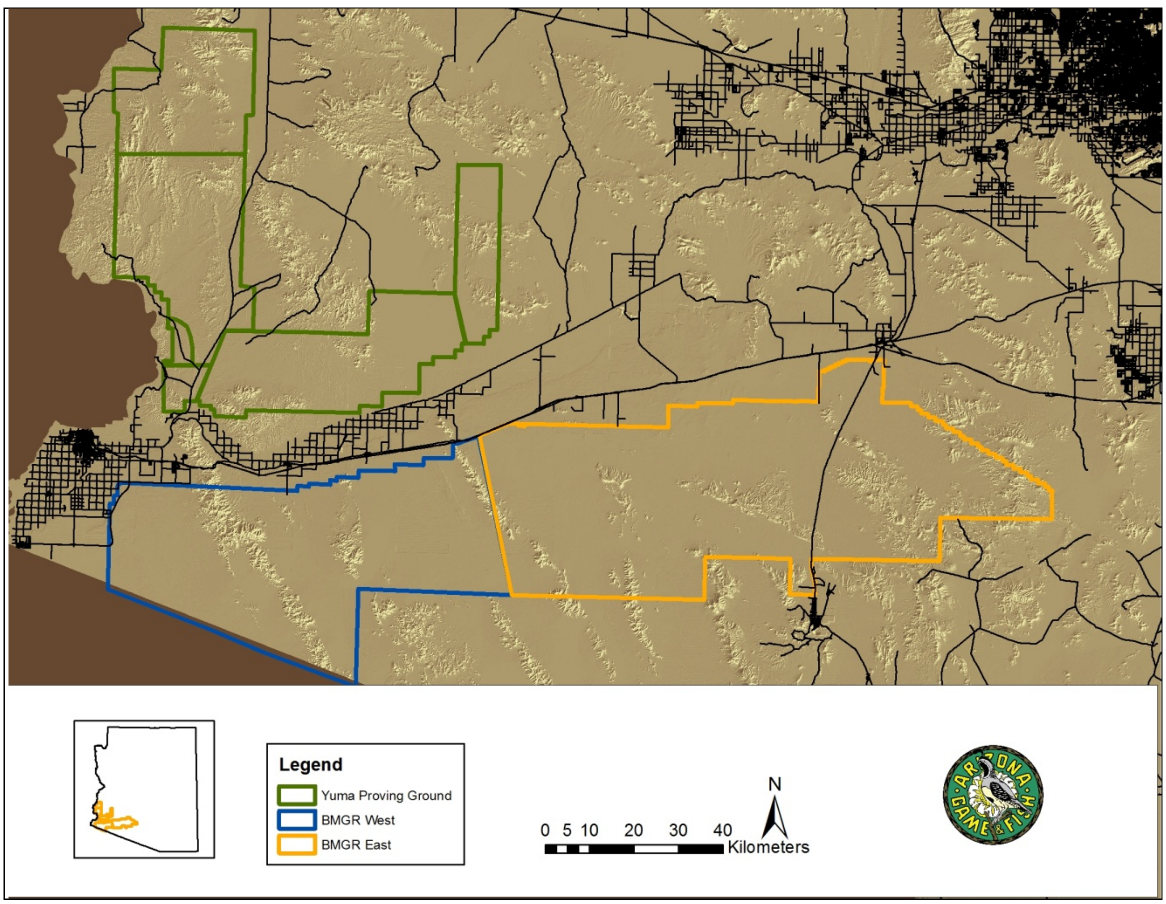

Figure 1. Occupancy surveys for Le Conte's Thrasher during 2011 and 2012 were located at YPG, BMGR East and BMGR West in southwestern Arizona, USA.

Material and Methods

Survey Methodology

Despite inhabiting very sparsely vegetated landscapes, Le Conte's Thrashers can be difficult to detect. Their cryptic plumage blends well with sand, and they typically forage on the ground beneath shrubs and trees making this species both secretive and elusive. Therefore, we employed the use of broadcast surveys with game callers (e.g. FOXPRO® NX3) programmed with Le Conte's Thrasher songs and calls to increase detections.

A total of 70 survey plots were randomly generated throughout the study site were randomly generated throughout the study area within Le Conte's Thrasher habitat using ArcGIS (ESRI 2012). Forty plots were surveyed three visits in 2011 and forty different plots were surveyed with four visits in 2012. We conducted surveys for Le Conte's Thrashers from January to April 2011 and 2012. Survey points were spaced 400 m apart along transects projecting out from the center of each randomly generated plot. Two observers began at the center of each randomly generated plot and walked in opposite directions (i.e. North/South or East/West). Both surveyors commenced broadcasting once they had walked 400 m from the original starting point (Figure 2). Transects included five points along one transect and five points along a second transect for a total of 20 broadcast points per survey plot (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 per survey plot. The second transects were parallel to the first transect and the direction that the surveyor chose to begin the second transect was contingent upon the suitability of the landscape to Le Conte's Thrasher occurrence.

