Department of Defense

Legacy Resource Management Program

PROJECT NUMBER (15-631)

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

Year 3 – 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 3

Prepared by:

J.M. Diamond, PhD, E. Scobie, M. D. Piorkowski, D. P. Sturla, and M.F. Ingraldi, PhD

Arizona Game and Fish Department, Wildlife Contracts Branch

5000 W. Carefree Highway

Phoenix, Arizona 85086

Submitted to:

Installation Partners of Department of Defense Legacy Program Project #15-631

Luke Air Force Base
Yuma Proving Ground
Marine Corps Air Station Yuma
Davis-Monthan Air Force Base
Arizona Army National Guard
Creech Air Force Base
Nellis Air Force Base
Fort Huachuca
El Centro Naval Station

2016 Final Report

Recommended Citation

Diamond, J.M., E. Scobie, M. D. Piorkowski, D.P. Sturla, and M.F. Ingraldi. 2016. Status and distribution modeling of golden eagles on southwestern military installations and overflight areas: assessing “take” for this sensitive species at risk – year 3. Final Report, Legacy 15-631. 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 15-631*).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AGFD	Arizona Game and Fish Department
AIC	Akaike's Information Criterion
ANOVA	analysis of variance
BCR	Bird Conservation Region
BGEPA	Bald and Golden Eagle Protection Act
BMGR	Barry M. Goldwater Range
DoD	Department of Defense
GOEA	golden eagle (*Aquila chrysaetos*)
INRMP	Integrated Natural Resources Management Plan
LSD	least significant difference
MTR	military training route
RTHA	red-tailed hawk (*Buteo jamaicensis*)
USFWS	U.S. Fish and Wildlife Service
VRM	Vector Ruggedness Measure, terrain ruggedness
WSMR	White Sands Missile Range
YPG	Yuma Proving Ground

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 (AGFD) Wildlife Contracts Branch designed a three year study to evaluate the impact of airborne military training activities on GOEAs. This document provides a summary of the findings of this three year study focused on three objectives: 1) Identify and survey potential GOEA nesting habitat within the Barry M. Goldwater Range (BMGR), Yuma Proving Ground (YPG), and overflight areas used by Luke AFB, Davis-Monthan AFB, Marine Corps Air Station Yuma, Arizona Army National Guard, Creech AFB, Nellis AFB, Fort Huachuca, El Centro Naval Station and White Sands Missile Range (WSMR) and their associated military training routes (MTRs); 2) Validate an existing landscape-level model previously funded by DoD Legacy and augmented with previous efforts by WSMR that will allow natural resource managers to identify GOEA nesting habitat within and adjacent (i.e., within the MTRs) to southwestern military installations, and; 3) Provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA statutes. This project was funded through the Department of Defense (DoD) Legacy Resource Program (Legacy Projects 12-631, 13-631 and 15-631).

For objective one, we located 914 GOEA nesting territories and sampled 521 nesting territories multiple times within year across the three year duration of this study. We were able to make parametric comparisons across Bird Conservation Region (BCR) and MTR*year. The only significant difference we found between MTR and non-MTR was a longer occupation period in MTR sites in year one of the study. This higher occupation time in year one is likely related to our lower sampling rate in non-MTRs during the third sampling period of year one. This study was designed as a landscape scale assessment of the impacts of MTRs on GOEA occupation of the breeding territory. At this large scale our finding indicate that MTRs had no detectable impact on GOEA breeding.

For objective 2, we used the 914 GOEA nests identified to create a nest presence/absence spatially explicit model. We ran independent models for each BCR and a global model. We used GOEA locational data from WSMR to test the inferential value of each model. These data and the developed models can identify precise areas that may harbor breeding GOEAs. Once identified, DoD Natural Resource Managers (in consultation with U.S. Fish and Wildlife Service (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.

We did not detect a significant difference in GOEA nesting between MTR and non-MTR; this was consistent with our findings from years one and two (2013; Piorkowski et al. 2014). Our findings indicate that GOEA nesting was driven by yearly conditions and not MTR. 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.

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.

GOEAs are afforded protection under the Bald and Golden Eagle Protection Act (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 eagle (*Haliaeetus leucocephalus*) or GOEA 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 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 two years' work (Legacy Projects 12-631 and 13-631), 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 third year of field work allowed for the development of more robust nesting habitat models that can begin to account for annual variability. With support from the DoD Legacy Resource Program and ten military installations in the southwestern United States, the Arizona Game and Fish Department's (AGFD) Wildlife Contracts Branch completed a third 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 GOEA nesting habitat within the Barry M. Goldwater Range (BMGR), Yuma Proving Ground (YPG), and overflight areas used by Luke AFB, Davis-Monthan AFB, Marine Corps Air Station Yuma, Arizona Army National Guard, Creech AFB, Nellis AFB, Fort Huachuca, El Centro Naval Station and White Sands Missile Range (WSMR) and their associated MTRs.;
2) Validate an existing landscape-level model previously funded by DoD Legacy and augmented with previous efforts by WSMR that will allow natural resource managers to identify GOEA nesting habitat within and adjacent (i.e., within the MTRs) to southwestern military installations.
3) Provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA statutes.

METHODS

Study Area

Our study area focused on portions of the southwestern United States including Arizona, southeastern California, southern Nevada and central New Mexico (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 the BMGR, YPG, and overflight areas used by Luke AFB, Davis-Monthan AFB, Marine Corps Air Station Yuma, Arizona Army National Guard, Creech AFB, Nellis AFB, Fort Huachuca, El Centro Naval Station and WSMR and their associated MTRs. 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, Marine Corps Air Station Yuma, the BMGR and WSMR in addition to the MTRs of the aforementioned military installations and adjacent landscapes (Figure 1).

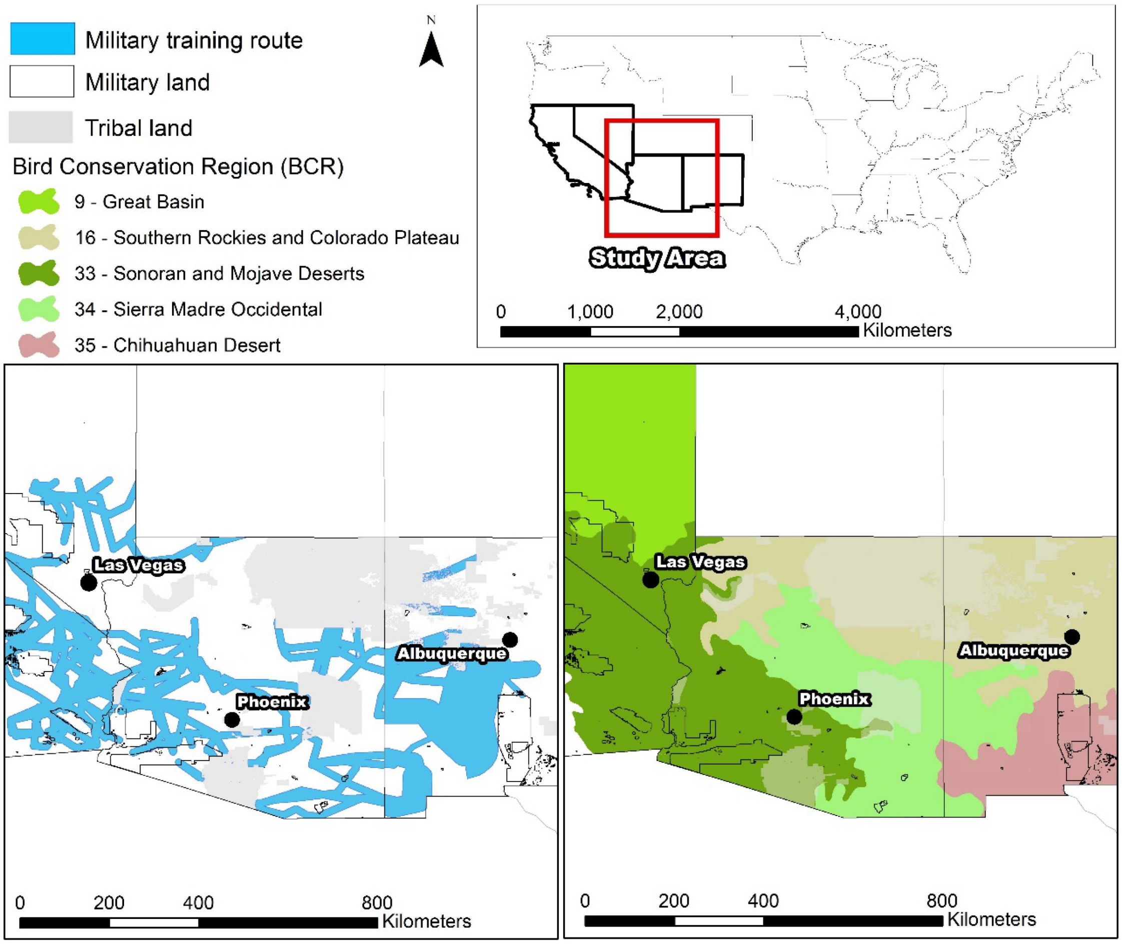

Figure 1. Study area for GOEA surveys on military lands (black outline) in the southwestern United States. MTRs (lower left) and BCRs (lower right) are shown. Tribal lands (gray fill; excluded from project) are displayed for reference.

Table 1. Area of federally designated military land and land directly under MTRs by state within our study area of the southwestern United States.

