Department of Defense

Legacy Resource Management Program

PROJECT NUMBER (13-631)

Status and Distribution Modeling of Golden Eagles on Southwestern Military Installations and Overflight Areas: Assessing "Take" for this Sensitive Species at Risk

Year 2 – Final Report

STATUS AND DISTRIBUTION MODELING OF GOLDEN EAGLES ON SOUTHWESTERN MILITARY INSTALLATIONS AND OVERFLIGHT AREAS: ASSESSING "TAKE" FOR THIS SENSITIVE SPECIES AT RISK – YEAR 2

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Submitted to:

Installation Partners of Department of Defense Legacy Program Project #13-631

Luke Air Force Base
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Marine Corps Air Station Yuma
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2015 Final Report

Recommended Citation

Piorkowski, M.D., D.P. Sturla, J.M. Diamond and M.F. Ingraldi. 2015. Status and distribution modeling of Golden Eagles on southwestern military installations and overflight areas: assessing "take" for this sensitive species at risk – year 2. Final Report, Legacy 13-631. Arizona Game and Fish Department, Wildlife Contracts Branch, Phoenix, Arizona, USA

Acknowledgments

We extend our appreciation to W. Crumbo and H. Nelson for their efforts with this project. This project's success would not have been possible without the coordinated efforts of the Arizona Game and Fish Department's Nongame Branch and those of K. Jacobson, K. McCarty, and K. Licence. We acknowledge C. Klinger of the Nevada Department of Wildlife for supplying and coordinating survey efforts during the breeding season. Furthermore, we thank the California Department of Fish and Wildlife for their coordination and access related to surveys conducted in southeastern California. We are grateful to our pilots P. Applegate, G. Labanow, and B. David for conducting fixed-wing nest surveys throughout Arizona. We thank our Department of Defense partners J. Arnett, A. Rosenberg, D. Steward, and their colleagues for review and comments throughout this project. Finally, we would like to extend our gratitude to T. Wade, R. Schweinsburg, R. Wilcox, and P. Kennedy for project administration, development, and draft review.

Project Funding

Project funding was provided through the Department of Defense Contract Management Agency agreement between the Department of Defense Legacy Program and the Arizona Game and Fish Department (*Legacy Project 13-631*).

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EXECUTIVE SUMMARY

Nest monitoring of golden eagles (*Aquila chrysaetos*; GOEA) has become a management priority in the desert southwest as revisions to the Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. § 668, *et seq.*) have led to a change in GOEA protection with the promulgation of take permits. Military activities, primarily fixed-wing aircraft and helicopter training should be assessed for their impacts on GOEA to ensure compliance with the BGEPA. The Arizona Game and Fish Department's Wildlife Contracts Branch (AGFD) designed a three year study to evaluate the impact of airborne military training activities on GOEAs. This document provides a summary of findings in year two of this three year study focused on three objectives: 1) identify and survey potential distribution of GOEA breeding areas across military landscapes; 2) create a landscape-scale model to predict likelihood of potential GOEA nesting habitat, and; 3) collect GOEA demographic information and provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the BGEPA. This project was funded through the Department of Defense (DoD) Legacy Resource Program and administered by the Military Interdepartmental Purchase Request W9132T-13-2-0026 with contributions from the U.S. Army Yuma Proving Ground (YPG; contract W912R-14-C-0001).

Finding from year-one (Legacy Project 12-631) of this project directed our year-two sampling. Year-one findings indicated that an expansion of spatial extent may allow for more robust understanding of airborne military training activities on nesting GOEAs. Specifically, we continued and expanded our efforts in Arizona and added efforts in southern California and southeastern Nevada. For Objective 1, we utilized a terrain ruggedness model to select areas of high likelihood for breeding GOEA in areas outside of Arizona (see Piorkowski et al. 2014 for methodology). Surveys of 7,946 km of potential nesting habitat detected 82 active and 333 suspected GOEA nests. We augmented these efforts with data collected by the Arizona Game and Fish Department's Nongame Branch totaling 153 occupied GOEA breeding areas across the study area.

We created a GIS simulation of GOEA nests versus non-nests based on surveyed areas between 2010 and 2014 from our previous efforts, the Nevada Department of Wildlife, and the Arizona Game and Fish Department's Nongame Branch to equalize sampling effort in a presence-absence framework (N = 1,102) to address Objective 2. Combining these dataset allowed us to develop Bird Conservation Region (BCR) specific models to predict likelihood of potential GOEA nesting habitat using the results of logistic regression on a suite of physical and climatic covariates that described GOEA nesting habitat. Top model performance improved from year-one with accuracy ranging from 77% to 86% in correctly identifying GOEA breeding areas.

For Objective 3, we randomly subsampled 268 GOEA nests with repeated visits to determine the demographics of nest occupancy and success. Breeding area occupancy on military lands and their training routes (MTR) versus non-military lands (non-MTR) were not significantly different in 2014 or across BCR's. However, we observed significantly higher nest success within MTR versus non-MTRs (p-value = 0.007). Program PRESENCE 9.3 (Hines 2006) estimated our population's occupancy resulting in a slightly higher occupancy rate (0.31) than our empirical data (0.29). Thus, no net-negative impact of military training routes on breeding area occupancy or nest success of GOEA was detected in 2014. Finally, our estimates from multi-season

occupancy models suggested low probability of annual breeding by GOEA in the southwest. This may add crucial biological context on the breeding phenology of GOEA in the southwestern United States (U.S.) and/or periodic nature of GOEA breeding in this region requiring a closer examination of the species breeding biology.

Our findings are based on GOEA nesting data collected during the 2013 and 2014 breeding seasons. At this point we found no evidence supporting additional take associated with military activities conducted within MTR-designated airspace. Combining consecutive breeding season datasets allowed us to increase both our spatial and temporal inference. However, the periodic nature of GOEA breeding (i.e., non-annual breeding) does limit our interpretations. A biologically appropriate temporal context is needed to make more informed recommendations and will require additional support. Our results and subsequent recommendations thus far provide crucial support for future mission decision by the DoD in consultation with U.S. Fish and Wildlife Service while maintaining compliance with the BGEPA by identifying areas of potential GOEA nesting.

INTRODUCTION

The Department of Defense (DoD) is responsible for natural resource conservation across vast areas of land in the southwestern United States. The management of these resources is directed by installation specific Integrated Natural Resources Management Plans (INRMP). While these INRMPs are restricted to the boundaries of DoD installations, military training routes (MTR) extend well beyond these boundaries. MTR are designated areas identified by the Federal Aviation Administration and the DoD where low-altitude, high-speed aviation exercises can occur. MTR exist above 63% of the land area in the southwestern United States (Figure 1). The additive impact of low-altitude, high-speed military aircraft within these MTR on the spatial and temporal distribution of the wide ranging golden eagle (*Aquila chrysaetos;* GOEA) is poorly understood. As part of the overall DoD mission and in compliance with Federal regulations, installations must have an understanding of the spatial and temporal distribution of this species of concern.

Golden eagles are afforded protection under the BGEPA (16 U.S.C. § 668, *et seq.*) which defines unlawful "take" as to pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest, or disturb without permits from the U.S. Fish and Wildlife Service (USFWS). For the purpose of the BGEPA, disturb is defined as: to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, (1) injury to an eagle, (2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or (3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior. In order for the DoD to comply with BGEPA it is imperative to evaluate the impact of military training activities on GOEAs as it pertains to "take". USFWS quantified take of Bald Eagles (*Haliaeetus leucocephalus*) not to exceed 5% of the Maximum Sustainable Yield; however, the GOEA is quantified as a net take of zero (USFWS 2009).

The GOEA occurs in North America, Europe, Asia and North Africa (Kochert et al. 2002). In North America, this species occurs from Alaska to central Mexico, primarily west of the 100th meridian, from sea level to 3,600 m (Corman and Wise-Gervais 2005, Wheeler 2003, Kochert et al. 2002). Nesting locations are typically associated with rugged terrain and are primarily a cliff nesting species but do occasionally nest in trees or on the ground (McIntyre et al. 2006; Kochert et al. 2002, Menkens and Anderson 1987). Nest sites are usually located in areas that offer high visibility of the surrounding area generally on rocky outcrops (Smith and Murphy 1982), and are within close proximity to hunting grounds (Bates and Moretti 1994, Beecham 1970, Camenzind 1969). The nest is constructed of sticks and lined with softer vegetation including shredded yucca (*Yucca* spp.), grasses, leaves, mosses and lichens (Gabrielson and Lincoln 1959, Jollie 1943, Dixon 1937, Slevin 1929). In the southwestern United States, GOEA nests average 175.7 cm long and 119.8 cm wide (Grubb and Eakle 1987). Additionally, nest use often changes when there is turn-over of at least one of the mated pair, even within the same breeding area (Kochert and Steenhof 2012).

This project expanded on our previous year's work, (Legacy Project 12-631) with our goal to understand the status and distribution of GOEA in order to inform DoD natural resource managers. These results can provide the necessary information on breeding GOEAs that allows southwestern military installations to sustain the viability of this potentially declining species, comply with the BGEPA, and maintain vital military training opportunities. Application of a second year of field work allowed for the development of more robust nesting habitat models that can begin to account for annual variability, specifically, in demographic parameters. With support from the DoD Legacy Resource Program and nine military installations in the southwestern United States, the Arizona Game and Fish Department's (AGFD) Wildlife Contracts Branch completed a second year of nest surveys to refine the existing landscape model to account for annual variability. In addition, we modeled our survey efforts by Bird Conservation Regions (BCR; CEC 1998; updated 2002 http://www.nabci-us.org/bcrs.htm) which is currently the described management unit by the USFWS for consideration of take thresholds (USFWS 2013).