At each broadcast point, surveyors first spent one minute quietly looking and listening for Le Conte's Thrashers. At the conclusion of the first minute, each surveyor broadcast a recording of Le Conte's Thrasher vocalizations for 90 seconds in a direction perpendicular to the transect line, followed by a 2-minute period of observation. The observer then broadcasted the vocalizations for another 90 seconds in the direction opposite of the first broadcast direction and perpendicular to the transect line, followed by another 2 minutes of observation. Thrasher 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. If no Le Conte's Thrashers were detected, total survey time at each point was 8 minutes. When Le Conte's Thrashers were detected and if the bird followed the observer, we reduced the likelihood of repeated counts of an individual bird by skipping adjacent broadcast points.

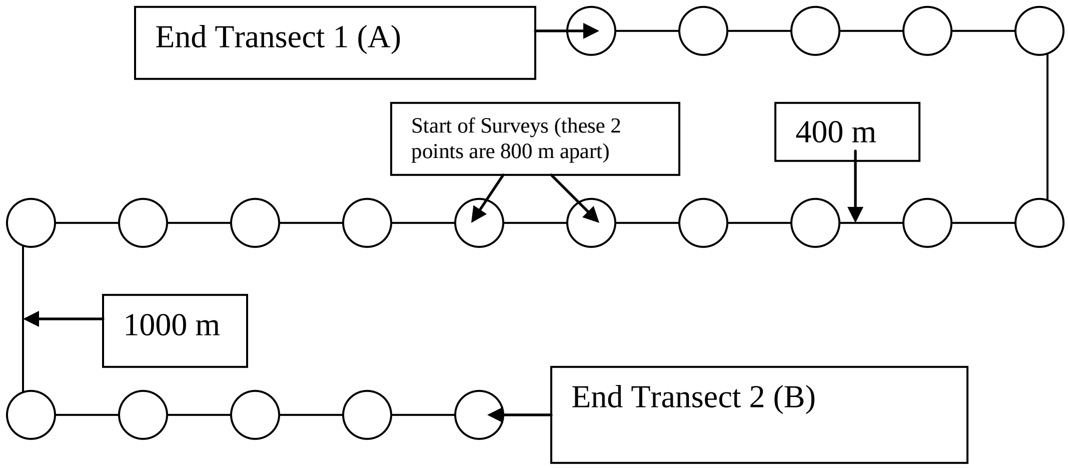

Figure 2. Schematic of parallel transects with call-broadcast survey points conducted by two surveyors walking in opposite directions. The middle 2 points are 800 m apart and are centered about a randomly-generated point. Other points on each transect are 400 m apart. Transects are 1 km apart.

Prediction of Occurrence Model

We used a Geographic Information System (GIS) model developed in 2010 to generate a Le Conte's Thrasher Prediction of Occurrence (PO) Model 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 thrasher detection locations (Blackman et al. 2010, Blackman et al. 2012). The PO model produced a 10-category ranking of potential Le Conte's Thrasher occurrence throughout the modeled area ranging from category one (least suitable habitat) to ten (most suitable 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 Le Conte's Thrashers.

The PO model was refined by including the results from 2011 and 2012 survey efforts and additional landscape-scale covariates. Le Conte's Thrasher detections from the 2011 and 2012 field seasons were imported and spatially joined to a feature-class reflecting all study plots. All physical covariates and remotely sensed data from WorldClim (www. worldclim.org) were imported into the model and classified to the study area. We assigned dominant parameters to each study plot using the following datasets: vegetation type (SWReGAP 2007), land cover feature (SWReGAP 2007), soil order (NRCS 2012), elevation (LANDFIRE 2012), and slope (LANDFIRE 2012). Roads and perennial stream layers (Tiger 2012, ASLD 2011) were also imported. Buffers defined by Euclidian distance (i.e., straight-line distance) were used to create "distance from" variables and assigned to the study plots. 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 obtained three climate GIS data layers from the WorldClim (www. worldclim.org) dataset with 2.5 arc-minute resolution (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.

We created Generalized Linear Models (GLM) using the R statistical software program (version 2.15.1; R Development Core Team 2012) to determine model fit (Hosmer and Lemeshow 2000). 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 by entering its inverse logit into the ArcGIS raster calculator. This transformation graphically represents the regression output in terms of probability (Figure 3). 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 Le Conte's Thrasher 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).