State	Military Land	Military Training Routes (MTRs)
Arizona	11,425 km^2	71,028 km^2
California	10,291 km^2	42,420 km^2
Nevada	12,093 km^2	15,311 km^2
New Mexico	10,223 km^2	60,464 km^2

Approach

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

We identified and surveyed potential GOEA nesting habitat within the BMGR, YPG, and overflight areas used by Luke AFB, Davis-Monthan AFB, Marine Corps Air Station Yuma, Arizona Army National Guard, Creech AFB, Nellis AFB, Fort Huachuca, El Centro Naval Station and their associated MTRs. We conducted a thorough search of all potential nesting habitats (e.g., rock outcroppings, cliff faces, etc.) during the nest-building and early breeding season (January-March). We concentrated our nest searching activities on the cooperating military installations and their MTRs. Using methods developed during year-one and year-two, 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 to eliminate duplicate effort. Furthermore, we requested any additional data collected by these agencies within our study area to augment our sample size.

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 and 2015), 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.

We selected a subset of the total GOEA territories (521) for multiple surveys within the same sample year across all three years. The purpose of these multiple surveys was to determine if nesting was attempted. If nesting was attempted, did the nest remain occupied long enough to produce fledglings. We created a three stage sampling design in order to categorize each nest. If we detected GOEA activity at a given nest during only the first survey we categorized the nest as attempted but failed (1). If we detected GOEA activity at the nest site during only the first and second survey we categorized the nest as successful into the nestling period (2). If GOEA activity was detected during all three survey periods we classified the nest as successful into the fledgling period (3). We used this design in order to estimate the GOEA nest success across the MTR status of each territory. Therefore, we were able to estimate the impact of MTRs on GOEA nesting activity by comparing the amount of time the territory remained occupied. We compared the GOEA nesting period status (1-3) across BCR and MTR*year. We used a fixed effect analysis of variance (ANOVA) and Fischer's least significant difference (LSD; $p<0.05$) to make these comparisons. This analysis allowed us to compare GOEA nest occupancy across MTR, BCR and sample year.

Objective 2: *Validate an existing landscape-level model previously funded by DoD Legacy and augmented with previous efforts by WSMR that will allow natural resource managers to identify GOEA nesting habitat within and adjacent (i.e., within the MTRs) to southwestern military installations.*

We utilized a GOEA nesting survey conducted by WSMR to validate the landscape-level model we produced in year one of this study and refined in years two and three (Piorkowski et al. 2014 and 2015). We produced landscape scale spatially explicit models using the presence/absence of nesting GOEAs in year one, two and three. We then further refined these models using the presence data collected under objective one of this year of the study. These data were classified by one of five BCRs and separated into discreet BCR-specific datasets for presence data (Figure 1). An equal set of absence data (non-nests) corresponding to each BCR and WSMR were created by applying an 800 m 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 ($N = 914$) within the remaining surveyed areas and a minimum of 800 m 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 used the 914 GOEA territories and 914 absence non-territories to create spatially explicit logistic regression models. These 1,828 sample points allowed us 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, included environmental and remotely sensed weather data (Hijmans et al 2005) imported into a Geographic Information System (GIS; version 10.1; ESRI 2012). 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 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 analyzed these results using logistic regression models to identify environmental variables that were associated with occupancy of nesting areas and compare the models with previous modeling efforts using AIC to assess the overall strength and then test the performance. We produced discrete models for each BCR and produced a global model for all BCRs combined. We used the presence/absence data at WSMR to test the performance of the global model and the four BCR models. We assigned predicted model probabilities to the test dataset and assessed model fit with a confusion matrix.

Table 2: Covariates considered to model GOEA nest occupancy likelihood in the Southwest.

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/

RESULTS

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

In the course of this study we identified and surveyed 914 discrete nesting territories (active nest with an 800m buffer). We detected 251, 415 and 248 in year one (12-631), two (13-631) and three (15-631), respectively. Of these 914 nesting territories we detected GOEAs in 269 territories. We suspected active use within our three years survey period at the remaining 645 territories. We used the presence of GOEA nesting habitat within these 914 nesting territories as the basis for our modeling exercise under objective two. While we used all 914 detected GOEA territories in our habitat model, we also resurveyed a subsample in order to estimate the impact of MTRs on active GOEA nesting. We surveyed a subset (521) of these territories multiple times in order to assess eagle nest success. In year one we surveyed 217 territories multiple times followed by 274 and 184 in years two and three, respectively. Over the three year period of this study we documented GOEAs within 237 of these nest territories. In the third year of this study we observed GOEAs in 107 territories followed by 78 in year one and 52 in year two. We did not detect eagles at 64% of sampled sites in year one and at 81% and 42% of sample sites in years two and three. Only 4%, 5% and 11% of eagle territories were occupied during the third sample period in years one, two and three, respectively. GOEA occupancy within the sample territories varied across MTR status and year (Figure 2). GOEA occupancy varied significantly across MTR and year ($F=2.29$; $p=0.0473$). We detected significantly greater numbers of GOEA nesting occupancy in year two than all other years. GOEA nesting occupancy did not vary between MTR and non-MTR in year two or year three (Figure 2). However, in year one GOEA nest occupancy was significantly lower in the non-MTR territories than in the MTR territories. We detected no significant difference in GOEA nest occupancy across the four BCRs sampled ($F=0.56$; $p=0.6939$) (Figure 3).

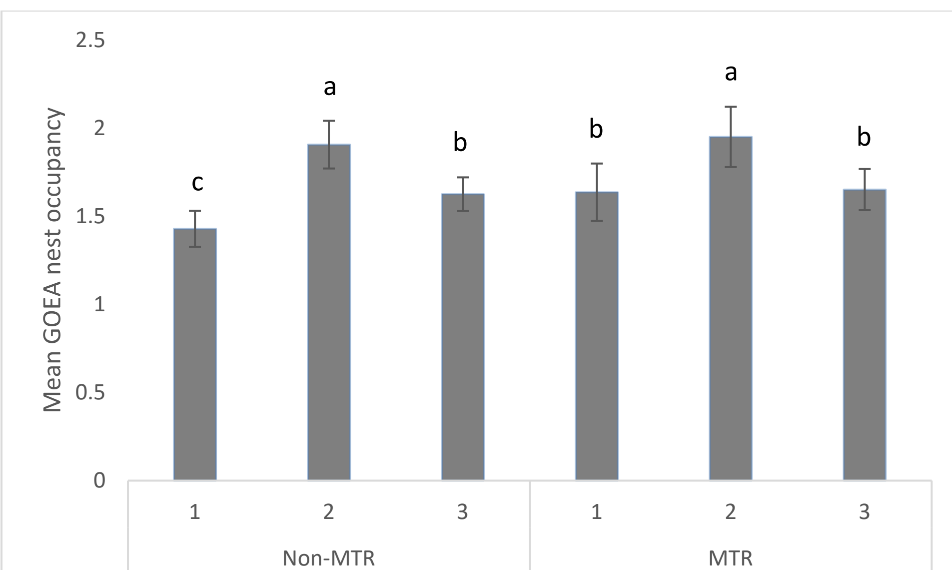

Figure 2. Comparison of calculated occupancy across year and status as an MTR or non MTR. Letters indicate statistical significance ($F=2.29$; $p=0.0473$) Fishers protected LSD ($p< 0.05$).

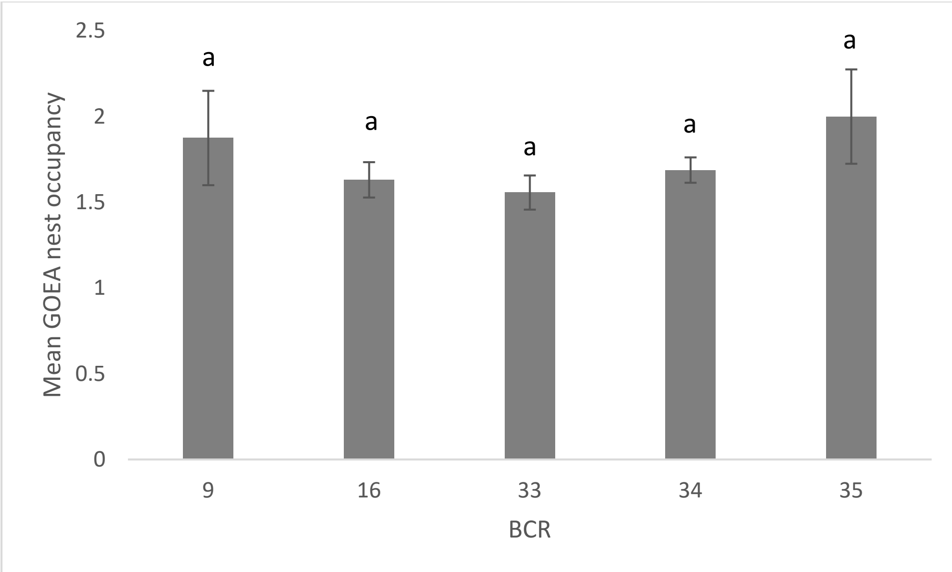

Figure 3. Comparison of calculated occupancy across BCR. Letters indicate statistical significance ($F=0.56$; $p=0.6939$) Fishers protected LSD ($p < 0.05$).

