Draft Appendix A

Covered Species Accounts

INTRODUCTION

This appendix includes the information on the 28 species proposed for coverage in the Clark County Multi-Species Habitat Conservation Plan (MSHCP) Amendment. The species habitat distribution model methods, species accounts, and species habitat distribution models which follow are extracted and compiled from previous reports prepared for the Desert Conservation Program (DCP). The original reports are SWECO 2018a[1], SWECO 2018b[2], UNR 2019[3], and UNR 2020[4]. Table 1 below shows each of the 28 species proposed for coverage, order within this appendix, and the source document for the species account and habitat distribution model. References included in the species accounts and models were also extracted from the original documents and are compiled at the end of this appendix for completeness. The methods which follow in this Introduction are excerpted from SWECO 2018a and UNR 2020. In compiling the accounts, only minor formatting was performed specific to heading, figure, and table numbering for consistency within the compiled accounts. No adjustments were made to content.

Table 1. Proposed Covered Species and Species Account Source Document

Appendix Number	Common Name	Scientific Name	Source Document
Plants			
A.1	sticky ringstem	*Anulocaulis leiosolenus* var. *leiosolenus*	UNR 2020
A.2	Las Vegas bearpoppy	*Arctomecon californica*	UNR 2020
A.3	threecorner milkvetch	*Astragalus geyeri* var. *triquetrus*	SWECO 2018a
A.4	alkali mariposa lily	*Calochortus striatus*	SWECO 2018a
A.5	Blue Diamond cholla	*Cylindropuntia multigeniculata*	SWECO 2018a
A.6	silverleaf sunray	*Enceliopsis argophylla*	SWECO 2018a
A.7	Pahrump Valley buckwheat	*Eriogonum bifurcatum*	UNR 2020
A.8	Las Vegas buckwheat	*Eriogonum corymbosum* var. *nilesii*	UNR 2020
A.9	sticky buckwheat	*Eriogonum viscidulum*	UNR 2020

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[1] [SWECO] Southwest Ecology. 2018a. Covered Species Analysis Support – Final Report. Prepared for the Desert Conservation Program, Contract 2011-SWECO-901B. March.

[2] [SWECO] Southwest Ecology. 2018b. Species habitat model for Joshua trees in Clark County, NV. Prepared for the Desert Conservation Program, Contract 2013-SWECO-1460D. March

[3] [UNR] University of Nevada, Reno. 2019. Draft Golden Eagle Habitat Model Report. Prepared by K. Nussear and E. Simandle for the Desert Conservation Program, Contract 2013-UNR-1460F. September.

[4] [UNR] University of Nevada, Reno. 2020. Covered Species Analysis Support – Final Report. Prepared by K. Nussear and E. Simandle for the Desert Conservation Program, Contract 2013-UNR-1460E. January.

Appendix Number	Common Name	Scientific Name	Source Document
A.10	white margined beardtongue	*Penstemon albomarginatus*	UNR 2020
A.11	Parish phacelia	*Phacelia parishii*	UNR 2020
A.12	St. George blue-eyed grass	*Sisyrinchium radicatum*	SWECO 2018a
A.13	Joshua tree	*Yucca brevifolia*	SWECO 2018b
Reptiles			
A.14	desert tortoise	*Gopherus agassizii*	UNR 2020
A.15	banded Gila monster	*Heloderma suspectum cinctum*	SWECO 2018a
Birds			
A.16	golden eagle	*Aquila chrysaetos*	SWECO 2018a (account) and UNR 2019 (habitat model)
A.17	western burrowing owl	*Athene cunicularia hypugea*	SWECO 2018a
A.18	yellow-billed cuckoo	*Coccyzus americanus*	UNR 2020
A.19	gilded flicker	*Colaptes chrysoides*	UNR 2020
A.20	southwestern willow flycatcher	*Empidonax traillii extimus*	UNR 2020
A.21	loggerhead shrike	*Lanius ludovicianus*	UNR 2020
A.22	Ridgway's rail	*Rallus obsoletus yumanensis*	UNR 2020
A.23	Bendire's thrasher	*Toxostoma bendirei*	UNR 2020
A.24	Le Conte's thrasher	*Toxostoma lecontei*	UNR 2020
A.25	Arizona Bell's Vireo	*Vireo bellii arizonae*	UNR 2020
Mammals			
A.26	desert pocket mouse	*Chaetodipus penicillatus*	UNR 2020
A.27	Townsend's big-eared bat	*Corynorhinus townsendii*	SWECO 2018a
A.28	spotted bat	*Euderma maculatum*	SWECO 2018a
References			
A.29	Combined references		

SPECIES HABITAT DISTRIBUTION MODELING METHODS[1, 4]

Species Data

This appendix summarizes habitat distribution modelling conducted for 28 species that occur within Clark County, Nevada and are proposed for coverage under the MSHCP (Table 1).[1, 2, 3, 4] Many of these species are rare and/or limited in their spatial distributions. Therefore, we searched available public databases (the Global Biodiversity Information Facility - http://www.gbif.org/; iNaturalist - http://www.inaturalist.org/; Biodiversity Information Serving Our Nation - https://bison.usgs.gov; Southwest Environmental Information Network, SEInet - http//:swbiodiversity.org/; the Consortium of CA Herbaria - http://ucjeps.berkeley.edu/consortium/; Vertnet - http://vertnet.org/; and HerpNET- http://www.herpnet.org) to supplement species observation records provided by Clark County, the Nevada Department of Wildlife (NDOW), the Nevada Natural Heritage Program (NNHP), the National Park Service (NPS), the US Forest Service (USFS), the Bureau of Land Management (BLM), the Nature Conservancy (TNC), and independent contractors who completed relevant studies under the MSHCP. We also digitized a few records from Department of Defense (DOD) reports where the data were not forthcoming from the source. Observations were visually assessed for accuracy prior to model fitting, and duplicate records and those without sufficient locality information were removed. For species that had undergone recent revisions in taxonomy, we used both historical and current names during searches.

For each species under consideration, we developed a conceptual model of suitable habitat based upon a review of the available scientific literature. We then selected environmental covariates describing the range of environmental conditions necessary for establishment, growth, reproduction, and survival. Habitat distribution models were based upon biologically relevant variables for which we had *a priori* hypotheses relating to each species' life-history when possible. This approach reduces the risk of spurious associations and potentially results in models with greater biological relevance (Austin 2002; Guisan and Thuiller 2005). We first ran the models with every reasonable variable thought to influence the species geographic distributions, and then reduced the number of variables to approximately 10 covariates to include in habitat models for each species.

Environmental Covariates

We evaluated a range of environmental covariates that might effectively discriminate habitat for multiple species within Clark County, including spatial layers available from the County, previously published datasets (Inman et al. 2014; Nussear et al. 2009), climatic interpolations (Hamann et al. 2013; Wang et al. 2016), satellite-based vegetation indices from the United States Geological Survey (USGS) Eros Center (http://phenology.cr.usgs.gov/), soil composition from the Soil Grids Project (http://soilgrids.org/ ; Hengl et al. 2017), and topographic features derived from a Digital Elevation Model (USGS National Elevation Dataset; http://ned.usgs.gov/). In total, we derived 34 covariate layers for potential inclusion in habitat distribution models (Table 2). These layers included climatic averages and extremes for precipitation and temperature, topographic features, and remotely sensed vegetation indices (e.g., Normalized Difference Vegetation Index [NDVI]). Environmental covariates were assessed for collinearity prior to model fitting, and variables that showed strong correlations ($r > 0.75$) were not included within the same models for a given species. Because many variables were expressed in different units, we standardized all variables prior to model fitting. Impervious surfaces were masked from the modelling extent based on the

National Land Cover Database 2011 percent developed imperviousness layer (Xian et al. 2011; https://www.mrlc.gov/). Grid cells were defined as impervious when greater than 20 % of their surface area were covered by at least 20 % imperviousness.

Quantitative Statistical Modelling Methods

The largest source of variability in habitat distribution model output stems from the type of algorithm used to generate predictions (e.g., Watling et al. 2015). For this reason, we used an ensemble modeling approach that incorporated three different algorithms: generalized additive models (GAM; using the *mgcv* method, Wood 2006), random forests (RF; implemented in the R package *randomForest*, Liaw and Wiener 2002), and maximum entropy (*MaxEnt*; version 3.4.1, Phillips et al. 2006); all executed from the“dismo” package in R, Hijmans et al. 2016 or *biomod2* package in R, Thuiller et al. 2009). The use of multi-algorithm Ensemble models renders predictions less susceptible to the biases, assumptions, or limitations of any individual algorithm, while broadening the types of environmental response functions that can be identified (Araujo and New 2006). Moreover, empirical evaluations have found GAM, RF, and MaxEnt to be consistently strong performers among habitat distribution modeling algorithms (Franklin 2010). All modeling was conducted in R versions 3.3.2 (R Core Team 2016) or 3.5.3 (R Core Team 2019) based on the source report date.

True absence points were not available for any of the study species at this time. For this reason, all models were fit using randomly generated background points (pseudo-absences). Random selections of background points are already implemented in MaxEnt software, and are also considered a reliable method for regression techniques including GAM (Wisz and Guisan 2009; Barbet-Massin et al. 2012). Background points were randomly selected from within the modelling extent (Thuiller 2009) from all grid cells where the study species was not present. Following the recommendations in Barbet-Massin et al. (2012), GAM models and RF models were fit with an equal number of presences and background points (Barbet-Massin et al. 2012).

To keep models interpretable and to improve their generalization across the study area, we also did not include interaction terms. Because presence points tended to be spatially aggregated, which can lead to substantial bias in model predictions, we first rasterized the presence points to the modeling resolution (i.e., such that only one presence point could occur within each grid cell) and subsequently applied a geographically-weighted resampling procedure in which a maximum of three observations could be sampled from cells on a uniform grid at a spatial resolution 10 times larger than the modelling extent (2.5 km resolution for the 250 x 250 m models). This systematic grid sampling approach for spatial thinning of presence points can be effective at reducing spatial bias under a variety of conditions (Fourcade et al. 2014). To further reduce bias in our predictions, we used cross-validations to fit and evaluate all habitat models. In this process, each algorithm was fit across 50 samples of randomly selected, spatially thinned presence points, with a 20% random sample (without replacement) withheld for model evaluation at each iteration (i.e., 80 % of presence points were used in model fitting, and 20% in model evaluation). Background points were also randomly drawn for each cross-validation.

Metrics of model prediction accuracy were calculated based on the evaluation data for each of the 50 cross-validation runs, and subsequently averaged across runs. Performance metrics included several threshold-independent measures: AUC (the area under the receiver operating characteristic; Fielding and Bell 1997), the Boyce Index (BI; Boyce et al. 2002; Hirzel et al. 2006), and the True Skill Statistic (TSS; Allouche et al. 2006). TSS takes into account both omission and commission errors and is insensitive to data prevalence (Allouche et al. 2006).

Habitat distribution models vary in their ability to effectively discriminate different classes of habitat along the full range of habitat suitability values (0 – 1; Hirzel et al. 2006). To evaluate this property, we calculated the continuous Predicted / Expected (P/E) ratio curves based on the BI (Hirzel et al. 2006) using the *ecospat* package (v 3.0) in R. These curves reflect how well each model deviates from random expectation, and inform the interpretation of biologically meaningful suitability categories by indicating the effective resolution of suitability scores for each model (i.e., the model's ability to distinguish different classes of suitability; Hirzel et al. 2006).

To generate predictive layers of habitat suitability for each species, we selected the top candidate models from each algorithm, based upon model performance metrics across cross-validation runs (AUC and/or TSS). Models were selected that consistently performed highest across different metrics. Raster surfaces representing each of the selected candidate models were generated by averaging model predictions across the 50 cross-validation runs, such that each model's prediction surface corresponded directly to its average performance scores. This procedure also limits the influence of sampling bias on individual model predictions. Ensemble predictions for individual algorithms were generated by taking the weighted average among candidate models for each algorithm type (i.e., one Ensemble prediction each for GAM, RF, and MaxEnt models), with the weights determined by TSS or AUC scores. Layers representing the standard error of the overall ensemble habitat suitability layer were calculated as the standard deviation in model predictions across all candidate models, divided by the square root of the number of candidate models considered. The same approach was used to derive standard error layers within each individual algorithm type. This Ensemble approach was conducted using the modeling package *biomod2* (3.3-7.1, Thuiller 2009).

Quantitative Model Interpretation

To facilitate biological interpretations of the ensemble models, we calculated the relative importance of environmental predictors across candidate models for each algorithm in *biomod2*.

To illustrate the shape of the relationships between predicted habitat suitability and important environmental covariates, we derived partial response curves for the top four environmental parameters for each of the three algorithms. Partial response curves show the predicted habitat suitability across a single covariate's range of values, while holding all other covariates at their mean value (e.g., Elith et al. 2005). To indicate the overall distribution of covariate values across the study region, we overlaid the response curve plots with histograms representing each environmental covariate. These histograms were calculated from the combined presence and pseudo-absence locations.

Qualitative Models

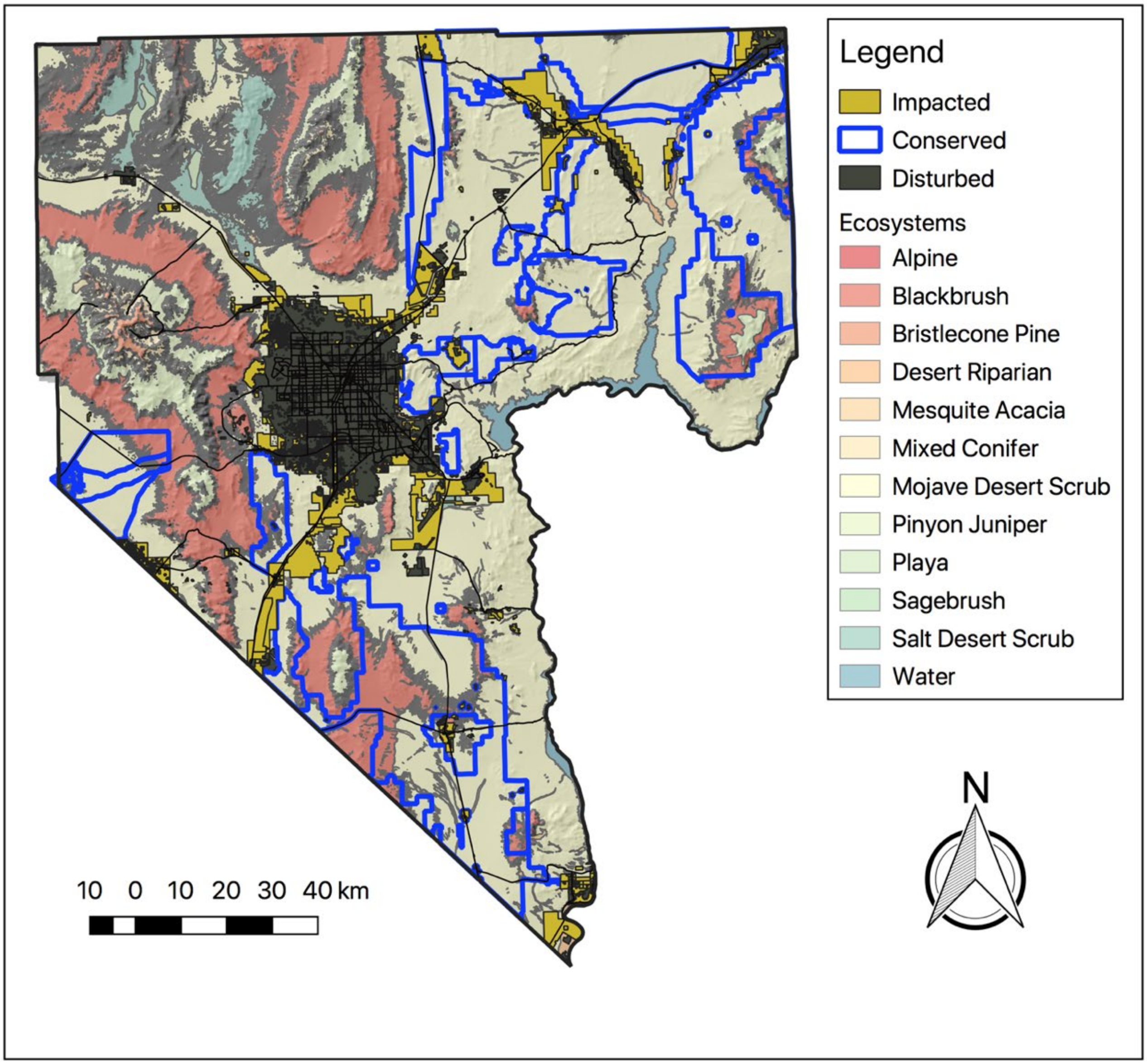
For two species [spotted bat (*Euderma maculatum*) and St. George blue-eyed grass (*Sisyrinchium radicatum*)], the number of available occurrence records was insufficient to support development of quantitative habitat distribution models. In these cases, rather than fit models likely to be biased by small sample sizes, we developed qualitative habitat models based on our knowledge of the species and their known distributions. Detailed methods for qualitative models are provided separately for each species in the respective sections below.

Ecosystem Assessments

For species habitat models that were produced during this project, the Ensemble model was reclassified into categorical indices of suitability as: 0-0.33 = Low, 0.33 – 0.66 = Medium, and 0.66

– 1 = High. The categorical Ecosystem raster provided by the Clark County Desert Conservation Program (DCP) developed by Heaton et al. (2011) (Figure i) was used for ecosystem intersections with the categorical habitat rasters. For each of the High, Medium and Low habitat categories for each species, the intersection of the habitat category with the Ecosystem assessment layer was calculated using standard raster algebra techniques. Tables and summaries of these intersections are included in each species account.

Figure i. Disturbed areas (charcoal), and projected areas that will be impacted (mustard), conserved (blue outline), and ecosystems located within Clark County, Nevada.



SPECIES ACCOUNTS

A.1 STICKY RINGSTEM (*ANULOCAULIS LEIOSOLENUS*)

Sticky ringstem (*Anulocaulis leiosolenus)* (formerly *Boer avia leiosolenus*) is a perennial forb in the Nyctaginaceae (Four O'clock) family. Members of the genus have flowers that bloom near dawn and close by mid-day (Holmgren et al. 2012). The flowers have greenish bronze tubes and white, pink, or rose-pink lobes flared from tube (Spellenberg 2003). The leaves occur in 2-3 pairs in basal quarter of plant and have small purple pustules (blister-like formations) (Spellenberg and Wootten 1999). The species was first recorded in 1858 in the Rio Grande Valley in western Texas. The name "*Anulocaulis*" was chosen to describe the prominent sticky bands that encircle the internodes, *anulus* meaning "ring" and *caule* meaning "stem" (Spellenberg 1993). The first collection of the species in Nevada was collected in 1938 by Percy Train (TNC 2007). There are four varieties of this species in North America (Spellenberg 2003). Sticky ringstem is the only variety that occurs in Clark County, Nevada. It is considered to be a gypsophile, meaning it lives on gypsum soils (Spellenberg and Wootten 1999). Sticky ringstem can be distinguished from other varieties by dull green leaves, the presence of hairs on the leaves, white to pale pink flowers, and a flower bud that is glabrous at the apex (Spellenberg 2003).

The US population flowers from May-June and again in October. Sphingid moths have been recorded visiting sticky ringstem in areas of its range outside of Clark County (Spellenberg 1993). As of 2007, no pollination studies specific to sticky ringstem had been done, but moths have been visiting flowers, and are thought be pollinators (TNC 2007). Pollinators that have been reported to visit other sticky ringstem varieties include Sphingid moths, bumblebees, and wasps (Spellenberg 1993). According to Meyer (1987), sticky ringstem has low seed output, and is thought to be long-lived.

A.1.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC 527): No status

NV Natural Heritage Program: Global Rank G4T3 State Rank S2

IUCN Red List (v 3.1): No status

CITES: No status

A.1.2 Range

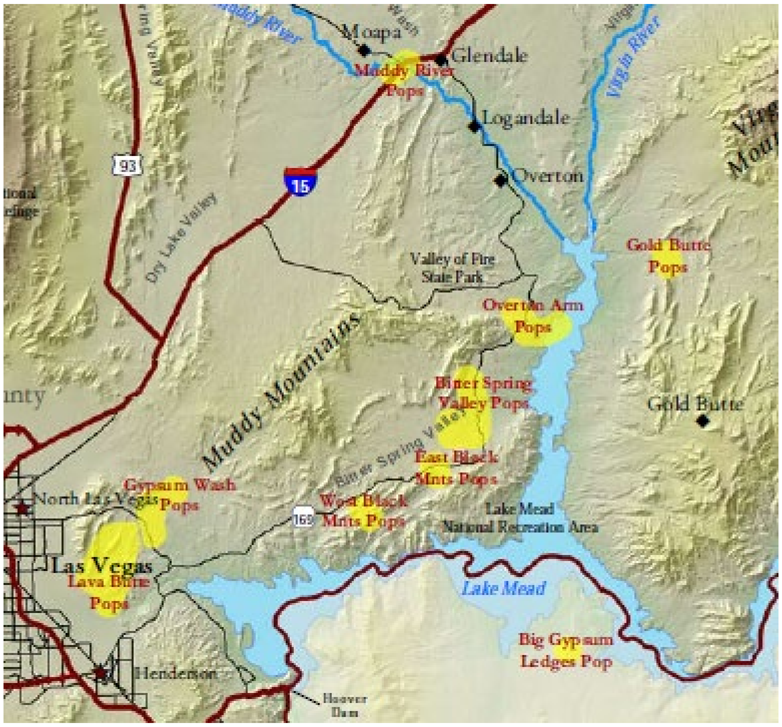
Sticky ringstem is endemic to arid regions of the southwestern U.S and adjacent Mexico. *Anulocaulis leiosolenus* var. *leiosolenus* has the largest range out of all of the varieties of sticky ringstem and also occurs in extreme western Texas, south-central New Mexico, north-central Arizona, and northern Chihuahua, Mexico (Spellenberg and Wootten 1999, Spellenberg 2003). It is considered to have two distribution centers (southern Nevada in Clark County and northeast Arizona in Coconino and Yavapai counties, and the second distribution center in New Mexico in Chaves and Doña Ana counties, in western Texas in Culberson, El Paso, Hudspeth, and Presidio counties, and in adjacent northern Mexico, northwest Chihuahua in Guadalupe and Coyame municipios) (Hernández-Ledesma et al 2010).

A.1.3 Population Trends

Very little specific data exist for viability estimates of sticky ringstem populations. In the 1980’s, Meyer measured an average density of 0.6 plants per 100 m^2 (Meyer 1987 in TNC 2007). The westernmost population, Lava Butte, has been documented as the largest area, but the plants are not abundant. The range-wide trend was reported to be stable as of 2000 (USFWS 2000), but not enough information is available to determine trends of populations in Nevada. NPS and BLM monitoring reports note that habitat condition for Las Vegas Bearpoppy may be applicable to sticky ringstem habitat (TNC 2007).

Few inventories include sticky ringstem, and surveys for the species have been sporadic in Clark County (Niles et al. 1999 in TNC 2007).

A.1.4 Distribution and Habitat Use



Sticky ringstem management areas, from (TNC 2007)

Sticky ringstem occurs in desert scrub on small to steep hillsides or flat ground, with alluvium, gypsum, limestone, rocky, slat, or clay soils from 400-1200 meters (Hernandez-Ledesma et al. 2010). It is only known to occur on gentle slopes around four degrees, and not exceeding 13 degrees (TNC 2007). The species is strongly associated with cryptogamic crusts, which are known to stabilize soil (Ladyman et al. 1998 in TNC 2007), increase germination and seedling success, and release essential nutrients such as nitrogen and chelating agents into the soil (Harper and Pendleton 1993). Sticky ringstem occurs on gypsum outcrops, rolling hills, and terraces in Mojave Desert scrub (which includes primarily creosote bush-white bursage) and salt desert scrub matrix ecological systems (Niles et al. 1999 in TNC 2007). Some common plants associated with sticky ringstem in Clark County include *Ephedra torreyana, Lepidium fremontii, Petalonyx parryi, Psorothamnus fremontii, Arctomecon californica, Enceliopsis argophylla, Mentzelia pterosperma, Tiquilia latior, Eriogonum insigne, Phacelia palmeri, Phacelia pulchella, and Psathyrotes pilifera* (Mistretta et al. 1996 in TNC 2007). Ecosystems within the county that contain both high and moderate predicted habitat suitability are largely restricted to Mojave Desert Scrub (Table A.1-3).

In a 2010 inventory and monitoring study conducted by the National Park Service (Newton 2010), a correlation was found between sticky ringstem and certain soil attributes. The following elements were found in significant levels on sites inhabited by sticky ringstem: Calcium, Iron, Nickel, Cobalt, Sulfate, Nitrate, Sodium, Magnesium, Boron, Lead, Chlorine, and sand. Sticky ringstem presence was also associated with lower available Phosphorous, total Nitrogen, pH, Copper, clay, silt, Total Energy, and bulk density.

When sites inhabited by sticky ringstem were compared to sites where it is absent, there was a negative correlation of ringstem presence with an increase in copper site Total Nitrogen had a negative correlation with sticky ringstem density among sites containing sticky ringstem.

Newton (2010) suggested that to gain understanding in sticky ringstem's soil associations, it may be beneficial to sample more gypsum soil series across a wider range of rare plant locations that were sampled in their study. It was also suggested that future soil surveys should include topographic position, as well as comparisons of distributions of other gypsophile and gypsocline species to further develop habitat models (Newton 2010).

A.1.5 Distribution and Habitat Use within Clark County

Sticky ringstem populations have been observed in Clark County in the following areas:

Lava Butte (BLM)

Gypsum Wash (BLM)

West Black Mountains

East Black Mountains (NPS)

Bitter Spring Valley (NPS and BLM)

Overton Arm (NPS)

Muddy River (Unmanaged Area)

Gold Butte (BLM)

The Clark County populations of sticky ringstem represent the westernmost region of the species' range. Within Clark County the species overlaps with habitat for another rare plant, the Las Vegas Bearpoppy (*Arctomecon californica*) (TNC 2007), but has a narrower range and is much less abundant than the bearpoppy in Clark County (Newton 2010).

The 2009 management strategy showed the distribution of known Clark County spatial data points by major landowner category for sticky ringstem as follows; 64.4% BLM, 31.7% NPS, 2.9 % Private, and 1% Water (NPS or BoR depending on fluctuating reservoir level) (Figure 9 in TNC 2007).

A.1.6 Habitat Model

The three model algorithms generally predicted similar habitat arrangements throughout the County. The GAM models generally predicted more habitat, but some of these areas have only moderate values of habitat suitability within the County (Figure A.1-1). The MaxEnt model predicted the smallest area of habitat, and when it was predicted, habitat suitability values were also only moderate. Key areas of similarity among models in the County included the City of Las

Vegas, and areas to the east and North of there, including: Nellis Air Force Base, Muddy Mountains, Gale Hill, Valley of Fire and the area in and around the dry lake in Eldorado Valley is also well supported, although recent surveys there found no evidence of this species occurring there (Rakestraw, pers comm.).

The Ensemble model outperformed the other models, with the highest (or equivalent) scores for AUC, BI, and TSS. Relative to other models, the RF model had a notably lower BI score than the others, and the MaxEnt models had moderately high BI and TSS scores (Table A.1-1).

The GAM and RF models shared Average Maximum temperature as a top influential variable (Table A.1-2). The MaxEnt and RF, models shared two of the top four influential environmental variables, where the Extreme Minimum temperature, and the Soil Gypsum Content were among the largest contributors (Table A.1-2). The standard error was relatively low throughout the County, where only the GAM model had values approaching 0.07 in many areas. All other models' standard errors were very low with the highest values of ca. 0.045 in the MaxEnt models (Figure A.1-2). The Continuous Boyce Indices showed good model performance in all algorithms (Figure A.1-3). The CBI for the MaxEnt models did show some variability where lower areas of predicted suitability, where there potentially intermittent performance calculations in density bins lacking points.