We addressed three objectives:

1) Identify and survey potential distribution of GOEA breeding areas across military landscapes;

2) Create a landscape-scale model to predict likelihood of potential GOEA nesting habitat, and;

3) Collect GOEA demographic information and provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA.

METHODS

Study Area

Our study area focused on portions of the southwestern United States including Arizona, southeastern California, and southern Nevada (Figure 1, Table 1) excluding tribal lands – hereafter all analysis and representation of this study area assumes exclusion of tribal lands unless otherwise noted. Cooperating military installations included: Luke Air Force Base (LAFB), Marine Corps Air Station Yuma (MCAS Yuma), and Yuma Proving Ground (YPG). Additional military support and coordination within MTRs included: Davis-Monthan AFB, Arizona Army National Guard, Creech AFB, Nellis AFB, Fort Huachuca, and El Centro Naval Station. Dominant land cover types ranged from low elevation creosote-bursage communities to higher elevation aspen-mixed conifer associations (Brown 1994). Elevation ranged from 75 m below sea level in southeastern California to 3,973 m in southern Nevada. Land use included military activities, grazing, outdoor recreation, and mining. Land ownership included the DoD, U.S. Bureau of Land Management, U.S. Forest Service, state municipalities, and private lands. Contained within this study area were the military ranges of YPG, MCAS Yuma, and the Barry M. Goldwater Range in addition to the MTRs of the aforementioned military installations and adjacent landscapes.

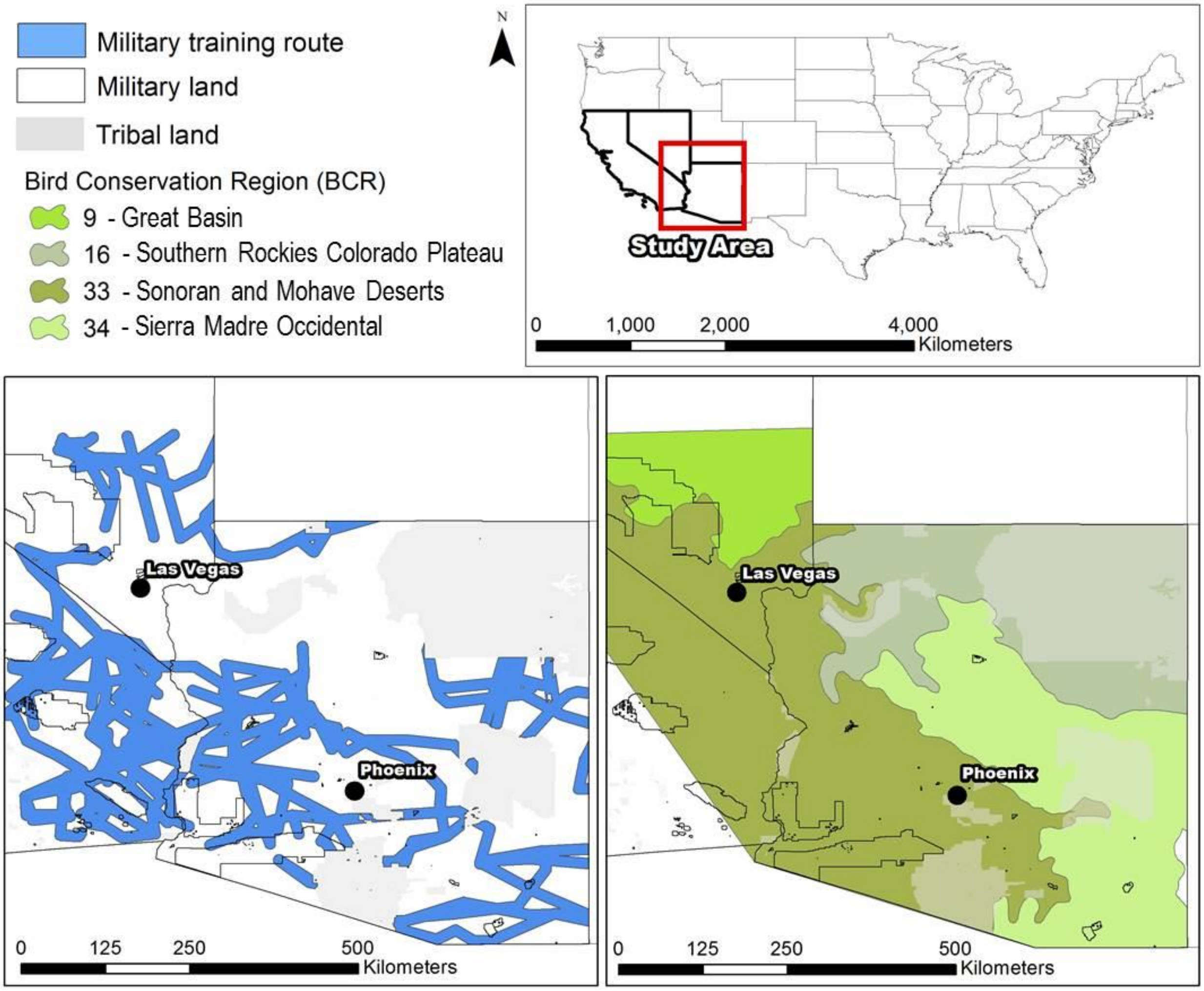

Figure 1. Study area for golden eagle surveys on military lands (black outline) in the southwestern United States, 2014. Military training routes (lower left) and Bird Conservation Regions (lower right) are shown. Tribal lands (gray fill; excluded from project) are displayed for reference. BCR 35 (Chihuahuan Desert) is not displayed in this figure but is located in a small portion in the southeastern extent of the study area.

Table 1. Area of federally designated military land and land directly under military training routes (MTR) by state within our study area of the southwestern United States in 2014.

State	Military land	Military training routes (MTR)
Arizona	11,425 km^2	128,767 km^2
California	10,291 km^2	42,420 km^2
Nevada	12,093 km^2	15,311 km^2

Approach

Objective 1: *Identify and survey potential distribution of GOEA breeding areas across military landscapes.*

Using methods developed during year-one, we used a terrain ruggedness model to focus survey efforts in highly rugged areas likely to support GOEA nesting cliff structure (see Piorkowski et al. 2014). We applied these methods to include southern California and southeastern Nevada to identify potential GOEA nesting habitat. We prioritized survey areas by the intersection of MTR and potential GOEA nesting habitat. We coordinated surveys and strategies with California Fish and Wildlife Service and Nevada Department of Wildlife (NDOW) to eliminate duplicate effort. Furthermore, we requested any additional data collected by these agencies within our study area to augment our sample size.

We searched for GOEA nests with helicopters, fixed-wing aircraft, and from the ground (hereafter ground surveys). Active GOEA nests were identified when we detected an adult incubating or an egg was present in a nest. Suspected GOEA nests were identified when we found large nests with bulky material and characteristics consistent with Dixon (1937) but no GOEA was present and no other evidence of breeding was detected at the nest (e.g., eggs or young). We increased the likelihood of detecting GOEA nests by double sampling using two trained and experienced observers during all surveys. Using methods developed by Boom et al. (2010) and Piorkowski et al. (2014), we conducted fixed-wing surveys (primary survey method) throughout the study area. Surveys completed by fixed-wing aircraft were also helpful in prioritizing areas that required more intensive searching with a helicopter or follow-up with ground surveys. We used helicopter surveys only in the most topographically challenging terrain that had been designated in our sampling framework or defined as not suitable for fixed-wing surveys. Helicopter sampling consisted of flights along the ridge tops and steep valleys of mountain and cliff areas primarily in southeastern Arizona. These surveys occurred under MTR and non-military airspace.

We used ground surveys to confirm the presence of nesting GOEA after sampling by aircraft was inconclusive. These surveys allowed us to collect descriptive data (e.g., nest activity status, species identification, and additional nest description). When conducting a ground survey, two observers, scanned cliffs up to 1 km away with 15x50 mm Vortex Viper HD binoculars and/or with variable 15-60 power Swarovski Scopes mounted on a tripod. Observers made at least two complete scans of the cliff by panning systematically from the top toward the bottom and from left to right. If a suspected GOEA nest was detected (see Dixon 1937), we recorded the same descriptive information as described above in aerial surveys. If an active nest was confirmed, observers recorded number of adults, breeding status, and number of nestlings.

Objective 2: *Create a landscape scale model to predict likelihood of potential GOEA nesting habitat.*

Nests in active GOEA breeding areas in Arizona (2010-2014; N = 484; see McCarty and Jacobson 2011, 2012; McCarty et al. 2013, 2014; Piorkowski et al. 2014) were combined with current and historical Nevada nest locations (N = 83); Nevada Department of Wildlife (unpublished *data*), and one California nest (total N = 568) to develop breeding GOEA distribution models (SDM) as defined by Elith and Leathwick (2009). Some of these nest locations (N = 17) existed outside the study area and were not used in model development. These data were classified by one of four BCRs and separated into discreet BCR-specific datasets for presence data. An equal set of absence data (non-nests) corresponding to each BCR were created by applying an 800m exclusion buffer to nests that were removed from each BCR along with urban areas, tribal lands, and major lakes and rivers. We randomly generated an equivalent set of non-nests (N = 551) within the remaining surveyed areas and a minimum of 800m spacing (considered saturation). We assumed that if a nest was present it was detected and documented while all other areas were absent of nests.