Objective 2: *Validate an existing landscape-level model previously funded by DoD Legacy and augmented with previous efforts by WSMR that will allow natural resource managers to identify GOEA nesting habitat within and adjacent (i.e., within the MTRs) to southwestern military installations.*

We performed a binomial backwards stepwise logistic regression with 1828 points (914 = 1 and 914 = 0) related to 10 predictive spatial covariates. We ran a discrete model for each of the four BCRs and a global model with all 1828 nest territories combined. The best models selected a combination of two or four variables to predict GOEA nesting (Table 3). The top fit model for the global analysis included a positive relationship with terrain ruggedness (Vector Ruggedness Measure; VRM), annual precipitation and annual mean temperature and a negative relationship with maximum temperature of the warmest month and minimum temperature of the coldest month. Our top fit model for BCR9 indicates that GOEA territory presence is positively associated with VRM and negatively with annual precipitation. The top model for BCR16 indicates that GOEA presence was associated positively with VRM, annual precipitation and maximum temperature of the warmest month. (Table 3). GOEA presence in BCR33 was positively associated with VRM and minimum temperature of the coldest month. Our top model for BCR34 indicates that GOEA presence was positively associated with VRM and negatively associated with minimum temperature of the coldest month and annual precipitation (Table 3). Uniformly, the VRM mask was the top predictor (β values ranging between 3.840 - 4.220) shared by all five models. Using the β values (Coefficients of Covariates) derived from our logistic regression analysis (Table 3), we graphically represented the top model for each of the four BCRs. In Figures 4 - 8, we used a color ramp to represent the predicted likelihood values across each BCR landscape within our study area. We then overlaid the top model for each BCR and the global model on the nests surveyed on WSMR.

Table 3. Top ranking regression models used to predict GOEA nest likelihood in southwestern BCRs.

	Sample size	Model
Global	1828	Y=3.9645(VRM)+0.00209(Bio12)-.00214(Bio5)+0.0427(Bio1)-0.0295(Bio6)
BCR 9	140	Y=13.42(VRM)-0.0118(Bio12)
BCR 16	368	Y=3.32(VRM)+0.00423(Bio12)+0.00592(Bio5)
BCR 33	664	Y=5.39(VRM)+0.0365(Bio6)-0.0448(Bio1)
BCR 34	636	Y=4.23(VRM)-0.0108(Bio6)-0.0044(Bio12)+0.00175(Aspect)
BCR 35	20	Sample size precluded modeling

(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.

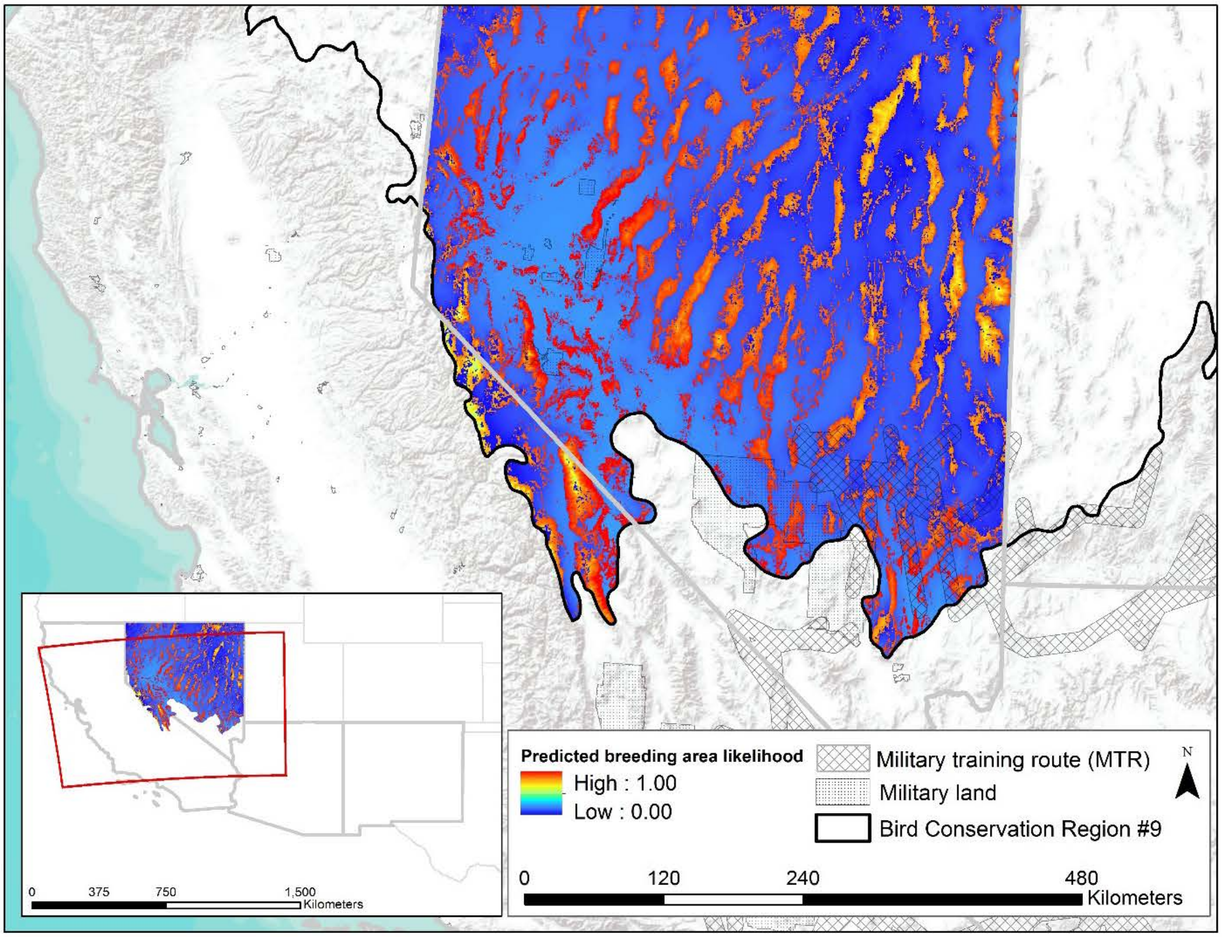

Figure 4. Predicted likelihood of GOEA nesting habitat in BCR 9 (Great Basin).

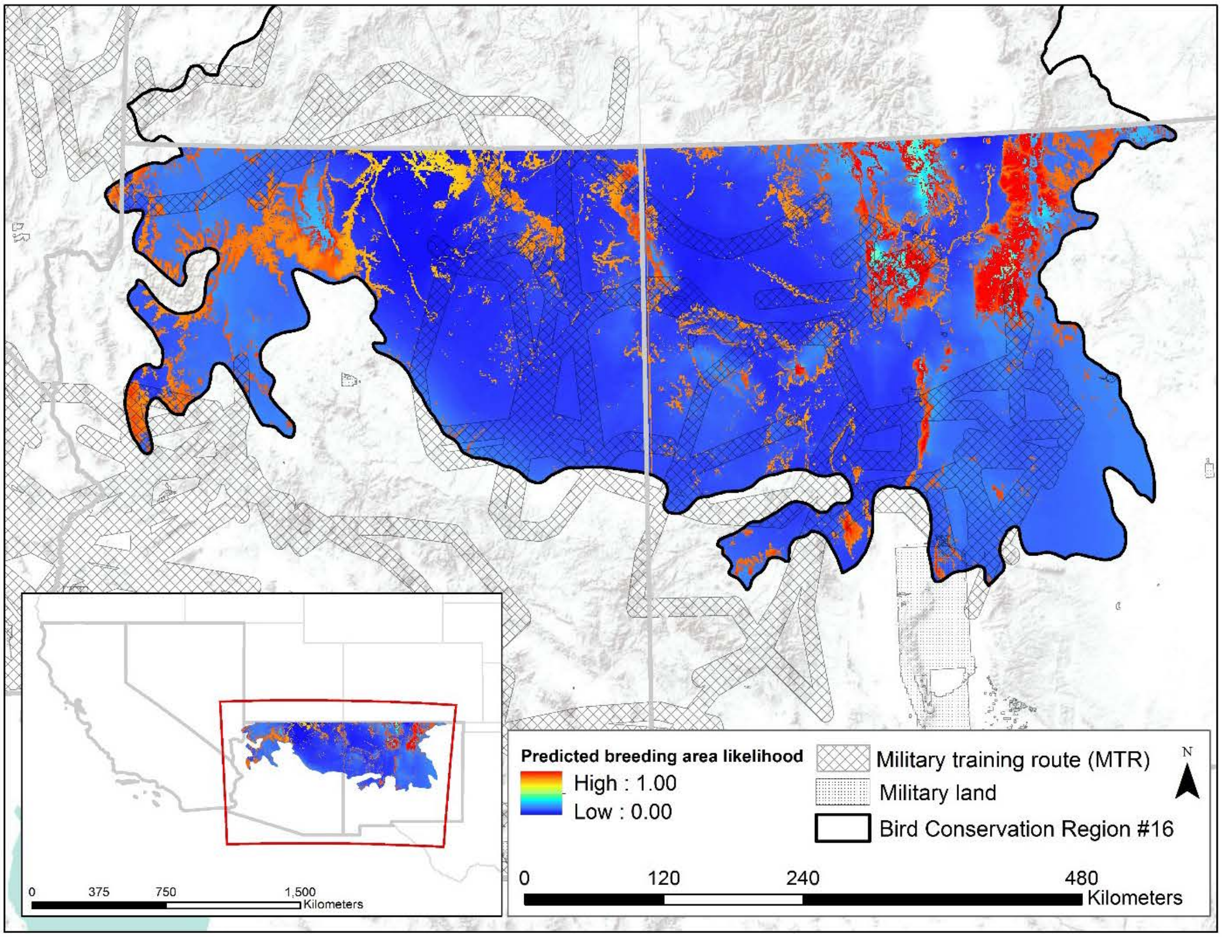

Figure 5. Predicted likelihood of GOEA nesting habitat in BCR 16 (Southern Rockies Colorado Plateau).