Table A.1-1. Model performance values for sticky ringstem models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	1	0.91	1	0.37
GAM	1	0.82	1	
Random Forest	0.99	0.33	0.98	
MaxEnt	1	0.76	0.84	

Table A.1-2. Percent contributions for input variables for sticky ringstem for ensemble models using GAM, Maxent and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	21.4	11.4	0.5
Ave Min Temp	7.2	12.8	4.5
Ave Spring Max Temp	13.6	3.9	0.2
CV Ave Spring Max Temp	11.9	7.9	0
CV Max Temp	6.5	10.7	6.2
Extreme Max Temp	10.9	10.8	0.5
Extreme Min Temp	8.4	18.9	12.8
Soil gypsum	1.6	18.3	43.7
NDVI Amplitude	10.9	2.9	23.3
Silt	7.5	2.4	8.3

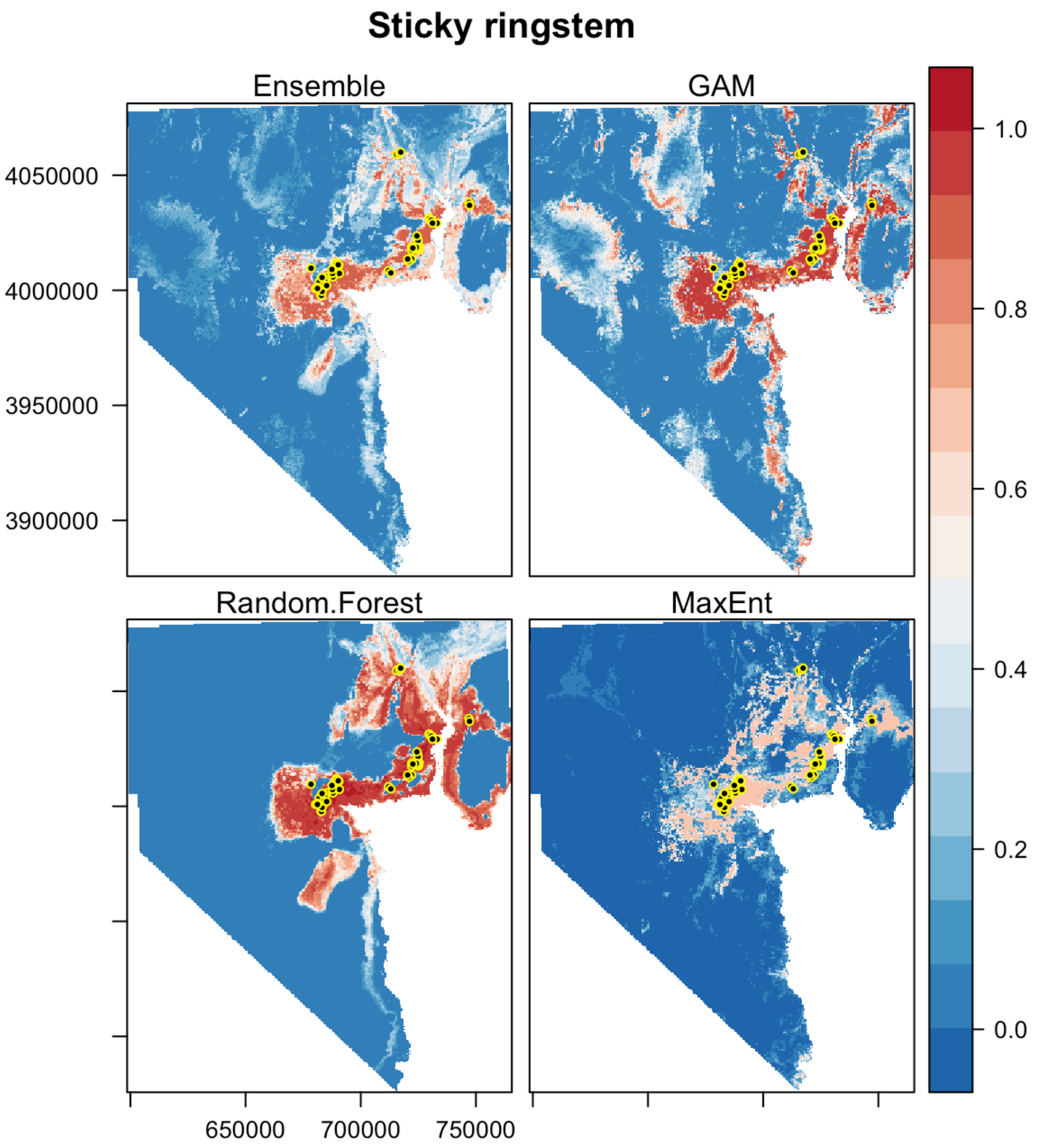


Figure A.1-1. SDM maps for sticky ringstem model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

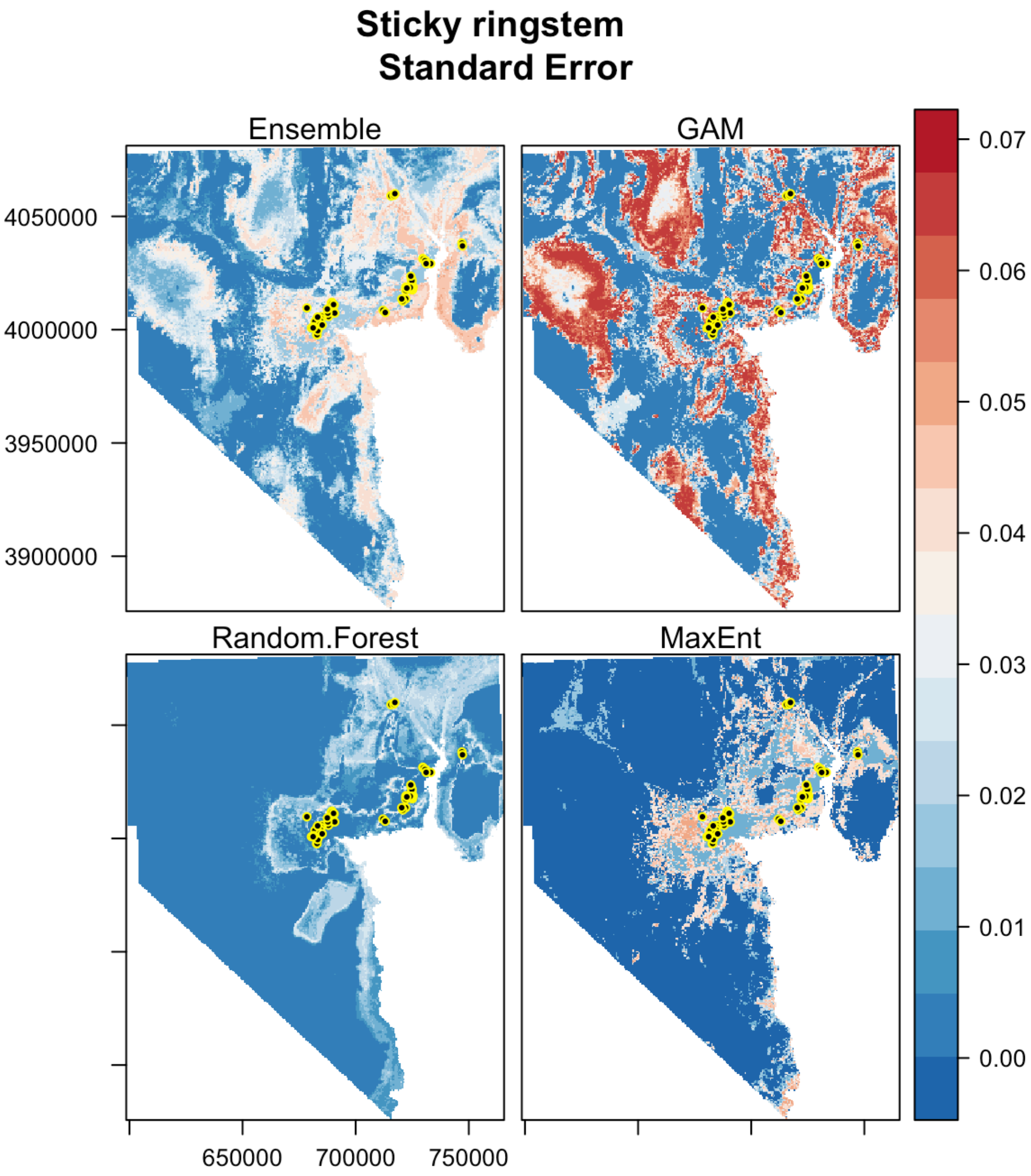


Figure A.1-2. Standard error maps for sticky ringstem models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

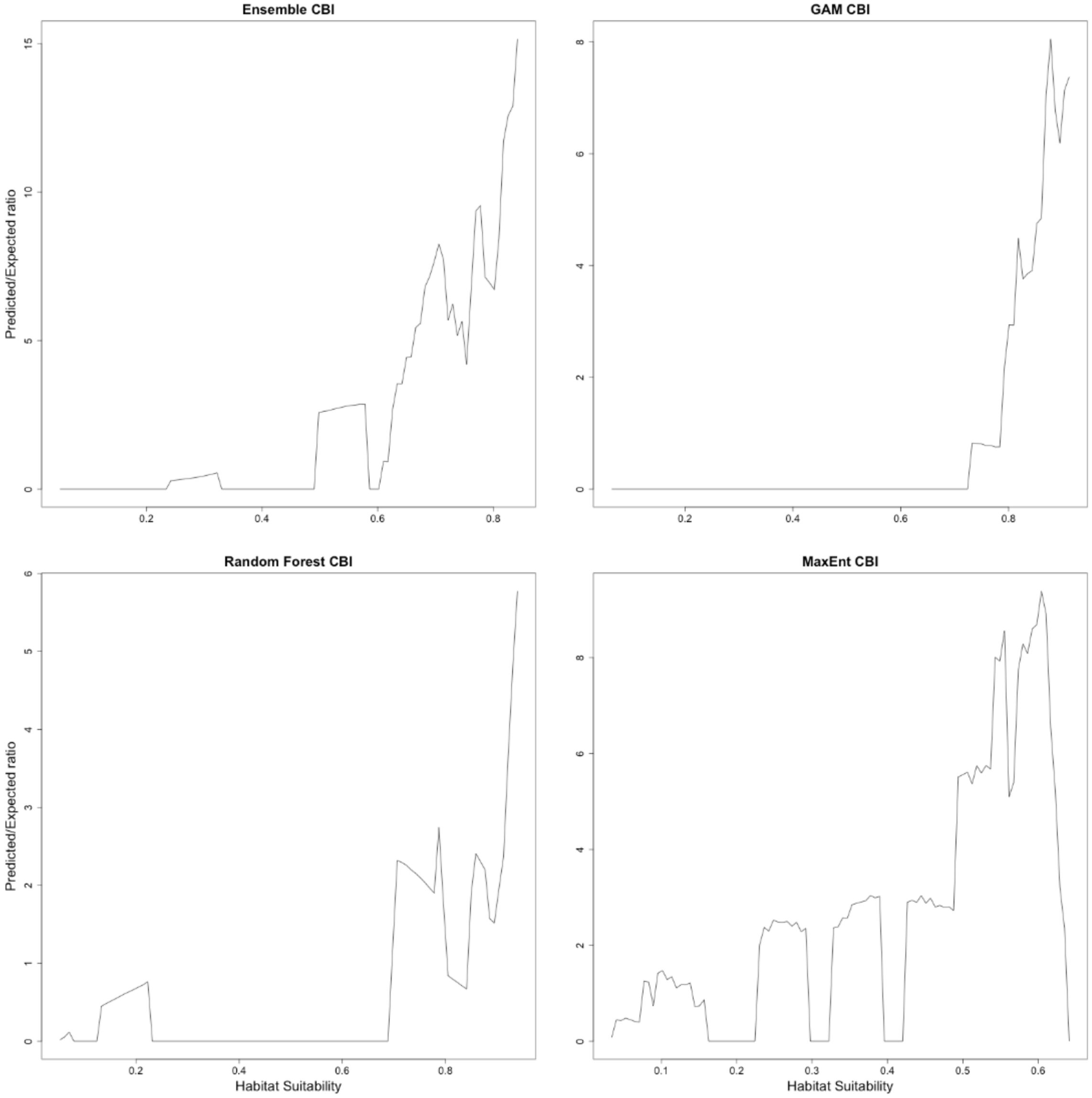


Figure A.1-3. Graphs of Continuous Boyce Indices [CBI] for sticky ringstem models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.1.6.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, CV Average Spring Maximum temperature, Winter Precipitation, and Extreme Maximum temperature, collectively accounting for 57.8% of total model contribution (Table A.1-2). Average Maximum temperature had relatively low values for habitat suitability until the values increase rapidly and peak at ca. 42 ºC, and then decline rapidly with higher temperatures (Figure A.1-4). Model scores peaked with an Average Spring Maximum temperature of ca. 33 ºC, but habitat values decrease rapidly at higher and lower temperatures (Figure A.1-4). Similarly, CV Average Spring Maximum temperature indicates high habitat values when CV is low (< 0.08), but then decreases rapidly to near zero with higher CV values (Figure A.1-4). Model scores were consistently very high with low Average Maximum temperatures, and declines precipitously when Average Maximum temperature exceeds 44 ºC (Figure A.1-4).

The GAM models had higher standard error values, indicating dissimilar predictions among the 50 model cross-validation runs (Figure A.1-3).

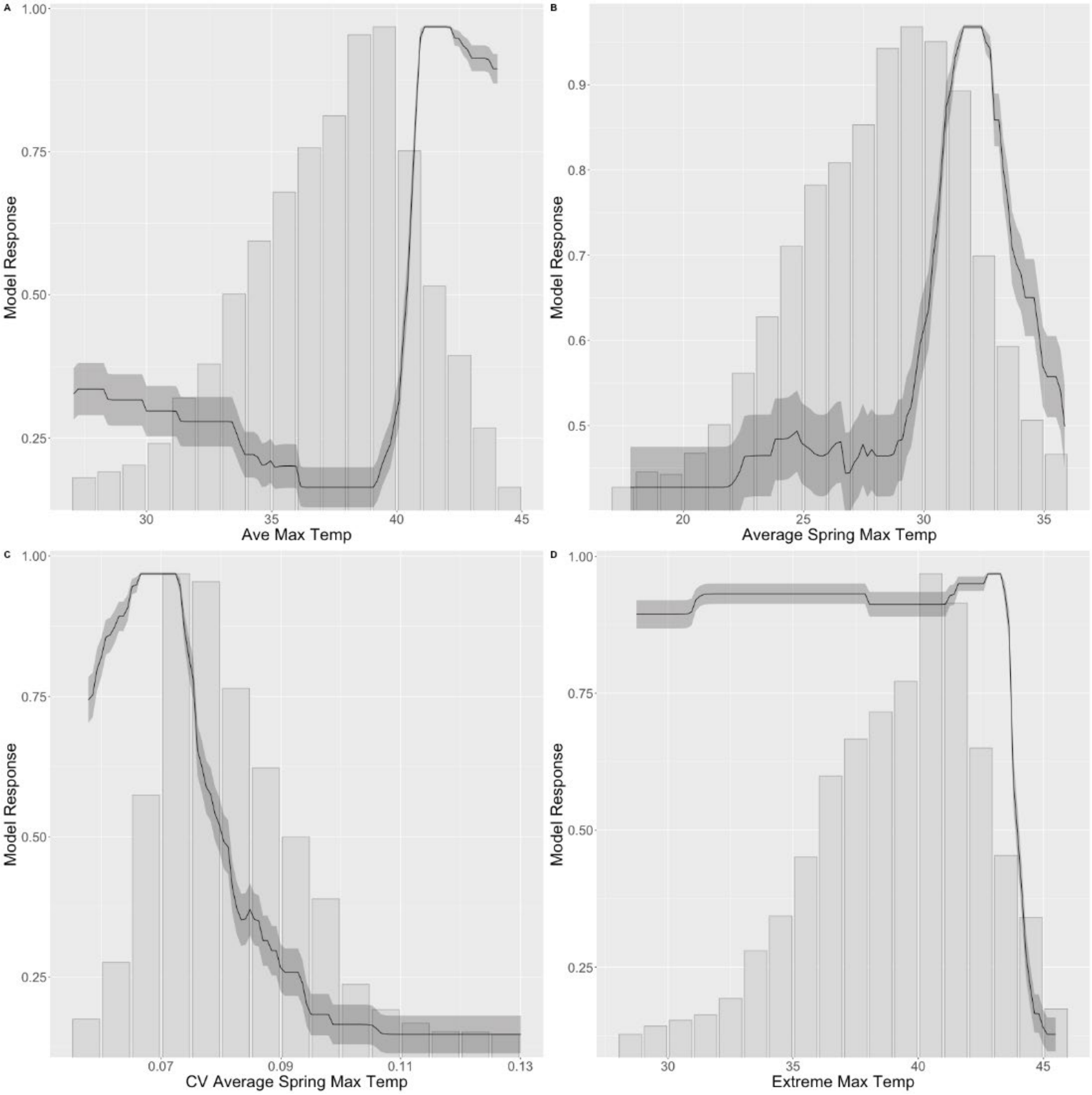


Figure A.1-4. GAM partial response curves for the top four variables in the sticky ringstem model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.1.6.2 Maxent Model

The MaxEnt models relied heavily on the two of the same four top variables as the RF models (Extreme Minimum temperature and Gypsum soil content). NDVI Amplitude, and Silt content of the soil were also an important contributor in the MaxEnt models. In total, these four variables accounted for 88.1% of total model contribution (Table A.1-2). The MaxEnt model had a very similar response curve as the RF models for the Extreme Minimum temperature variable, where habitat values were lower with low Extreme Minimum temperatures, but rose rapidly at -4 to -6 ºC and plateaued at high values thereafter (Figure A.1-5, Figure A.1-6). The MaxEnt models also had a similar response curve as the RF model to the Gypsum soil content variable, with low habitat values only being predicted when Gypsum soil content was < 10 %, and plateauing at high values thereafter. (Figure A.1-5, Figure A.1-6). The similarity of these response curves in different algorithms indicating relatively robust model selection (Figure A.1-5, Figure A.1-6). The predicted response for the NDVI Amplitude showed a threshold response with suitability at high values only when NDVI Maximum was low (< 7; Figure A.1-5, Figure A.1-6). The Silt variable, while important in the models, did not vary significantly across the narrow range of Silt content present in the environment.

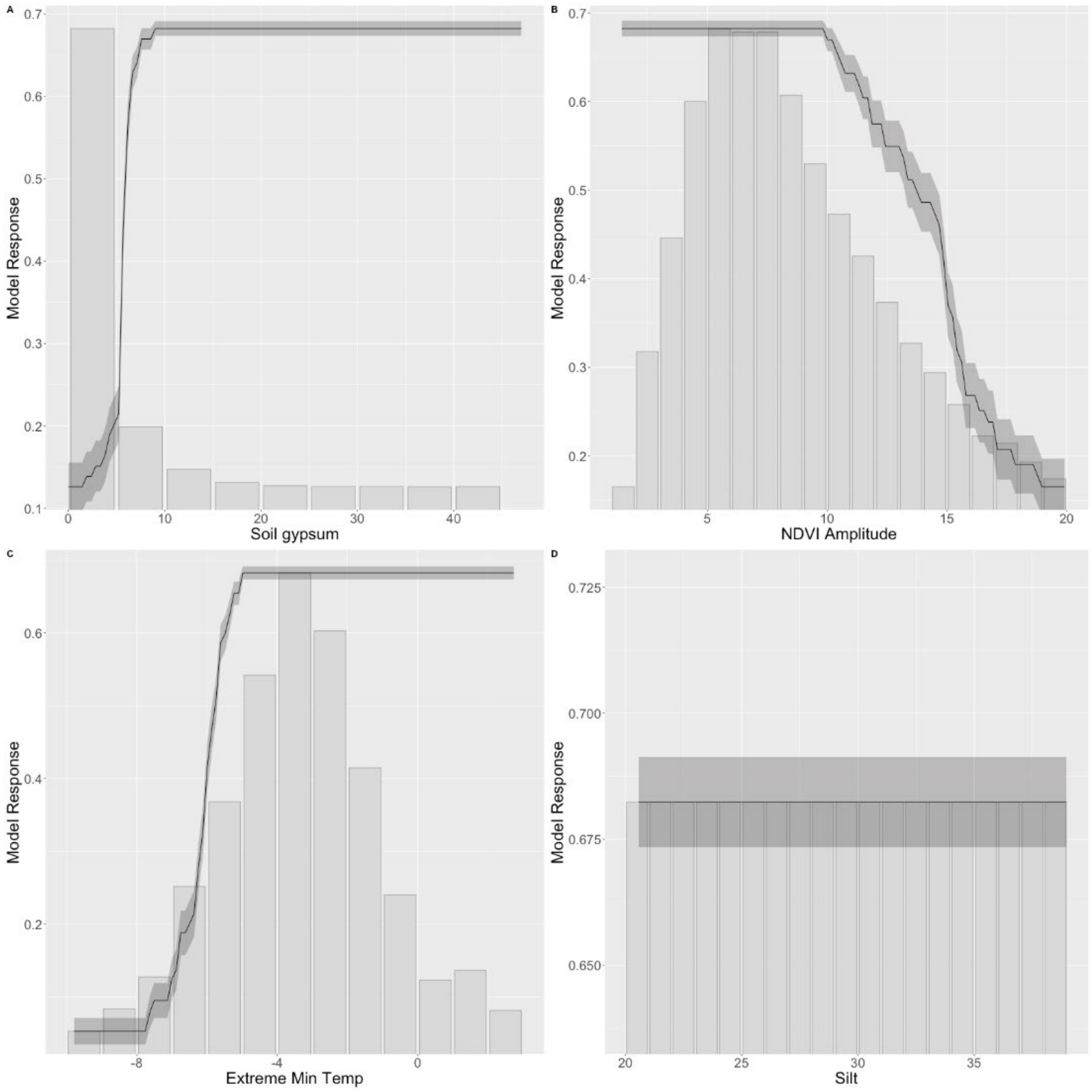


Figure A.1-5 Partial response curves for the top environmental variables included in the Maxent ensemble model for sticky ringstem. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.1.6.3 Random Forest Model

The Random Forest model was largely driven by Extreme Minimum temperature, Average Minimum temperature, Average Maximum temperature, and Gypsum soil content (collectively 61.4%; Table A.1-2) Extreme Minimum temperature and Average Minimum temperature both show lower values of habitat suitability at low temperature and increase rapidly to a plateau above a threshold temperature (Figure A.1-6). These models are concordant with the MaxEnt model for Extreme Minimum temperature, and show a similar threshold of ca. -4 ºC. Average Maximum temperature showed a similar response as the GAM models, with higher habitat values when the Average Maximum temperature is above 40ºC. However, the RF model does not show a decrease in habitat values at higher temperatures, whereas the GAM model does (Figure A.1-4, Figure A.1-6).

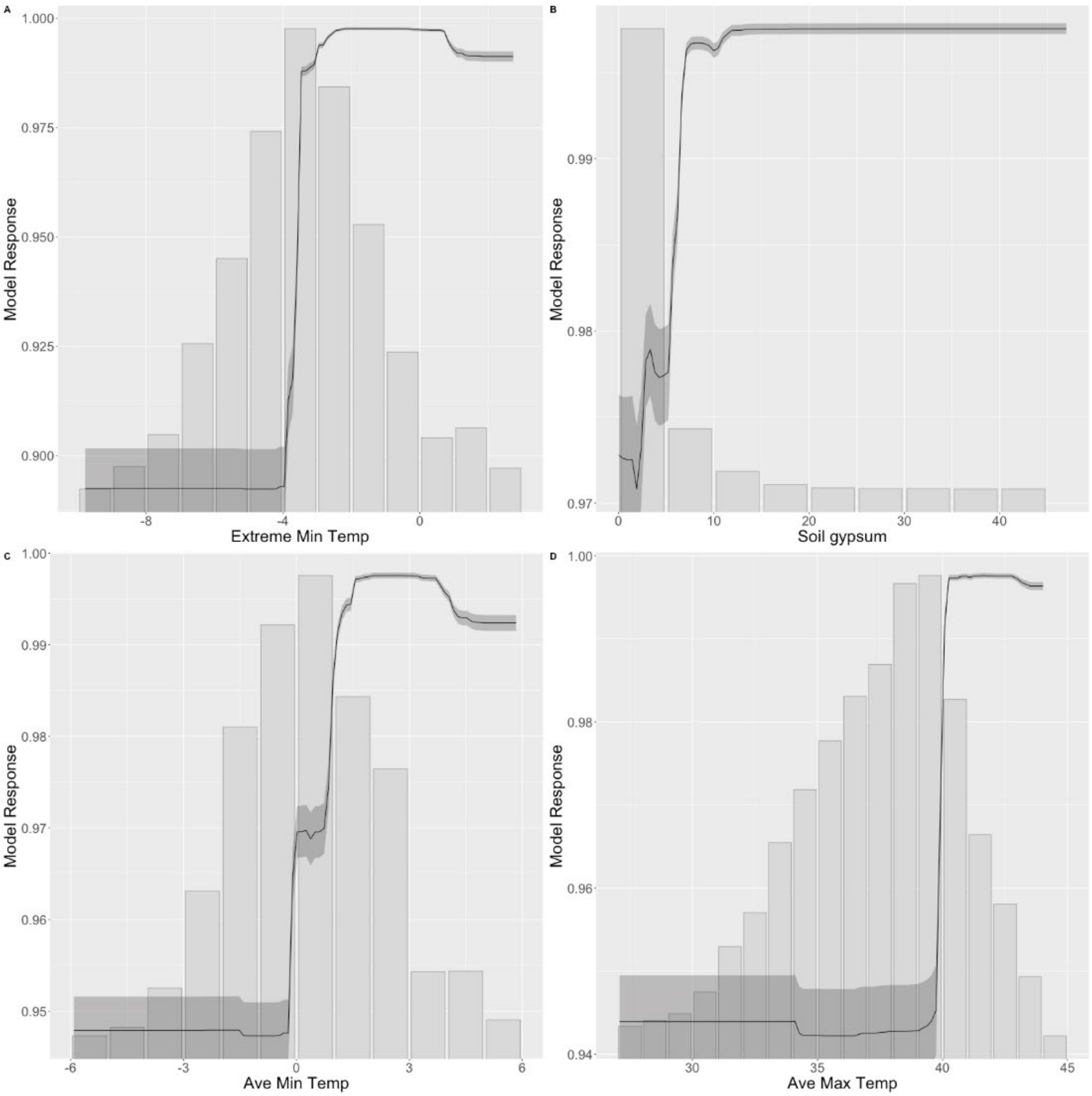


Figure A.1-6. Partial response curves for the environmental variables included in the Random Forest ensemble model for sticky ringstem. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.1.6.4 Model Discussion

Habitat for sticky ringstem is predicted to occur in Clark County in and around the City of Las Vegas, as well as areas to the east and north. These areas include the Nellis Air Force Base, Gale Hills, Bitter Springs Valley, White Basin, Valley of Fire and areas in the pass between the Virgin Mountains, and the south Virgin Mountains, as well as portions of the Moapa Valley. However, the model indicates other areas of high habitat suitability where the species has not been detected. In particular all three models, predict high habitat suitability in an area including the Eldorado Valley dry lake (although recent surveys have indicated the absence of this species in that location (Rakestraw pers comm.), additional habitat near the Moapa Valley, and areas surrounding Gold Butte.

The locality data for this species consisted of 337 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 72 records.