Occupancy Modeling

We used occupancy modeling (MacKenzie et al. 2002) to estimate the occurrence probability and detectability of Le Conte's Thrashers throughout the study area within an information-theoretic context (Burnham and Anderson 2002). 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*. Randomization and a lack of specific pre-existing knowledge of site occupancy eliminated site selection bias (MacKenzie and Royle 2005, Collier et al. 2010).

We developed *a priori* models, formed on the basis of biology and life history strategies, as a foundation for models used for estimating Le Conte's Thrasher 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., NRCS soil association, vegetative association, elevation and precipitation) that Le Conte's Thrasher presence was associated. We reduced the number of candidate models by evaluating the influence of survey pass on detection probability while holding occupancy constant [ψ(.) *p*(time)]. We then used the most parsimonious model of detection probability [ψ(.) *p*(survey)] to model the influence of habitat covariates on occupancy (Kroll et al. 2007, Hansen et al. 2011).

We used the software program PRESENCE version 5.8 (Hines 2013) to model the probability of detection and occupancy of Le Conte's Thrashers across the study areas. Akaike's Information Criterion (AIC) was used to 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 <2Δ*AIC* of the highest ranked model were considered to be best supported by the data and competed with the most parsimonious model.

Results and Discussion

Call-broadcast Surveys

Across the three DoD properties, we detected 183 Le Conte's Thrashers at 107 points within 28 plots in 2011.   In 2012, we detected 140 Le Conte's Thrashers at 80 points within 26 plots. Le Conte's Thrasher breeding was documented during surveys. We found three different active nests in 2011 and 2012, respectively. Two birds were simultaneously detected from 43 points within 20 plots in 2011, and from 48 points within 21 plots in 2012, potentially consisting of pairs.

We conducted relatively few surveys on YPG (n=8, 20% in 2011 and n=3, 10% in 2012 of all surveys) because of restricted access and unsuitable habitat.

Surveys detected Le Conte's Thrashers at 53 locations within 10 of 14 (71%) plots in 2011 on BMGR East. Six plots were randomly distributed in 2012 within BMGR East and Le Conte's Thrashers were detected at 37 locations within all six plots.

A large proportion (18 of 40, 45% in 2011 and 20 of 30, 67% in 2012) of our survey plots occurred within BMGR West. Le Conte's Thrashers were detected at 64 locations within 15 of the 18 survey plots (83%) in 2011 and 49 locations within 17 plots in 2012.

We did not detect birds at plot locations predominated by desert pavement. Le Conte's Thrashers were detected on plots where the soil surface was composed of softer sands and sparse gravel.

Prediction of Occurrence Model

The PO Model contains a color ramp representing a PAO from 0-80% (Figure 3). When the color ramp is partitioned into three categories, Class one (PAO 20-40%) contained the most plots without Le Conte's Thrasher detections for both survey years.   Class 2 (PAO 40-60%) contained a lower ratio between Le Conte's Thrasher detections and non-detections for 2011 and 2012. All survey plots within class 3 (PAO 60-80%) contained detections.