We coded GOEA nests as present (1) or absent (0) for a total of 1,102 nests and completed a series of logistic regression models to identify significant variables (Table 2) influencing nest likelihood (Elith et al. 2008). We calculated spatially explicit covariates to model the presence/absence of GOEA nesting habitat (Table 2). These data, including environmental and remotely sensed weather data from WorldClim (Hijmans et al 2005), were imported into a Geographic Information System (GIS; version 10.1; ESRI 2012) where they were re-projected and constrained to the study area. We generated "Aspect" as a derivative of elevation using the spatial analyst extension in ArcGIS (Gesch et al. 2002). The resulting related dataset was exported as a table for regression analysis. We reserved a random selection of 20% each of nests and non-nests as a validation dataset. The remaining 80% of these data were used in the regression model development, hereafter training dataset.

We tested for multi-collinearity in SPSS (version 20.0; IBM Corp. 2011) and removed covariates that were significantly correlated. We used a binomial backward step-wise logistic regression and ranked models according to Akaike's Information Criterion values (AIC; Akaike 1973). We reported top ranking models with ΔAIC_c or $\Delta QAIC_c \leq 2$ (Burnham and Anderson 2002; Buckland et al. 1997). These models were considered to be well supported by the data and the model with the lowest AIC value was identified as the top performing model (Akaike 1973). We used a parsimonious approach to model selection and avoided averaging in the case of fundamentally similar models (Burnham and Anderson 2002). We transformed the resulting logit function to the natural log of odds (probability) with graphical interpretation in ArcGIS using raster math (spatial analyst extension; map algebra). We assigned predicted model probabilities to the test dataset and assessed model fit with a confusion matrix.

Table 2: Covariates considered to model golden eagle nest occupancy likelihood in the Southwest, 2014.

VARIABLE (RESOLUTION)	VARIABLE -DESCRIPTION	SOURCE
Landcover ($30m^2$)	LANDCOVER - US National Vegetation Classification	USGS: http://gapanalysis.usgs.gov/
Latitude	LAT - UTM Northing	Modeled in ArcGIS 10.1
Bioclim1 ($875m^2$)	Bio1 - Average mean temperature	Hijmans et al. 2005: http://www.worldclim.org/bioclim
BioClim5 ($875m^2$)	Bio5 - Max temperature of the warmest month	Hijmans et al. 2005: http://www.worldclim.org/bioclim
BioClim6 ($875m^2$)	Bio6 - Minimum temperature of the coldest month	Hijmans et al. 2005: http://www.worldclim.org/bioclim
BioClim12 ($875m^2$)	Bio12 - Annual precipitation	Hijmans et al. 2005: http://www.worldclim.org/bioclim
BioClim19 ($875m^2$)	Bio19 - Precipitation of the coldest quarter	Hijmans et al. 2005: http://www.worldclim.org/bioclim
VRM_mask ($60m^2$)	VRM mask - Vector Ruggedness Measure: Terrain ruggedness (≥.010)	Sappington et al. 2007: http://arcscripts.esri.com/details.asp?dbid=15423
Aspect ($30m^2$)	Aspect - Physical Orientation	Modeled in ArcGIS 10.1
Elevation ($60m^2$)	ELEV - National Elevation Dataset	USGS: http://ned.usgs.gov/

Objective 3: *Collect GOEA demographic information and provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA.*

We combined GOEA survey data from our efforts with data from collected by AGFD Nongame Branch to summarize 2014 breeding demographics (occupancy and nest success); the combined data only included locations within Arizona as data from NDOW did not contain repeated visit occupancy information. Initial surveys during the early breeding season (February through end of March) searched all known nests within a breeding area and documented any suspected new nests.

We used the statistical package R (version 3.2.0 "Full of Ingredients"; The R Foundation for Statistical Computing, 2015) to conduct all empirical data analysis (i.e., not modeling analysis). We compared the combined sample of active breeding areas within an MTR with our sample of active breeding areas outside of MTR using a Welch t-test (Welch 1974). A Welch t-test was used because the samples are non-overlapping and there is unknown variance within each sample set. Nest demographics included primarily occupancy and nest success (Steenhof and Kochert

1982). An occupied nest, for this study, was defined as a nest with a GOEA incubating on it or a nest with at least one young GOEA in it. We delineated BCRs and constrained each to the extent of our study area (*see* Figure 1; bottom right image) with those updated in the National Bird Conservation Initiative (http://www.nabci-us.org/bcrs.htm). We completed a one-way Analysis of Variance (ANOVA) with BCR as the factor and the dependent variable as nest occupancy. If mean occupancy was significantly different from the ANOVA, we completed a Tukey's Honest Significant Difference (HSD) pair-wise comparison (Tukey 1949) to identify which BCR-derived means were significantly different from another. For comparison purposes, we completed the same BCR ANOVA for data collected in the 2013 GOEA breeding season reported in Piorkowski et al. (2014). We compared the nest success demographic between MTRs and non-MTRs using a Pearson's Chi-squared test (Pearson 1900) to determine if there was a difference in observed versus random results.

We modeled occupancy with repeated visits following methods described by MacKenzie et al. (2002). We estimated occupancy (ψ) and detection (p) probabilities in program PRESENCE 9.3 (Hines 2006) using site covariates described in Tables 3 and 4. We tested each site covariate in a single-season model analysis, with p set as constant to test the null hypothesis (H_0) that breeding area occupancy was constant across the landscape. Assuming survey independence, we modeled nest failure rates in a second multi-season analysis (visited at least twice during the breeding season with an assumption of surveys as inputs for seasons) Nest failure rates were modeled as a surrogate to identify the nest success component of GOEA nest demographics, (e.g., 1 minus nest failure rate equals nest success rate). We included missing observations in order to estimate parameters of ψ, p, colonization (γ) and extinction (ε) probabilities (MacKenzie et al. 2002). We defined γ as the probability of late nesting attempts (i.e., nests not active on the first visit, but active on the second visit (late breeder) and ε the probability of nest failure (nests active on the first visit, but not active on the second visit).

Models were ranked using AIC values with the top three models compared to H_0 using AIC_c difference. We calculated ΔAIC_c and Akaike weight (w_i; Buckland et al. 1997) for each model to assess model uncertainty, parsimony, and the likelihood of each candidate model. Failure rates (i.e., extinction probability) of occupied breeding areas were compared to the calculated value from the data (i.e., proportion of the sample data for occupied breeding areas that failed). Finally, we compared simple multi-season models from data collected in 2013 and 2014 to estimate parameters of ψ, p, γ, and ε. For this exercise we defined γ as the probability that a breeding area became occupied in 2014 given it was unoccupied in 2013, and ε as the probability that a breeding area became unoccupied (2014) given that it was occupied (2013). These models were compared using the same resulting parameters identified in the single-season models.

Table 3: Covariates used in program PRESENCE 9.3 to model golden eagle occupancy in the Southwest, 2014.

VARIABLE (RESOLUTION)	VARIABLE -DESCRIPTION	SOURCE
TMAX2013 (4 km^2)	PRISM data on the maximum temperature in May 2013	PRISM 2015: http://www.prism.oregonstate.edu/recent/
TMAX2014 (4 km^2)	PRISM data on the maximum temperature in May 2014	PRISM 2015: http://www.prism.oregonstate.edu/recent/
PPT2013 (4 km^2)	PRISM data. Computed as a sum of precipitation from January through June of 2013	PRISM 2015: http://www.prism.oregonstate.edu/recent/
PPT2014 (4 km^2)	PRISM data. Computed as a sum of precipitation from January through June of 2014	PRISM 2015: http://www.prism.oregonstate.edu/recent/

RESULTS

Objective 1: *Identify and survey potential distribution of GOEA breeding areas across military landscapes*

We detected 82 active and 333 suspected GOEA nests during 2014 (Table 4; Figure 2). We surveyed (eleven fixed-wing flights and eight helicopter flights) approximately 4,158 linear-km of MTR and 3,788 linear-km of non-MTR in Arizona, California, and Nevada (Table 3). Fixed-wing surveys were completed in March with several flights completed in February, May, June, and August depending on the availability of air space. Surveys over the Tonto National Forest and north-central Arizona provided an additional 71 active GOEA nests in 2014 (McCarty et al. 2014). Combined efforts resulted in 153 occupied GOEA nests.

Table 4. Summary of golden eagle survey effort throughout military lands (MTR) and in adjacent landscapes (non-MTR) in our study area through DoD Legacy-funding, 2014.

METHOD	SURVEY MTR (KM)	SURVEY NON-MTR (KM)	NUMBER OF FLIGHTS	TIME (PERSON-DAYS†)	ACTIVE NESTS*	SUSPECTED NESTS**
Fixed-wing	3,967	2,853	11	22	-†	-†
Helicopter	191	935	8	16	-†	-†
Total	**4,158**	**3,788**	**19**	**38**	**82**	**333**

*Active nests were defined as nests with golden eagles demonstrating breeding behavior on or adjacent to nest (e.g., nest building, copulating, incubating, etc.)

**Suspected nests were defined as nests suitable in size, location, and material for golden eagles, but lacked golden eagle presence at site.