A.1.6.5 Standard Error

The standard error map for the ensemble model indicated relatively low error (< 0.05) throughout much of the study area (Figure A.1-8), with moderate error, located in the areas that were predicted as high quality habitat that are outside of the species known range. Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

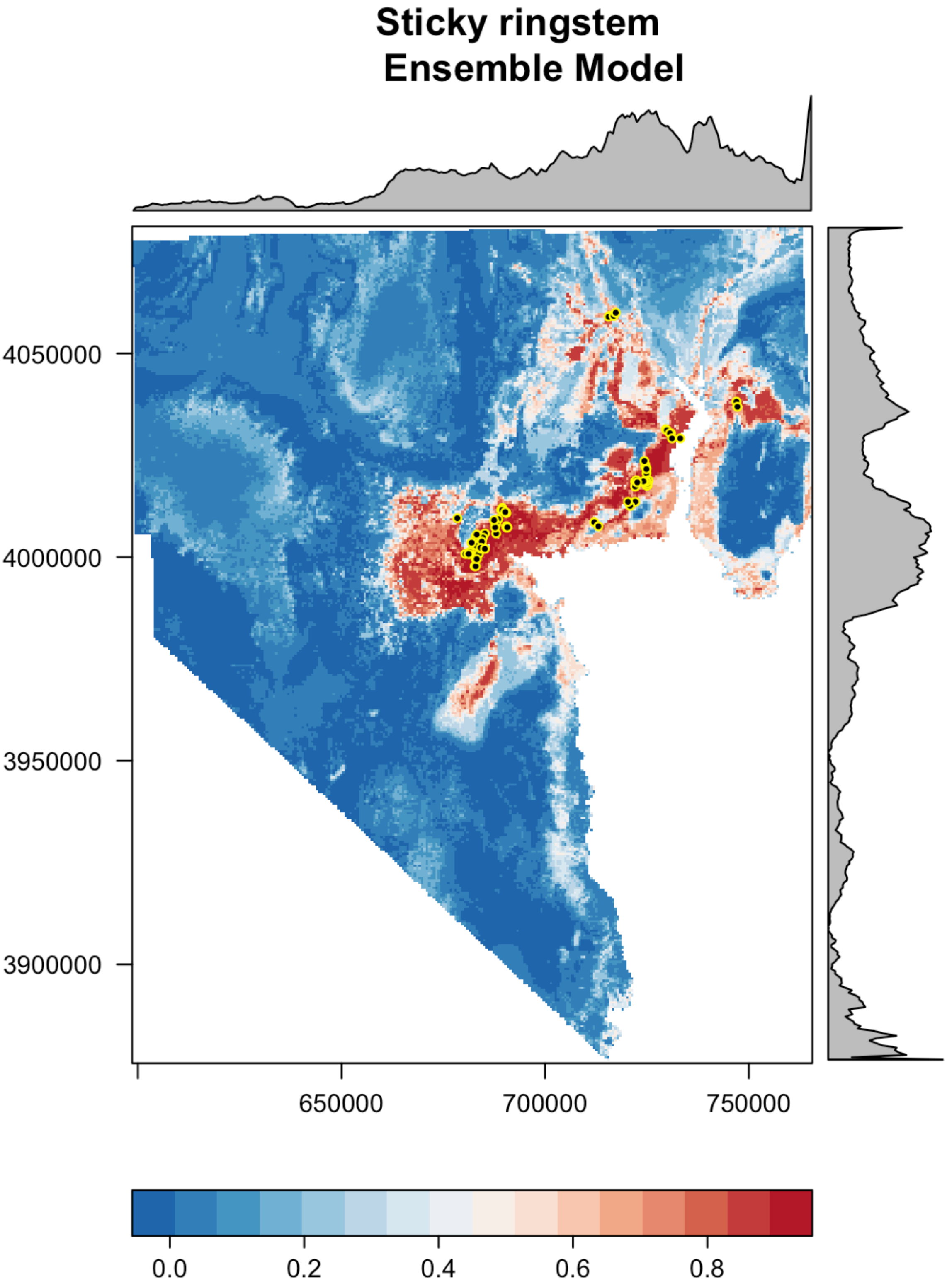


Figure A.1-7. SDM map for sticky ringstem Ensemble model for Clark County, NV.

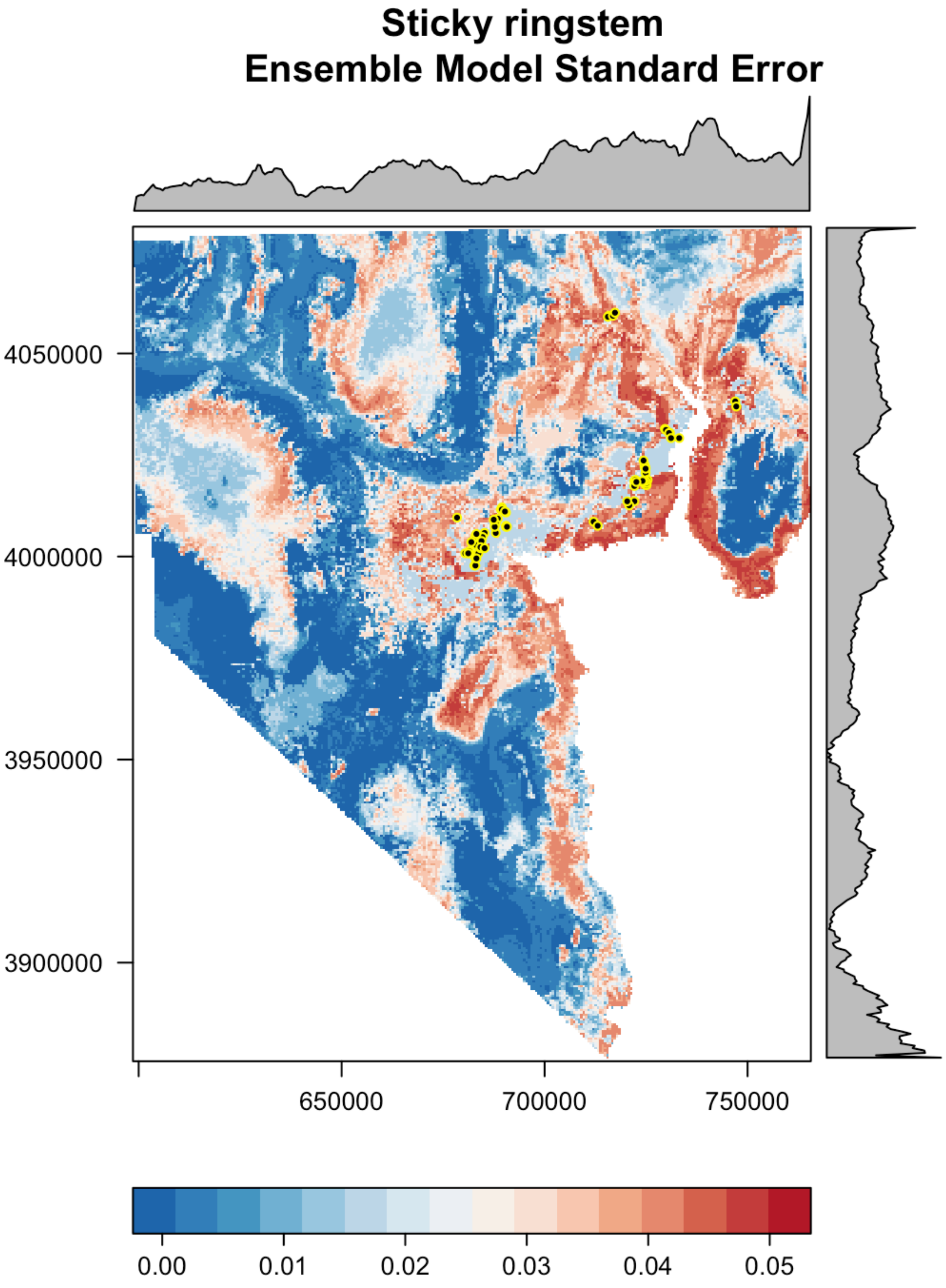


Figure A.1-8. Standard Error map for the sticky ringstem Ensemble model for Clark County, NV.

A.1.7 Ecosystem Level Threats

Among the ecosystems listed as present in the MSHCP, this species is found in Mojave Desert Scrub, Salt Desert Scrub, Desert Riparian, and Mesquite Acacia habitats, and is further distinguished by being gypsophilic (Table A.1-3). The limitation to gypsum soils further limits the distribution of this species and gypsum dominated soils are fairly well known for this county.

Sticky ringstem is one of numerous rare plant species covered under the Clark County Multiple Species Habitat Conservation Plan (MSHCP). A Conservation Management Strategy (CMS) sponsored by Clark County and The Nature Conservancy (TNC 2007) identifies several direct and indirect threats to rare plants in Clark County that increase loss, degradation, and fragmentation of habitat. Clark County's CMS lists threats to the species which also pose threats at an ecosystem level including catastrophes, chance events, and climate change (TNC 2007). The sources of these threats include Off Highway Vehicle use (OHV), invasive species, rural development, land disposal, fire, utility corridor and rights-of way development, highway and road development, agricultural practices, military activities, Lake Mead inundation, gypsum mining, and commercial development (TNC 2007).

Table A.1-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415269	0	0
Bristlecone Pine	7565	0	0
Desert Riparian	6225	3188	387
Mesquite Acacia	15713	2883	1607
Mixed Conifer	27339	0	0
Mojave Desert Scrub	978229	199308	178006
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	78431	1837	2323

A.1.8 Threats to Species

The 2007 CMS (TNC 2007) lists direct threats to sticky ringstem in Clark County including gypsum mining, vehicle use and trail development, feral horse and burros, rural and urban development, utility corridor construction and maintenance related sprawl, federal land disposal, invasive plant species, legal recreation use, habitat inundation and shoreline fluctuation, and trespass grazing.

Wild horse and burros pose a threat as they can easily damage gypsum and cryptobiotic surface crusts where sticky ringstem grows. Once damaged, these areas are susceptible to erosion and plant invasion. A population discovered in Echo Wash was in an area with heavy burro damage (Niles et al. 1999 in TNC 2007). Feral horses and burros may also pose a threat from grazing sticky ringstem at Lake Mead National Recreation Area, particularly in the drier months (Powell 2004 in TNC 2007). Enforcement of the laws that protect these habitats is important. For example, the Lava Butte area has regulations in place for OHV use, but it is not effectively enforced (TNC 2007). The threats listed above have resulted in population losses by direct mortality, and further loss or fragmentation of habitat (TNC 2007).

During field surveys in summer 2009 and spring 2010 conducted by ICF Jones and Stokes, a private consulting company, it was observed that trail evidence and OHV use was more common on sticky ringstem and Las Vegas Bearpoppy habitat than on other rare plant habitats surveyed. It was speculated that the habitat is easier to navigate in using OHVs, due to the open, mostly un-vegetated, soft soils, lacking large rocks, etc. (ICF Jones & Stokes 2010).

A.1.9 Existing Conservation Areas/Management Actions

A.1.9.1 Monitoring

Lake Mead National Recreation Area (managed by the National Park Service) developed monitoring protocols for sticky ringstem (as well as other species) and pilot monitoring was implemented in 2007 (Sutter et al. 2009). The monitoring protocols were reviewed and revised in 2008 and 2009. In 2007, Clark County completed a “Conservation Management Strategy for Nine Low Elevation Rare Plants in Clark County, Nevada”, including sticky ringstem*.* As of 2009, sticky ringstem was actively monitored (Sutter et al. 2009).

The 2007 CMS suggests that in order to manage the species, more applied research needs to be done to fill information gaps on population viability in order to develop management plans in Clark County. The CMS suggests that this species has inadequate, dated, missing, or confounded information to assess current viability of populations and that more additional landscape scale research is needed for management strategies. The CMS states that revision is needed for the monitoring protocols to improve power analyses and increase efficiency of conservation measures (TNC 2007).

In 2009, habitat models were developed for eight rare plant species including sticky ringstem using pre-existing soil models and presence/absence survey data that were collected (Terra Spectra 2011, Sutter et al. 2009). The sticky ringstem habitat model was grouped with the Las Vegas Bearpoppy model due to their similar predictive habitat models (Hamilton and Kokos 2011). During field surveys for this study, sticky ringstem was recorded two times within survey plots, and two times incidentally when traveling to or from the survey plot (ICF Jones & Stokes 2010). In a 2010 inventory and monitoring study, transects (200-300 m long) were placed randomly in sites previously known to contain populations. Sticky ringstem was present in 5 out of 9 transects (Newton 2010).

Updated species distribution models were created as a part of this research.

A.1.9.2 Management

Sticky ringstem is found in an area known as the Sunrise Management Area. One stated objective of the Sunrise Management Area Interim Management Plan is to protect sensitive species including sticky ringstem, by specific protections, habitat rehabilitation, and instituting law enforcement measures while still providing recreational opportunities (BLM 2000 in TNC 2007). The BLM has designated some sticky ringstem habitat as Areas of Critical Environmental Concern

(ACEC). The 2003 Lake Mead Management Plan outlines direction for management of rare plants (including sticky ringstem) on sandy soils along the Lake Mead shoreline in heavy recreational use areas (National Park Service 2003 in TNC 2007).

As of 2007, no management actions had been implemented by Clark County specifically for sticky ringstem, but some populations were protected as a result of measures taken to protect gypsum habitat and Las Vegas Bearpoppy. Some populations occur in Wilderness Areas and designated ACECs and have some protection as a result. The Gold Butte, Gypsum Wash, and Lava Butte populations occur at least partially in ACECs, National Conservation Areas (NCA), or Wilderness Areas. As of 2007 no measures had been taken to restore the species on previously disturbed habitat in Clark County (TNC 2007).

The majority of presence points data known for sticky ringstem (as of 2007) occurred in the highest protective management category of Intensively Managed Areas (IMA), but not on the next level of protective management category, Less Intensively Managed Areas (LIMAs). These categories were developed by Clark County's Multiple Species Habitat Conservation Plan (MSHCP) (TNC 2007).

Conservation Action Number BLM (220) in Clark County's MSHCP (Multiple Species Habitat Conservation Plan) calls to designate important bearpoppy habitat in Lovell Wash, Muddy Mountains, and Bitter Springs as ACECs, and recommends that the areas be closed to OHV competitive evens, and limited to road and trail use. Because sticky ringstem and bearpoppy occupy similar habitats, this plan has the potential to also protect sticky ringstem habitat (TNC 2007).

The 2000 Clark County MSHCP outlines a CMS which identified nineteen objectives aimed to reduce existing and potential threats of rare plants and their habitats on Federal lands and improve indicators of population viability (Clark County 2000) Some of these objectives which apply to sticky ringstem include removing OHV impacts by 2020, controlling invasive plant species by 2020, addressing altered fire regimes over the next century, ensuring gypsum mining will not significantly impact habitats, ensuring long-term viability is not significantly impacted by rural development and sprawl, ensuring disposal of federal lands will not significantly impact populations, and managing viable populations in utility corridors and within potential rights-of-way corridors. These objectives are detailed in the CMS (TNC 2007).

A.2 LAS VEGAS BEARPOPPY (*ARCTOMECON CALIFORNICA*)

Las Vegas bearpoppy *(Arctomecon californica)* is narrowly precinctive to three counties in the Mojave Desert: Clark County, Nevada; Washington County, Utah (introduced by seed); and Mohave County, Arizona. This species is taxonomically distinct with restricted distributions in Clark County (Hickerson and Wolf 1998). It was named after the territorial name at the time, which was a region of Mexico, Alta Californica, where the explorer, Frémont, first collected the species (Mistretta et al. 1996). Las Vegas bearpoppy has been found at 610 – 1710 m on south- and east-facing aspects with population numbers typically declining above 608 m (Nelson and Welsh 1993; Childers 2004). According to Mistretta et al. (1996), 12% of the population has been extirpated due to development activities in the Las Vegas Valley, and another 16% were likely to be lost due to development after 1996. It is unclear what development activities Mistretta et al. (1996) refers to, and whether those populations have been extirpated. The Las Vegas bearpoppy is a short-lived perennial herb in the poppy family (*Papaveraceae*) with showy yellow flowers that bloom in March-June. Germination occurs during winter months in years with sufficient rainfall (Thompson and Smith 1997, Meyer 1987, Megill et al. 2011). Plants are most vulnerable in the early life stage, and losses of buds may hinder reproduction in years with low rainfall (Thompson and Smith 1997). Its limited range and dependence on gypsum soil outcrops, and reduced viability in fragmented habitat make it particularly vulnerable to local extirpation.

A.2.1 Species Status

The Las Vegas bearpoppy is a former Category 2 candidate for threatened or endangered status under the Endangered Species Act of 1973. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that the Las Vegas bearpoppy proposal for listing may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (US Fish and Wildlife Service 1993).

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): Critically endangered

NV Natural Heritage Program: Global Rank G3, State Rank S3

IUCN Red List (v 3.1): No Status

CITES: No Status

A.2.2 Range

The Las Vegas bearpoppy is found in Clark County, Nevada and Mohave County, Arizona (NNHP 2001). Las Vegas bearpoppy occurs from the western edge of Las Vegas in Clark County, Nevada, extending to the north of Lake Mead and west of the Virgin River and Overton Arm of Lake Mead, with a few sites south of Lake Mead eastward to the lower Grand Canyon in Mohave County, Arizona (TNC 2007, Thompson and Smith 1997, Megill et al. 2011), although the Arizona populations are thought to represent an undescribed variant which lives on limestone (Mistretta et al. 1996).

A.2.3 Population Trends

The Las Vegas bearpoppy was described as declining rapidly in the state of Nevada in 2001 (Nevada Natural Heritage Program 2001). The species is considered critically endangered by the state of Nevada, with extirpation of 30 out of 91 potential populations due to rapid urban expansion (Mistretta et al. 1996). A more recent assessment, however, indicates a more stable trend on federal lands when population fluctuations due to climate variability are taken into account (TNC 2007).

A.2.4 Habitat Model

The three model algorithms generally predicted similar habitat arrangements throughout the County, although the relative areas differed. The GAM and RF models generally predicted more habitat than did the MaxEnt models (Figure A.2-1). The MaxEnt model predicted the smallest area of habitat, and when it was predicted, habitat suitability values were somewhat lower overall. Key areas of similarity among models in the County included the City of Las Vegas, and areas to the East and North of there, including: Nellis Air Force Base, Muddy Mountains, Gale Hill, Valley of Fire and some areas at lower elevations surrounding Gold Butte. A smaller area in Eldorado Valley near the dry lake is also moderately well supported (Figure A.2-1).

The Ensemble model outperformed the other models, with the highest (or equivalent) scores for AUC, BI, and TSS. The MaxEnt models had moderately lower BI and TSS scores than the other models (Table A.2-1).

The GAM and MaxEnt models shared Average Maximum temperature, and Average Spring Maximum temperature as top influential variables (Table A.2-2). The GAM and RF models shared two of the top four influential environmental variables, CV Average Spring Maximum temperature, and CV Winter Precipitation (Table A.2-2). The standard error was low throughout the County, where only the GAM model had values approaching 0.05 in a few small areas. All other models' standard errors were very low with the highest values of ca. 0.03 in the MaxEnt models (Figure A.2-2). The Continuous Boyce Indices showed good model performance in all algorithms (Figure A.2-3). The CBI for the MaxEnt models did show some variability where there was a more gradual increase in the predicted/expected ratio at higher habitat values.

Table A.2-1. Model performance values for Las Vegas bearpoppy models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.97	0.86	0.54
GAM	0.96	0.92	0.86	
Random Forest	0.97	0.85	0.85	
MaxEnt	0.89	0.77	0.7	

Table A.2-2. Percent contributions for input variables for Las Vegas bearpoppy for ensemble models using GAM, Maxent and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	**GAM**	**RF**	**MaxEnt**
Ave Max Temp	31.5	2.2	21.9
Average Spring Max Temp	9.9	1.5	5
CV Average Spring Max Temp	22.9	13.6	4.5
CV Max Temp	5	12.8	1.3
Extreme Max Temp	8.6	7	0.7
Soil gypsum	3.5	11.6	34
NDVI Amplitude	2.1	10.4	23.6
Sand	5.3	13.5	4.9
Silt	1.8	2.6	3.5
CV Winter Precip	9.4	24.7	0.6

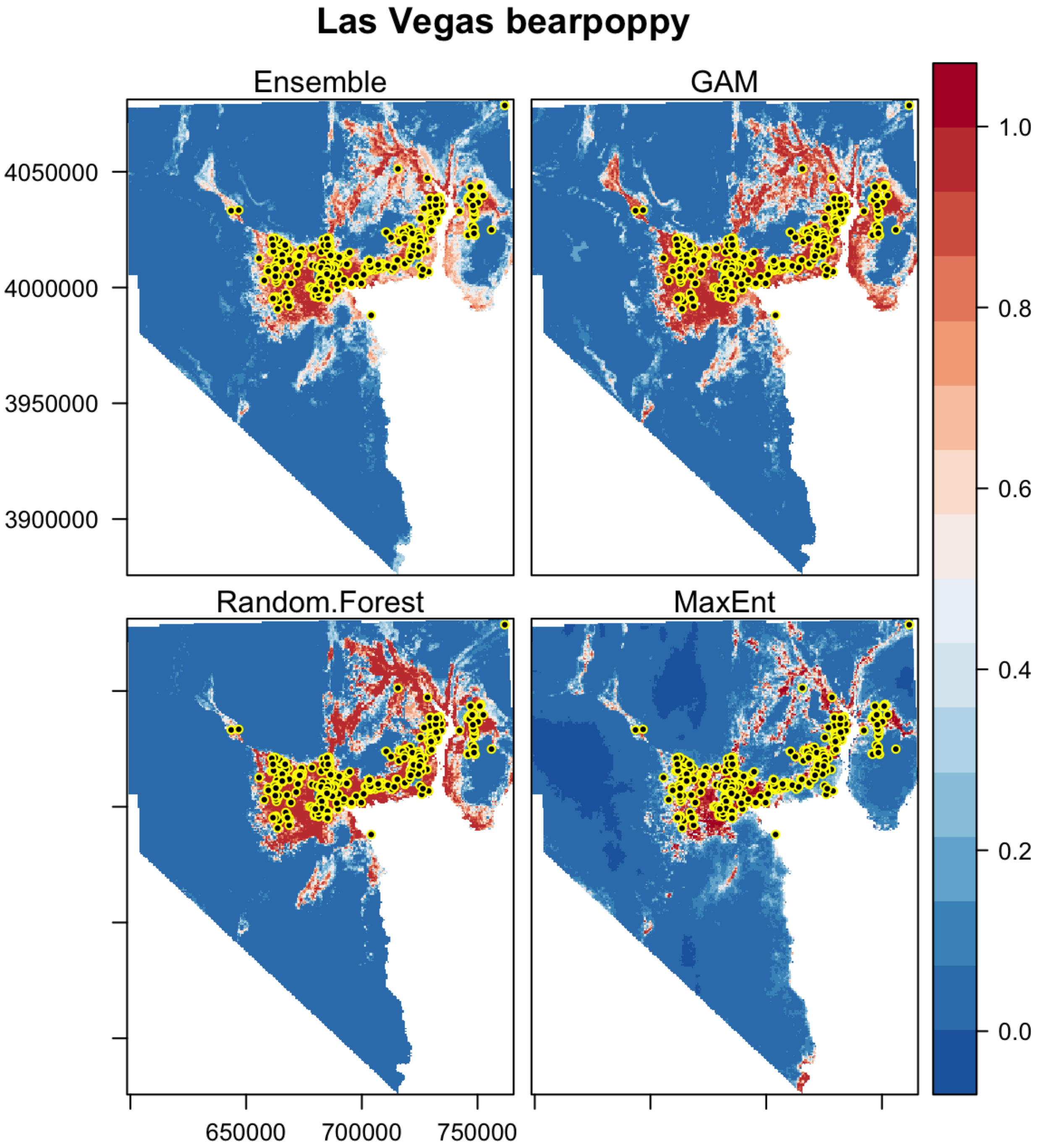


Figure A.2-1. SDM maps for Las Vegas bearpoppy model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

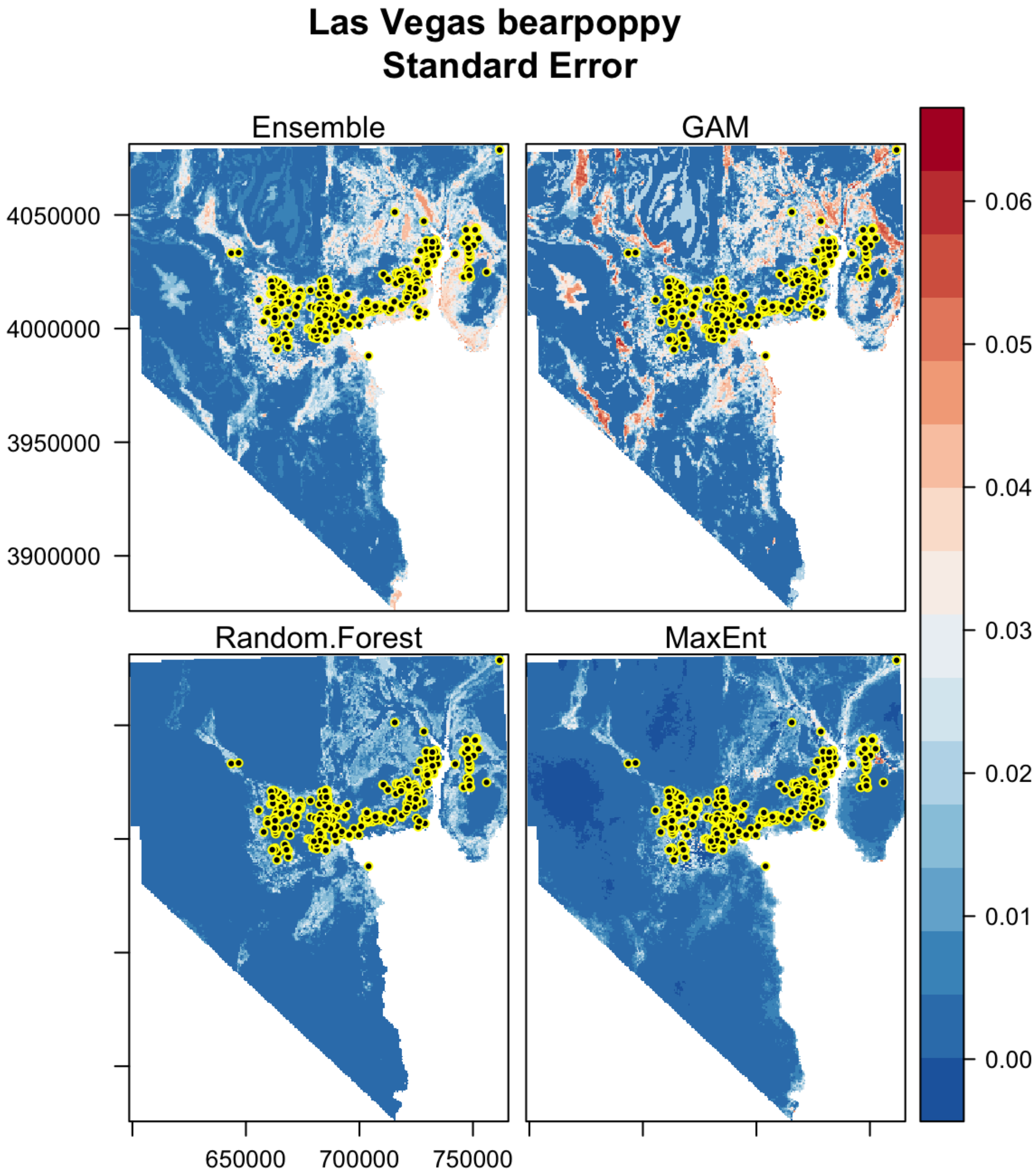


Figure A.2-2. Standard error maps for Las Vegas bearpoppy models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (Upper left).