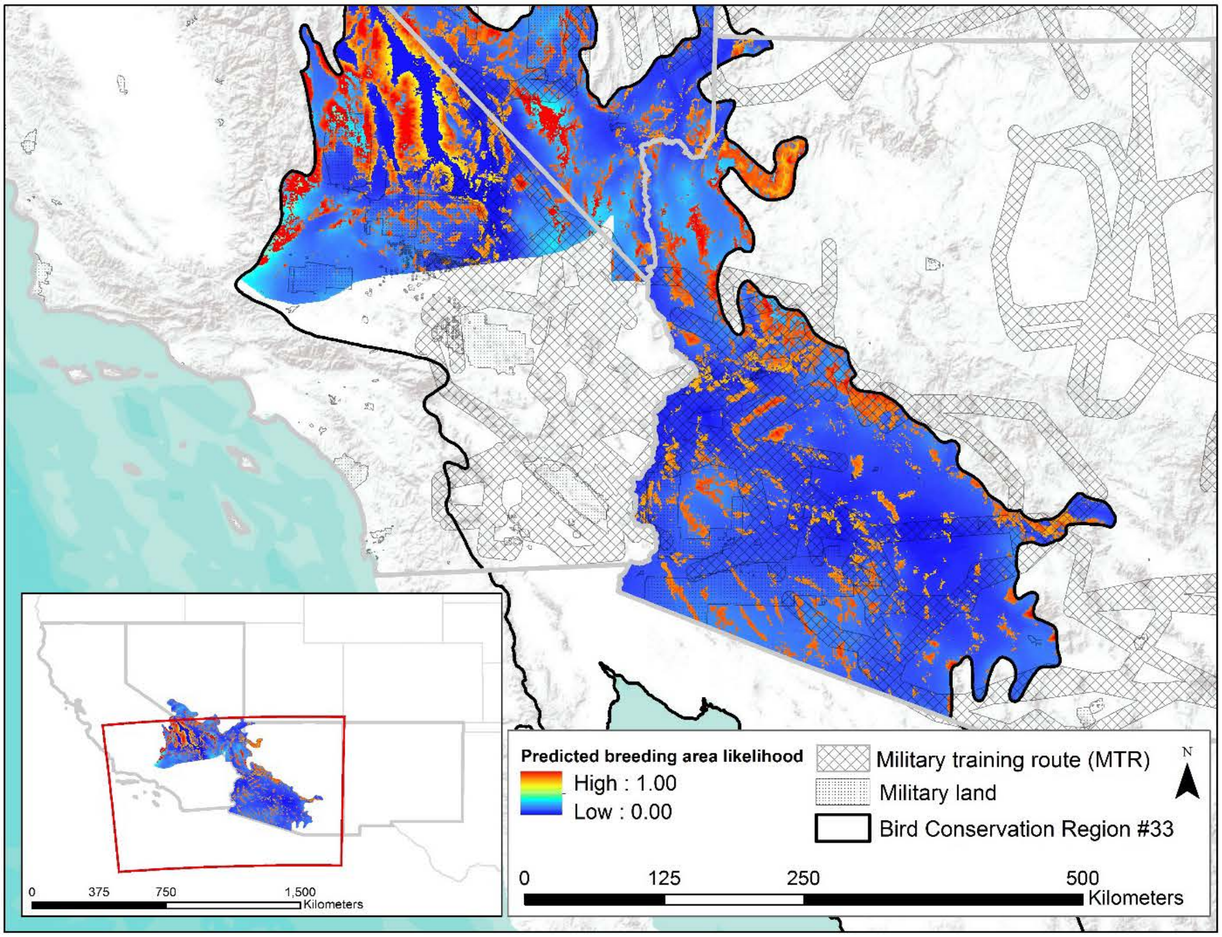

Figure 6. Predicted likelihood of GOEA nesting habitat in BCR 33 (Sonoran and Mohave Deserts).

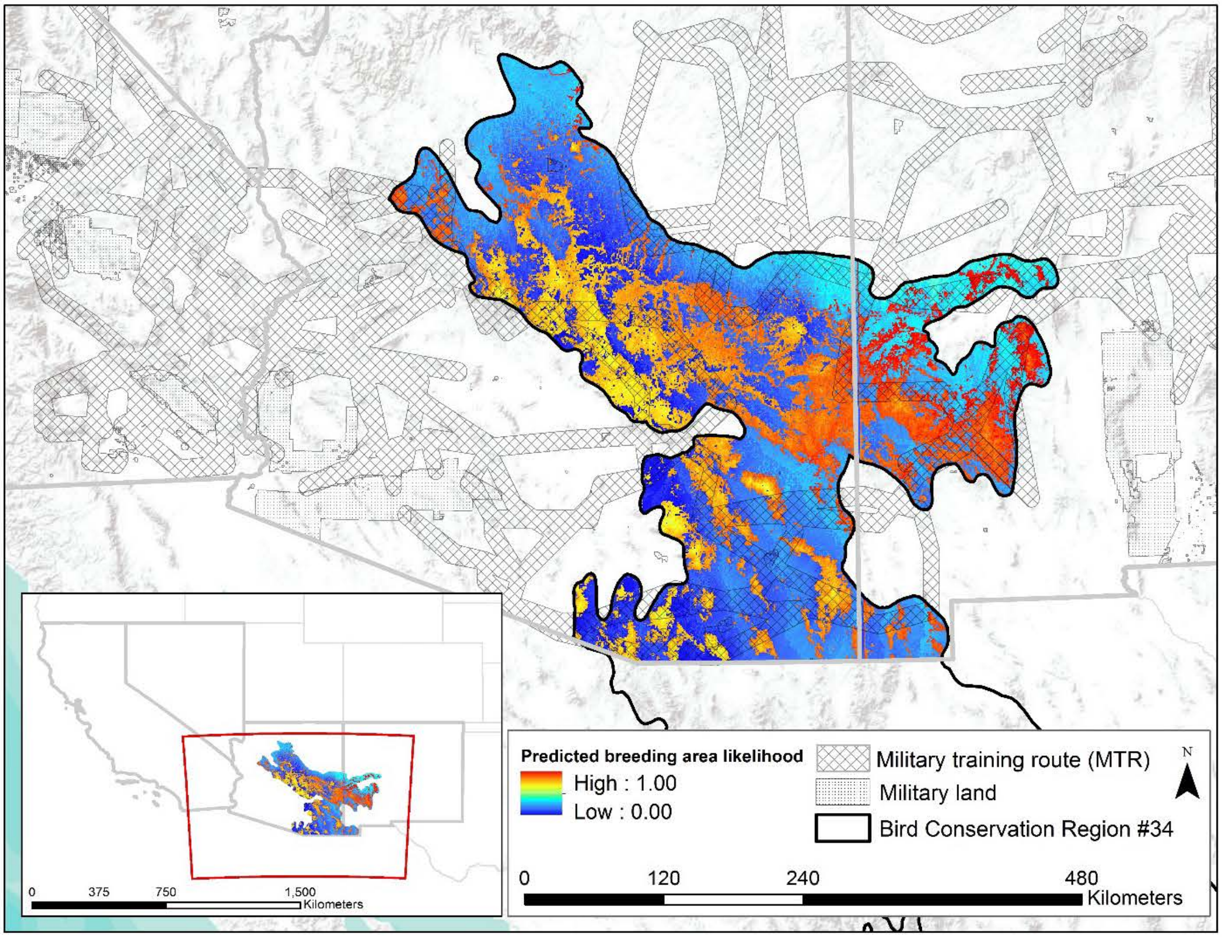

Figure 7. Predicted likelihood of GOEA nesting habitat in BCR 34 (Sierra Madre Occidental).