† All surveys are displayed by linear KM, and we did not separate nests by survey method due to multiple survey methods needed to confirm nest status.

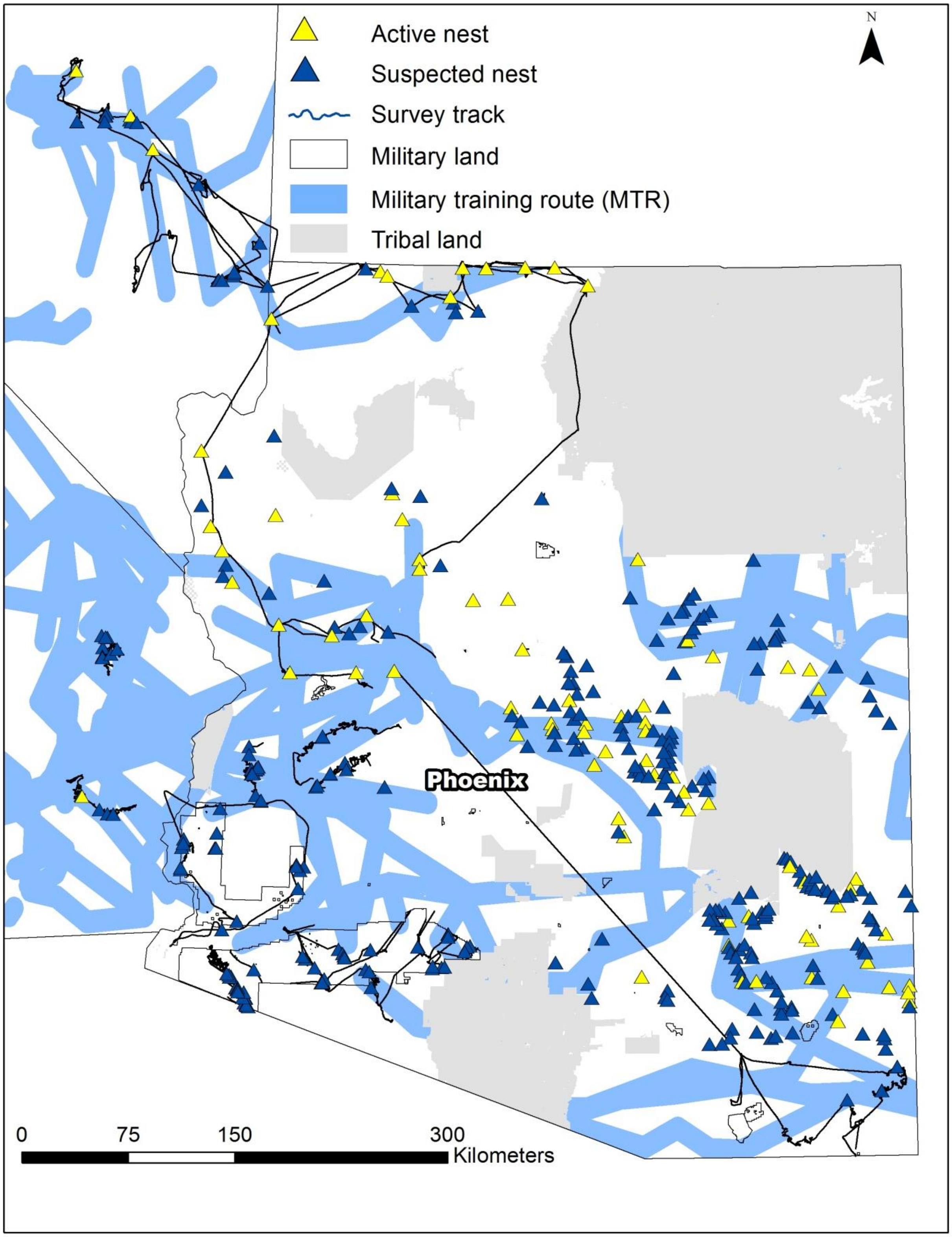

Figure 2. Results of golden eagle nest surveys (by fixed-wing, helicopter, and ground; Survey track) in the southwestern United States, 2014. Active nests defined by nesting behavior while suspected nests are defined by historic activity. Displayed survey tracks are those of the AGFD Wildlife Contracts Branch only.

Objective 2: *Create a landscape-scale model to predict likelihood of potential GOEA nesting habitat*

We performed a binomial backwards stepwise logistic regression for four data sets with 1,102 points (551 = 1 and 551 = 0) related to 10 predictive spatial covariates. The best models selected a combination of two or three variables to predict GOEA nesting likelihood ([see Table 5; Annual mean temperature (-), annual precipitation (- , +), and the VRM mask (+)] with the VRM mask being the top predictor (β values ranging between 3.840 - 4.220) shared by all. Together the top ranking models correctly classified the training dataset (84.00%; Table 6) but did not perform as well with the validation dataset (79.5%). Overall the combined data averaged 81.825% accuracy.

Using the β values (Coefficients of Covariates) derived from our logistic regression analysis (Table 5), we graphically represented the top model for each of the four BCRs. In Figures 3 - 6, we used a color ramp to represent the predicted likelihood values across each BCR landscape within our study area.

Table 5. Top ranking regression models used to predict golden eagle nest likelihood in southwestern BCRs, 2014.

Model Rank	Coefficients of Covariates	BCR	Sample size (0,1)	AIC	Δ AIC	-2 Log likelihood
1	**1.)** 0.135 + 4.22**0**(VRM_mask) – 0.010(Bio12)	9	76	62.279	-	58.279
2	**2.)** -1.098 +4.167(VRM_mask) – 0.012(Bio12) – 0.021(Bio6)	9	-	64.724	2.445	58.724
1	**1.)** 16.312 + 3.384(VRM_mask) + 0.011(Bio12) + 0.033(Bio5)	16	206	181.657	-	175.657
1	**1.)** 9.701 + 3.858(VRM_mask) + 0.051(Bio6) – 0.070(Bio1)	33	316	192.911	-	186.911
1	**1.)**-0.847 + 3.840(VRM_mask) – 0.006(Bio12) – 0.012(Bio6) + 0.002(Aspect)	34	322	309.773	-	301.773
2	**2.)** 1.461 + 3.950(VRM_mask) – 0.005(Bio12) – 0.015(Bio6) + 0.003(Aspect) + 0.410(Veg3)	34	-	310.559	0.786	300.559

(Bio1) = Annual Mean Temperature, (Bio5) = Max temperature of the warmest month, (Bio6) = Minimum temperature of the coldest month, (Bio12) = Annual Precipitation, (Veg 3) = Semi Desert, (VRM_mask) = Terrain Ruggedness (VRM) ≥ 0.010.

Table 6. Confusion matrix of training and validation datasets used to develop predictive models for golden eagle nesting likelihood in southwestern BCRs, United States, 2014.

BCR 9; Great Basin

Training Set	0	1	% Correct	Validation Set	0	1	% Correct	
0	30	8	78.9%		8	2	80%	Combined
1	4	34	89.5%		1	9	90%	Accuracy
Overall			84.2%				85%	84.6%

BCR 16; Southern Rockies Colorado Plateau

Training Set	0	1	% Correct	Validation set	0	1	% Correct	
0	83	20	80.6%		22	3	88.0%	Combined
1	13	90	87.4%		12	13	52.0%	Accuracy
Overall			84.0%				70.0%	77%

BCR 33; Sonoran and Mohave Deserts

Training Set	0	1	% Correct	Validation Set	0	1	% Correct	
0	137	21	86.7%		33	6	85.0%	Combined
1	11	147	93.0%		9	30	77.0%	Accuracy
Overall			89.9%				81.0%	85.5%

BCR 34; Sierra Madre Occidental

Training Set	0	1	% Correct	Validation Set	0	1	% Correct	
0	104	57	64.6%		34	6	85.0%	Combined
1	14	147	91.3%		8	32	80.0%	Accuracy
Overall			78.0%				82.5%	80.25%