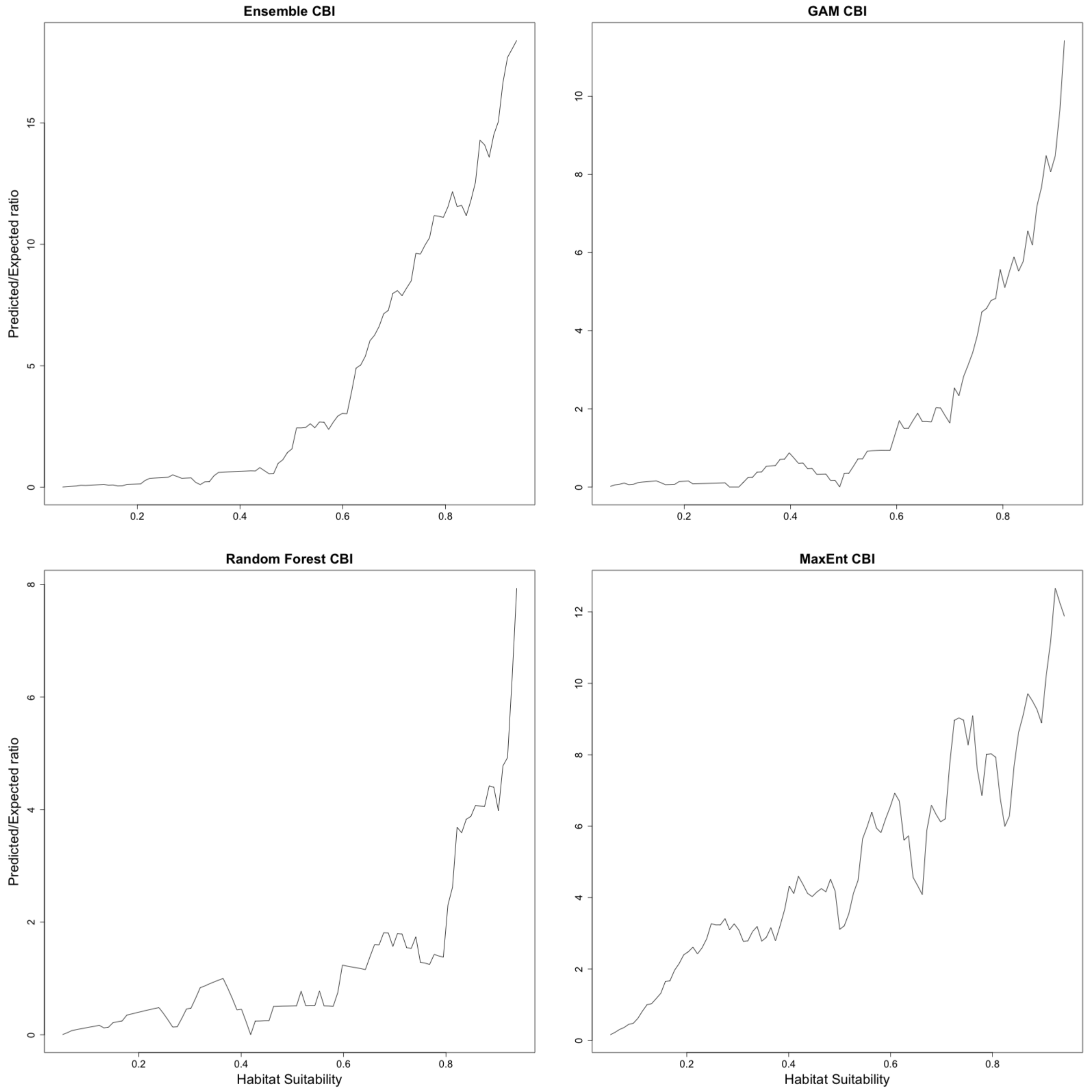


Figure A.2-3. Graphs of Continuous Boyce Indices [CBI] for Las Vegas bearpoppy models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.2.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, CV Average Spring Maximum temperature, Average Spring Maximum temperature, and CV Winter Precipitation collectively accounting for 73.7% of total model contribution (Table A.2-2). Average Maximum temperature had relatively low values for habitat suitability until the values increase rapidly and peak at ca. 41 ºC, and then remain high (note: Ave Max Temp did not increase much above this value in the environment; Figure A.2-4). A similar response with higher habitat values where Average Maximum temperature is high was shown by the MaxEnt model (Figure A.2-4, Figure A.2-5).

Habitat values for CV Average Spring Maximum temperature are high only in a narrow peak where CV = 0.07 and decline rapidly with either higher of lower CV values. (Figure A.2-4). This same peak response, where CV = 0.07, is seen in the RF models (Figure A.2-6). Model scores peaked with an Average Spring Maximum temperature of ca. 33 ºC, but habitat values decrease rapidly at higher and lower temperatures (Figure A.2-4). Model scores were consistently very high with low Average Spring Maximum temperatures and declines precipitously when Average Maximum temperature exceeds 31 ºC (Figure A.2-4). This is concordant with the results for this variable in the MaxEnt models, however, the habitat values for the MaxEnt models decrease much more slowly at higher and lower temperatures (Figure A.2-5).

Habitat values for CV Winter Precipitation were very high in the range of 0.68 – 0.73 and lower at all other values (Figure A.2-4). The RF model response to the CV Winter Precipitation variable was nearly identical.

The GAM models had moderate standard error values, indicating a fair degree of agreement for predictions among the 50-model cross-validation runs (Figure A.2-4).

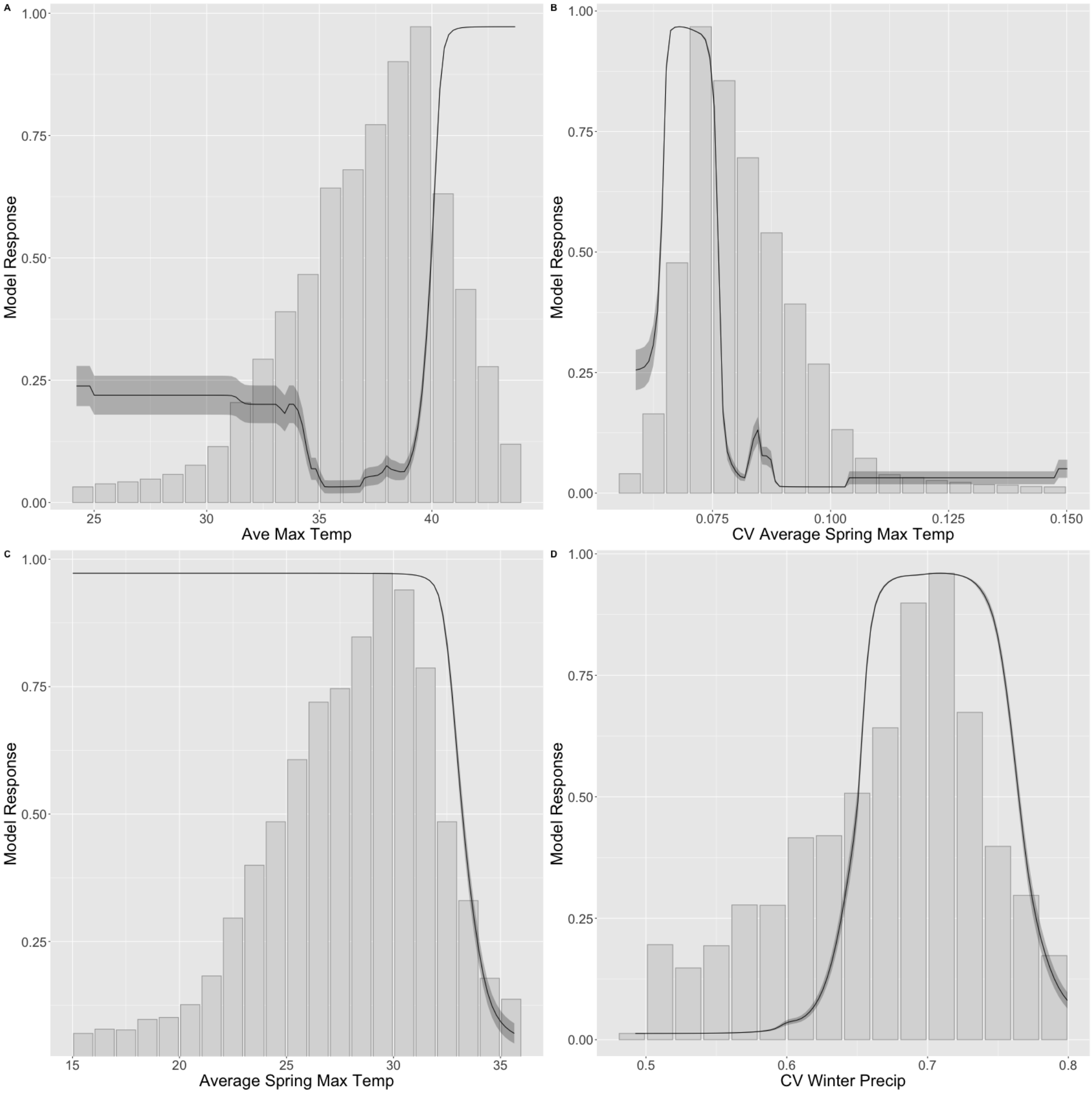


Figure A.2-4. GAM partial response curves for the top four variables in the Las Vegas bearpoppy model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.2.4.2 MaxEnt Model

The MaxEnt models relied heavily on the Average Maximum temperature, and Average Spring Maximum temperature variables as a top four (shared with the GAM models; Table A.2-2). NDVI Amplitude, and Soil Gypsum were also important contributor in the MaxEnt models. In total, these four variables accounted for 84.5% of total model contribution (Table A.2-2).

The MaxEnt model had a very similar response curve as the GAM models for the Average Maximum temperature, and Average Spring Maximum temperature variables as described previously (Figure A.2-4, Figure A.2-5). The similarity of these response curves in different algorithms indicates relatively robust model selection. The MaxEnt models predict high habitat values for the Gypsum soil content variable when Gypsum content is high, with very low habitat values only being predicted when Gypsum soil content was < 10 % (Figure A.2-5). The predicted response for the NDVI Amplitude showed a threshold response with suitability at high values only when NDVI Maximum was low (Figure A.2-5).

The MaxEnt models had low standard error values, indicating a general agreement for predictions among the 50 model cross-validation runs (Figure A.2-3).

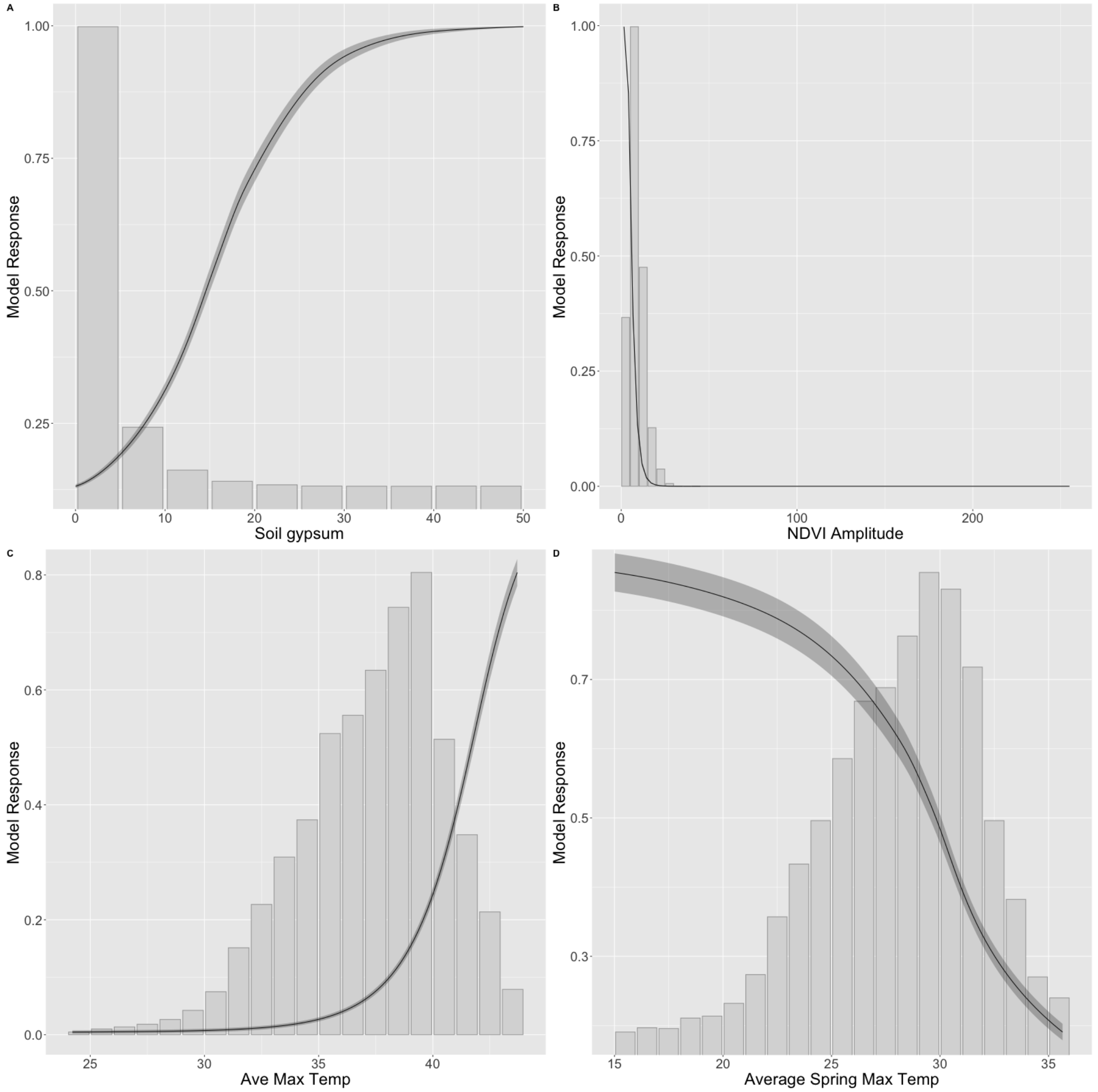


Figure A.2-5. Partial response curves for the top environmental variables included in the MaxEnt ensemble model for Las Vegas bearpoppy. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.2.4.3 Random Forest Model

The Random Forest model was most influenced by CV Winter Precipitation, CV Spring Minimum temperature, Average Spring Maximum temperature, and Sand soil content (collectively 64.6%; Table A.2-2). CV Winter Precipitation, and CV Spring Minimum temperature, were variables shared with the GAM models. In both cases, the predicted habitat values were similar in magnitude ant pattern to the GAM models, as noted previously (Figure A.2-4, Figure A.2-6).

CV Maximum temperature showed a pattern of low habitat values when CV is low, followed by a dramatic increase followed by a plateau in habitat values when CV reaches ca. 0.023, however, it should be noted that the range of CV values for this variable is quite narrow (Figure A.2-6). The

RF model predicts high habitat suitability for the Sand content variable until about 0.63, followed by a rapid decrease to only moderate habitat suitability with higher values for the variable.

The RF models also had low standard error values, indicating a general agreement for predictions among the 50 model cross-validation runs (Figure A.2-3).

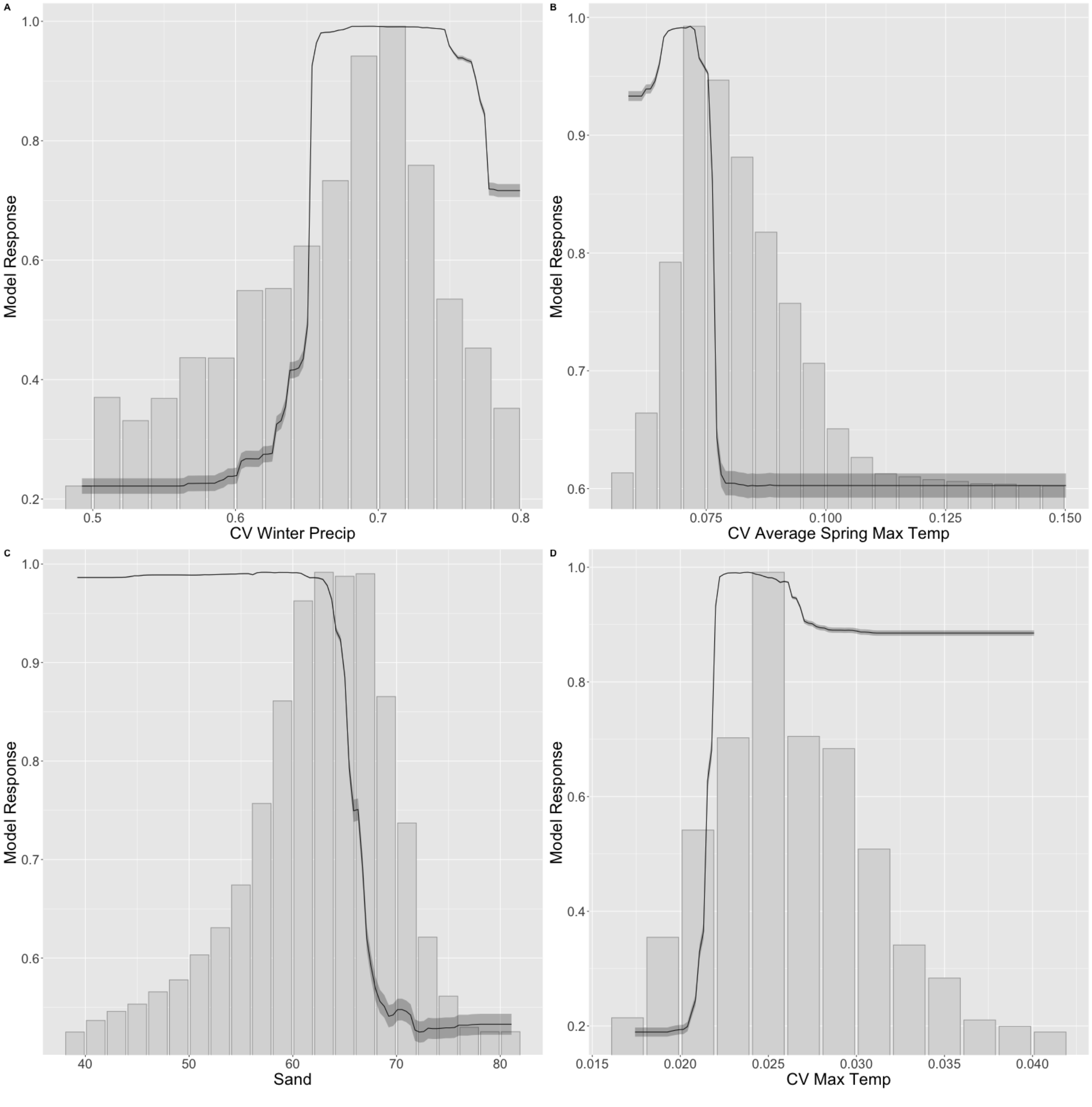


Figure A.2-6. Partial response curves for the environmental variables included in the Random Forest ensemble model for Las Vegas bearpoppy. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.2.4.4 Model Discussion

Predicted habitat for Las Vegas bearpoppy occurs in Clark County in the areas surrounding the City of Las Vegas, as well as areas to the east and north (Figure A.2-7). These areas include the Nellis Air Force Base, Gale Hills, Bitter Springs Valley, White Basin, Valley of Fire and areas near the Virgin Mountains as well as portions of the Moapa Valley. However, the model indicates other areas of high habitat suitability where the species localities were not present, such as along the I-15 corridor, additional habitat near the Moapa Valley, and areas along the shorelines of Gold Butte. There is also an area of higher predicted suitability in near the dry lake in Eldorado valley, although this may be an unlikely prediction.

The locality data for this species consisted of 11,537 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 432 records.

A.2.4.5 Standard Error

The standard error map for the ensemble model indicated relatively low error (< 0.05) throughout much of the study area (Figure A.2-8), with moderate error, located in the areas that were predicted as high quality habitat that are outside of the species known range (e.g., the Mormon Mesa near Glendale). Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

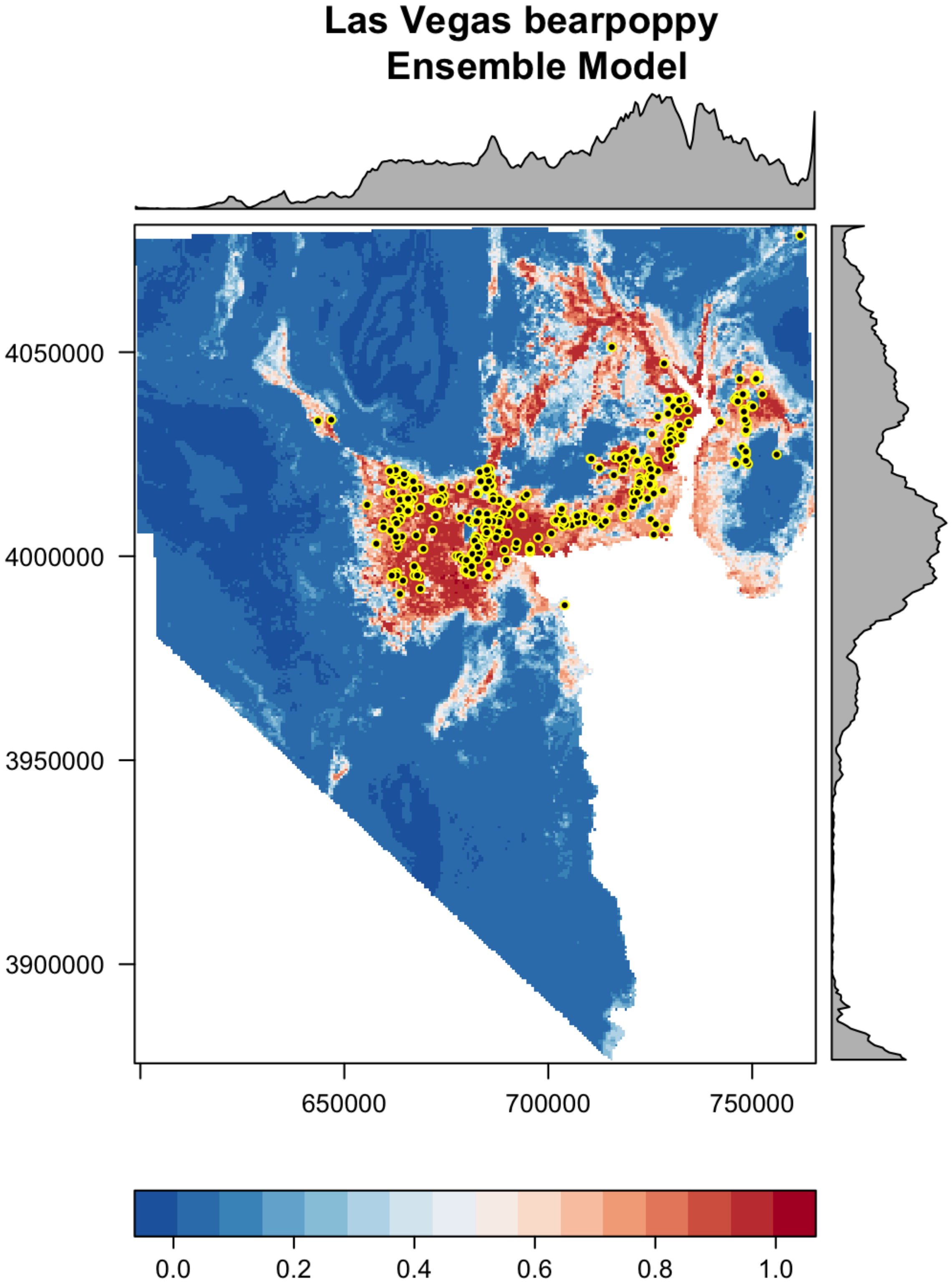


Figure A.2-7. SDM map for Las Vegas bearpoppy Ensemble model for Clark County, NV.

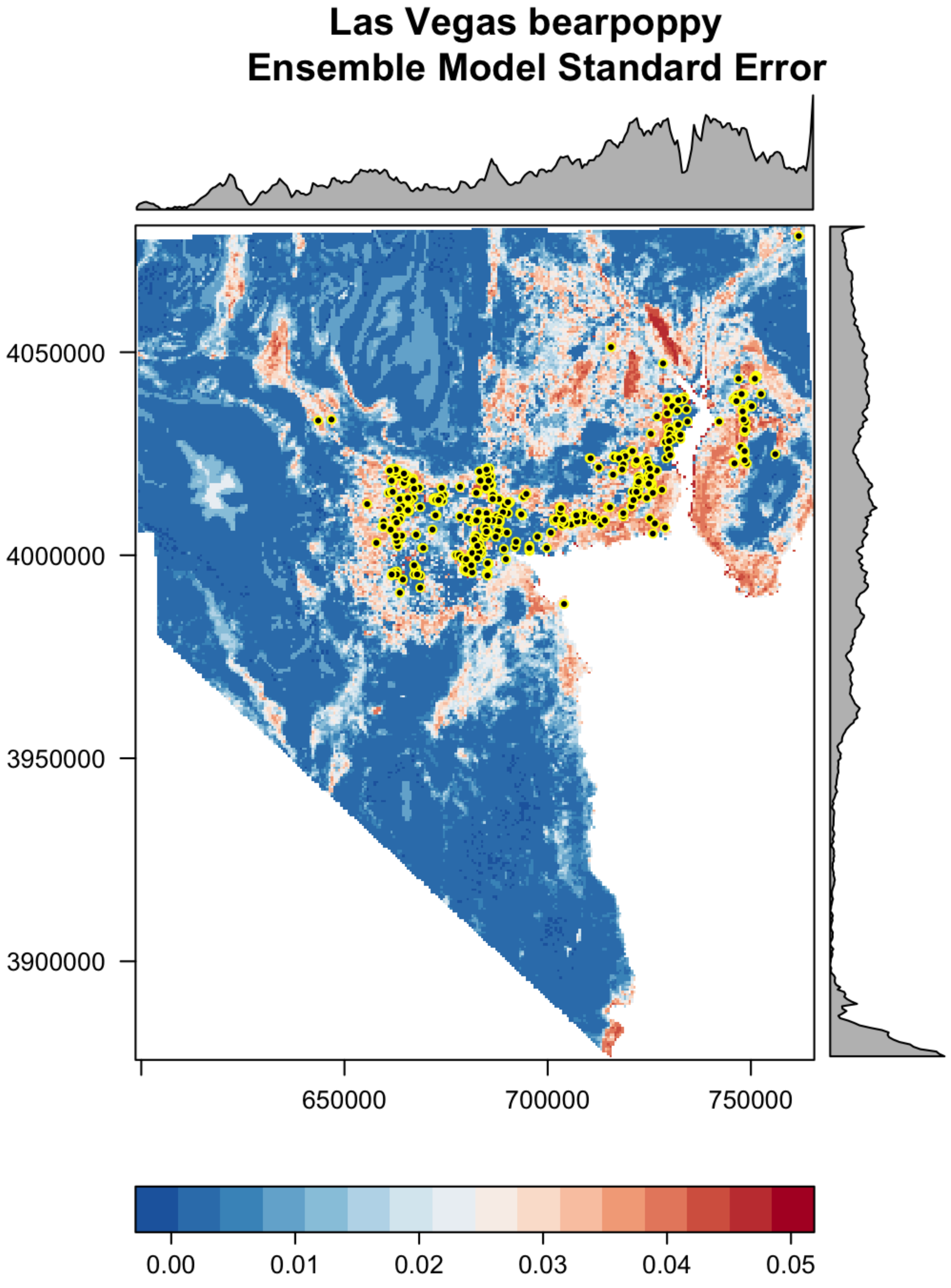


Figure A.2-8. Standard Error map for the Las Vegas bearpoppy Ensemble model for Clark County, NV.