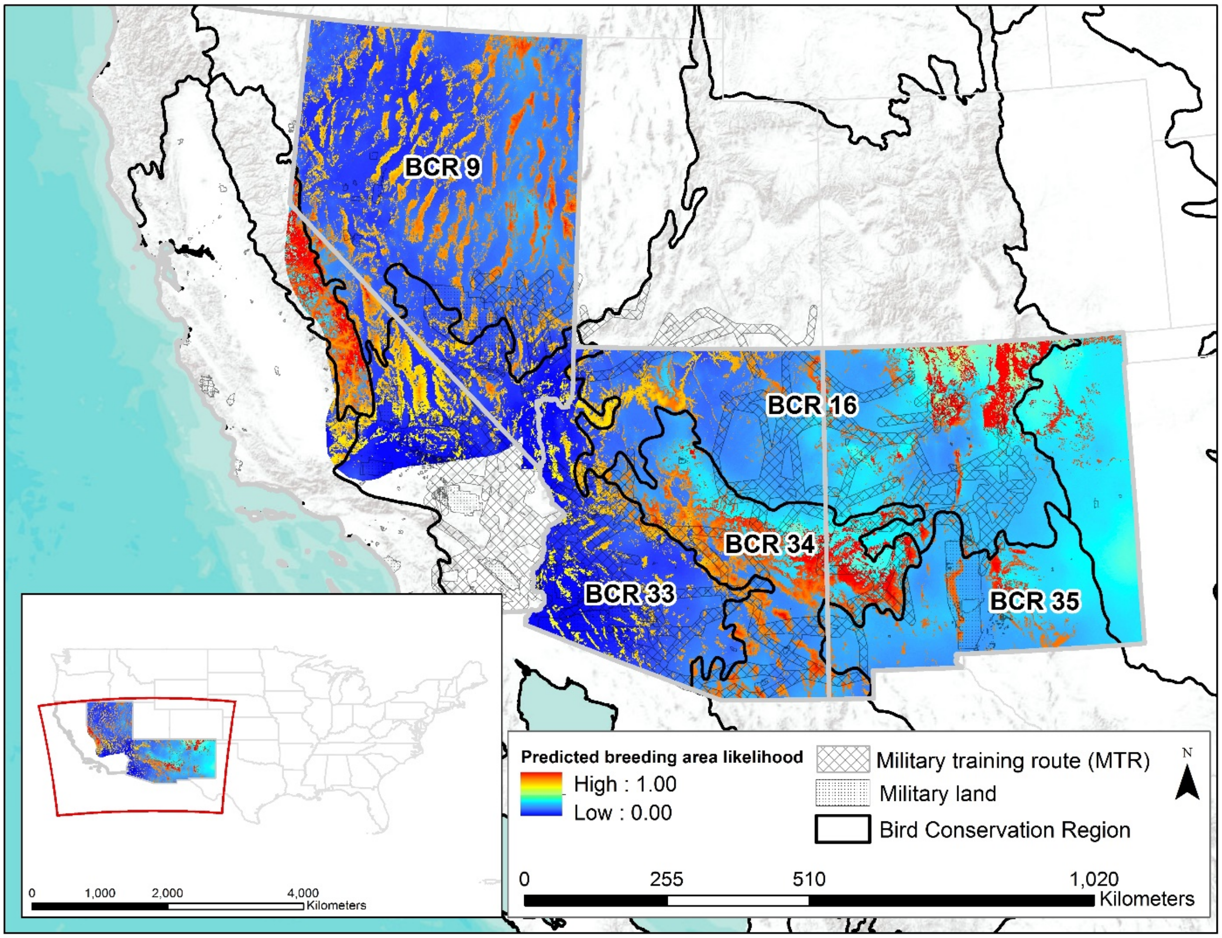

Figure 8. Predicted likelihood of GOEA nesting habitat in using our global model.

In order to assess the predictive value of our spatially explicit models we used 20% of the entire data sample as a validation data set and projected each model onto GOEA nest territories in WSMR (Table 4). The validation model for BCR 9 indicates that this model predicted nest presence better than absence and had a mean correct classification of 82%. When the BCR 9 model was projected to WSMR it correctly identified 98% of presence and 83% of absences for mean correct classification of 91%. In total the BCR 9 model correctly classified 86% of GOEA presence and absence (Table 4; Figure 9). Our validation of the BCR 16 model indicates that this model performed better at predicting absence (89%) than presence (65%). The BCR 16 model performed poorly at predicting GOEA nests at WSMR, correctly classifying only 26% of absences and 2% of presence events (Figure 10). BCR 16 had the poorest overall fit (46%). The BCR 33 model validation shows that this model correctly classified 91% of absences and 92% of presence events (Table 4). Our BCR 33 model performed better at predicting absence than presence and correctly classified 78% of events. Overall, the BCR 33 model had a total accuracy of 85% (Figure 11). The BCR 34 model validation indicates that this model was slightly better at predicting absence than presence and correctly classified 86% of events. Our BCR 34 model correctly classified 86% of absence events and 98% of presence when projected onto the WSMR nests (Table 4). The BCR 34 model had a total accuracy estimate of 89% (Figure 12). Our global model performed well at predicting absence and presence in the validation data set for a total correct classification of 89%. The global model also performed well at predicting presence and absence at

WSMR, correctly classifying 92% of events. Overall, the global model correctly classified 90% of events (Table 4; Figure 13).

Table 4. Confusion matrix of training and validation datasets used to develop predictive models for GOEA nesting likelihood in southwestern BCRs, United States.

BCR 9									
Validation					WSMR				
		0	1	% Correct		0	1	% Correct	Total Accuracy
	0	11	3	79%	0	196	39	83%	
	1	2	12	86%	1	5	230	98%	
				82%				91%	86%
BCR 16									
Validation					WSMR				
		0	1	% Correct		0	1	% Correct	Total Accuracy
	0	33	4	89%	0	62	173	26%	
	1	13	24	65%	1	230	5	2%	
				77%				14%	46%
BCR 33									
Validation					WSMR				
		0	1	% Correct		0	1	% Correct	Total Accuracy
	0	121	12	91%	0	201	34	86%	
	1	10	123	92%	1	69	166	71%	
				92%				78%	85%
BCR 34									
Validation					WSMR				
		0	1	% Correct		0	1	% Correct	Total Accuracy
	0	117	10	88%	0	201	34	86%	
	1	15	112	84%	1	5	230	98%	
				86%				92%	89%
Global									
Validation					WSMR				
		0	1	% Correct		0	1	% Correct	Total Accuracy
	0	282	29	91%	0	201	34	86%	
	1	40	271	87%	1	5	230	98%	
				89%				92%	90%

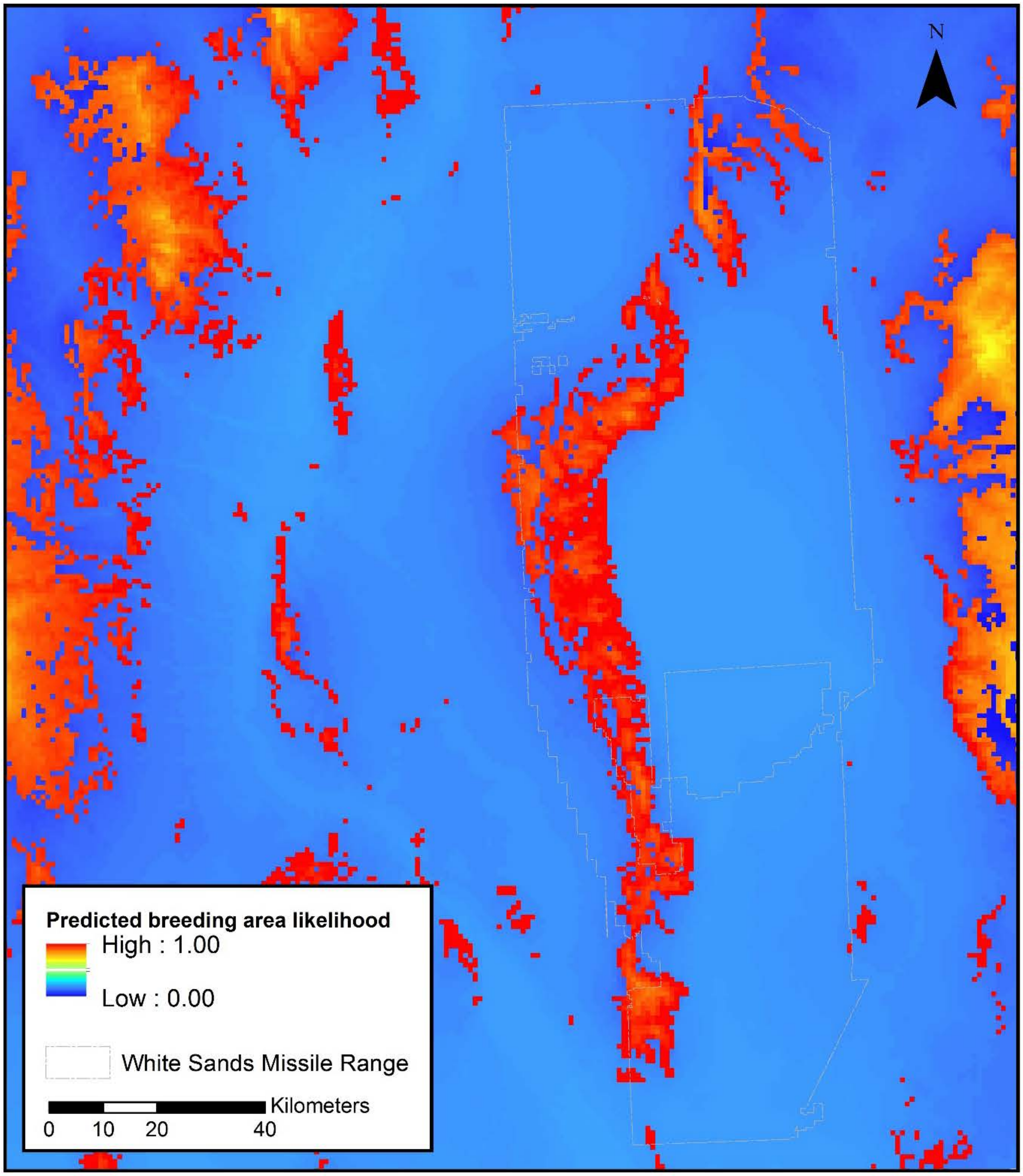

Figure 9. Predicted likelihood of GOEA nesting habitat on WSMR using our BCR 9 (Great Basin) model.