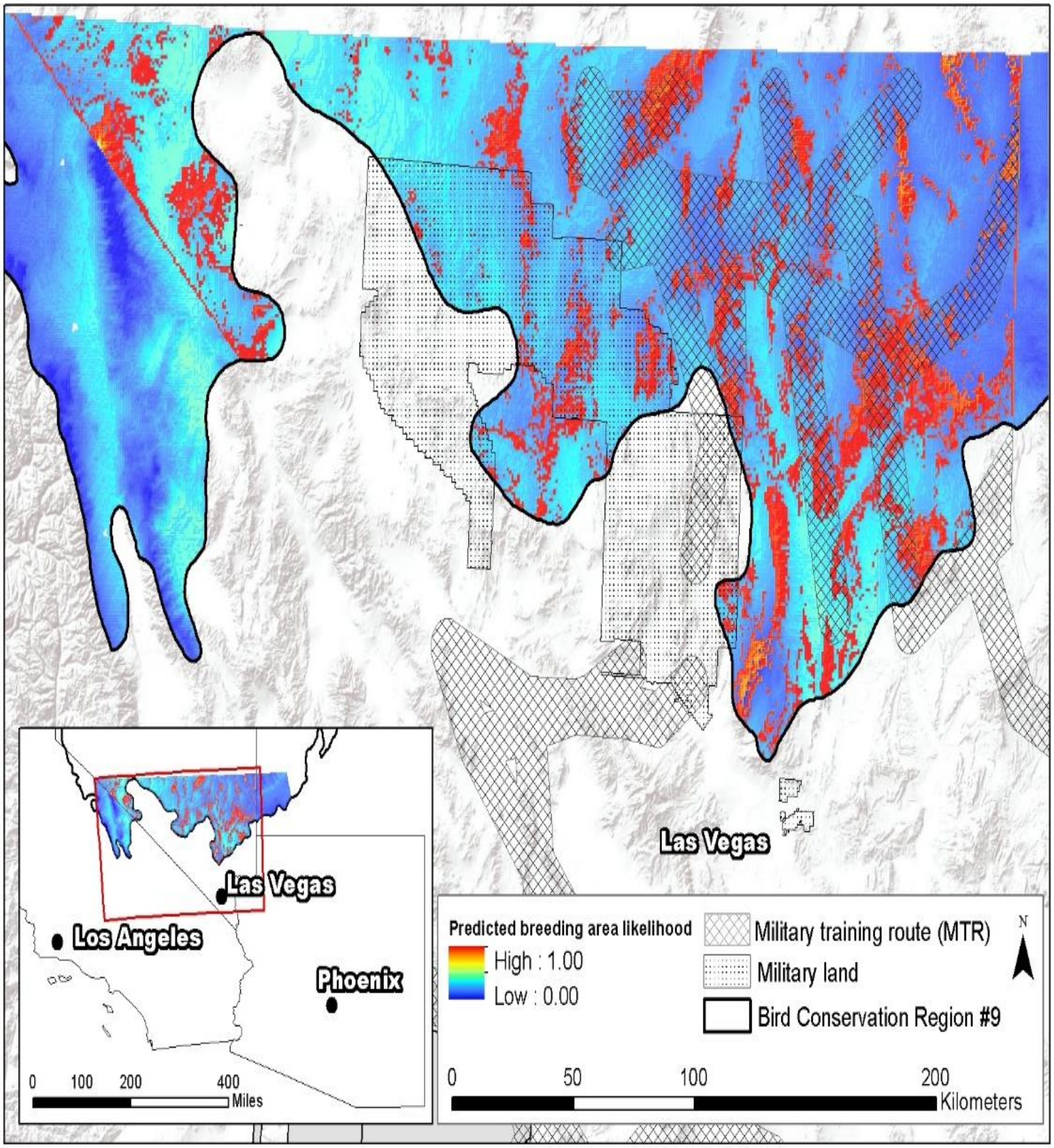

Figure 3. Predicted likelihood of golden eagle nesting habitat in BCR 9 (Great Basin), 2014.

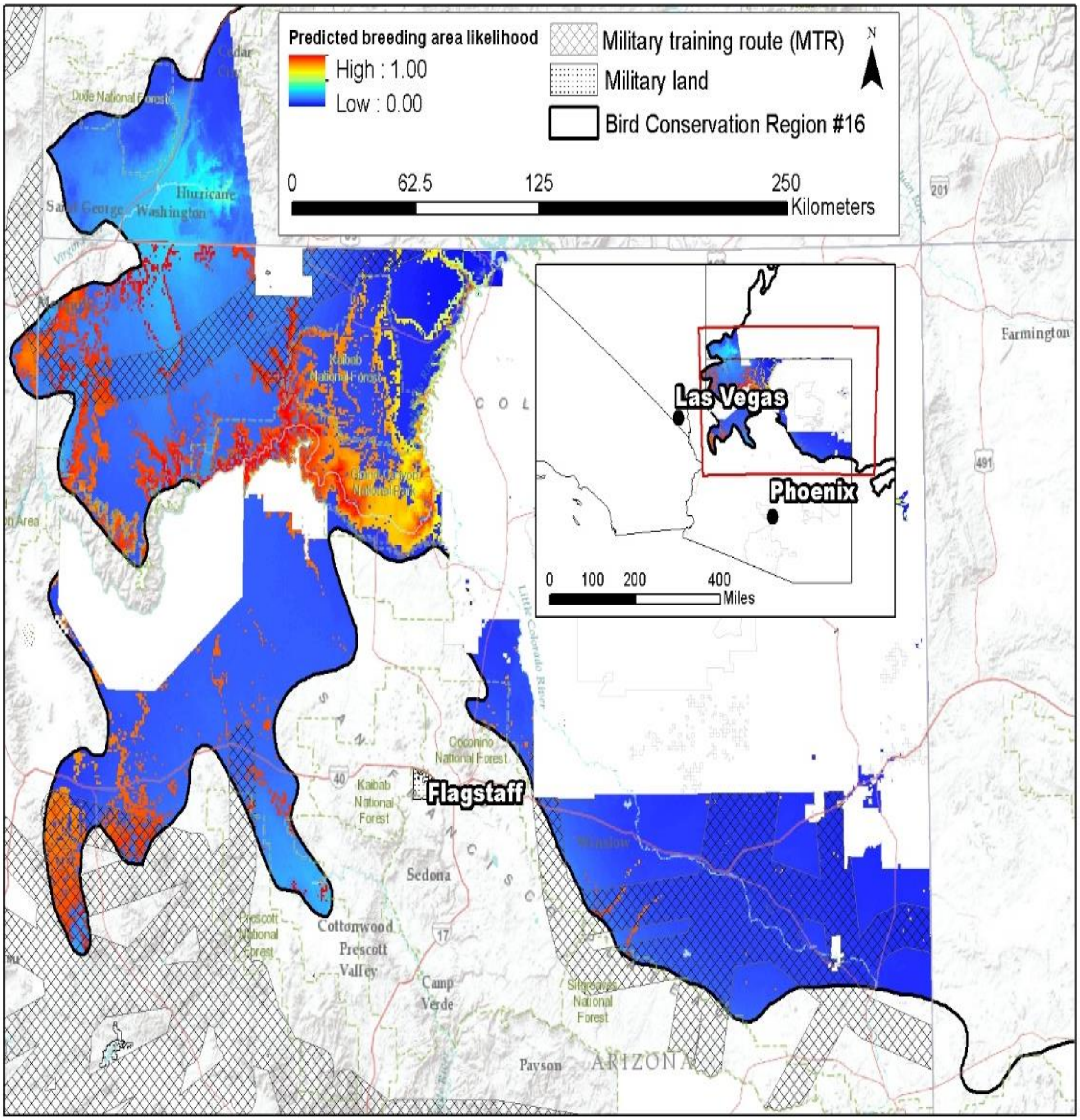

Figure 4. Predicted likelihood of golden eagle nesting habitat in BCR 16 (Southern Rockies Colorado Plateau), 2014.

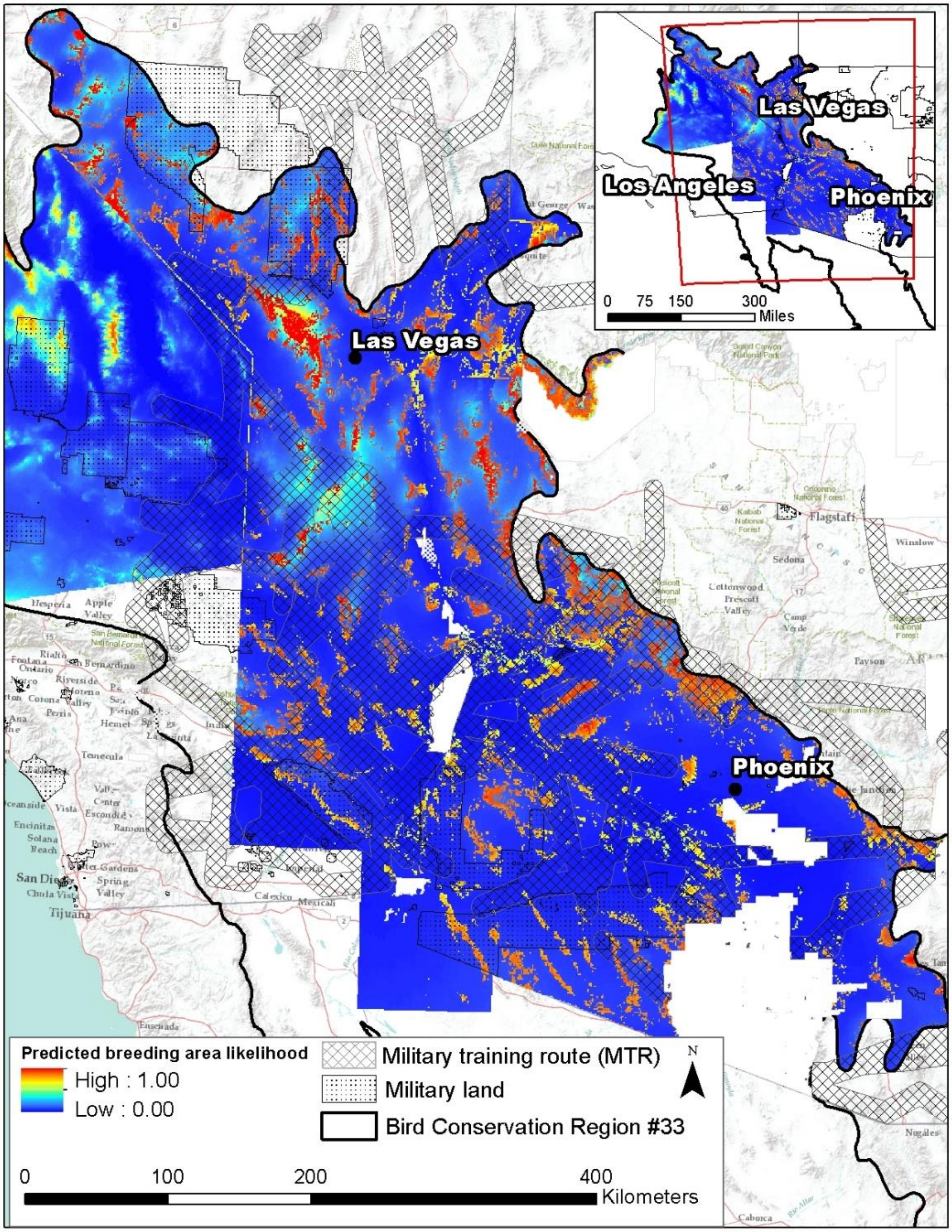

Figure 5. Predicted likelihood of golden eagle nesting habitat in BCR 33 (Sonoran and Mohave Deserts), 2014.