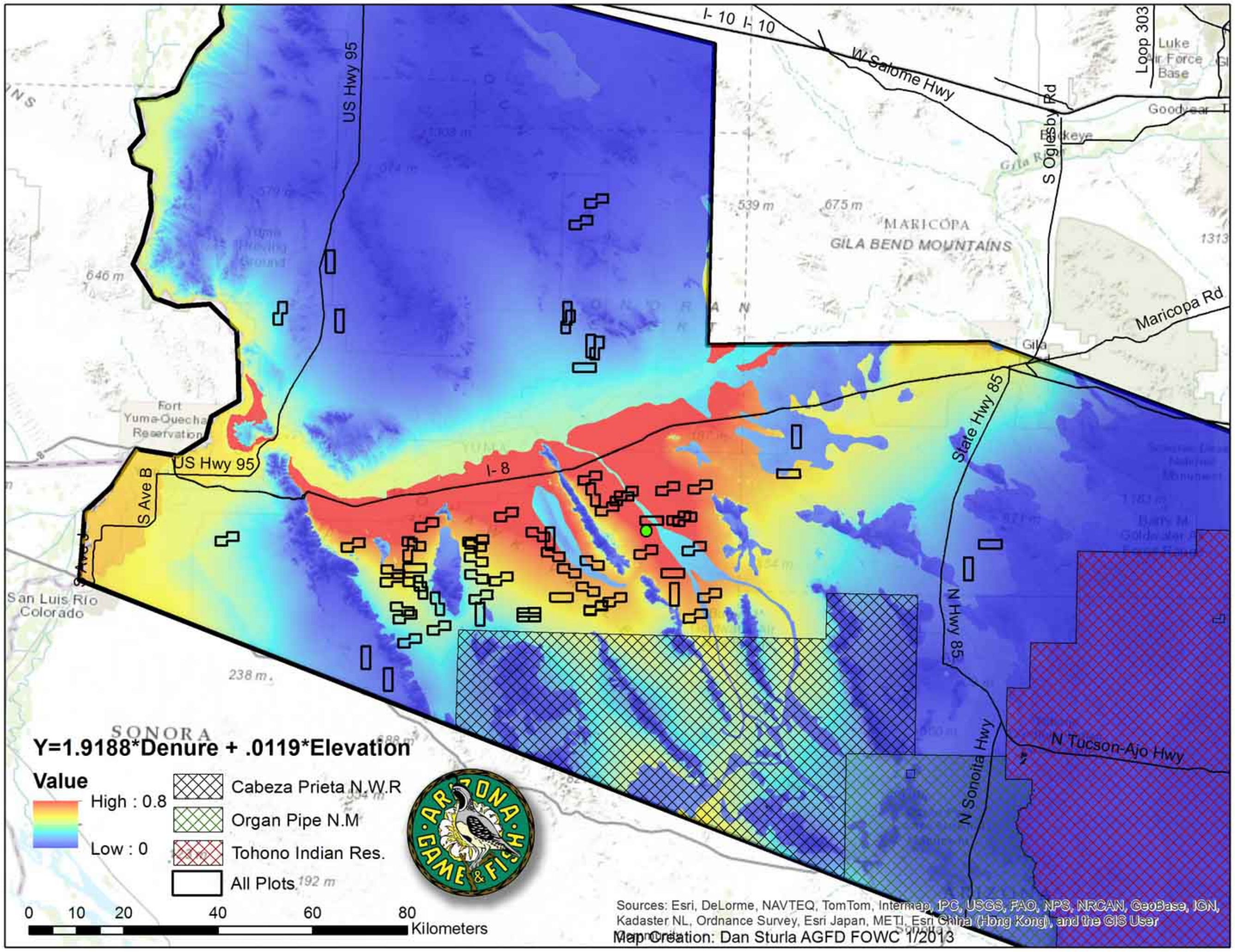

Figure 3. Le Conte's Thrasher Prediction of Occurrence Model; 2011 and 2012 survey plots overlaid.

Occupancy Estimation

In 2011, the estimated PAO of Le Conte's Thrasher across the three DoD properties was 0.76 (SE ±0.08). The probability of detection across the study area was 0.64 (SE ±0.09).

In 2012, the estimated PAO across the three DoD properties was 0.83 (SE ±0.08) and the naïve abundance estimate was 0.80. The detection probability of Le Conte's Thrashers across the three DoD properties was 0.53 (SE ±0.097).

Three detection models were run for the 2012 survey data 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 1).

Table 1. 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

Occupancy models were run using the most supported detection model [p(Survey)] and 21 site-specific occupancy covariates (Table 2). The global occupancy model provided an adequate fit to the data (GOF: χ^2 = 29.727, P = 0.103) (Table 2). 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 2). 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 3). We summed the AICw for covariates represented in the most competitive models ranking within <2Δ*AIC* of the highest ranked model. Model selection uncertainty of the most supported models was fairly low (AICw >0.30) (Table 3). We examined unconditional parameter estimates from covariates included in the best supported models (models within <2 Δ*AIC*) (Table 3).

Table 2. 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
psi(SoilS282 + VegS069 + Slope + RoadLength), p(Survey)	288.58	-136.29	8	291.021	844.458	5.337	0.04
psi(SoilS282 + VegS069 + StreamDist), p(Survey)	289.06	-137.53	7	290.927	845.168	6.047	0.03
psi(SoilS282 + VegS069), p(Survey)	289.48	-138.74	6	290.857	845.634	6.513	0.02
psi(SoilS282), p(Survey)	291.14	-140.57	5	292.108	852.688	13.568	0.00
psi(.), p(Survey)	295.34	-142.67	5	296.308	874.942	35.822	0.00
psi(Soil), p(Survey)	294.51	-135.26	12	300.183	886.188	47.067	0.00
psi(VegS069), p(Survey)	298.55	-144.28	5	299.518	892.142	53.022	0.00
psi(StreamDist), p(Survey)	299.04	-144.52	5	300.008	894.782	55.662	0.00
psi(Veg), p(Survey)	298.92	-142.46	7	300.787	898.373	59.253	0.00
psi(StreamLength), p(Survey)	303.63	-146.82	5	304.598	919.702	80.581	0.00
psi(Slope), p(Survey)	305.92	-147.96	5	306.888	932.262	93.141	0.00
psi(MeanTemp), p(Survey)	310.15	-150.08	5	311.118	955.684	116.563	0.00
psi(Precip), p(Survey)	310.15	-150.08	5	311.118	955.684	116.563	0.00
psi(Elevation), p(Survey)	310.15	-150.08	5	311.118	955.684	116.563	0.00
psi(MinTemp), p(Survey)	310.15	-150.08	5	311.118	955.684	116.563	0.00
psi(RoadLength), p(Survey)	311.25	-150.63	5	312.218	961.822	122.701	0.00
psi(SoilS282 + VegS069 + Slope + Elevation), p(Survey)	316.15	-150.08	8	318.591	998.380	159.259	0.00
psi(Global), p(Survey)	346.15	-150.08	23	371.241	1286.921	447.801	0.00