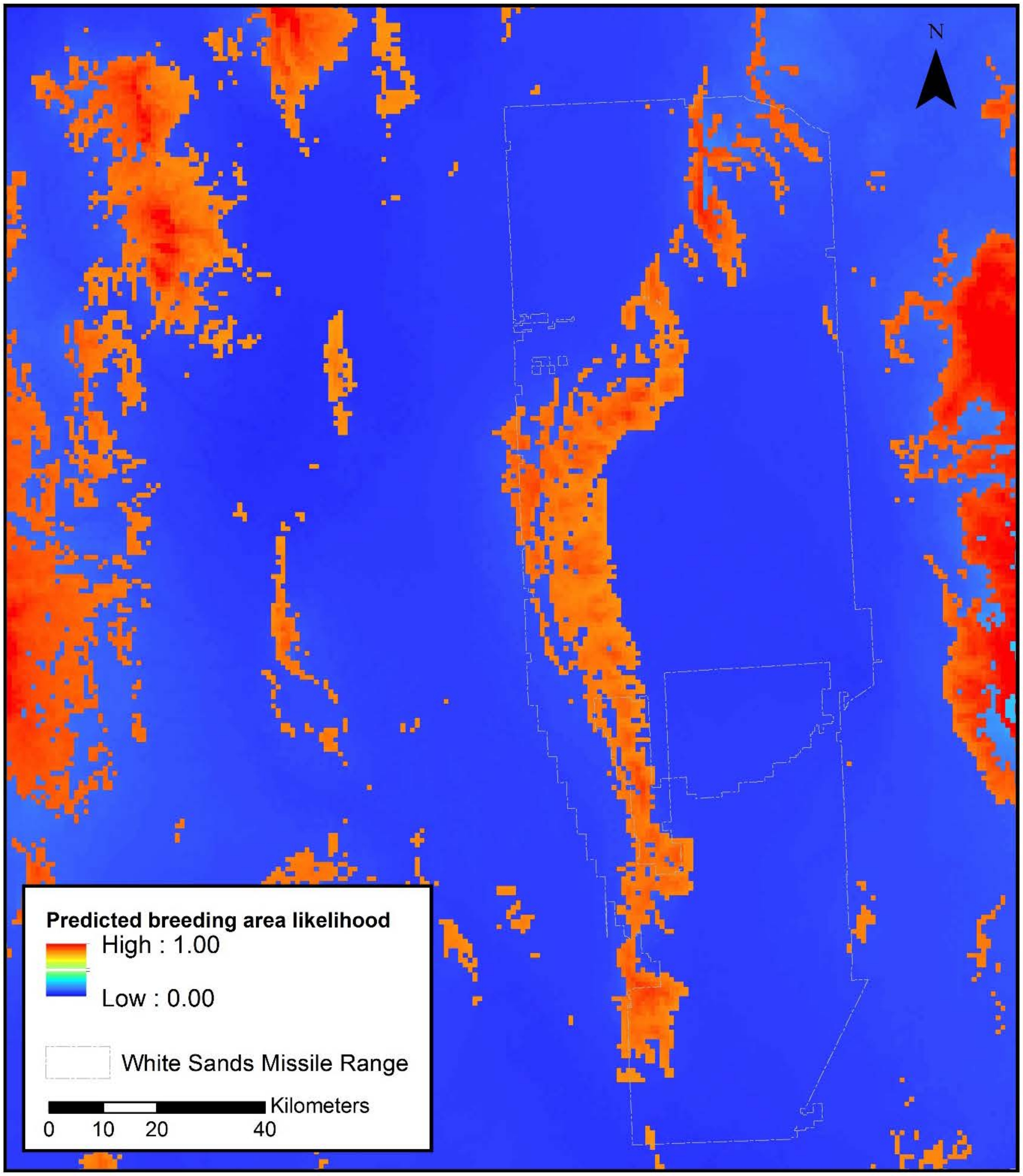

Figure 10. Predicted likelihood of GOEA nesting habitat on WSMR using our BCR 16 (Southern Rockies Colorado Plateau) model.

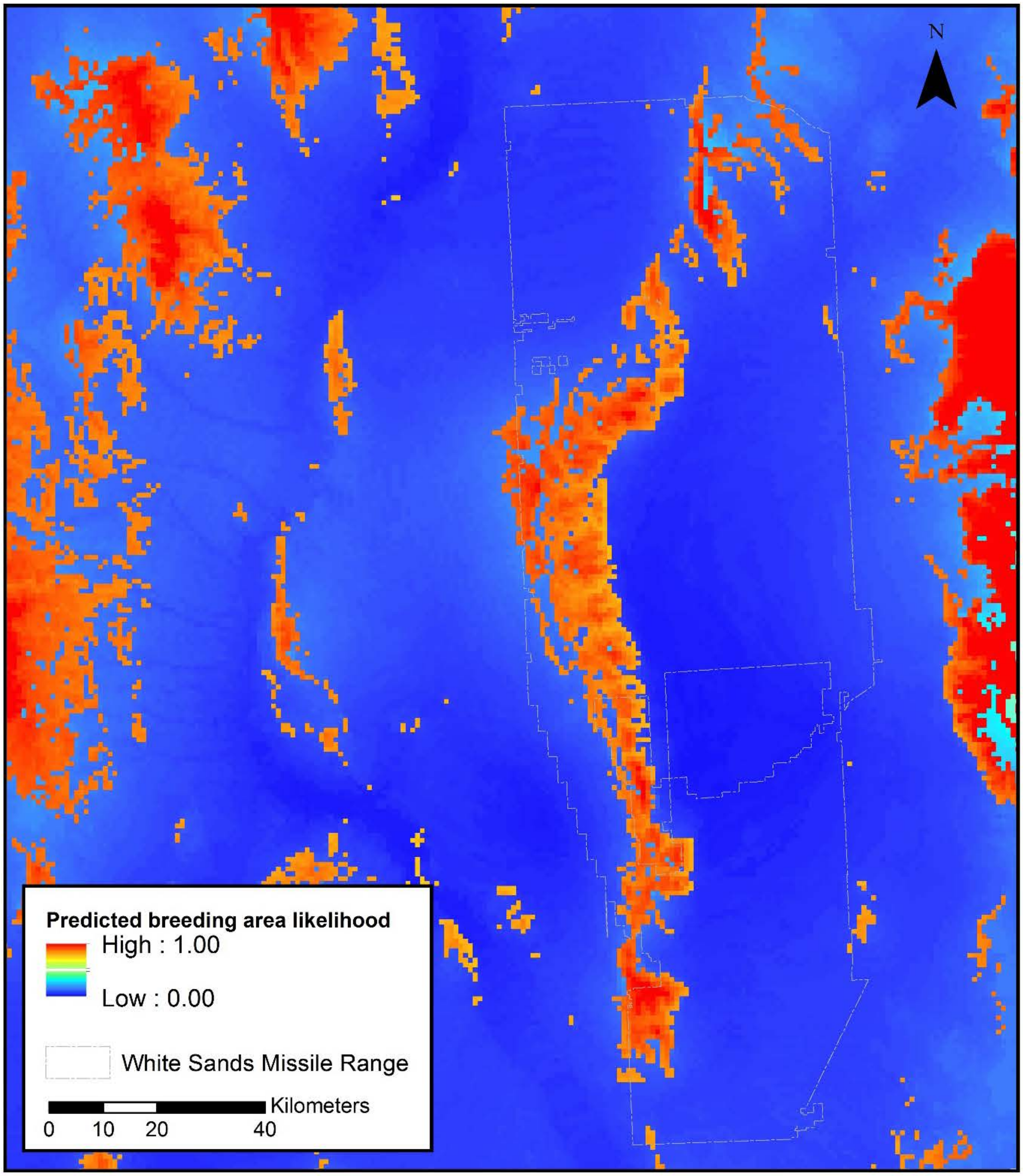

Figure 11. Predicted likelihood of GOEA nesting habitat on WSMR using our BCR 33 (Sonoran and Mohave Deserts) model.