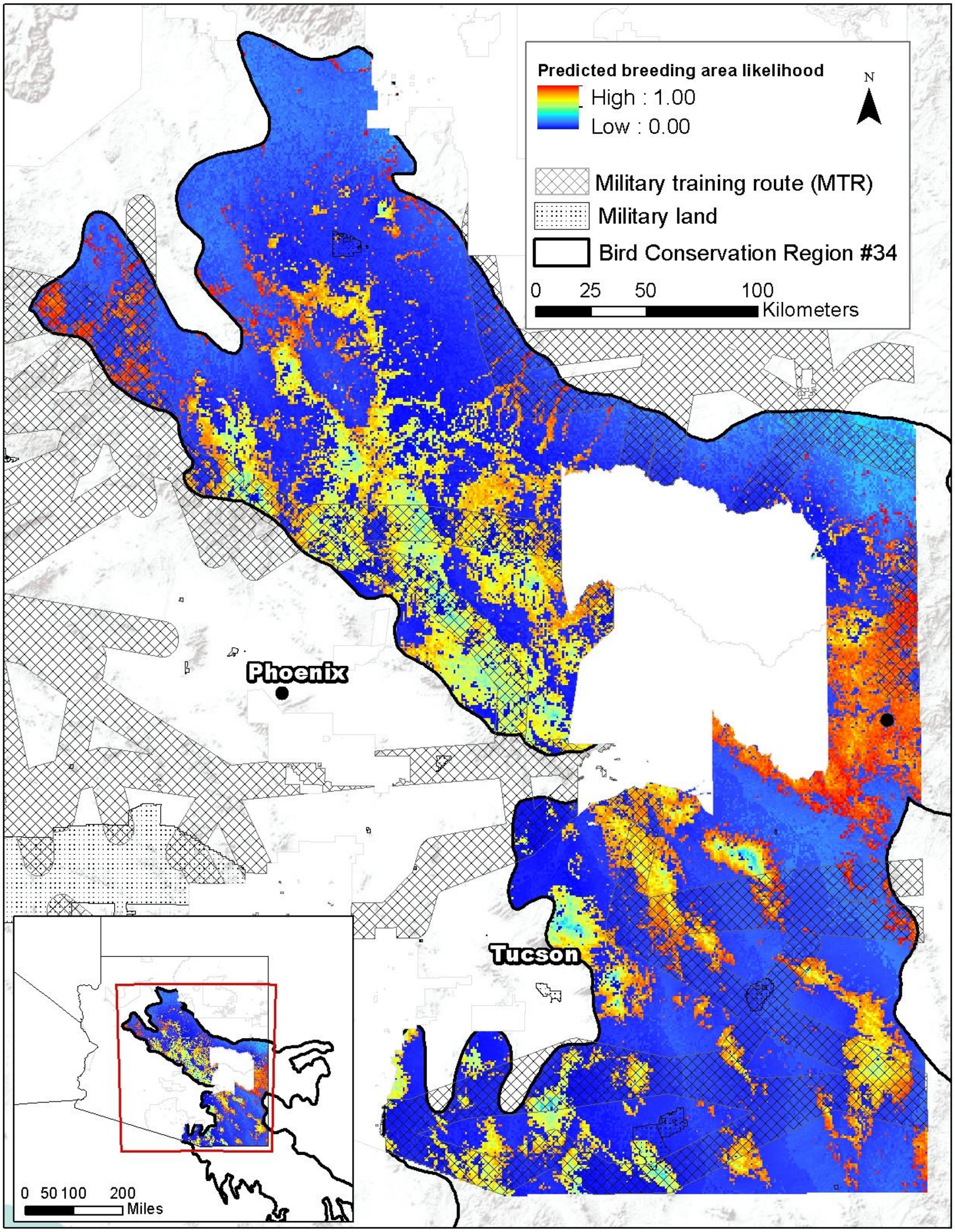

Figure 6. Predicted likelihood of golden eagle nesting habitat in BCR 34 (Sierra Madre Occidental), 2014.

Objective 3: *Collect GOEA demographic information and provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA.*

Out of the 486 GOEA breeding areas, 268 were surveyed with multiple visits in 2014 (McCarty et al. 2014). All of these repeated surveys were completed within Arizona. Seventy-seven of these breeding areas were occupied with 23 successful nesting attempts (Table 7). Table 7 shows the calculated nest success ratio for occupied breeding areas by MTR versus non-MTR with higher nest success observed under MTRs in 2014 (Chi-squared = 7.381; Table 7). We calculated active breeding area occupancy rate of 0.29 (SE = 0.03) for surveyed breeding areas (N = 268). Calculated breeding area occupancy rates from empirical data within MTR was (ψ) = 0.30 (SE = 0.05), while occupancy outside of MTR was (ψ) = 0.28 (SE = 0.03). There was no significant difference in GOEA nest site occupancy between nest sites in MTRs and non-MTRs (t = -0.466; p-value = 0.642; Table 8). Similarly, there was no significant difference in 2014 occupancy by any of the four BCRs (Table 8). Data from 2013 are also displayed in Table 8 for comparison. Pair-wise comparisons (using Tukey's HSD results) are indicated using Alpha superscripts.

Table 7. Nest status of occupied breeding areas in 2014 across military lands and their training routes (MTR) and non-MTR lands within Arizona.

Nest Designation	Occupied	Succeeded (S)	Failed (F)	Unknown	Success Ratio (S:F)
MTR	31	12	9	10	1.33 : 1
non-MTR	46	11	26	9	0.42 : 1
Total	77	23	25	19	0.65 : 1

* Pearson's Chi-squared test on nest success $\chi2$ = 7.381, df = 1, p-value = 0.007

Table 8. Calculated occupancy (ψ) from surveys conducted in 2013 and 2014 for Bird Conservation Regions (BCR) and military lands (MTR) in Arizona.

	2013			2014		
	N*	Ψ (mean)	SE	N	Ψ (mean)	SE
BCR 16	49	0.37^{AB}	0.07	43	0.40^{A}	0.08
BCR 33	91	0.27^{A}	0.05	30	0.40^{A}	0.09
BCR 34	77	0.47^{B}	0.06	193	0.24^{A}	0.03
BCR 35	-	-	-	2	0.50^{A}	0.49
MTR	66	0.33	0.06	102	0.30	0.05
non-MTR	154	0.38	0.04	166	0.28	0.03
Totals	220	0.36	0.03	268	0.29	0.03

* For BCR, total breeding areas included a total of 217 sites. Three sites were removed due to incomplete data.
** Significant pair-wise differences computed by year with Tukey's HSD (α=0.05).

The top ranking single-season breeding area occupancy model identified a negative association with annual precipitation (Bio12; Hijmans et al 2005; Table 9). Although this was the top ranking model overall, it was not considered significantly different than the second top model

(Bio5; Table 9) or the null model being less than 2 delta-AIC (Akaike's Information Criteria) units apart (Burnham and Anderson 2002; Table 9). This single model weighed more than the others with an AIC weight (w_i) of 0.22. All single-season breeding area occupancy models estimated slightly higher occupancy rates over the empirical survey results.

Table 9. Single-season models of golden eagle breeding area occupancy (*N* = 268) in Arizona, 2014.

MODEL FORMULA†	AIC	Δ AIC	AIC w_I	MODEL LIKELIHOOD	K‡	Ψ†	STD. ERR.
Calculated*	-	-	-	-	-	0.29	0.03
p(.) Ψ(Bio12)	568.10	0	0.22	1	3	0.311	0.058
p(.) Ψ (Bio5)	568.81	0.71	0.16	0.701	3	0.313	0.044
p (.) Ψ (.)	569.16	1.06	0.13	0.589	2	0.312	0.031

† Ψ = occupancy, *p* = probability of detection, (.) = estimated as constant, (Bio12) =Annual Precipitation, (Bio5) = Maximum temperature of the warmest month.

‡ k = number of parameters.

* Calculated value from sample dataset.

Using the same multi-season framework developed in year-one (Piorkowski et al. 2014), we produced multi-season models to estimate proportions of late breeders and nest failures depicted in Table 10. Our top multi-season model for 2014 indicated a slightly negative relationship of occupancy by annual precipitation (Bio12). Combined failure rates (ε) in all top models ranged from 0.30 to 0.60 encompassing the actual calculated value of 0.45 (Table 10). The probability of late breeders (γ) ranged from 0.19 to 0.33 also encompassing the calculated rate of 0.27 (Table 10).