A.2.5 Distribution and Habitat Use within Clark County

Las Vegas bearpoppy is found in the central and eastern portion of Clark County, from the Las Vegas Valley, along the north and west side of Lake Mead, and east of Lake Mead in Gold Butte (TNC 2007). In Clark County 91 populations at 78 sites have been documented and are presumed extant (Mistretta et al. 1996). Surveys have been conducted in most areas of suitable habitat and Mistretta et al. (1996) considered that the remaining un-surveyed habitat was unlikely to add more than 25% to the existing population estimate. In Clark County, Las Vegas bearpoppy is thought to be restricted to soils with high gypsum contents—up to 69 percent of the soil at some sites (Meyer 1987 in Mistretta et al. 1996)—that often support a well-developed cryptogamic crust (NNHP 2001). Thompson and Smith (1997) reported that *Arctomecon* populations occurred on gypsum soil outcrops with a "badlands" appearance in which the soils are whitish in color, fluffy in texture, and tend to form raised crusts that are easily disturbed, while flatter areas with rockier surfaces and desert pavement tended to be absent of this species. These gypsum soils form relatively barren, low-competition sites that support a distinctive gypsum-tolerant herbaceous plant community within creosote bush, saltbush, and occasionally blackbrush scrub ecosystems (TNC 2007). The gypsum soils in which this species grow are higher in sulfur, calcium, and soluble salts, with lower phosphorous contents and pH than the surrounding habitats supporting the shrub community (Thompson and Smith 1997). Estimated high and medium suitability habitat for this species is predicted to be nearly exclusive to the Mojave Desert Scrub ecosystem (Table A.2-3).

Table A.2-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415164	103	0
Bristlecone Pine	7565	0	0
Desert Riparian	5322	2999	1440
Mesquite Acacia	13160	1804	5257
Mixed Conifer	27339	0	0
Mojave Desert Scrub	886155	173800	295887
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	63895	8807	9832

A.2.6 Ecosystem Level Threats

The primary threat to the Las Vegas bearpoppy is habitat clearing for urban and residential development and associated highway construction and maintenance (Thompson and Smith 1997, TNC 2007). Damage from off-road vehicle use has been observed at most sites (Thompson and Smith 1997, TNC 2007). Other threats include gypsum mining, flood-control projects, dumping, and pollinator declines due to habitat fragmentation (Meyer 1986, Mistretta et al. 1996, Nevada Natural Heritage Program 2001, TNC 2007). This species is also sensitive to the destruction of the cryptogamic soil crust from trampling by feral horses and burros—this crust is believed to be critical to the maintenance of seed banks of this species and may enhance soil-surface nutrient levels and water retention (Mistretta et al. 1996). Invasive plants may be an emerging threat for some populations (TNC 2007).

A.2.7 Threats to Species

Las Vegas bearpoppy is the best studied of Clark County's rare plants. Demographic data that have been collected for over 30 years have enabled the development of a population viability analysis that has provided useful information on conservation approaches (Meyers and Forbis 2006). This analysis showed that reproductive output depends on three factors: genetic variation, plant age, and precipitation, the most important environmental variable; the authors concluded that even large, intact populations are at risk of extirpation if a series of several dry years prevent seedling germination and recruitment and that small, fragmented populations suffer severe pollen limitation and set few seed—these small, fragmented populations were predicted to have low production.

As a short-lived perennial, Las Vegas bearpoppy populations are susceptible to local extirpation during long runs of dry years when adult plants produce few seeds and most or all plants may die; the survival of populations then depends on a viable seed bank and sufficient rain for germination and survival of young plants (Meyer and Forbis 2006). Once a population is locally extirpated and the seed bank is diminished, recolonization is unlikely because of low seed dispersal and the isolated distribution of the gypsum habitats (Meyer 1987 in Mistretta et al. 1996).

Another threat to this species – a result of small, isolated, and fragmented populations – is reduced numbers of pollinators and low seed set as this species has little ability to self-fertilize (Mistretta et al. 1996, Hickerson 1998, Megill et al. 2011). This has resulted in measurable reductions in genetic variation in fragmented areas (Hickerson 1998). Some collection pressure has occurred by local residents and scientific collectors. Most transplants of this species are unsuccessful and this likely only serves to deplete local populations and impact local soils (Mistretta et al. 1996). This species has been observed with infestations by an unknown, dark blue, leaf fungus; effects on the Las Vegas bearpoppy by this fungus are currently unknown and will need to be studied further (Mistretta et al. 1996), and no further research has been found on this fungus.

A.2.8 Existing Conservation Areas/Management Actions

A conservation strategy specific to this species was developed by The Nature Conservancy for the Clark County Desert Conservation Program (TNC 2007). The recommended conservation actions for this species include the following:

- proactively protect and manage for long-term viability of all populations on federal lands;
- manage viable populations by removing significant casual off-road vehicle use;
- control weeds in low-elevation rare plant habitats;
- ensure that disposal of federal lands in Clark County will not significantly impact conservation of rare plant populations;

- manage viable populations of all covered rare plants in utility corridors and potential rights-of-way corridors;
- management of viable populations on federal lands; and ensure that gypsum mining will not significantly impact the habitat of the Las Vegas bearpoppy;
- manage populations of Las Vegas bearpoppy at Nellis to ensure positive long-term viability trend within ten years;
- ensure gypsum mining will not significantly impact habitat of Las Vegas bearpoppy by 2008;
- conserve remaining genetic diversity of Las Vegas bearpoppy in its western populations in Las Vegas Valley (by 2015); and
- alleviate loss of Las Vegas bearpoppy and habitat from BLM recreation management actions at Nellis (Las Vegas) Dunes (TNC 2007).

Under a 2007 permit granted by the Nevada Division of Forestry for the Nellis Air Force Base to develop a portion of the base’s land, the Air Force will set aside more than 230 acres for permanent conservation of bearpoppy habitat in an agreement in cooperation with USFWS and the Nevada Natural Heritage Program (Nevada Department of Conservation and Natural Resources 2007, USFWS 2014). In addition, a ~300 acre conservation easement was also established near the North Las Vegas Airport (USFWS 2014).

A.3 THREECORNER MILKVETCH (*ASTRAGALUS GEYERI VAR. TRIQUETRUS*)

Threecorner milkvetch (*Astragalus geyeri* var. *triquetrus*) is a tiny, prostrate, sand-loving (i.e., psammophylic), winter annual plant in the bean family (Fabaceae) and is one of the first plants to bloom in early spring (Swearingen 1981, Bangle 2012). Their abundance is highly variable, likely due to variable precipitation and temperature for this region (Powell 1999). Originally this species was described as occupying consolidated dunes (Niles et al. 1995), however, recent observations describe the threecorner milkvetch on unconsolidated dunes as well (Powell 1999). Because this rare plant inhabits unconsolidated dunes, it is possible that shifting dune surfaces would either bury or expose propagules in the seed bank intermittently, thus potentially increasing the variability of abundance that might be measured during surveys in any given year (Powell 1999), and this must be considered when assessing population trends.

A.3.1 Species Status

Threecorner milkvetch is a former Category 2 candidate for threatened or endangered status under the Endangered Species Act of 1973. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that the threecorner milkvetch proposal for listing may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (USFWS 1993, USFWS 2009).

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): Critically endangered

NV Natural Heritage Program: Global Rank G4T2T3, State Rank S2S3

IUCN Red List (v 3.1): No Status

CITES: No Status

A.3.2 Range

Almost the entire range of threecorner milkvetch is in Clark County, with the northeast extreme of the range crossing into Lincoln County at Sand Hollow Wash, extreme eastern Clark County in the sands near St. Thomas Gap, and to the northeast at Coon Creek, in Mohave County, Arizona (Swearingen 1981, Bangle 2012). The southernmost range is on the north shore of Boulder Basin at Lake Mead National Recreation Area (LMNRA) and the westernmost known limit is in Dry Lake Valley, Clark County (Bangle 2012). Sixteen of the 17 known population groups occur in northeast Clark County (TNC 2007).

A.3.3 Population Trends

Population data are insufficient to derive population trends for this species (Powell 1999, Bangle 1012, NNHP 2001, TNC 2007). As an annual plant species the population numbers fluctuate greatly from year to year in response to rainfall and winter and spring temperatures. As a result, the species may not be seen for years at a time because it requires average to above-average rainfall to germinate (TNC 2007).

In 2007/08, monitoring plots identified and mapped 3,968 individual plants at Sandy Cove on LMNRA. Several sites that were surveyed and known to produce plants in previous years did not yield any observation of the plant during this survey. Seed bank studies might be used to reduce variability in surveys for this and other species with irregular germination.

A.3.4 Habitat Model

Threecorner milkvetch had 1234 point localities available for modeling distributed largely in the northeastern quarter of the County. Similar patterns of predicted suitability were produced by the three modeling algorithms with a slightly broader range of higher suitability predicted by the GAM model than the others. The consensus model predicted areas of higher habitat suitability in the Muddy and Virgin river areas, the margins of Mormon Mesa, Moapa Valley, and Gold Butte, and the Apex/Crystal area (Figure A.3-1).

Performance was high in all models, with the highest overall for the Ensemble model. The RF had the second highest performance, followed by MaxEnt and then GAM models (Table A.3-1). AUC was nearly equivalent among all models, but the Ensemble model had higher BI, and Correlations than the others, while the RF model had a higher TSS score than the others (Table A.3-1).

The Continuous Boyce Index [CBI] indicated good performance among all models with an irregular pattern in the MaxEnt model (Figure A.3-3). Standard Errors were generally low among the three modeling algorithms, with low error in the predictions near the confluence of the Muddy and Virgin Rivers. The among model error shown in the Ensemble model indicated moderately low error (0.04 – 0.06) in the same area, and low (0.02 – 0.04) SE along the I-15 corridor. Approximated bins for the ensemble model based on the CBI were 0-0.3 unsuitable, 0.3-0.375 marginal, 0.4 to 0.5 suitable, and > 0.5 optimal habitat; with a suggested cutoff threshold near 0.4 (Figure A.3-3) and the threshold value calculated from the AUC analysis for the ensemble model was 0.39 (Table A.3-1).

Table A.3-1. Model performance values for threecorner milkvetch models.

Performance	**GAM**	**RF**	**MaxEnt**	**Ensemble**
AUC	0.97	0.99	0.98	0.98
BI	0.83	0.85	0.78	0.89
TSS	0.88	0.93	0.89	0.90
Correlation	0.68	0.76	0.84	0.89
Cut-off*	0.54	0.45	0.14	0.39

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.3-2. Percent contributions for input variables for threecorner milkvetch in an ensemble model combining GAM, MaxEnt, and RF algorithms

Term	**GAM**	**RF**	**Max**	**Average**
Winter Precipitation	0.0	8.0	3.4	8.2
Summer Maximum Temperature	31.4	13.9	45.7	37.9
Winter Minimum Temperature	37.0	9.7	17.3	26.7
Temperature Range	2.9	12.2	4.6	13.2
NDVI Amplitude	0.0	0.0	0.2	0.1
NDVI Maximum	0.0	5.6	0.6	5.2
NDVI (Landsat 8)	0.0	10.9	0.9	9.9
Slope	0.0	6.6	0.3	6.0
Topographic Position (TPI)	0.0	5.8	0.5	5.2
Silica Index	22.0	16.9	23.7	30.1
Sandy Soils	6.7	10.4	2.8	12.3

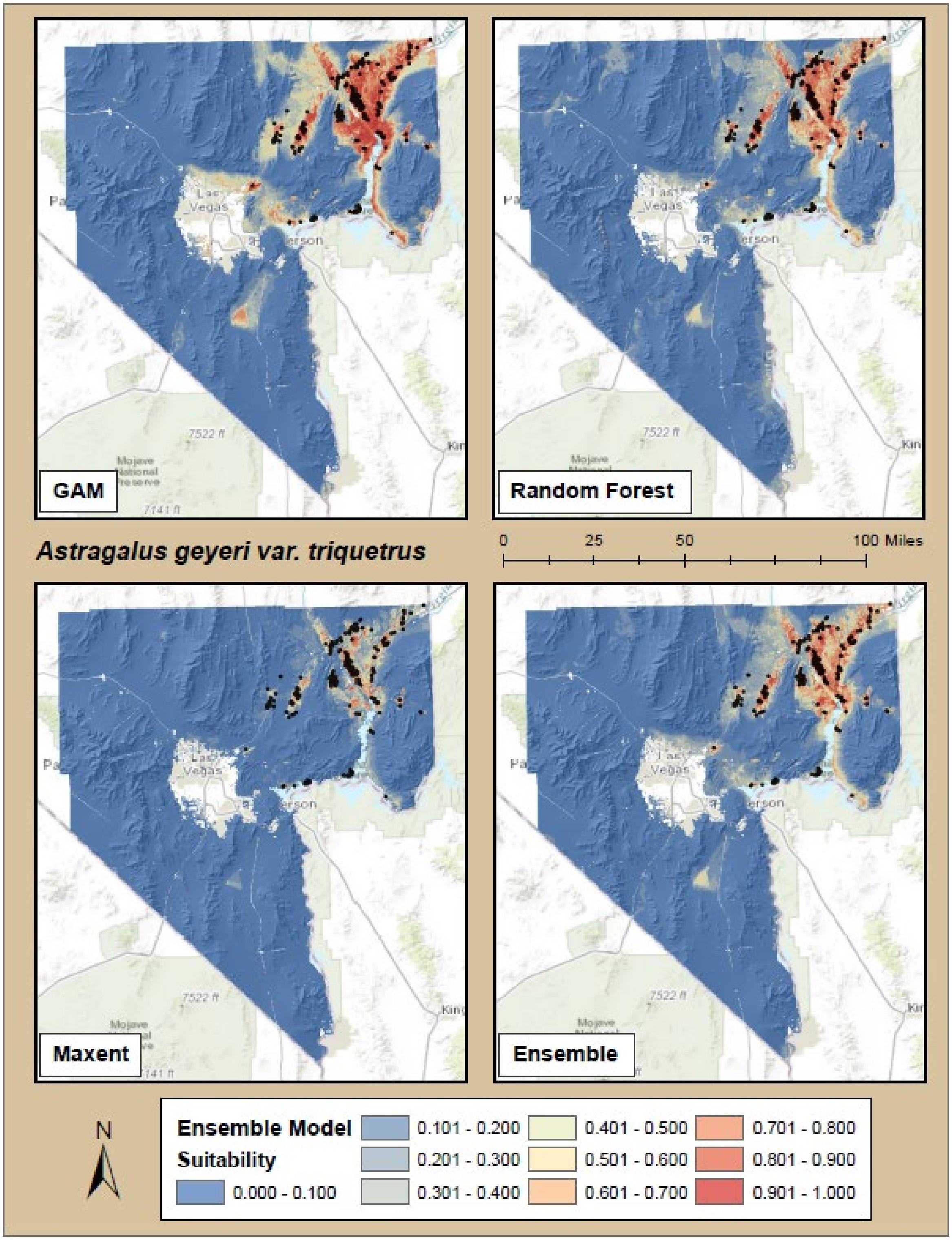


Figure A.3-1. SDM maps for threecorner milkvetch for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

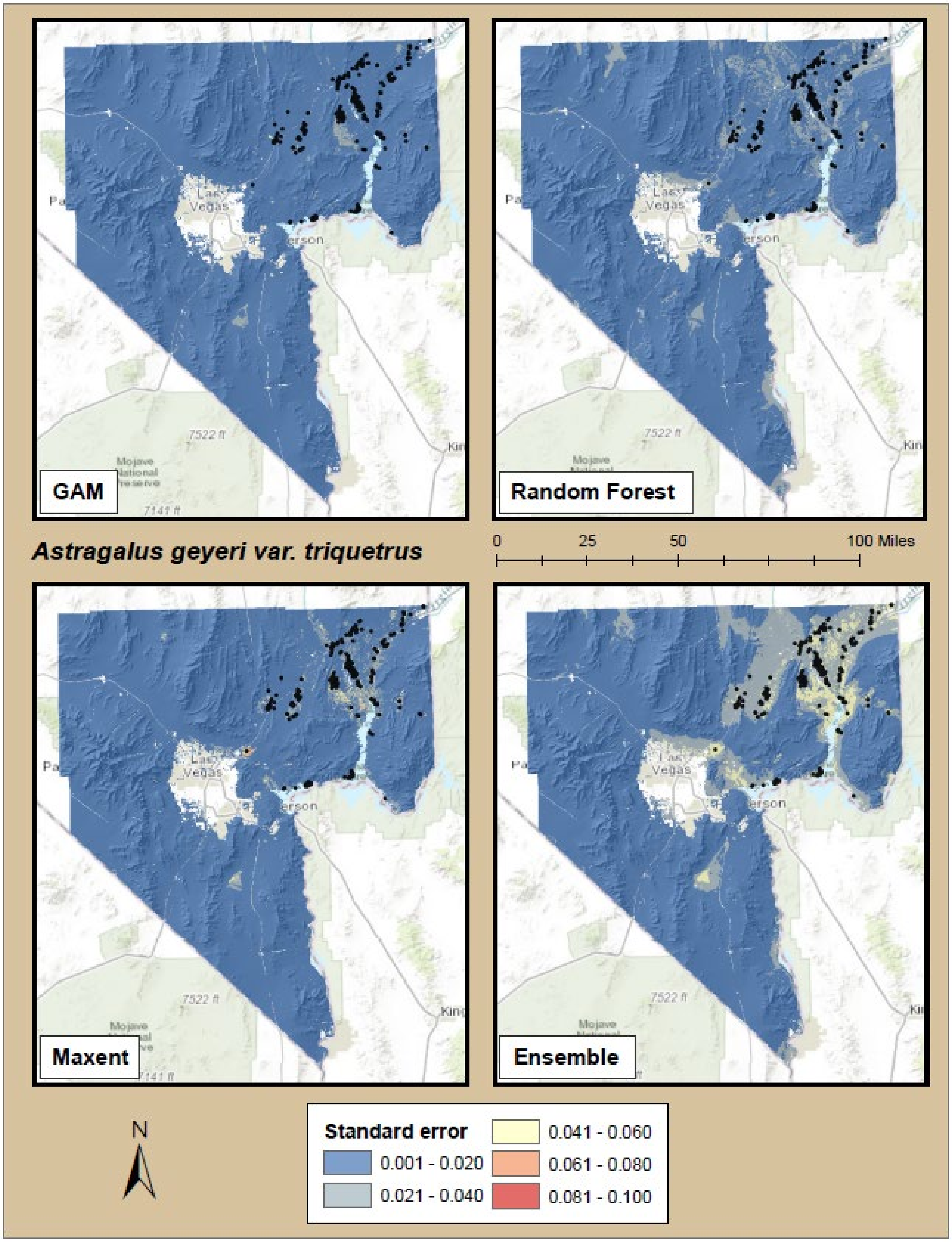


Figure A.3-2. Standard error maps for threecorner milkvetch models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an Ensemble model averaging the previous three (Lower Right).

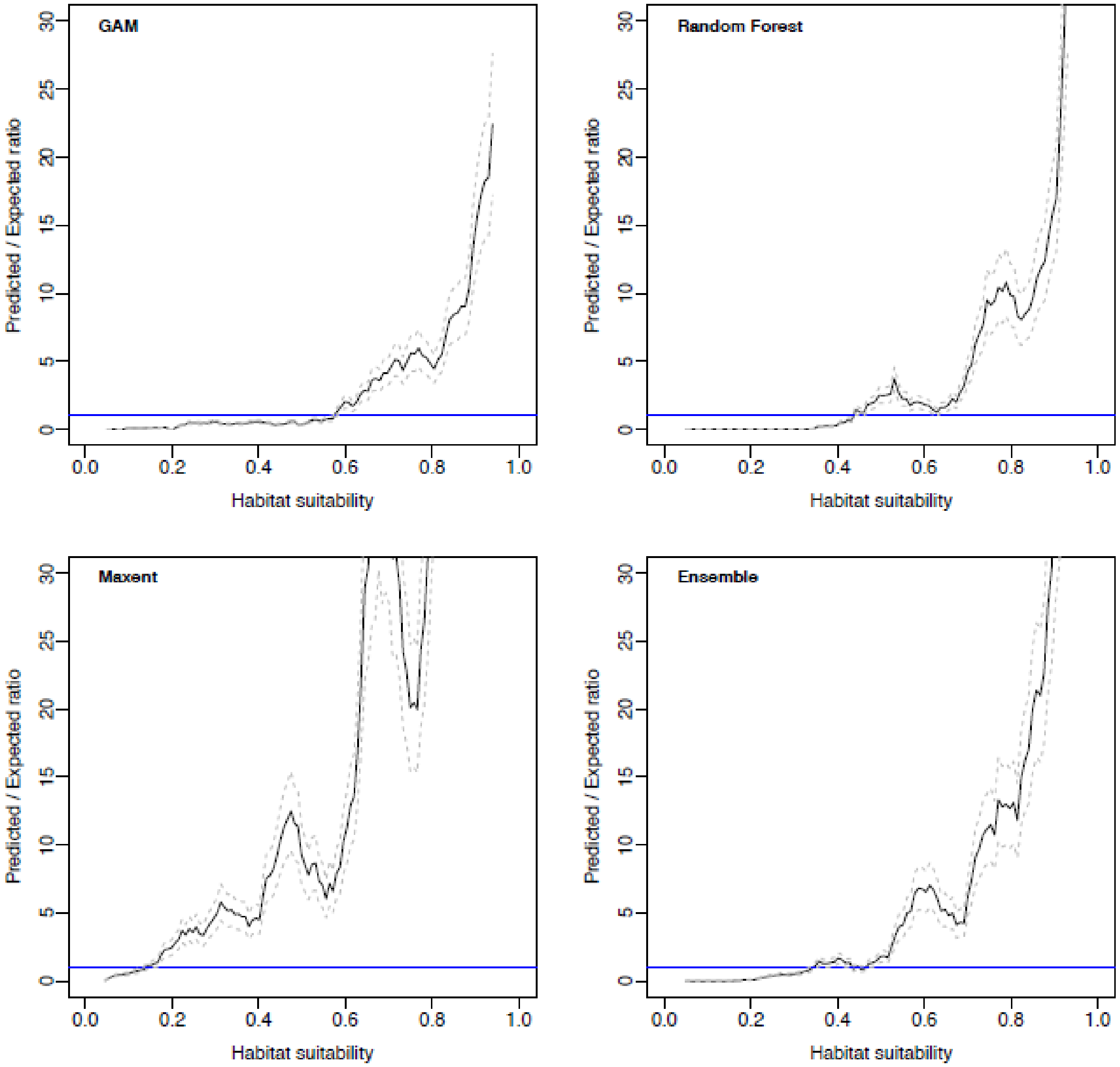


Figure A.3-3. Graphs of Continuous Boyce Indices [CBI] for threecorner milkvetch models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

A.3.4.1 GAM Model

Three variables contributed 20% or more from the GAM model ensemble totaling 90% of model contribution (Table A.3-2). Winter Minimum Temperature was the strongest contributor with 37% model contribution, and peaked relationship, where habitat suitability was higher in areas that had relatively warmer minimum temperatures, but leveling off above 2 ºC and decreasing above 4 ºC (Figure A.3-4).

Summer Maximum Temperature (31%) was generally linear and positive, with positive predictions of habitat above 35 ºC (Figure A.3-4). Silica Index contributed 22% to the overall model, and had a positive relationship, with positive habitat predictions above levels of 1.03, consistent with this species preference for sandy substrates. The sandy soils layer, had a 6% contribution (Table A.3-2).

The GAM model predicted the largest extent of habitat for this species. Highest habitat predictions were in the Overton and Mormon Mesa areas, with habitat predicted all along the Gold Butte Shoreline along the Virgin River and Lake Mead. High habitat suitability was also predicted for the Apex and I-15 corridor areas, the Las Vegas Bay and Government Wash, and near Nellis AFB (Figure A.3-1). One pocket of habitat was predicted hear the Roach Lake/Jean area, but no localities are reported there, and this was also an area of higher Standard Error in the Ensemble model due to this (Figure A.3-2). Standard error for the models within this algorithm were generally low throughout the County (Figure A.3-2).

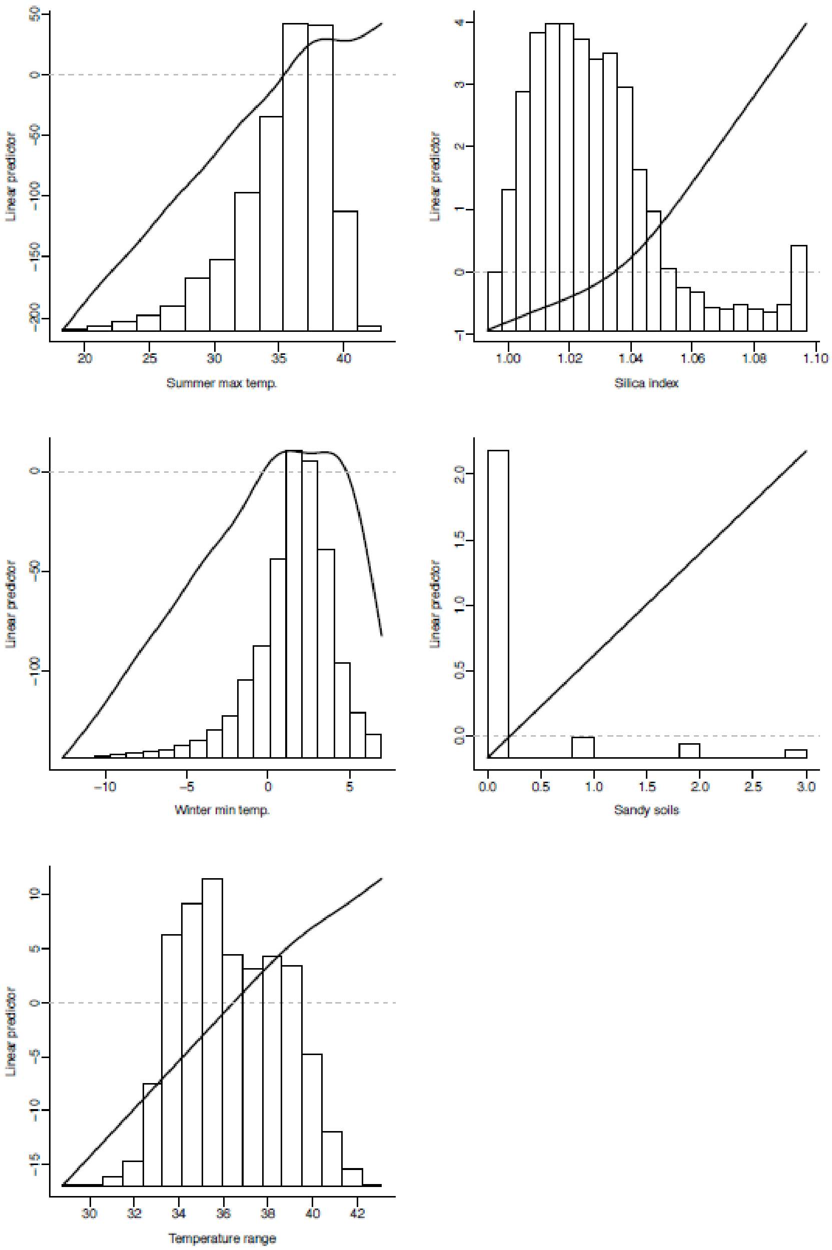


Figure A.3-4. GAM partial response curves for the threecorner milkvetch model overlaid over distribution of environmental variable inputs in the study area.