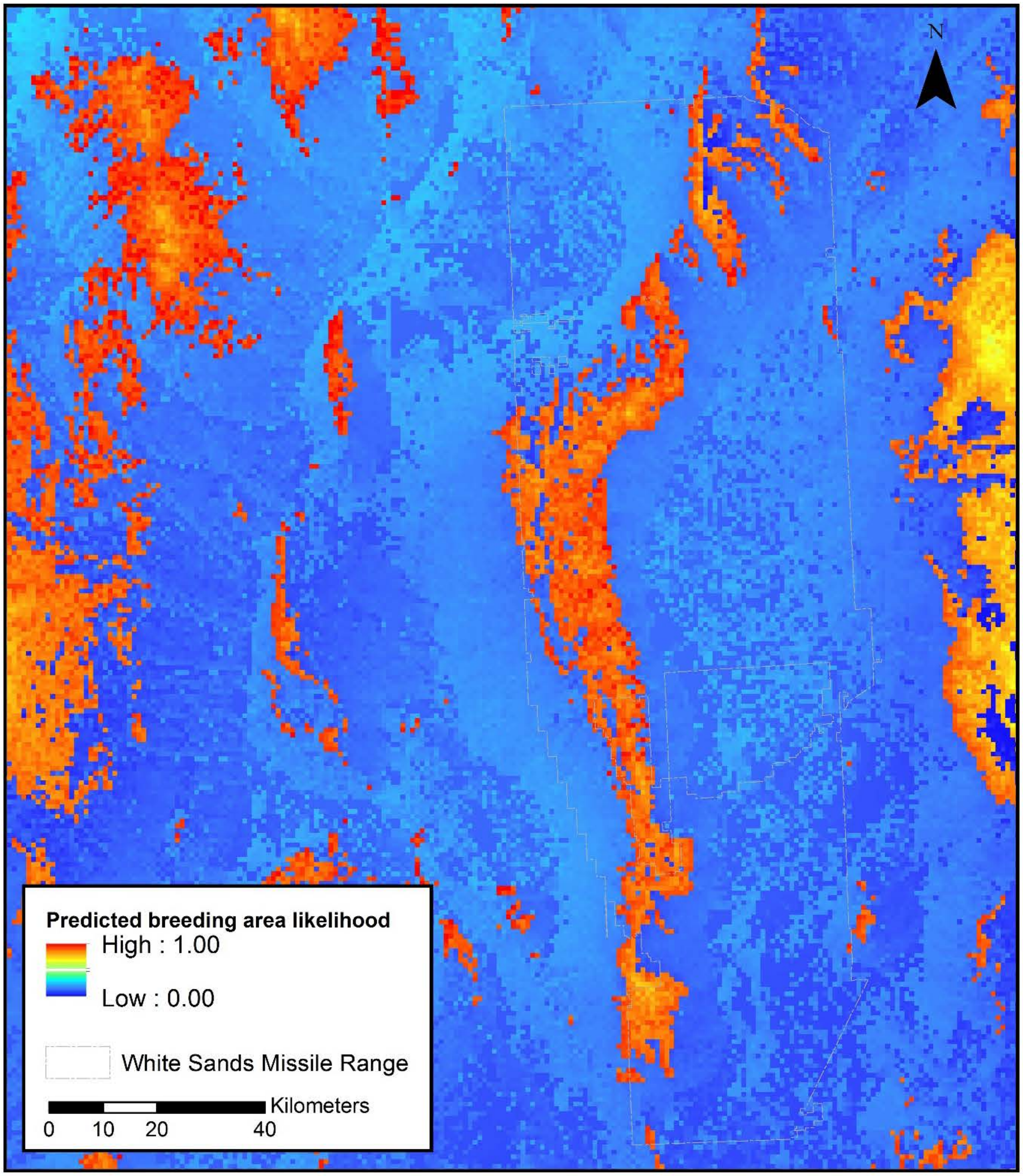

Figure 12. Predicted likelihood of GOEA nesting habitat on WSMR using our BCR 34 (Sierra Madre Occidental) model.

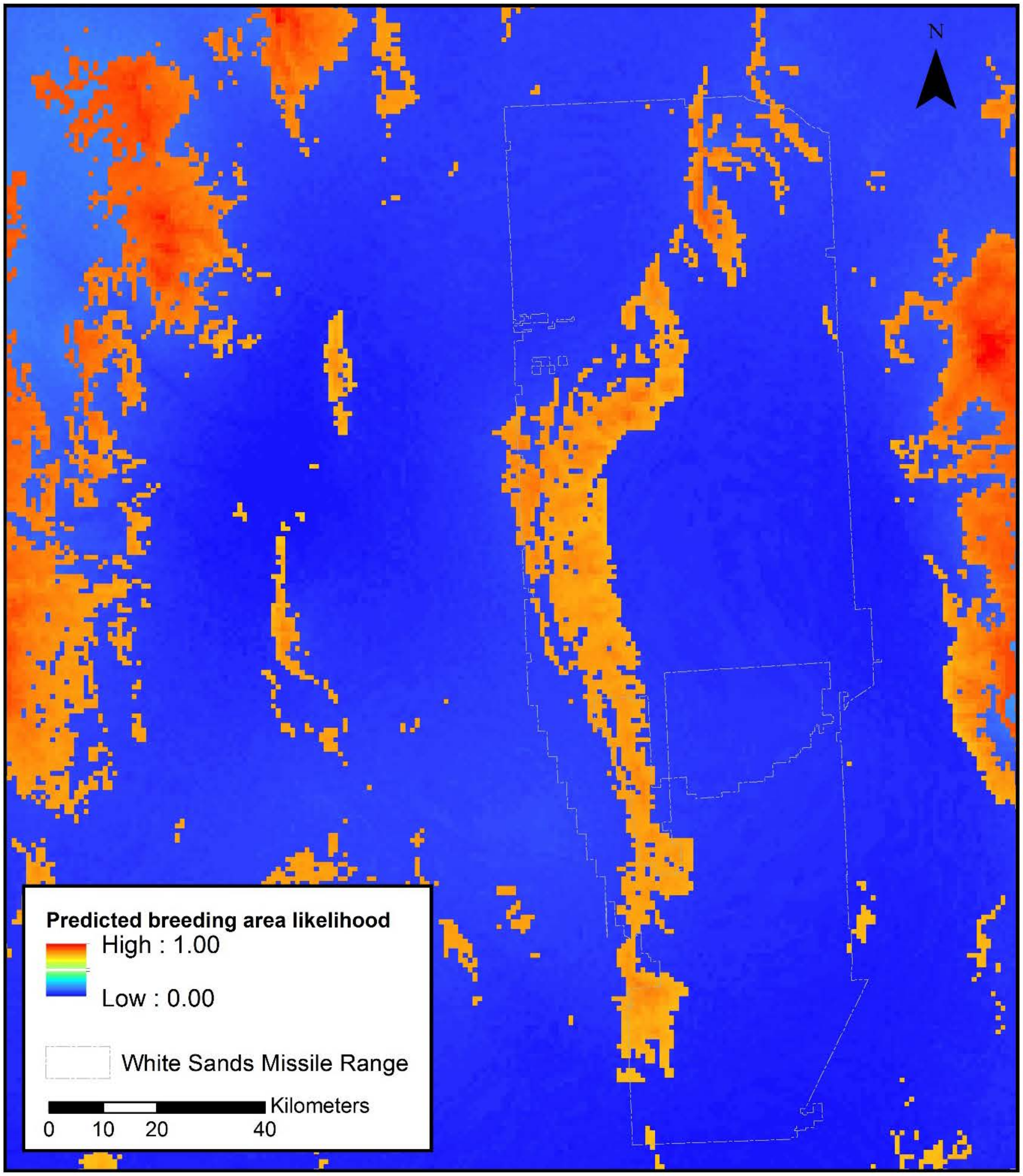

Figure 13. Predicted likelihood of GOEA nesting habitat on WSMR using our Global model.

DISCUSSION

We found GOEA nests distributed throughout the study area with no evidence to support current military activities causing additional take under MTR-designated airspace (Figures 2 and 3). However, the lack of occupied GOEA nest on surveyed military lands (YPG and the 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 from year one and year two (Piorkowski et al. 2014 and 2015) to increase our predictive power to identify high quality GOEA nesting habitat. Model refining using the combined data from all three years improved resolution, precision, and incorporates environmental variation within this large geographic region of the southwestern United States (*see* Figure 8). We were also able to test the inferential value of our model by projecting in onto WSMR and comparing model outputs with the actual distribution of GOEA habitat (Table 4). These data and corresponding models compare USFWS eagle management units when considering take thresholds (USFWS 2013). Finally, we provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA statutes. Discussion topics 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. 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 the 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 the 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 three sample years of this study 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).

By sampling 521 GOEA nesting territories multiple times within year across the three year duration of this study we were able to make parametric comparisons across BCR and MTR*year. While we detected variation in the amount of time a territory was occupied across BCR, we detected no significant differences (Figure 3). These findings indicate that occupied nests remain occupied at a similar rate across BCR. We detected several significant differences across MTR and year combined (Figure 2). Non-MTR nests in year one were occupied less time than all other years and MTR status. We also observed a significantly greater amount of time occupied in year two for both the MTR and non-MTR sites. The time a nest was occupied did not differ between non-MTR and MTR in year three. Our findings indicate that the time eagles spend within the nesting territory is a function of yearly variation not MTR. The only significant difference we found between MTR and non-MTR was a longer occupation period in MTR sites in year one of the study. This higher occupation time in year one is likely related to our lower sampling rate in non-MTRs during the third sampling period of year one. This study was designed as a landscape scale assessment of the impacts of MTRs on GOEA occupation of the breeding territory. At this large scale our finding indicate that MTRs had no detectable impact on GOEA breeding.

Objective 2: *Validate an existing landscape-level model previously funded by DoD Legacy and augmented with previous efforts by WSMR that will allow natural resource managers to identify GOEA nesting habitat within and adjacent (i.e., within the MTRs) to southwestern military installations.*

An expanded survey extent allowed us to produce species distribution models 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. 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 BCR specific models performed well identifying the training data set but the inferential value of the models varied. The BCR 16 model performed poorly with the training data set and the prediction of GOEA nesting habitat on WSMR. This BCR model was passible at predicting absence within the training data set and marginal at predicting presence. The BCR 16 model correctly categorized only 14% of presence/absence events at WSMR. BCR 16 has the least similarity in available habitats to the WSMR habitat, thus it was expected that this model would have poor inferential value on WSMR. The BCR 33 modeling efforts had a good fit with the training data set but only correctly categorized 78% of WSMR nests. BCR 33 consists of the most arid portion of the study area while WSMR provides both higher elevation and more mesic habitats. Thus, the moderate inferential value of the BCR 33 model is likely due to the habitat dissimilarity with WSMR. In contrast, the BCR 9 and BCR 34 models had a better fit with WSMR than their validation data sets. Both of these BCRs have similar habitat types and climatic conditions and correctly identified over 90% of WSMR nests. These findings indicate that the best use of these predictive models was to apply them only to very similar habitat and climatic types.
These data 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: *Provide management recommendations that will allow southwestern military installations to maintain their military training opportunities while complying with the revised BGEPA statutes.*

We did not detect a significant difference in GOEA nesting between MTR and non-MTR; this was consistent with our findings from years one and two (2013; Piorkowski et al. 2014). Our findings indicate that GOEA nesting was driven by yearly conditions and not MTR. 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.