Table 10. Multi-season occupancy models with estimated late breeders (γ) and failure rates (ε) parameters for golden eagles in Arizona, 2014.

MODEL FORMULA†	AIC	Δ AIC	AIC w_I	MODEL LIKELIHOOD	K‡	ψ†	γ*	ε**
Calculated	-	-	-	-	-	0.29	0.27	0.45
Ψ (Bio12) *gamma* (.) *eps* (.) *p*(.)	425.11	0.00	0.81	1.00	5	0.19	0.08	0.60
Ψ (Bio19) *gamma* (.) *eps* (.) *p*(.)	429.07	3.96	0.11	0.14	5	0.19	0.08	0.60
Ψ (VRM) *gamma* (.) *eps* (.) *p*(.)	432.72	7.61	0.02	0.02	5	0.19	0.08	0.60
Ψ (.) *gamma* (.) *eps* (.) *p*(.)	434.05	8.94	0.01	0.01	4	0.33	0.02	0.30

† Ψ = occupancy, *p* = probability of detection, (.) = estimated as constant, (Bio12) = Annual Precipitation, (Elev) = Elevation, (Bio19) = Precipitation of Coldest Quarter.

‡ k = number of parameters; * γ = colonization rate (i.e., late breeding rate); ** ε = extinction rate (i.e., failure rate)

From data collected in year-one (2013) and combined with year-two (2014), we modeled 16 site covariates resulting in 4 competing models compared to the null model (Table 11). Occupancy (ψ) in all competing models ranged from 0.41 to 0.46; similar to the H_0 [null model expressed with no covariates ψ(.) gamma(.) eps(.) p(.)]. Colonization of GOEA breeding areas (γ) were most consistent while there was higher variation in estimating the extinction parameter (ε; Table 11).

Table 11. Competing golden eagle breeding area multi-season occupancy models estimating the parameters of occupancy (ψ), colonization (γ), and extinction (ε) between 2013 and 2014 breeding seasons.

MODEL FORMULA†	AIC	Δ AIC	AIC w_I	MODEL LIKELIHOOD	K‡	ψ†	γ*	ε**
Ψ (Bio1) *gamma* (.) *eps* (.) *p*(.)	1016.9	0	0.21	1	5	0.41	0.17	0.49
Ψ (PPT2013) *gamma* (.) *eps* (.) *p*(.)	1017.9	1.06	0.12	0.59	5	0.45	0.20	0.57
Ψ (Bio12) *gamma* (.) *eps* (.) *p*(.)	1018.1	1.26	0.11	0.53	5	0.46	0.20	0.58
Ψ (DEM) *gamma* (.) *eps* (.) *p*(.)	1018.4	1.51	0.10	0.47	5	0.42	0.17	0.51
Ψ (.) *gamma* (.) *eps* (.) *p*(.)	1024.3	7.43	0.01	0.02	4	0.41	0.16	0.48

† Ψ = occupancy, *p* = probability of detection, (.) = estimated as constant, (Bio1) = Average mean temperature, (PPT2013) = Precipitation total in 2013 from January to June, (Bio12) = Annual Precipitation, (DEM) = Elevation

‡ k = number of parameters

* γ = colonization rate (i.e., probability that a breeding area will be occupied in the next season given that it is currently unoccupied)

** ε = extinction rate (i.e., probability that a breeding area will not be occupied in the next season given that it is currently occupied)

DISCUSSION

In 2014, we found GOEA nests distributed throughout the study area (Figure 2) with no evidence to support current military activities causing additional take under MTR-designated airspace (Table 8). However, the lack of occupied GOEA nest on surveyed military lands (YPG and BMGR) does not warrant the same conclusion as they consist of absence-only data. Occupied GOEA nests on these military lands may require additional protection from disturbance, specifically terrestrial disturbance. We built upon our GOEA nest likelihood models and occupancy results from year-one (Piorkowski et al. 2014) to increase our predictive power to identify high quality GOEA nesting habitat. Model refining by BCR improved resolution, precision, and incorporates environmental variation within this large geographic region of the southwestern United States (*see* Figure 1). We added to our demographic result metrics and presented these by unique landscapes – specifically, by BCR and by military lands and their training routes (MTR) – and compared results from 2013 with those of 2014 (Table 8). These data and corresponding models compare to USFWS eagle management units when considering take thresholds (USFWS 2013). Finally, we completed first-step analyses of multi-year modeling using empirical data in the analysis framework identified in year-one of this project (Piorkowski et al. 2014). Discussion topics of our 2014 GOEA breeding season results are organized by objective below.

Objective 1: *Identify and survey potential distribution of GOEA breeding areas across military landscapes.*

Aerial surveys allowed observers to sample a larger area than ground surveys due to the limitations associated with remote, rugged terrain. Helicopter sampling allowed for high precision of nest surveys but was much less cost effective than fixed-wing sampling. Fixed-wing costs were 14% of helicopter sampling and allowed entire mountain ranges to be surveyed rapidly. We used fixed-wing aircraft for the majority of surveys due to their cost and similar detection probabilities as helicopter searches (Boom et al. 2010). However, it should be noted that fixed-wing aircraft have limited maneuverability and higher speeds (~90 knt). Ewins and Miller (1995) do not recommend using fixed-wing aircraft for productivity surveys. Our data set indicates that fixed-wing aircraft may be more cost-effective and suitable for detecting GOEA breeding areas at large spatial scales. Ground surveys were advantageous in areas with restricted airspace access (i.e., military lands) or as a follow-up to assess status of a nest given that a suitable observation point could be located.

We found that the core distribution of nesting GOEA extended from the northwestern to southeastern part of the study area. The density of nesting GOEA was much lower in the southwestern portion of our study area (*see* Figure 2). Previous research indicates that 80% of the breeding GOEA population occurs north of our study area (Millsap et al. 2013; USFWS 2009). Researchers have also detected slightly declining GOEA populations in southern BCRs and lower latitudes (Millsap et al. 2013) and more specifically with juvenile GOEA in southern BCRs (Nielson et al. 2014). One active nest in southeastern California was identified with an incubating GOEA in the Chuckwalla Mountains. We documented numerous suspected GOEA nest in the southwestern portion of the study area but no other active nests. Several of these suspected GOEA nests were identified with incubating Red-tailed Hawks [(*Buteo jamaicensis*; RTHA) (Sturla et al. 2014)]. Other raptor species will opportunistically use GOEA-built nests if a GOEA does not breed due to less than suitable breeding conditions (prey availability, climatic variables; Steenhof et al. 1997). This can cause significant difficulty correctly identifying use of GOEA-built nests when the species is not present at the time of survey. Although GOEA are usually tolerant of other raptor species (Dixon 1937), Fitch et al. (1946) concluded that RTHA are particularly hostile toward GOEA and pose a significant handicap on GOEA behavior (including nesting). The combination of these two conclusions, suggest that once a RTHA is nesting (potentially in a GOEA nest) that GOEA will not be tolerated within the RTHA territory. However, Craig and Craig (1984) indicated that other nesting raptors may be more tolerant of nesting GOEA.

The military installations of YPG and BMGR make up much of our sampling area in southern Arizona. Terrestrial disturbances associated with military maneuvers and activities are likely additional stressors related to low GOEA nesting density. Previous studies indicate that GOEA disturbance and nest abandonment is associated with terrestrial disturbance intensity (Steenhof et al. 2014; Frackler et al. 2014). Four of our helicopter surveys occurred through collaborative efforts to identify and document all potentially suitable GOEA nest across YPG and BMGR and were completed in August. While these August surveys were outside of the active nesting period they detected a series of suspected nests that should be used as the highest priority monitoring areas on these installations. During the past two years, we have consistently documented adult GOEA within the southwestern part of our study area suggesting that they may breed when environmental and climatic conditions are suitable (McIntyre 2002; Steenhof et al. 1997) or when there is less disturbance (Steenhof et al. 2014).

Our combined efforts (Figure 2) with those of others – including AGFD Nongame Branch and NDOW – can establish baseline data for future landscape comparisons. Furthermore, these data are the backbone of our GOEA nesting habitat model development in Objective 2 of this project.

Objective 2: *Create a landscape scale model to predict likelihood of potential GOEA nesting habitat.*

An expanded survey extent allowed us to produce SDMs with greater spatial precision and accuracy (Hernandez et al. 2006) within each BCR. Mountain ranges across BCRs varied in likelihood values with BCR 34 reflecting the most variation. Our top models predicted the lowest likelihood of GOEA nesting habitat in the interspaces between rugged terrain (Figures 3 - 6). Models for BCR 9 and BCR 34 had a negative association with the Bio12 variable (annual precipitation [mm]). This negative association with annual precipitation is biologically meaningful for GOEA foraging (i.e., selecting areas like grasslands and desert bajadas that lack dense vegetation rather than forest habitats). This same association may also funnel prey to patchy, isolated, perennial water sources (e.g., springs, water tanks, etc.). Furthermore, this negative association suggests that GOEA are more likely to nest in the arid portions of these BCRs dominated by grasslands and desert scrub and away from the higher precipitation areas of forested landscapes. In contrast, our top model for BCR 16 had a positive association between GOEA presence and annual precipitation. Incidentally this BCR is also one of the primary regions for prairie dogs (*Cynomys* spp.) in Arizona (AGFD *unpublished data*). Relationships between prairie dog colonies and GOEA have been suggested previously (Cully 1991). The general increase in mammalian species richness of rabbits (*Sylvilagus* spp.) and hares (*Lepus* spp.) adjacent to prairie dog colonies also likely contributes to high GOEA nesting densities (Koford 1958). Years with more annual precipitation likely provide more forage for prairie dog colonies, therefore, temporarily increasing prey abundance for all associated species.