A.3.4.2 MaxEnt Model

The MaxEnt model had the same three variables as the GAM model contributing 15% or more each, accounting for 87% of model contribution. Three additional variables contributed minimally (Table A.3-2). Summer Maximum Temperature was the largest model contributor (46%) and had a strongly positive relationship with predicted habitat suitability above 37ºC (Figure A.3-5). Silica Index was the next most important (24%), with a non-linear positive relationship with predicted habitat. Winter Minimum Temperature contributed 17%, with a peaked response – where habitat was highest between 0 ºC and 4 ºC, peaking at 2.5 ºC and falling at higher values (Figure A.3-5).

Habitat prediction for this model was concordant with the point locations for the species (Figure A.3-2), with habitat centered in the Moapa Valley, and Virgin River, Beaver Dam Wash, Apex and the I-15 Corridor (Figure A.3-2).

Standard Error was low (0.02 – 0.04) to moderate (0.04 – 0.06) where habitat was predicted, with the highest levels (0.06 – 0.08) in a few small patches (e.g. near Nellis AFB, and Near Valley of Fire State Park). Error throughout the rest of the County was predicted to be low (Figure A.3-2).

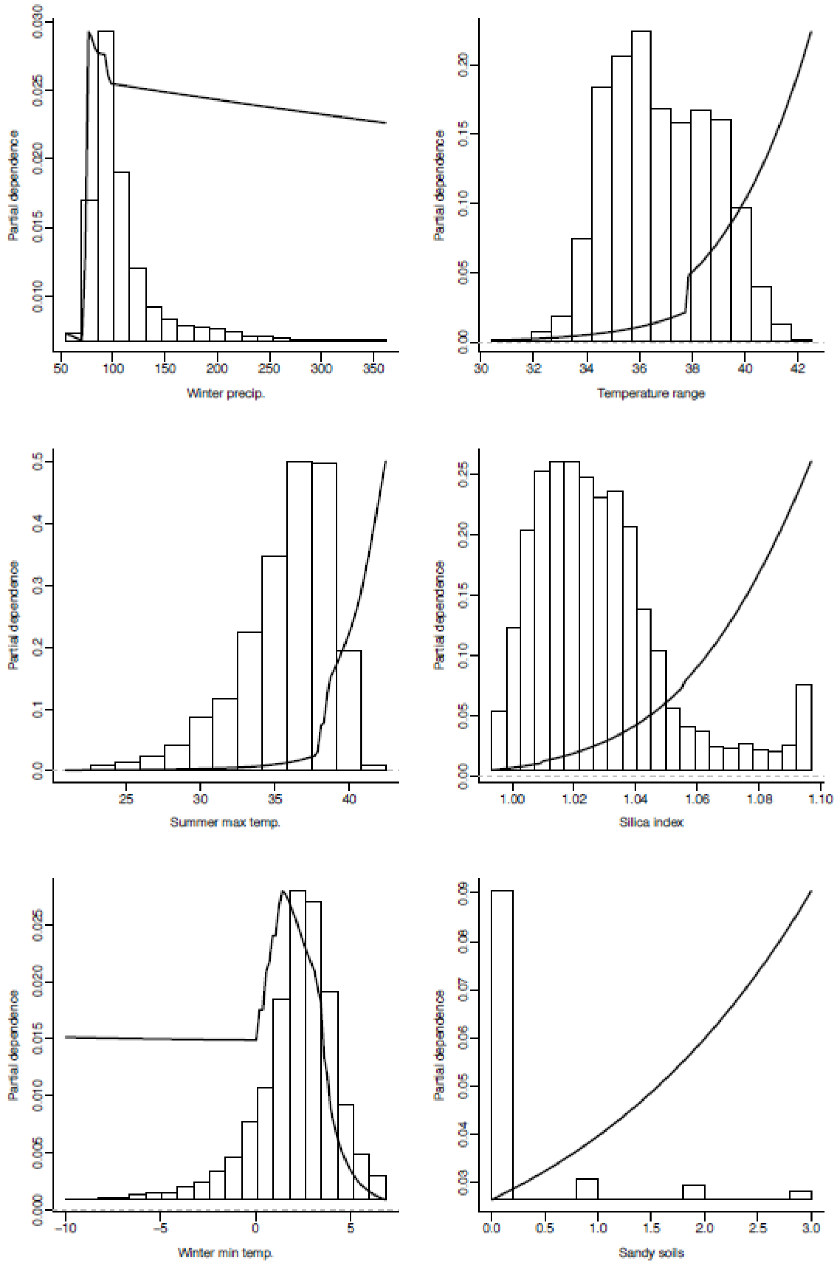


Figure A.3-5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for threecorner milkvetch.

A.3.4.3 Random Forest Model

The RF models had six environmental variables contributing ~ 10% or more collectively accounting for 74% of the total model influence, with four additional variables contributing lesser, but not minimal amounts (Table A.3-2).

Silica Index had the highest influence (17%), with a strong logistic shaped threshold curve, with higher habitat suitability predicted at indices above 1.05 (Figure A.3-6). Summer Maximum Temperature contributed 14%, and also had a strong threshold response, with suitable habitat predicted at max summer temperatures above 37 ºC. Annual Temperature Range (12%) had a similar threshold response at temperature ranges above 37 (Figure A.3-6), NDVI derived from Landsat 8 contributed 11% also had a threshold response, with higher habitat suitability predicted above 0.05. Sandy Soils (10%) also contributed positively. Winter Minimum Temperature (10%) had a peaked response as seen in the other models, where habitat suitability was highest between 0 ºC and 5 ºC minimum winter temperature, peaking at 2.5 ºC (Figure A.3-6).

Standard error maps for this model indicated low (0.02 to 0.04) error rates generally surrounding areas of predicted habitat (Figure A.3-2, Figure A.3-1). Low SE was also predicted in the southern extent of Eldorado Valley, Extreme north Las Vegas Valley, and on the Nevada National Security Site (Figure A.3-2). Habitat suitability was predicted to be highest in the Moapa Valley, and Virgin River, Mormon Mesa, and along the Western Shoreline of Gold Butte. One patch of marginal habitat is predicted for southern Eldorado Valley (Figure A.3-1).

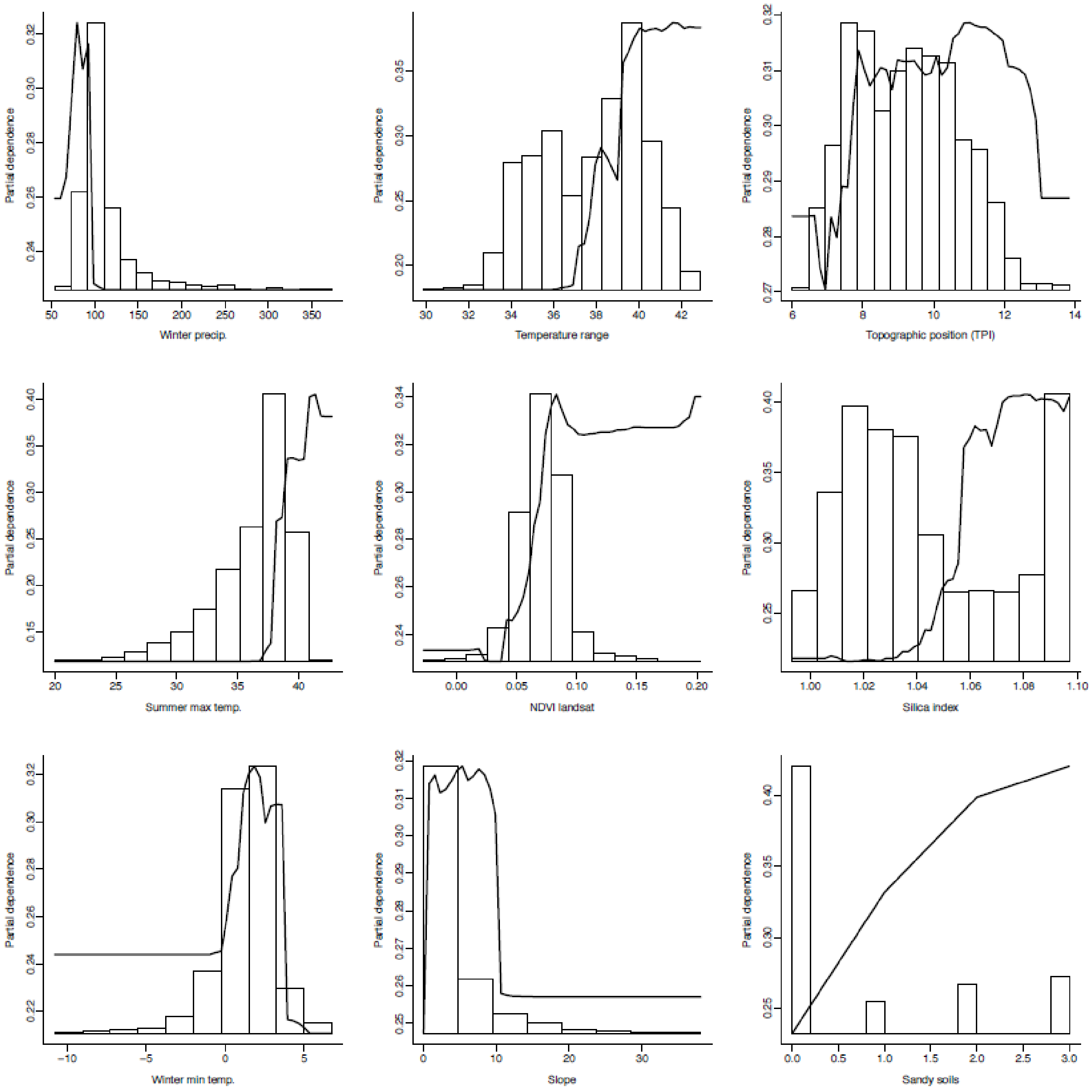
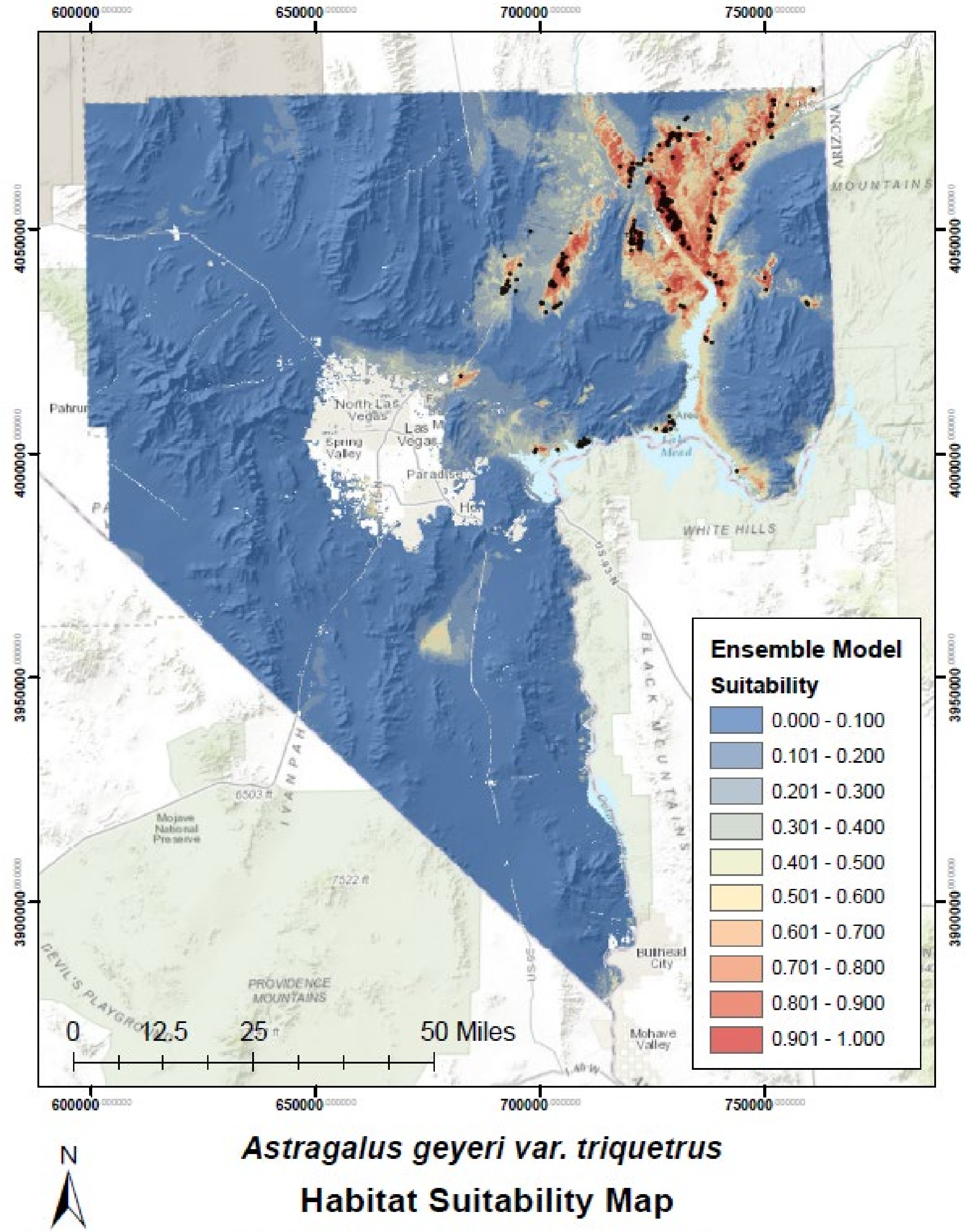


Figure A.3-6. Partial response surfaces for the environmental variables included in the RF ensemble model for threecorner milkvetch. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



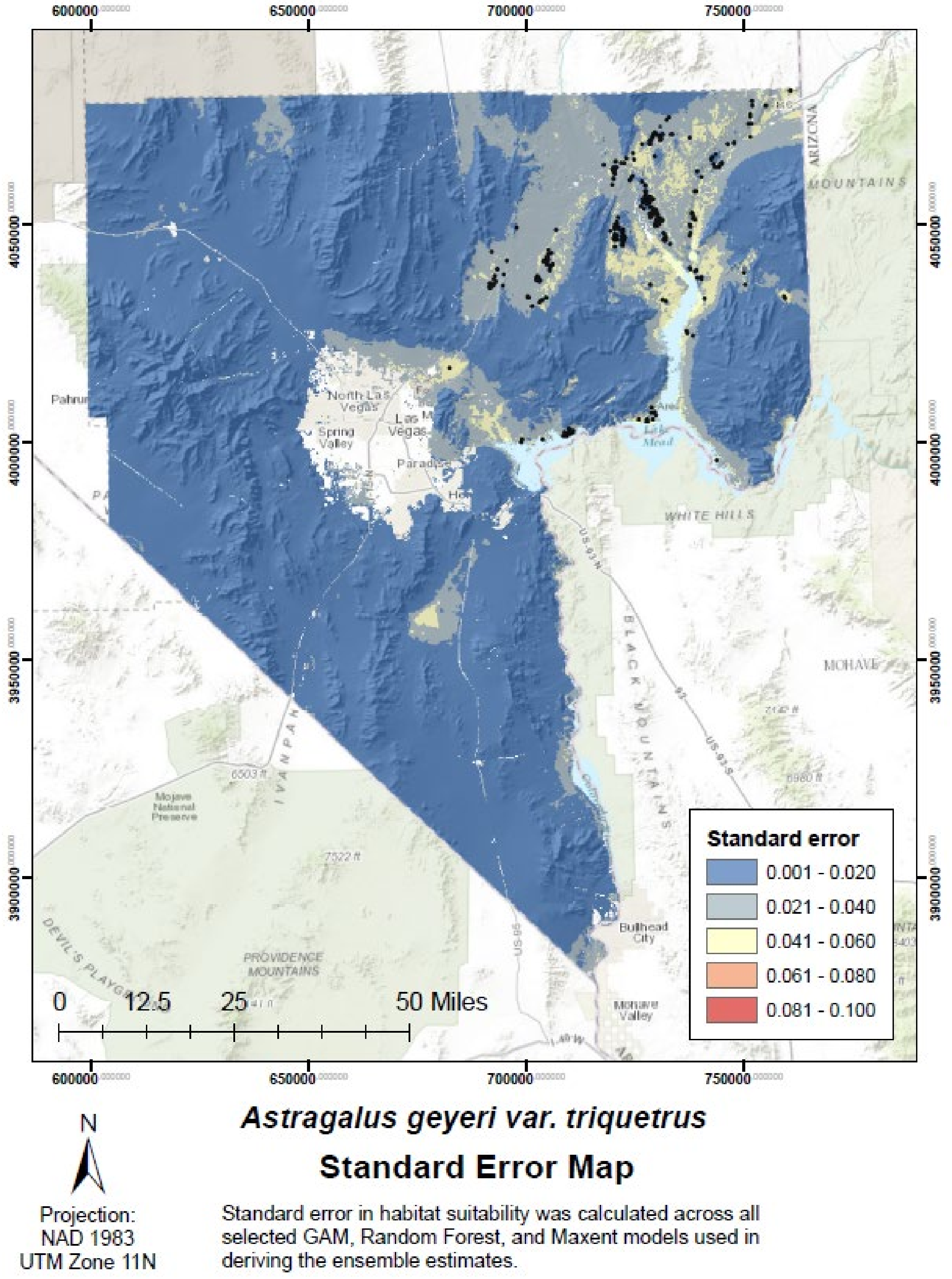
Astragalus geyeri var. triquetrus

Habitat Suitability Map

Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and MaxEnt.

Figure A.3-7. SDM map for the threecorner milkvetch Ensemble model.



Astragalus geyeri var. triquetrus

Standard Error Map

Projection:
NAD 1983
UTM Zone 11N

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

Figure A.3-8. Standard Error map for threecorner milkvetch Ensemble model.

A.3.4.4 Model Discussion

Distribution of Localities – Localities (N=1234) for threecorner milkvetch are distributed only in Northeastern Clark County especially in sandy areas along the Moapa and Virgin river valleys, within the large wash bisecting Gold Butte, and in the Apex andI-15 corridor area especially South of Glendale, NV, and on the I-15 corridor from north of the Logandale exit extending all the way to Mesquite (Figure A.3-7). Additional points are located along the northern Shoreline of Lake Mead near Government Wash and Las Vegas Bay (Figure A.3-7).

Standard Error - Moderate Standard Error (0.04 – 0.06) is indicated in Figure A.3-8, with patches near Las Vegas Bay, Nellis AFB, and the Badlands area in and around Boulder Beach, and the corresponding latitude across Lake Mead in Gold Butte.

Southern Eldorado valley also has a patch of moderate SE in the drainage area coming in from the Highlands Range (Figure A.3-8).

A.3.5 Distribution and Habitat Use within Clark County

Within Clark County, three-corner milkvetch occurs on sandy soils derived from the Tertiary-aged Muddy Creek Formation and redistributed as Aeolian and fluvial deposits along the Muddy and Virgin rivers and the Overton Arm of Lake Mead from Sandy Cove and Middlepoint to the Mormon Mesa (NNHP 2001, Niles et al. 1995, Bangle 2012). The range extends from Dry Lake Valley in the west to the confluence of the Muddy and Virgin rivers in the east, and from Sandy Cove and Ebony Cove on the north shore of Boulder Basin at Lake Mead in the south to the Virgin River drainage in the far northeast of the county, including populations near the Muddy River drainage (Niles et al. 1995, TNC 2007, Bangle 2012).

Native plants associated with threecorner milkvetch include *Ambrosia dumosa, Larrea tridentata, Krameria erecta, Ephedra torreyana, Tiquilia canescens, Opuntia basilaris*, and *Psorothamnus fremontii* (Powell 1999). Native annuals include *Chamaesyce polycarpa, Plantago ovata, Palafoxia arida, Chorizanthe brevicornu, Eriogonum inflatum*, and *Oenothera deltoids* (Powell 1999). Ecosystems associated with higher suitability habitat include Sagebrush, Blackbrush and Mixed Conifer, and Mojave Desert Scrub (Table A.3-3). Moderate habitat is found within the same ecosystems.

Modeled habitat in the County is predicted to be highest in the Virgin and Muddy river valleys, and the valley along the I-15 corridor South of Glendale, with habitat extending northward along I-15 and on Mormon Mesa all the way to Mesquite. The low-elevation areas bisecting Gold Butte from east and west, is also indicated as habitat. (Figure A.3-7). Within that area, the red Aeolian sands of Devil’s Kitchen and St. Thomas Gap are habitat hotspots for this species. The North Shore of the Boulder Basin of Lake Mead is also predicted to be habitat from the Narrows extending westward to Las Vegas Bay (Figure A.3-7).

Table A.3-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem

Ecosystem	Low	Medium	High
Alpine	119	5	0
Blackbrush	198877	207858	8103
Bristlecone Pine	124	0	0
Desert Riparian	415493	0	0
Mesquite Acacia	7565	0	0
Mixed Conifer	3274	4972	2390
Mojave Desert Scrub	16461	2596	626
Pinyon Juniper	27339	0	0
Sagebrush	1076863	121514	82707
Salt Desert Scrub	115854	0	0

A.3.6 Ecosystem Level Threats

Threecorner milkvetch occupies habitats identified by the DCP as desert riparian, mesquite/acacia, and Mojave desert scrub ecosystems. The primary threats to this ecosystem include modification and destruction of habitat by urban and suburban development, off-road vehicle use, surface water development, invasive plant species (especially Sahara mustard, *Brassica tournefortii*, and Mediterranean grass (*Schismus* spp.), utility corridor construction and maintenance, agriculture, and inundation by shoreline fluctuations; other identified threats include livestock grazing, sand and gravel mining, wild horse and burro management, and legal and illegal ORV use (TNC 2007, Bangle 2012, Powell 1999).

A.3.7 Threats to Species

Within Clark County, some reports identify OHV and boater recreation as burgeoning threats to threecorner milkvetch, and others have identified trespassing livestock and feral burros as potential threats (Powell 1999, Bangle 2012), but there was not broad agreement on these items in the available references. Sahara mustard (*B. tournefortii*) and Mediterranean grass (*Schismus* sp.) were both identified as potential habitat threats. Active control of *B. tournefortii* has been undertaken in threecorner milkvetch habitats at LMNRA (Powell 1999).

A.3.8 Existing Conservation Areas/Management Actions

A conservation strategy specific to this species was developed by The Nature Conservancy for the Clark County Desert Conservation Program. The ten recommended conservation actions for this species include:

- proactively protect and manage for long-term viability of all populations on federal lands;
- manage viable populations by removing significant casual off-road vehicle use;
- control weeds in low elevation rare plant habitats;
- ensure that long term viability of low elevation rare plants is not significantly impacted by rural development and sprawl;
- ensure that disposal of federal lands in Clark County will not significantly impact conservation of rare plant populations;
- manage rare plants in sandy habitats for long term viability by addressing altered fire regimes (increased fire frequency and intensity) over the next century;
- manage viable populations of all covered rare plants in utility corridors and potential rights-of-way corridors;
- management of viable populations on federal lands;
- protect threecorner milkvetch populations along Muddy and Virgin rivers from significant agricultural impacts over the next fifty year;
- ensure conservation management for threecorner milkvetch populations at LMNRA above high water line and manage populations below high water line during Lake Mead low water years; and
- ensure construction of the Mesquite Airport does not significantly impact viability of threecorner milkvetch on public lands (TNC 2007).

NPS controls the invasive Sahara mustard in and around threecorner milkvetch populations along the north shoreline of Lake Mead and conducts annual monitoring of the Sandy Cove population (TNC 2007). Four populations growing on lands managed by BLM occur at least partly within designated ACECs.

It is clear that actively managing landscapes for such rare species as the threecorner milkvetch has high priority and many useful management recommendations are provided. However, in the absence of population monitoring there is no way of accurately determining the population status of these species. Furthermore, it is clear that monitoring plants as they are expressed in sample populations can yield volumes of highly variable data. Quantifying propagules in the seed bank is a relatively straightforward endeavor in very sandy soils – such as those where the threecorner milkvetch occurs. While seedbank estimates are also notoriously variable it is possible that they may provide a more reliable and cost effective estimate of population status than monitoring plants on an annual basis. Furthermore, a seed bank investigation could also be used to determine the efficacy of invasive species control programs in these high-value habitats.

A.4 ALKALI MARIPOSA LILY (*CALOCHORTUS STRIATUS*)

Alkali mariposa lily (*Calochortus striatus*) is a rare bulbiferous perennial forb (USDA 2016 2016) in the Liliaceae family. It was originally described in 1901 from a collection at Rabbit Springs in San Bernardino County, California (Parish 1902). The plant grows 1-5 cm tall with 10-20 cm long basal leaves. It has an umbel-like inflorescence with 1-5 erect flowers with irregularly toothed, white to lavender, purple veined petals with sparse hairs near the densely hairy nectary. The conspicuously purple-veined petals lacking spots is a defining feature of this species (Baldwin 2002).

The plant is reported to be pollinated by bees and flies. It flowers from April to June and spreads seeds via gravitational dispersal (Baldwin 2002). It is unknown whether reproduction occurs primarily from bulb division or seedling establishment (Green and Sanders 2006). The bulb remains dormant in drought years (Bagley 1989).

Little is known about this species of *Calochortus*. There are minimal recent data and minimal data on the Clark County populations in Red Rock Canyon National Conservation Area.

A.4.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): No Status

US Forest Service (Region 4): No Status

State of Nevada (NAC 527): No Status

NV Natural Heritage Program: Global Rank G2; State Rank S1

IUCN Red List (v 3.1): No status

CITES: No status

In 1975, in accordance with the Endangered Species Act of 1973, the Smithsonian Institution submitted a report to the US Department of the Interior identifying the alkali mariposa lily, along with over 3,000 other plants, as a candidate for endangered or threatened status (40 FR 27924). The US Fish and Wildlife Service (USFWS) considered the report to be enough justification to warrant a review (40 FR 27924). In 1990 (55 FR 6184), and again in 1993 (58 FR 51144), USFWS determined that the proposal to list alkali mariposa lily as endangered or threatened was possibly appropriate, but that additional data on biological vulnerability and threat were needed before a final determination could be made.

A.4.2 Range

Alkali mariposa lily has been found in five counties in southern California (CNPS 2016) and two counties in southern Nevada (Morefield and Knight 1991, NNHP 2001). It grows in desert meadows formed by springs and streams, and in low-laying mountain meadows on the leeward side of slopes (McDonald 1997). In Nevada, the species has not been systematically surveyed for (Morefield 2001), and is known only to occur in Ash Meadows National Wildlife Refuge in Nye County (Knight and Clemmer 1987, Ballard 2012), and in Red Rock Canyon National

Conservation Area in Clark County (BLM 2005). It is not seen every year at those locations (Mozingo and Williams 1980).

A.4.3 Population Trends

While the species occurs in several areas, most populations are small (Bowen 1984 cited in Greene and Sanders 2006).

The following are records published by the California Department of Fish and Game in 1997:

- 1982: 100 plants reported below Box "S" Springs (north of Cushenbury Springs) (CDFG, 1997b)
- 1988: 400 plants reported at three sites around Lancaster in LA County (CDFG, 1997b)
- 1988-1992: 6,000 plants reported for Kern County (CDFG, 1997b)
- 1989: 1,500 plants reported at Paradise Springs near Fort Irwin (CDFG, 1997b)
- 1990: 133 plants reported at Red Cock Canyon (CDFG, 1997b)
- 1993: 50 plants reported at Cushenbury Springs (CDFG, 1997b)
- 1993: 100 plants reported at Rabbit Springs (CDFG, 1997b)
- 1998: 165,000 plants in 67 areas documented on EAFB (Los Angeles and Kern Counties: Bagley, *pers. comm.*, 1998 – *cited in* Greene and Sanders 2006 dmg.gov paper).