After three consecutive years of GOEA surveys and monitoring, we have no evidence supporting additional “Take” in lands under MTR-designated airspace. At current levels, 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.

LITERATURE CITED

Akaike, H. 1973. Maximum likelihood identification of Gaussian autoregressive moving average models. Biometrika 60: 255-265.

Andersen, D.E., O.J. Rongstad, and W.R. Mytton. 1986. The behavioral response to a Red-tailed Hawk to military training activities. Raptor Research 20: 65-68.

Bates, J. W. and M. O. Moretti. 1994. Golden Eagle (*Aquila chrysaetos*) population ecology in eastern Utah. Great Basin Nat. 54:248-255.

Beecham, Jr., J. J. 1970. Nesting ecology of the Golden Eagle in southwestern Idaho. Master's Thesis. Univ. of Idaho, Moscow.

Boom, T.L., P.F. Schempf, B.J. McCaffery, M.S. Lindberg, and M.R. Fuller. 2010. Detection probability of cliff-nesting raptors during helicopter and fixed-wing aircraft surveys in Western Alaska. Journal of Raptor Research 44:175–187.

Brown, D. E. (ed.) 1994. Biotic Communities: Southwestern United States and Northwestern Mexico, University of Utah Press, Salt Lake City, Utah.

Buckland, S.T., K.P. Burnham, and N.H. Augustin. 1997. Model selection: and integral part of inference. Biometrics 53: 603-618.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical-theoretic approach. Second edition. Springer-Verlag, New York, New York.

Camenzind, F. J. 1969. Nesting ecology and behavior of the Golden Eagle *Aquila chrysaetos* L. EC (Commission for Environmental Cooperation). 1998. A proposed framework for delineating ecologically-based planning, implementation, and evaluation units for cooperative birds conservation in the U.S. Montreal, Canada.

Corman, T. E. and C. Wise-Gervais. 2005. Arizona Breeding Bird Atlas. University of New Mexico Press, Albuquerque, New Mexico.

Craig, T.H. and E.H. Craig. 1984. Results of a helicopter survey of cliff nesting raptors in a deep canyon in southern Idaho. Raptor Research 18: 20-25.

Cully, J.F., Jr. 1991. Response of raptors to reduction of a Gunnison’s prairie dog population by plague. American Midland Naturalist 125: 140-149.

Dixon, J. B. 1937. The Golden Eagle in San Diego County, California. Condor 39:49-56.

Elith, J. and J.R. Leathwick. 2009. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution, and Systematics. 40: 677-697.

Elith, J., J.R. Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. Journal of Animal Ecology 77: 802-813.

ESRI 2012. ArcGIS Desktop Release 10.1. Redlands, CAL Environmental Systems Research Institute.

Ewins, P. J. and M. J. R. Miller. 1995. Measurement error in aerial surveys of osprey productivity. Journal of Wildlife Management 59:333-338.

Fitch, H.S., F. Swenson, and D.F. Tillotson. 1946. Behavior and food habits of the Red-tailed Hawk. The Condor 48: 205-237.

Frackler, P.L., K. Pacifici, J. Martin, and C. McIntyre. 2014. Efficient use of information in adaptive management with an application to managing recreation near golden eagle nesting sites. PLoS ONE 9: e102434.

Gabrielson, I. N. and F. C. Lincoln. 1959. Birds of Alaska. Stackpole Co., Harrisburg, PA, and Wildl. Manage. Inst. Washington, D.C.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., and Tyler, D., 2002, The national elevation dataset: Photogrammetric Engineering and Remote Sensing, v. 68, no. 1, p. 5–11.

Grubb, T. G. and W. L. Eakle. 1987. Comparative morphology of Bald and Golden Eagle nests in Arizona. Journal of Wildlife Management 51:744-748.

Hernandez, P.A., C.H. Graham, L.L. Master, and D.L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography 29: 773-785.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Hines, J.E. 2006. PRESENCE. Software to estimate patch occupancy and related parameters. USGS-PWRC http://www.mbrpwrc.usgs.gov/software/presence.html.

IBM Corp. 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Jollie, M. T. 1943. The Golden Eagle-its life history, behavior, and ecology. Master's Thesis. Univ. of Colorado, Boulder.

Kochert, M. N., K. Steenhof, C. L. Mcintyre and E. H. Craig. 2002. Golden Eagle (Aquila chrysaetos), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/684 doi:10.2173/bna.684

Kochert, M. N. and K. Steenhof. 2012. Frequency of nest use by golden eagles in southwestern Idaho. The Journal of Raptor Research 46: 239-247.

Koford, C.B. 1958. Prairie dogs, whitefaces, and blue grama. Wildlife Monographs, Vol.3. Pp 78.

MacKenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J.A. Royle, and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

McIntyre, C. L. 2002. Patterns in nesting area occupancy and reproductive success of Golden Eagles (*Aquila chrysaetos*) in Denali National Park and Preserve, Alaska, 1988-99. Journal of Raptor Research 36: 50-54.

McIntyre, C. L., M. W. Collopy, J. G. Kidd, and A. A. Stickney. 2006. Characteristics of the landscape surrounding golden eagle nest sites in Denali National Park and Preserve, Alaska. The Journal of Raptor Research 40:46-51.

Menkens, Jr., G. E. and S. H. Anderson. 1987. Nest site characteristics of a predominantly tree-nesting population of Golden Eagles. Journal of Field Ornithology. 58:22-25.

Millsap, B.A., G.S. Zimmerman, J.R. Sauer, R.M. Nielson, M. Otto, E. Bjerre, and R. Murphy. 2013. Golden eagle population trends in the western United States: 1968-2010. Journal of Wildlife Management 77: 1436-1448.

Nielson, R.M., L. McManus, T. Rintz, L.L. McDonald, R.K. Murphy, W.H. Howe, and R.E. Good. 2014. Monitoring abundance of Golden Eagles in the western United States. Journal of Wildlife Management 78: 721-730.

Piorkowski, M.D., D.P. Sturla, W.L. Crumbo, and J.M. Diamond. 2014. Status and distribution modeling of Golden Eagles on southwestern military installations and overflight areas: assessing "take" for this sensitive species at risk – year 1. 2014 Final Report. Arizona Game and Fish Department, Wildlife Contracts Branch, Phoenix, Arizona, USA.

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.

PRISM (PRISM Climate Group). 2015. Oregon State University. accessed 6 July 2015, http://prism.oregonstate.edu.

Sappington, J.M., K.M. Longshore, and D.B. Thomson. 2007. Quantifying landscape ruggedness for animal habitat analysis: A case study using bighorn sheep in the Mojave desert. Journal of Wildlife Management 71: 1419 -1426.

Slevin, J. R. 1929. A contribution to our knowledge of the nesting habits of the Golden Eagle. Proceedings of the California Academy of Science 4 18:45-71.

Smith, D.G. and J.R. Murphy. 1982. Spatial relationships of nesting golden eagles in central Utah. Raptor Research 16:127-132.

Snyder, N.F.R., H.W. Kale II, and P.W. Sykes. 1978. An evaluation of some potential impacts of the proposed Dade county training jetport on the endangered Everglade Kite, Patuxent Wildlife Research Center, U.S. Forest and Wildlife Service.

Steenhof, K. and M. N. Kochert. 1982. An evaluation of methods used to estimate raptor nesting success. Journal of Wildlife Management 46:885-893.

Steenhof, K., M. N. Kochert, and T. L. McDonald. 1997. Interactive effects of prey and weather on golden eagle reproduction. Journal of Animal Ecology 66:350-362.

Steenhof, K., J.L. Brown, and M.N. Kochert. 2014. Temporal and spatial changes in golden eagle reproduction in relation to increased off highway vehicle activity. Wildlife Society Bulletin doi: 10.1002/wsb.451.

Sturla, D.P., M.D. Piorkowski, and J.M. Diamond. 2014. Planning level surveys to determine the distribution and nesting status of golden eagles on Yuma Proving Ground in southwestern Arizona. Technical Report for contract W912R-14-C-0001. Pp 21.

Tyre, A. J., H. P. Possingham, and D. B. Lindenmayer. 2001. Matching observed pattern with ecological process: can territory occupancy provide information about life history parameters? Ecological Applications 11:1722-1738.

U.S. Fish and Wildlife Service (USFWS). 2009. Final Environmental Assessment – Proposal to take provided under the Bald and Golden Eagle Protection Act. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Branch of Policy, Permits, and Regulations, Arlington, Virginia, USA.

U.S. Fish and Wildlife Service (USFWS). 2013. Eagle Conservation Plan Guidance. Module 1 – Land-based wind energy version 2. U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Branch of Policy, Permits, and Regulations, Arlington, Virginia, April 2013.

Wheeler, B. K. 2003. Raptors of Western North America. Princeton University Press, Princeton, New Jersey.