The predictive models performed well identifying the training data set, but did not always perform as well with the validation dataset (Table 6). This was not unexpected since absences were randomly generated (with constraints) and assumed habitat saturation. If areas were not saturated with breeding GOEA, then absences may have in fact been pseudo-absences. Other methods may be more appropriate if these are in fact pseudo-absences (Warton and Shepherd 2010). Comprehensive searches along mountain ranges previously surveyed by fixed-wing aircraft may provide information on whether these absences are in fact pseudo-absences. Our top model for BCR 16 performed the lowest overall when validated with the test data set. This is likely attributed to its large spatial distribution of this dataset and accuracy of the data collection. For instance, some occupied nest locations were recorded as being non-rugged habitat immediately adjacent to rugged terrain likely due to a recorded observation point rather than the actual nest location. The other limitation is the large spatial extent, with most locations clustered in the northwest and southwest of the BCR. Missing data from tribal lands make it difficult to model continuously across this BCR. Expanding efforts and possible collaboration in these areas as well as correcting nest locations will likely improve future models' accuracy. Furthermore, comparison of developing models in adjacent landscapes (*see* Tack and Fedy 2015), may allow for more wide-ranging assessments of GOEA nesting habitats and distribution.

BCR 33 has the largest extent of the four BCRs modeled (1,000 km^2) within our study area. We detected 79 active GOEA nests in this large BCR primarily in the northern portion of this region. Within the southern portion of this BCR – including YPG, MCAS Yuma, and BMGR – we identified only a single active GOEA nest (i.e., the Chuckwalla Mountains, California), however the model predicted habitat in the middle range of likelihood values suggesting that the landscape may support fewer nesting GOEAs. We were able to incorporate efforts conducted in 2013 and 2014 by NDOW into these models, increasing our inference but potentially biasing our model to favor specific habitat types associated to Mohave Desert which contains different vegetation and elevation gradients that the Lower Sonoran Desert. These variables may have indirect effects on GOEA status and distribution across this expansive landscape; however, landcover was used as a covariate within this model. Separating these two biomes may provide unbiased modeling results within this region.

These data (Objective 1) and the developed models can identify precise areas that may harbor breeding GOEAs. Once identified, DoD Natural Resource Managers (in consultation with USFWS and potentially other authoritative agencies) can determine if additional surveys, avoidance measures, or take are needed prior to changes in military activities. To make informed decisions, we must understand how breeding GOEAs are responding to current levels of military activities and quantify those responses to the local GOEA population.

Objective 3: *Collect GOEA demographic information and provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA.*

In the 2014 GOEA breeding season, we did not detect a significant difference in nest occupancy rates between MTR and non-MTR; this was consistent with our findings from year-one (2013; Piorkowski et al. 2014). Overall GOEA occupancy decreased from year-one to year-two (0.36 to 0.29 respectively). However, nest success was significantly higher in MTR than in non-MTR (Table 8). These results indicate that breeding GOEA are benefiting in some way from MTR designation. It is likely that GOEA are responding to the remoteness and low level of ground disturbance provided by the MTR rather than military activities within the MTR. Developing covariates to that measure various "remoteness" parameters – such as road density, proximity to urban areas, artificial light, etc. – could provide quantitative evidence of potential disturbance. Steenhof et al. (2014) suggests that the timing, proximity, duration, and frequency of disturbance may play roles in GOEA nest productivity. GOEA nest success may be dependent on the types of military activity being conducted, specifically ground disturbance or aerial fly-overs as in MTR. For example, Andersen et al. (1986) quantified temporary displacement of a raptor only during active military activities but returned once the activity ceased. Our data indicates that the potential remoteness and low ground disturbance within the MTR may override disturbance associated to low frequency fly-overs similar to conclusions by Snyder et al. (1978) on other raptor species.

We completed three types of occupancy modeling efforts: single-season, one year multi-season, and two-year multi-season. Results from our single-season analyses were similar to our year-one results in that annual precipitation had the strongest influence on occupancy. However, unlike our year-one results, the top model of annual precipitation did not perform significantly better than our null model as it was not greater than two AIC units difference (Table 9). At this point, it is unclear why in year-one there was a positive association in year-two as there was a negative association with the same covariate. There may be some critical threshold in annual precipitation that was experienced between the two years, or we may be observing lag effects in precipitation such those used in modeling effort in other parts of the country (Tack and Fedy 2015). Inclusion of MTR as a factor in our occupancy modeling did not improve model performance. Likewise our two new variables of PPT2014 (total precipitation in 2014 from January through June), and TMAX2014 (maximum temperature in May 2014) did not improve model performance. However, variations in temperature (such as TMAX2014) may be a more informative predictor of occupancy earlier in the breeding season, while later in the season this variable may contribute to more informative models in estimating nest failure. Continued use of sampling programs designed to estimate occupancy generally require less effort than programs focused on abundance or density estimation (MacKenzie et al. 2002; Manly et al. 2002; Tyre et al. 2001). However, there may be critical information from abundance or density estimation that could provide additional support and statistical strength that current military activities have no statistical impact on occupied GOEA nests.

Our second modeling effort attempted to estimate late breeders (γ) and nest failure rates (ε) using a multi-season analysis. Similar to the single-season models, Bio12 (annual precipitation) was the strongest driver with a negative relationship between model parameters and the covariate. Our year-one models resulted in estimated nest failure rates between 0.46 – 0.58 (Piorkowski et al. 2014). Modeled results from year-two data estimated those nest failure rates between 0.30 – 0.60 (Table 10). With an additional 48 breeding areas monitored, seasonal variation may have contributed to this metric widening rather than narrowing suggesting higher levels of variation than previously anticipated. Furthermore, it may suggest that estimating nest failure rates or nest success rates in this way may not be best monitoring parameter in any one year; rather this may need to be inclusive of multiple years of data. Further evidence of this may be explained in our final modeling effort.

We combined the data from year-one and year-two to assess stability of these breeding areas from year to year; however, multi-year analysis increases in strength with three years of data (MacKenzie et al. 2002). This model calculated occupancy, colonization, and extinction by breeding season rather than single-year occupancy. We addressed two central questions with this model: 1) What is the probability that a breeding area will be occupied in the next season (in this case the next year) given that it is currently unoccupied (γ), and; 2) What is the probability that a breeding area will not be occupied in the next season given that it is currently occupied (ε). The results reported in Table 11 suggest that a GOEA will occupy a previously unoccupied breeding area approximately 17% – 20% of the time while they will likely not re-occupy a breeding area 49% to 58% of the time. This gap in yearly occupancy suggests that GOEA in this landscape do not necessarily breed every year. This is consistent with previous work on GOEA concerning both resource (McIntyre 2002; Steenhof et al. 1997) and climatic patterns (Steenhof et al. 1997). Estimating this potential breeding phenology for GOEA may provide crucial biological context to derive successful management strategies for this species.

In 2014 our data along with a multi-state collaboration, provided information on breeding GOEAs throughout the southwestern U.S. We used these data to improve existing models (developed under Legacy Project 12-631) and refine potential GOEA nesting habitat by four BCRs to increase model precision and resulting interpretations. These models can be augmented with corresponding data such as occupancy and nest success to quantify current GOEA breeding metrics across the landscape. These demographic parameters can be expanded upon with continued monitoring of active and historic GOEA nests.

Management Recommendations

After two consecutive years of GOEA surveys and monitoring, we have no evidence supporting additional "Take" in lands under MTR-designated airspace. At current levels (i.e., 2014), military activities within these MTRs do not appear to have adverse impacts to breeding GOEAs. The USFWS assess "Take" thresholds under the BGEPA preservation standard based on "local-area eagle populations" (USFWS 2013). We recommend consideration of "experimental advanced conservation practices" (see USFWS 2013 for definition) be explored in accordance with Eagle Take Permits and consultation with USFWS to avoid "Take", reduce incidental "Take", and investigate relevance of an adaptive management regime. As new information becomes available, military activities change, or these activities expand in the future, flexibility in GOEA conservation practices can benefit both the military and the species. We recommend that practices include the following:

1) Continue monitoring known and suspected GOEA nests on military installations.
2) Coordinate with local, state, and regional authorities on current GOEA distribution and status to inform continued and future military activities in compliance with BGEPA.
3) Develop avoidance zones around known GOEA nest locations during the breeding season, specifically those that were occupied with in past five years.
4) Avoid disturbance around suspected GOEA nesting activity during the early breeding season. Nest sites described as "suspected" have the opportunity to provide suitable structure to a nesting GOEA even if no GOEA has been identified using it in any particular year. In effect, unoccupied does not mean non-use of a suspected GOEA nest. Normal military training activities can resume in the area once all "suspected" nests have been determined as unoccupied for that breeding season.
5) Avoid heavy ground and aerial disturbance during the early breeding season within modeled habitat that has a high likelihood of potential GOEA nesting habitat. By using these precise models, reduction of heavy disturbance activities in areas of high likelihood may reduce or eliminated incidental take even if surveys to document nesting GOEAs have not been completed in those areas. Future model validation should allow us to quantify thresholds associated to high likelihood habitat in these modeled estimates.

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