A.4.4 Habitat Model

We modeled habitat with 127 localities for the mariposa lily which were largely concentrated on the eastern slopes of the Spring Range, near Red Rock Canyon National Conservation Area (NCA) and the community of Blue Diamond, with other localities in the Virgin River drainage at the extreme northeast extent of the county, near Mesquite. Habitat was predicted quite differently among the three model algorithms. The GAM models predicted large areas of marginal habitat, typically in low elevation drainages, but with "hot spots" of higher suitability habitat values predicted near springs (Figure A.4-1). The RF model was less influenced by these springs, which were predicted as moderately suitable habitat, but predicted broad areas of higher suitability habitat in the Trout Canyon and Goodsprings/Red Rock Canyon NCA areas. The MaxEnt model was highly restrictive, predicting habitat only where springs are located (Figure A.4-1).

The three modeling algorithms predicted habitat in similar geographic areas, but with differing areal extent and suitability values. GAM models predicted the most area, followed by the RF model, which had diminished values overall, and reductions in habitat in the Bird Spring Range/Goodsprings area and the Ivanpah Valley, while MaxEnt predicted very restricted habitat patches relative to the other two models (Figure A.4-1).

While all models had similar AUC scores, TSS scores, and Correlation values, performance was highest in those scores for the RF model followed by the Ensemble, MaxEnt, and finally, the GAM models (Table 43). The MaxEnt model had a much reduced Boyce Index (BI) (Table A.4-1). Similarly, the continuous Boyce Index indicated performance issues with the MaxEnt model, specifically with habitat suitability in the 0.6 to 0.8 range where a significant reduction in performance occurred (Figure A.4-3). Continuous Boyce Indices (CBI) were similar for the GAM and RF models indicating good performance, but with a few dips at higher habitat suitability values in the GAM curve, and one in the RF model. The MaxEnt model also had a rather erratic CBI, peaking early (where Habitat Suitability = ~ 0.5), and becoming unstable above that point (Figure A.4-3). The Fixed BI for this algorithm was also the lowest among the group (Table A.4-1). The CBI for the ensemble model indicated good performance, with a short transition area from unsuitable to suitable habitat occurring at predicted habitat suitability values of 0.4 (Figure A.4-3), which was similar to the Precision Recall Break Even (PRBE) cutoff value (Table A.4-1). Standard errors were greatest for the GAM model, with elevated error (i.e., 0.6 to 1.0) relative to the other algorithms.

Table A.4-1. Model performance values for alkali mariposa lily models.

Performance	GAM	RF	MaxEnt	Ensemble
AUC	0.956	0.987	0.965	0.976
BI	0.738	0.695	0.617	0.751
TSS	0.827	0.943	0.873	0.923
Correlation	0.603	0.699	0.727	0.694
Cut-off	0.476	0.578	0.202	0.408

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.4-2. Percent contributions for input variables for alkali mariposa lily ensemble models using GAM, MaxEnt, and RF algorithms.

Term	GAM	RF	Max	Avg
Winter Precipitation	33.1452	14.69	25.598	25.69
Winter Min Temp	26.889	16.85	29.634	25.85
Summer Maximum Temp	21.169	10.25	13.767	15.909
Spring Density	13.427	19.68	20.916	19.631
Topographic Position (TPI)	2.7398	10.01	4.681	6.637
NDVI Maximum	1.628	3.64	1.392	2.521
Slope	1.0016	11.50	3.708	6.355
NDVI Amplitude	0.0001	3.83	0.233	1.669
Surface Texture (ATI)	0	6.47	0	2.692
Soil Water Stress	0	3.07	0.069	1.301

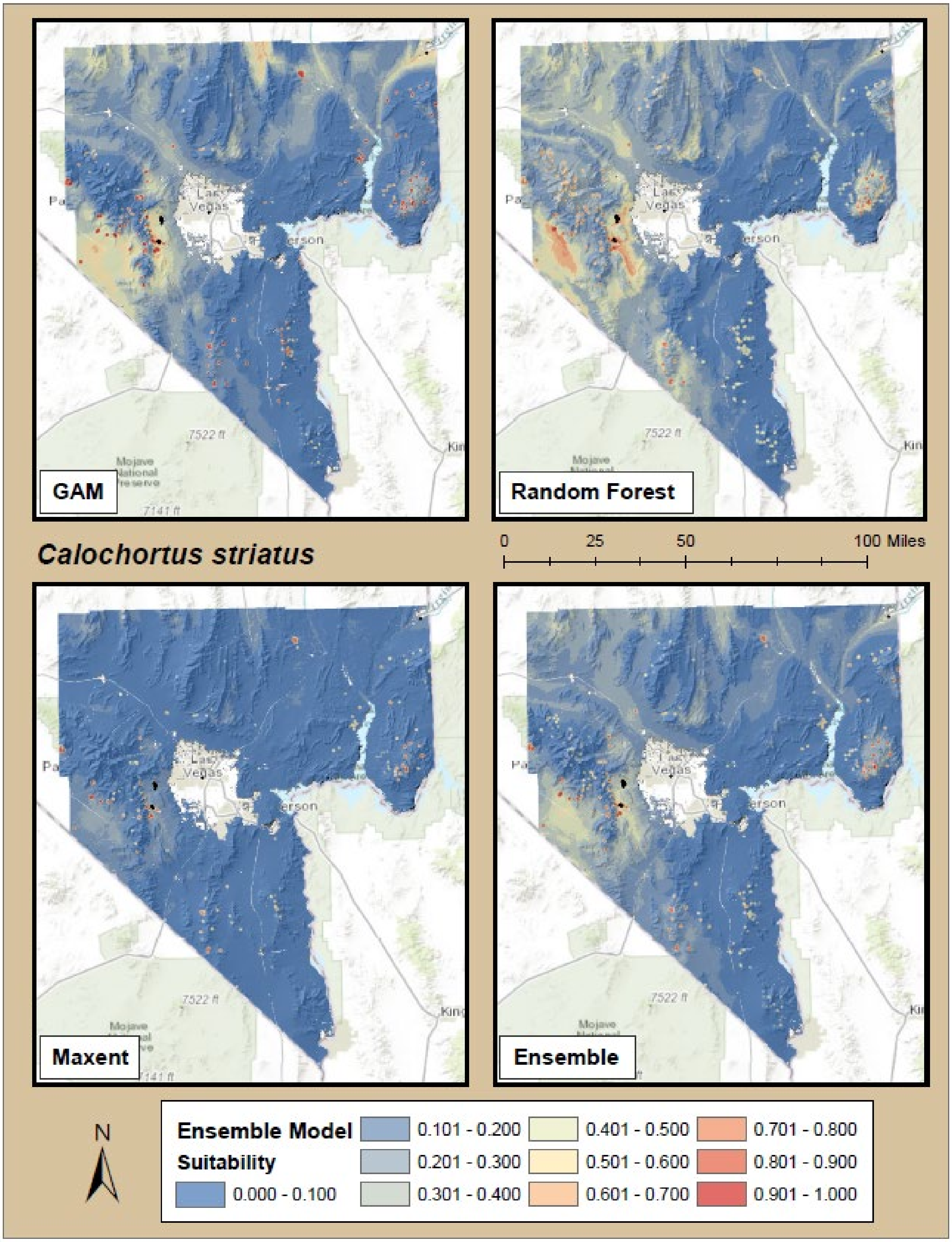


Figure A.4-1. SDM maps for alkali mariposa lily for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right). Black dots indicate presence points for the species.

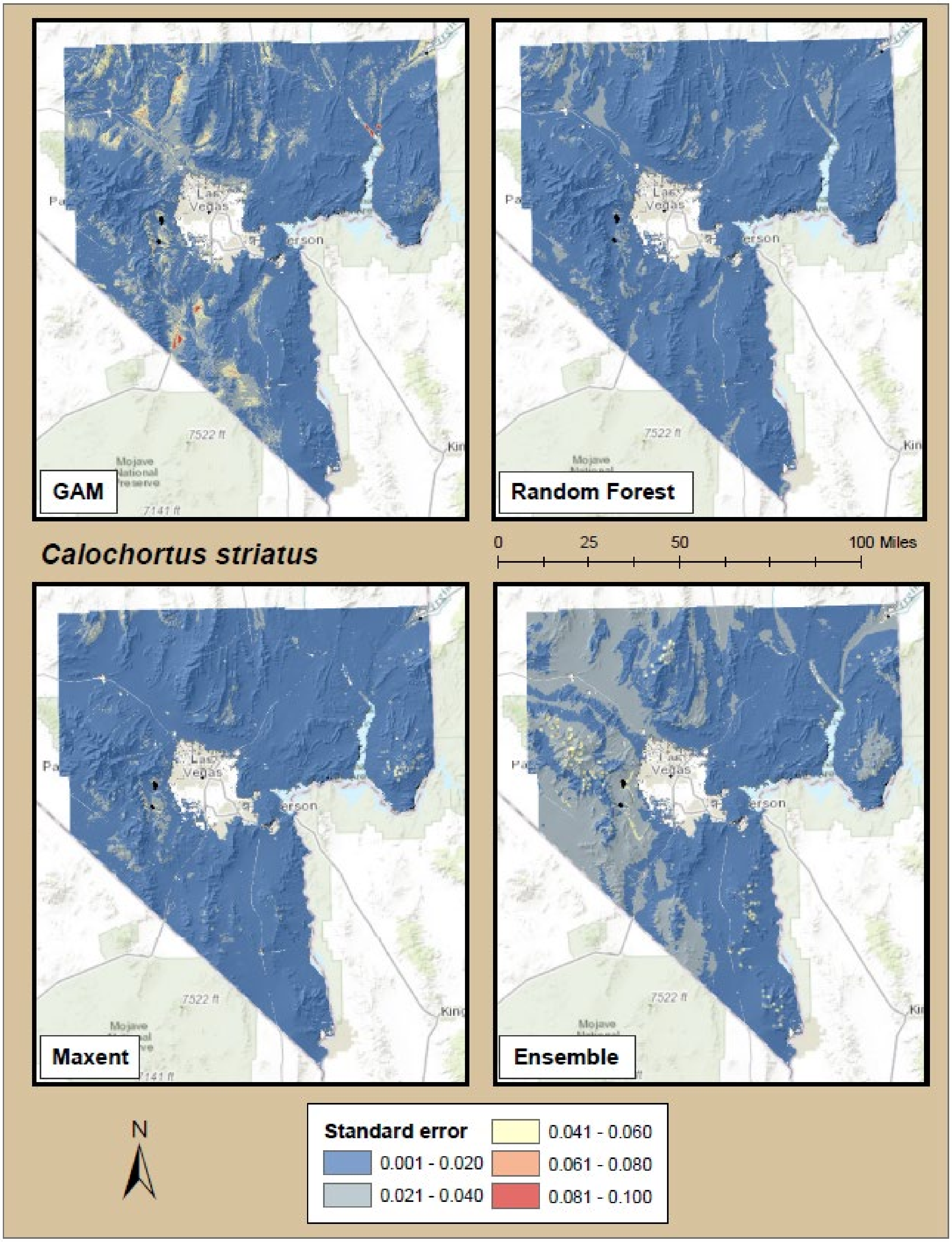


Figure A.4-2. Standard error maps for alkali mariposa lily models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

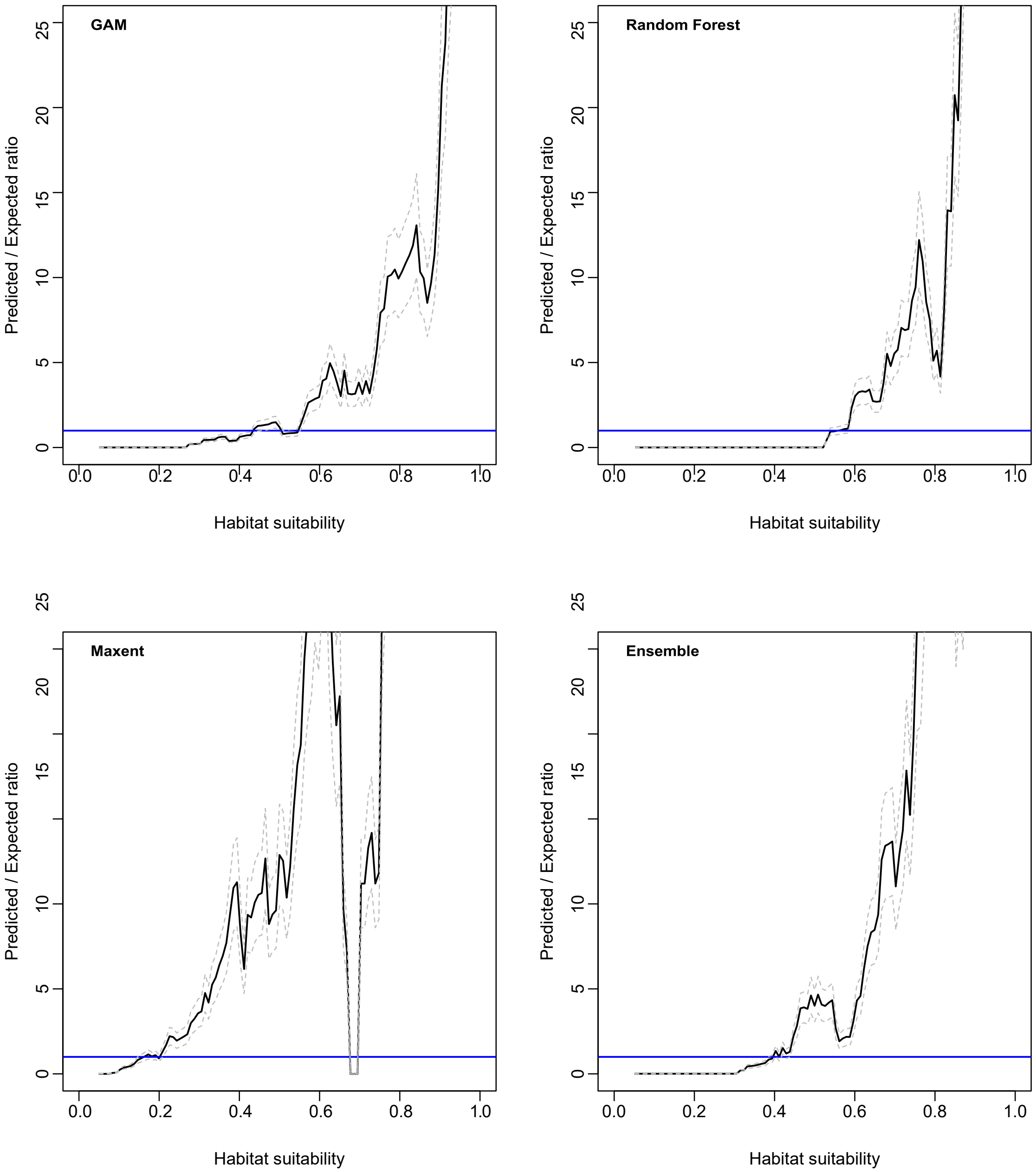


Figure A.4-3. Continuous Boyce Indices for alkali mariposa lily models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an Ensemble model averaging the three (Lower Right).

A.4.4.1 GAM Model

The partial model contributions for the GAM model covariates identified 4 variables with more than 10% contribution toward the model, and representing 95% of the model contribution (Table A.4-2. Winter Precipitation was the highest contributor (33%), and had a peaked response, with positive contribution to habitat suitability at values above 100 mm, peaking at 350 mm, and becoming a negative influence above 500 mm (Figure A.4-4). Winter Minimum Temperature (27%) also had a peaked response, with positive associations with habitat suitability above ~ -5 ºC, peaking for areas at - 2 ºC and becoming negative in areas above 2 ºC, which was reflective of the pattern in this measure within the county (see histograms, Figure A.4-4). There was a positive linear relationship with Summer Maximum Temperature (21%), with a predicted positive influence on habitat suitability at temperatures above ~ 37 ºC. Spring Density was also influential in the model with a 13% contribution, and a strong positive contribution at all levels (Figure A.4-4). The remaining 6 environmental variables provided little to no contribution (Table A.4-2).

The GAM model predicted habitat for this species at isolated spring sites throughout the county (Figure A.4-1). With medium levels of suitable habitat throughout the Pahrump/Trout Canyon area, and around the points concentrated in the Red Rock Canyon NCA/Blue Diamond Area, with other areas of moderate habitat near the Coyote Springs valley west of Moapa, and the upper Virgin River drainage in the county. There were several areas of higher standard error (0.06 to 0.1) in the habitat predicted on the outwash plains south of Indian Springs, in the southern valleys on the Nellis Bombing Range, north and south of Fossil Ridge in the Desert National Wildlife Area (DNWA), the lower reaches of the Virgin and Muddy rivers (and along the eastern shore of the Overton Arm of Lake Mead, west of Searchlight in the Wee Thump Wilderness Area and northern Piute Valley, Roach/Jean Dry Lake Valley, and in eastern Ivanpah Valley (Figure A.4-2).

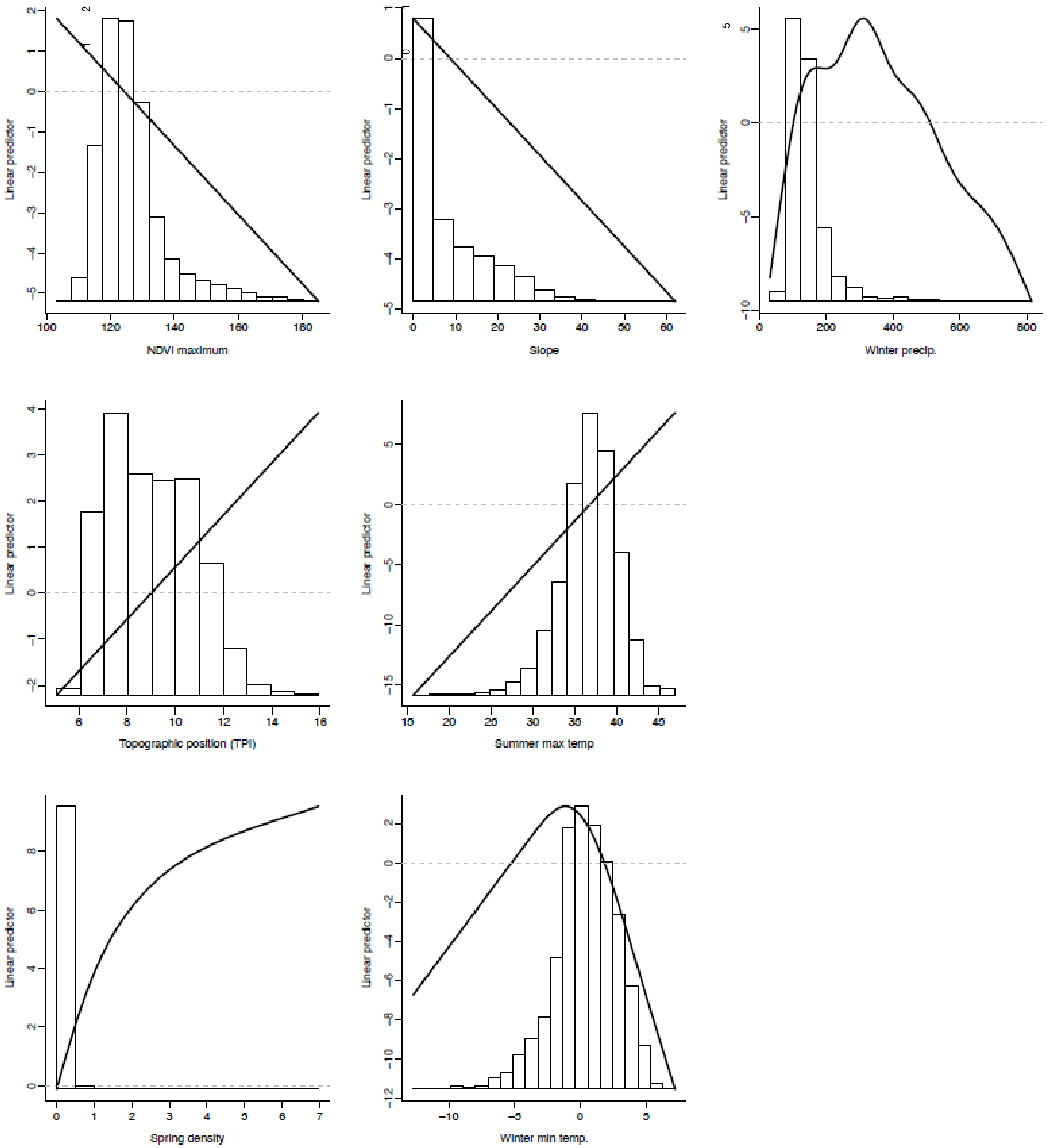


Figure A.4-4. GAM partial response curves for the alkali mariposa lily model illustrated over the distribution of environmental variable inputs in the study area.

A.4.4.2 MaxEnt Model

The MaxEnt model had four variables contributing 10% or more each, accounting for 90% of model contribution (Table A.4-2). The four environmental variables were the same as those contributing to the GAM model, but with different orders of contribution. Winter Minimum Temperature had the highest model contribution (29%) and a peaked response with the highest influence at -2 ºC which is slightly lower than the mean minimum winter temperature distribution across the study area (Figure A.4-5). Winter Precipitation also had a peaked response – predicting increased habitat suitability for alkali mariposa lily in areas with the highest precipitation values in the county. Spring Density had a response curve similar to that of the GAM model, with a positive correlation as spring density increased. Summer Maximum Temperature was positively associated with habitat suitability, increasing sharply at levels above 35 ºC (Figure A.4-5).

Predicted habitat area for the MaxEnt model was extremely limited, with higher levels of habitat predicted only near springs, and with very low, but somewhat widespread levels of habitat suitability in the Pahrump/Trout Canyon and Red Rock Canyon NCA/Blue Diamond areas than the GAM model (Figure A.4-1). The standard error map for this algorithm also had the least areas illustrated with standard error level, and these occurred mostly in and around the areas of predicted habitat (Figure A.4-2).

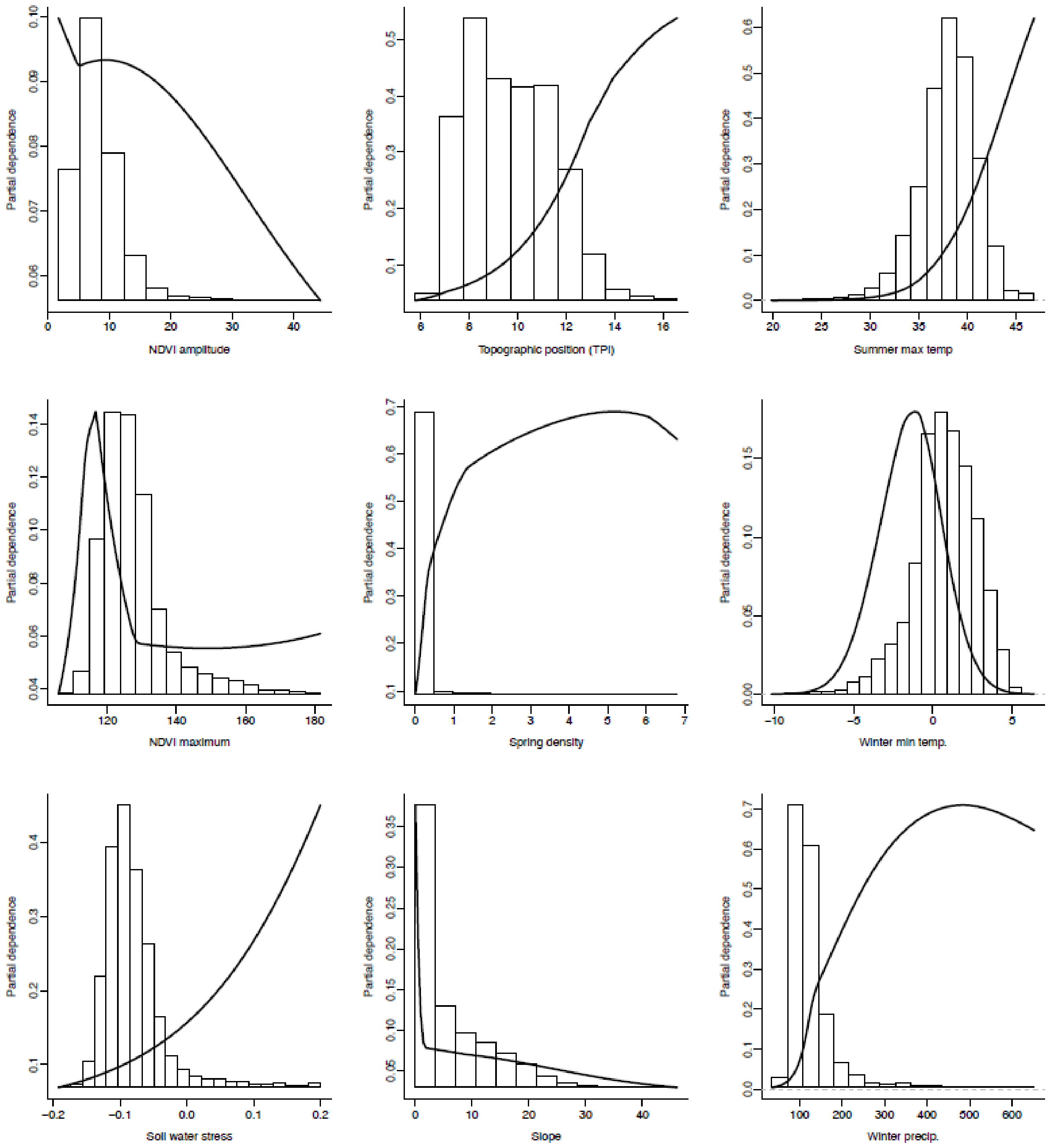


Figure A.4-5. Response surfaces for the top 9 environmental variables included in the MaxEnt ensemble model for alkali mariposa lily.

A.4.4.3 Random Forest Model

The RF models had six environmental variables contributing 10% or more totaling 83% of total model influence. Spring Density was the highest contributing covariate with 20% model contribution (Table A.4-2), and again, sharp positive contributions to all levels with Spring Density above zero (Figure A.4-6). Habitat suitability was higher at lower Winter Minimum Temperatures, and decreased sharply as winter minimum approached 0 ºC. Winter Precipitation had a threshold response, with higher habitat predicted above 100 mm, and peaking above 300mm (Figure A.4-6). Habitat suitability was high only in flatter areas (low slope) with a high Topographic Position index (bottoms of local drainages). Habitat suitability was also higher in areas with a Summer Maximum Temperature above 35 ºC (Figure A.4-6). The RF models also highlighted habitat around springs, but had broader connecting habitat of mid to upper range suitability in and around spring sites. Areas of higher habitat prediction were in the Red Rock Canyon NCA/Blue Diamond area on the west side of the Las Vegas Valley, and the eastern portion of the Pahrump Valley. Other low-level habitat areas are predicted in valleys on the western side of the county and in the springs in the southern portion of Gold Butte National Monument (Figure A.4-1). Standard errors were low throughout the county, with low level error highlighted along the US 95 corridor, Mormon Mesa, and valleys dispersed throughout the county (Figure A.4-2).