Table 3. Model averaged estimates and standard errors for parameters included in the most well supported ($\Delta QAIC_c \leq 2.0$) 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

Soils282 contained the highest parameter importance, followed by, in decreasing order of importance, VegS069, slope and stream distance (Table 3). All covariates in the most parsimonious models contained parameter estimates indicating a positive relationship except for slope. Thus, our model results corroborate that Le Conte's Thrasher respond negatively to increasing slope. Our models also indicate that Le Conte's Thrashers respond positively to the proximity of washes. However, these covariates operate at a broad scale.

The Distance to Road covariate consistently had large standard errors relative to the parameter estimates. When included in occupancy models containing other covariates, the Distance to Road covariate inflated standard errors with other covariates, a pattern that was remedied when this covariate was excluded from respective models. In some cases, inclusion of Distance to Road caused parameter estimates to change from + to -. It is unclear why the Distance to Road covariate affected occupancy modeling and may be indicative of collinearity between Distance to Roads and other parameters. Based on these modeling results we omitted Distance to Roads from further occupancy analyses but included Length of Roads within each plot. Our occupancy modeling determined that the length of Roads within survey plots is negatively related to Le Conte's Thrasher occupancy. According to these results, the more roads are present, Le Conte's Thrasher are less likely to occur.

Our study areas were either undeveloped or within restricted access sites on DoD lands and the model is directly applicable to areas where military training may impact Le Conte's Thrasher habitat; however, the model can be geospatially overlaid onto maps of surrounding areas. Thus, it is possible to extrapolate the model to areas threatened by urbanization, technology development (e.g., solar and wind energy projects) and agricultural footprints.

Our results indicate that Le Conte's Thrashers have an inherently low detection probability and demonstrate that we were able to examine the influence of survey-specific covariates on PAO and detection probabilities under the occupancy modeling framework. These detection results with respect to survey pass help explain the low detection probability relative to 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.

Conclusions

Occupancy models are useful tools, especially if relationships between habitat attributes and response variables can be discovered (Mackenzie 2006, Kroll et al. 2007, Henneman and Andersen 2009, Hansen et al. 201). Long-term research is critical for separating natural from anthropocentric fluctuations in wildlife populations and occupancy modeling can provide a reliable alternative to more costly and labor intensive methods for estimating abundance. High occupancy rates through time at repeated survey locations can indicate a relatively healthy population within areas spared from high anthropogenic impacts. However, occupancy modeling is not in itself an exclusive monitoring technique for determining whether the Le Conte's Thrasher population is self-sustaining. In 2013, we will use the revised Le Conte's Thrasher PO Model to guide surveys in the three PAO categories. This occurrence data will be used to further refine the PO model and guide nest monitoring efforts. Nests will be monitored until juveniles are old enough to capture and attach radio-transmitters to obtain juvenile movement data.

The US Census Bureau projected that Arizona would add 5.6 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 1997). Within BMGR and YPG are large expanses of relatively undisturbed Sonoran Desert, mostly of the Lower Colorado River Subdivision. The borderlands region of the U.S. experiences a multitude of Off-Highway Vehicle (OHV) disturbance from illegal activity and border patrols. Surveyors noted that OHV footprints were ubiquitous throughout the study area and will continue to be difficult to police. While Le Conte's Thrashers persisted in many of these areas, the borderlands region receives regular traffic from OHVs and reducing this traffic falls under the auspices of the Department of Homeland Security. The importance of these un-fragmented areas to Le Conte's Thrashers and many other lowland desert species will continue to increase as the landscape surrounding these DoD properties is rapidly developed for agriculture, industries such as alternative energy (solar), and urban expansion.

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