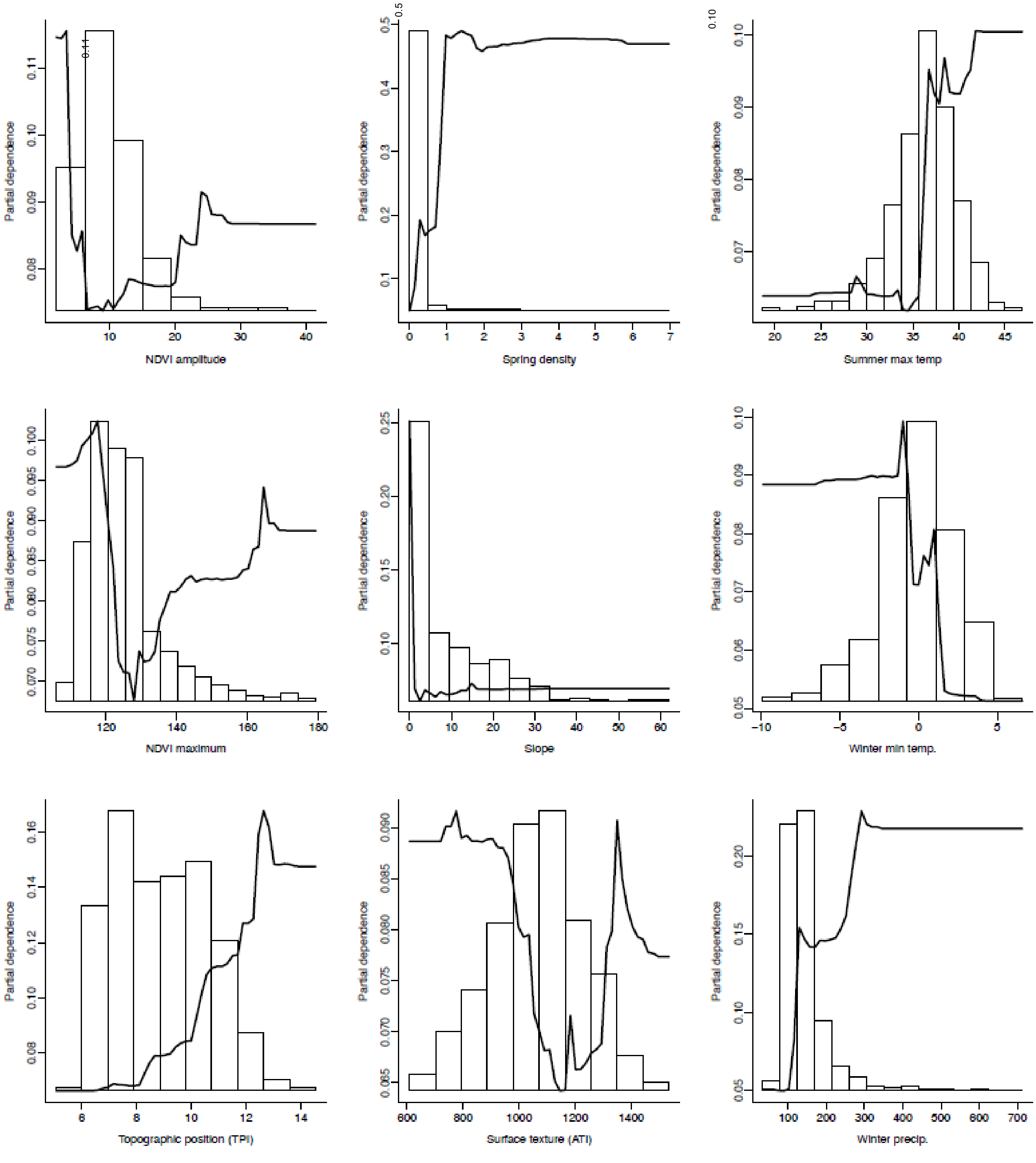
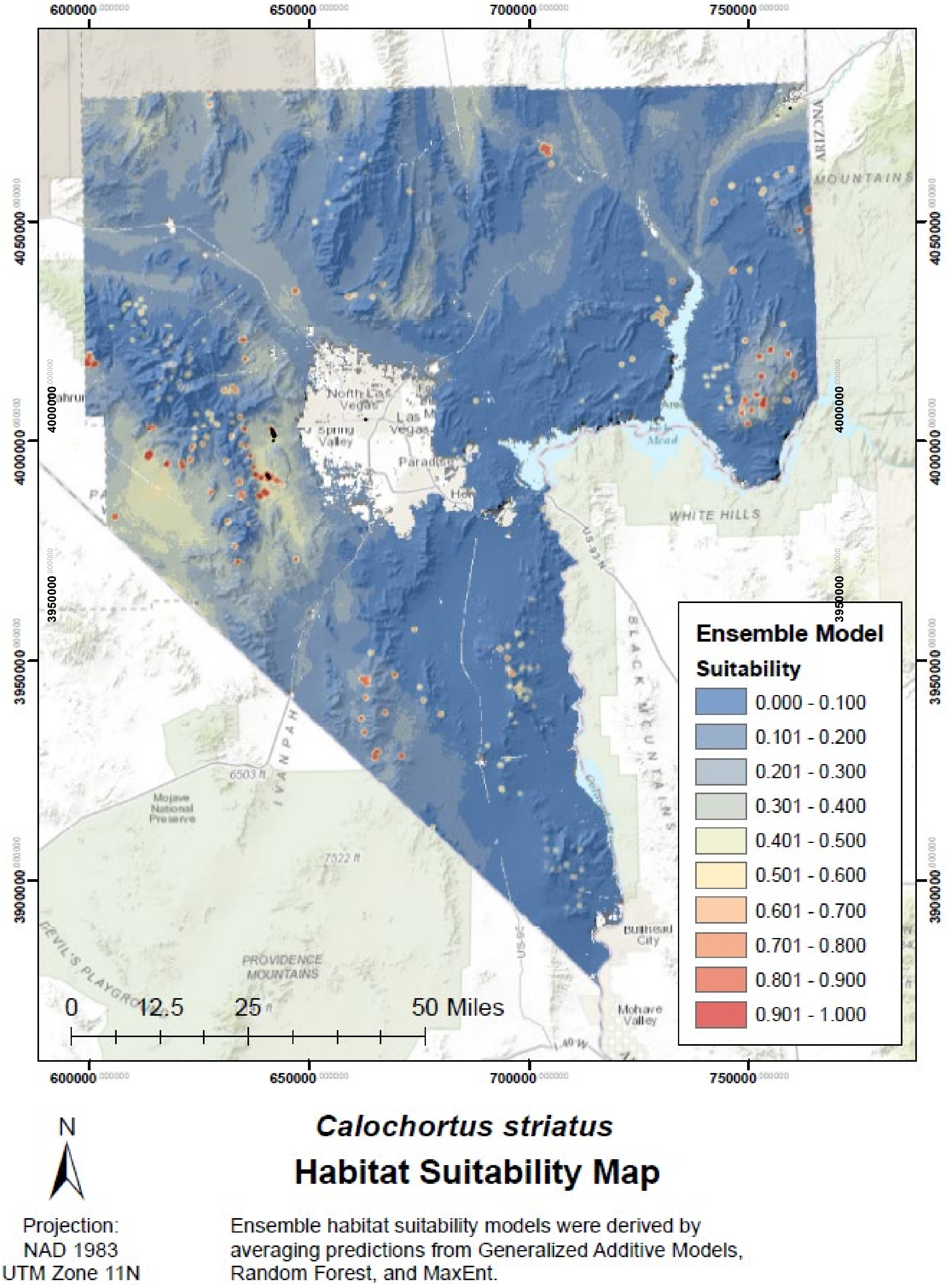


Figure A.4-6. Response surfaces for the environmental variables included in the RF ensemble model for alkali mariposa lily. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability



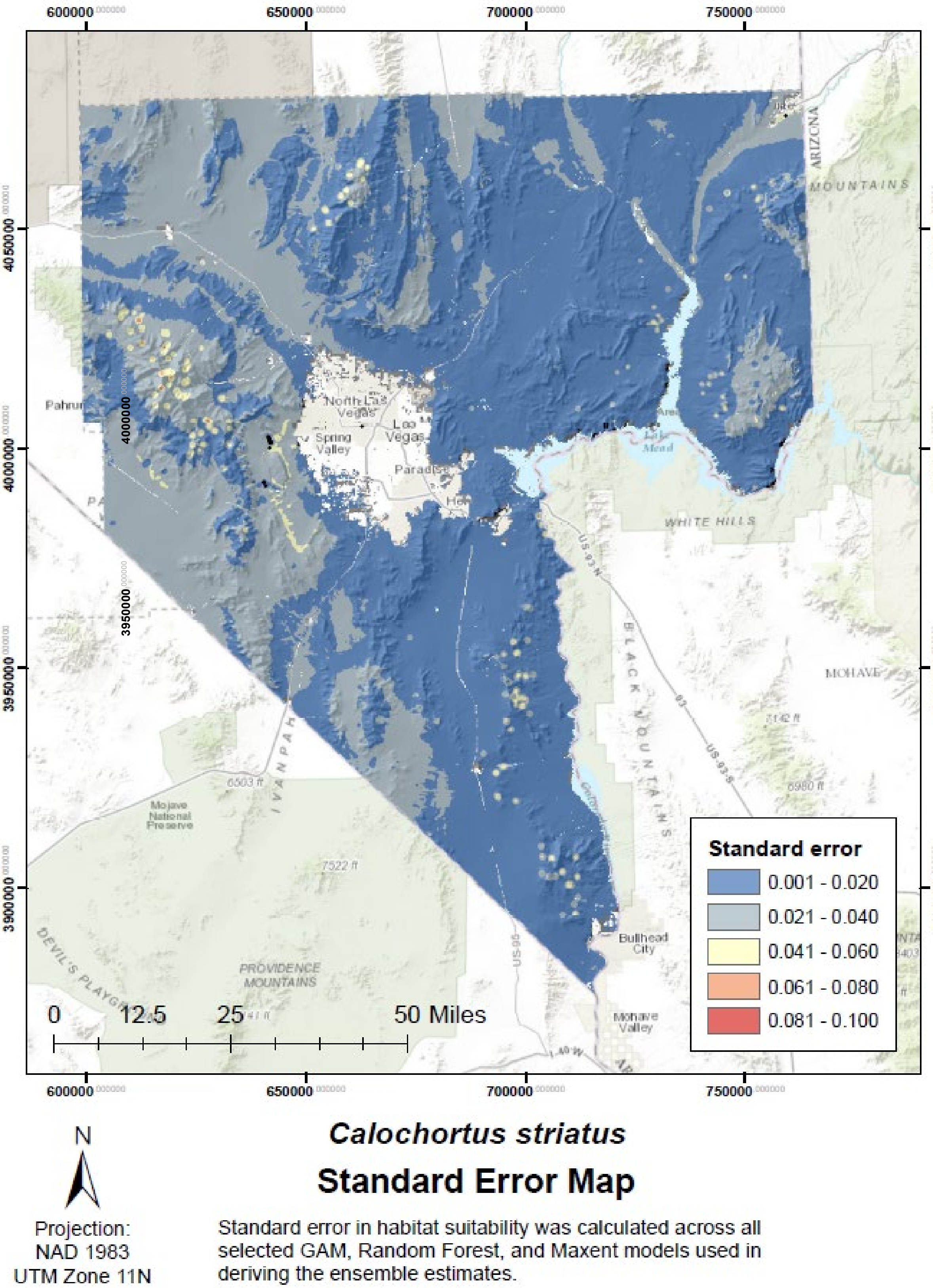
Calochortus striatus

Habitat Suitability Map

Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and MaxEnt.

Figure A.4-7. SDM map for the alkali mariposa lily ensemble model



Calochortus striatus

Standard Error Map

Projection:
NAD 1983
UTM Zone 11N

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

Figure A.4-8. Standard Error map for the alkali mariposa lily ensemble model.

A.4.4.4 Distribution of Localities

Localities (N=127) for alkali mariposa lily are known in Clark County only in the Red Rock Canyon NCA, near Mesquite, and the Blue Diamond area west of Las Vegas (Figure A.4-7).

A.4.4.5 Standard Error

Moderate levels of SE (0.04 – 0.06) are indicated in most spring areas, with lower error levels in valleys throughout the western portion of the county, typically but not always in lower elevation areas (Figure A.4-8).

A.4.5 Distribution and Habitat Use within Clark County

In Clark County, alkali mariposa lily is known to occur within Red Rock Canyon National Conservation Area, specifically at Calico Springs, Red Springs, Ash Springs, and Lone Willow Springs (Mozingo and Williams 1980, BLM 2005).

This species is found in alkaline meadows and moist creosote-bush scrub ranging in elevation from 800-1400 meters (Baldwin 2002). It grows in calcium-rich sandy soil (Fiedler 1985) in seasonally moist alkaline habitats (Mozingo and Williams 1980), ephemeral washes, vernal moist depressions, at seeps within saltbush scrub (*Atriplex* spp.) (Fiedler and Ness 1993), in chaparral habitat, and in Mojave Desert scrub (CNPS 2016). The plant is not found on soil with surface salts, or in wetter areas with permanent standing water (Mitchell 1988 *cited in* Green and Sanders 2006).

Associated plants include *Distichlis spicata var. stricta*, *Cleomella brevipes*, *Iva acerosa*, *Anemopsis californica*, and *Dodecathon pulchellum var. pulchellum* (Knight and Clemmer 1987). Its predicted habitat among Clark County ecosystems indicates that this is likely a rare/sparsely distributed species, with low areas of high suitability habitat predicted in Blackbrush, and to a lesser extent Mojave Desert Scrub (Table A.4-3). Moderate habitat is predicted more broadly in these habitats, among many others with the lowest habitat area predicted for the higher elevation ecosystems (Table A.4-3).

Modeled habitat in the county is predicted to be high in the foothill areas generally surrounding the localities. Pockets of habitat are predicted at springs throughout the county due to the strong association of known localities to springs (Figure A.4-7. Lower levels of habitat suitability are found surrounding the localities east of the spring range, and in the Pahrump/Trout Canyon/Sandy valley area (Figure A.4-7). However, consistent with current databases, alkali mariposa lily is not documented in the Desert Range at this time (Ackerman 2003). Other isolated patches of habitat are predicted throughout the county, typically associated with springs (e.g., Warm Springs – northwest of Moapa, Rogers Spring, and southern Gold Butte NM).

Table A.4-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	352595	54112	7950
Bristlecone Pine	7513	50	0
Desert Riparian	7733	2190	137
Mesquite Acacia	17554	1182	521
Mixed Conifer	26911	422	0
Mojave Desert Scrub	1177042	78426	2619
Pinyon Juniper	110078	4302	1443
Sagebrush	4620	61	26
Salt Desert Scrub	71652	5216	111

A.4.6 Ecosystem Level Threats

Threats to the alkaline meadow habitat of alkali mariposa lily include grazing and urbanization, trampling, road construction, and hydrological alterations such as water diversions that result in lowering the water table. Horticultural collecting and non- native plant invasions are also thought to be possible potential threats (Baldwin 2002, CNPS 2016).

Lowering water tables is thought to be the greatest threat to alkali mariposa lily. Another imminent threat is urbanization, especially in Lancaster, California, where the largest populations exist. Trampling and grazing have the potential to reduce reproductive capacity of the species (Tollefson 1992). Road construction is also a threat. One known population was extirpated at Whiskey Springs in the 1920's by the construction of Highway 18 (CDFG 1997b). The Cushenbury Springs population was indirectly affected by the expansion of Kaiser Cement in 1988, which resulted in diversion of water flow from the spring and the addition of a parking lot (CDFG 1997b). In the Kern River Preserve, it is suspected that competition among taller grasses and non-native barley species may be contributing to population declines, but this may not be an applicable threat to all populations (Tollefson 1992).

A.4.7 Threats to Species

According to Greene and Sanders (2006) alkali mariposa lily faces four major threats:

1. Lowering water tables
2. Grazing
3. Competition with weedy species

4. Land development

These are all potential threats faced by the known populations of alkali mariposa lily in Clark County, all of which lie within Red Rock Canyon National Conservation Area (RRCNCA). The Conservation Area is used heavily for recreational purposes, receiving approximately half a million visitors annually. The proximity of private property to wildlife habitat and riparian systems within RRCNCA is also a concern (BLM 1998, BLM 2005).

Greene and Sanders (2006) suggest that negotiating with local water authorities is necessary to maintain/restore water tables to historic water levels and removing and/or modifying obstructions to natural springs or seep flows.

Feral horses and burros can cause extensive damage to riparian areas by residing near water sources and springs, causing trampling and grazing of vegetation, soil churning, erosion, and the reduction of spring flow. alkali mariposa lily depends on sheet flows (CNPS 2016) and thus could be exposed to these indirect effects from horse and burro activity. Soil and vegetation disturbance from horses and burros could also indirectly increase the amount of invasive plants (BLM 2005). This resulting competition with non-native plants could have the potential to outcompete populations of alkali mariposa lily (Tollefson 1992). Horse and burro trails have the potential to further increase human activity, which could bring human-related disturbance to these sensitive populations of alkali mariposa lily. Greene and Sanders (2006) suggest fencing off known populations to prevent livestock from trampling and grazing, as well as non-native weed management in order to improve reproductive success of the species.

A.4.8 Existing Conservation Areas/Management Actions

The known Clark County populations of alkali mariposa lily exists within Red Rock Canyon National Conservation Area (RRCNCA), an established conservation area managed by the Bureau of Land Management. Because of this, some of the threats to populations that exist in other areas are not applicable to the Clark County population.

The Red Rock Canyon National Conservation Area Resource Management Plan recommends conducting an ongoing program of population monitoring for this species (BLM 2005). It also recommends the management of humans, burros, and horses to protect riparian habitat (BLM 2005).

Authorized off-roading recreation and development are not pertinent concerns to the Clark County population of alkali mariposa lily, as all motor vehicles are limited to designated roads in the RRCNCA (BLM 2005).

The RRCNCA management plan states that the management plan for Red Spring requires further review due to its ecological sensitivity, but should continue to provide interpretive and picnicking opportunities (BLM 2005).

The plan also calls for the removal of burros from Calico Basin, rerouting trails out of riparian areas near Red Springs, fencing spring sources where needed, and eliminating tamarisk from 15 springs which will reduce salt loading to the surface water and reduce competition among native species (BLM 2005). These could all have potential beneficial effects for existing alkali mariposa lily populations within RRCNCA.

Due to its requirements for wetter environments and sheet flows, hydrology plays an essential role in maintaining existing alkali mariposa lily populations (CNPS 2016). Periodic natural inundation for the species is important (Edwards AFB 2002). As of 2003, The California Native Plant Society does not accept maintaining sheet flow as an acceptable long-term conservation strategy as they do not recognize any guarantees in maintaining sheet flows that the species relies on. The CNPS suggests appropriating water rights as an option for assuring continued water to alkali mariposa lily habitat. CNPS supports the acquisition of isolated springs, seeps, and meadows from sellers for species conservation, but warns that these should not be counted on as assurance for conservation due to these types of acquisitions/conservation areas would not be assured. The CNPS supports the establishment of conservation areas within the range of alkali mariposa lily. CNPS suggests grazing restrictions through the fruit maturation period at Green Spring in Kelso Valley to allow for seed dispersal as opposed to take permits (CNPS 2016).

Long term monitoring is required to protect this species due to large fluctuations in population numbers (Tollefson 1992).

A.5 BLUE DIAMOND CHOLLA (*CYLINDROPUNTIA MULTIGENICULATA*)

Blue Diamond cholla (*Cylindropuntia multigeniculata*), once thought to be precinctive to Clark County Nevada, is considered by the State of Nevada to be critically endangered. Despite concern for this species, little information exists on its habitat affinities or environmental requirements. It was formerly considered a hybrid subspecies (Hunt et al. 2006). They are sometimes hard to distinguish from other closely related species as they hybridize with *C. acanthocarpa* (Baker 2005), and many of the others are closely related polyploids of similar ancestral origin, but have since been recognized as a full species (Baker and Cloud-Hughes 2014).

A.5.1 Species Status

This species was once considered for federal listing due to its rarity (Baker 2005), but was removed from the candidate list due to a conservation agreement designed to reduce threats to this species and its habitat (USFWS 2001). This agreement apparently consists of provisions within the BLM Red Rock Canyon NCA conservation plan, and is designed to protect 83% of its known habitat (Clark County 2000, BLM 2005). Recent legislation has supported land exchanges to protect habitat for this species near the type locality with the BLM Red Rock Canyon NCA (S.B.159, 2013).

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No Status

State of Nevada (NAC 527): Critically endangered

NV Natural Heritage Program: Global Rank G2 State Rank S2

IUCN Red List (v 3.1): Least Concern

CITES: Appendix ii

A.5.2 Range

Blue Diamond cholla is found in several sparsely distributed locations, most of them in Clark County, Nevada. They range from Gass Peak in North Las Vegas south to just north of Blue Diamond, Nevada (the type locality) and southeast into the McCullough range including the Sloan Canyon National Conservation Area [NCA] (Baker 2005, Baker and Cloud-Hughes 2014). They also inhabit Gold Butte near Bonelli Peak and along the southern margin of Gold Butte just north of Lake Mead (Baker 2005, Nussear et al. 2011), and in Mohave County Arizona in the Black Mountains and White Hills near Willow Springs Ranch (Baker 2005, Baker and Cloud-Hughes 2014, Beckstrom et al. 2014).

A.5.3 Population Trends

While formerly a candidate for federal listing, consideration was removed in 2001 due to a conservation agreement that satisfied the perceived need for protection by the USFWS (USFWS 2001). This conservation agreement included the type locality and was within the conservation plan for the Red Rock Canyon NCA (BLM 2005). The IUCN lists this species as one of least concern, citing that while this species does have a restricted range the species is known from ten subpopulations, most of which occur in protected areas, with no significant threats to its persistence identified, and listing the current population trend as stable (IUCN 2013).

A.5.4 Habitat Model

Blue diamond cholla was modeled using 162 localities and was predicted to be in similar areas throughout Clark County by the three modeling algorithms and the subsequent ensemble model, with differences apparent in the magnitude of the suitability scores, but similar in most other aspects (Figure A.5-1). Performance was highest for the Ensemble Model, followed by the RF model, which had higher AUC and TSS than the other models. The MaxEnt model ranked third and the GAM model had the lowest performance, although it should be noted that all four of the models had very good performance among all performance measures (Table A.5-1). Standard error maps for the models indicated that the GAM model had the highest level of SE with more patches of higher values (SE 0.06 – 0.08) and moderate values (0.04 – 0.06) throughout the county, but most prominently in mountainous areas in the Spring, Sheep, and McCullough ranges, and in the Virgin Mountains. The MaxEnt model had a similar pattern of SE, but with moderate levels of error, while the RF model tended to have more error in lower slopes than the other two algorithms (Figure A.5-2).

The CBI for the Ensemble mode indicated good model performance (Figure A.5-3), and was the second highest reported BI compared to the three algorithms. Approximated bins for the ensemble model based on the CBI were 0-0.42 unsuitable, 0.43-0.65 marginal, 0.65 to 0.7 suitable, and 0.7 -1 optimal habitat; with a suggested cutoff threshold of ~ 0.6 (Figure A.5-3) while the threshold value calculated from ROC statistics for the ensemble model was 0.64 (Table A.5-1).

Table A.5-1. Model performance values for Blue Diamond cholla models

Performance	**GAM**	**RF**	**MaxEnt**	**Ensemble**
AUC	0.934	0.986	0.953	0.963
BI	0.699	0.551	0.587	0.61
TSS	0.852	0.94	0.857	0.887
Correlation	0.511	0.604	0.694	0.84
Cut-off*	0.638	0.753	0.46	0.643

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.5-2. Percent contributions for input variables for Blue Diamond cholla for ensemble models using GAM, MaxEnt and RF algorithms

Term	GAM	RF	Max	Avg
Summer Heat/Moisture Index	34.9	12.0	29.8	27.2
Summer Max Temp	4.0	8.1	15.1	10.2
Summer Precipitation	0.0	10.8	12.9	9.4
Winter Precipitation	0.0	9.5	11.4	8.3
Topographic Position (TPI)	0.0	11.8	8.0	8.3
NDVI Maximum	17.8	10.6	7.4	13.4
Roughness (TRI)	32.4	15.0	7.4	20.4
Surface Texture (ATI)	5.1	10.6	5.8	8.7
Winter Min Temp	5.8	6.9	1.3	5.6
Temperature Range	0.0	4.6	0.5	2.4
Slope	0.0	0.0	0.4	0.1

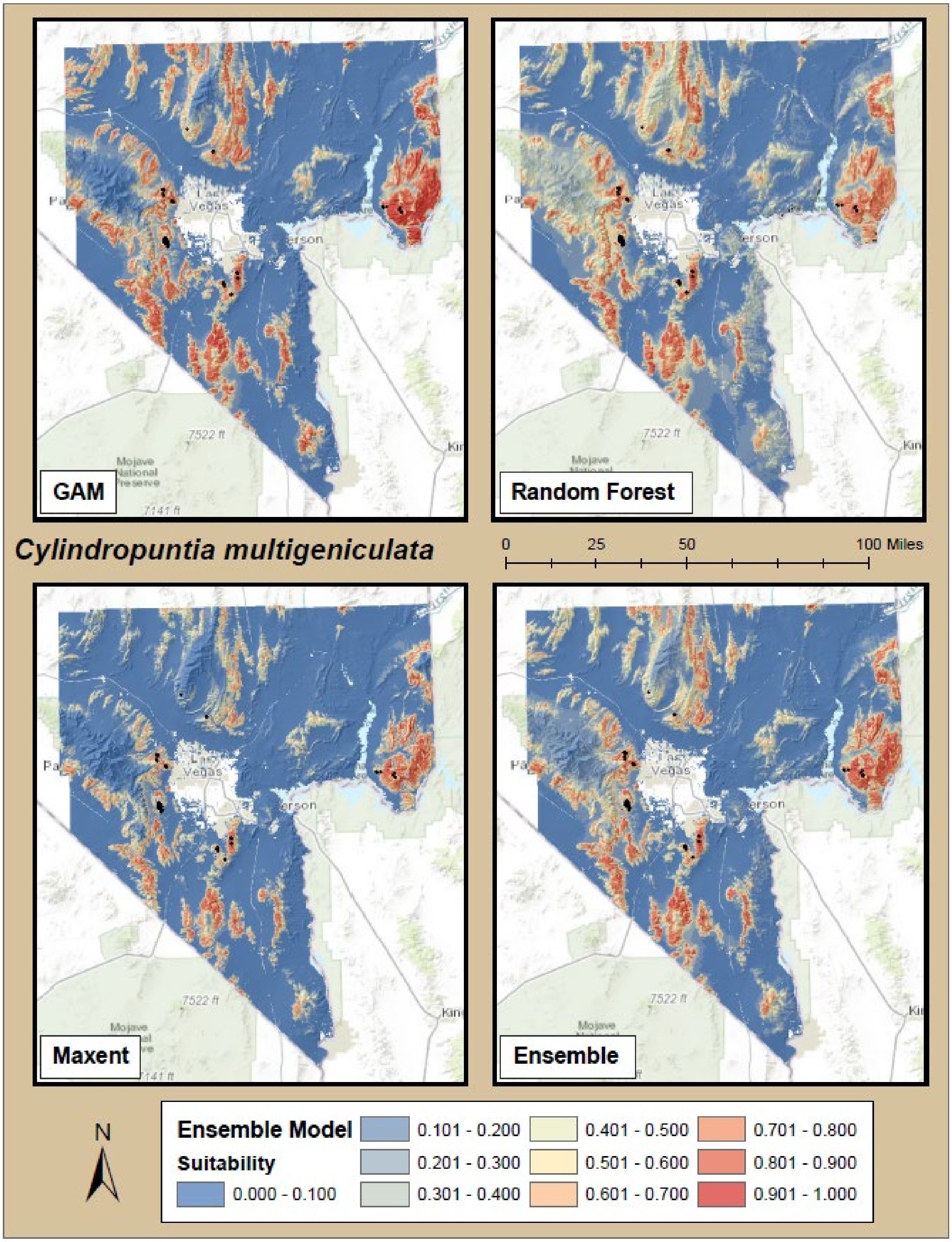


Figure A.5-1. SDM maps for Blue Diamond cholla for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

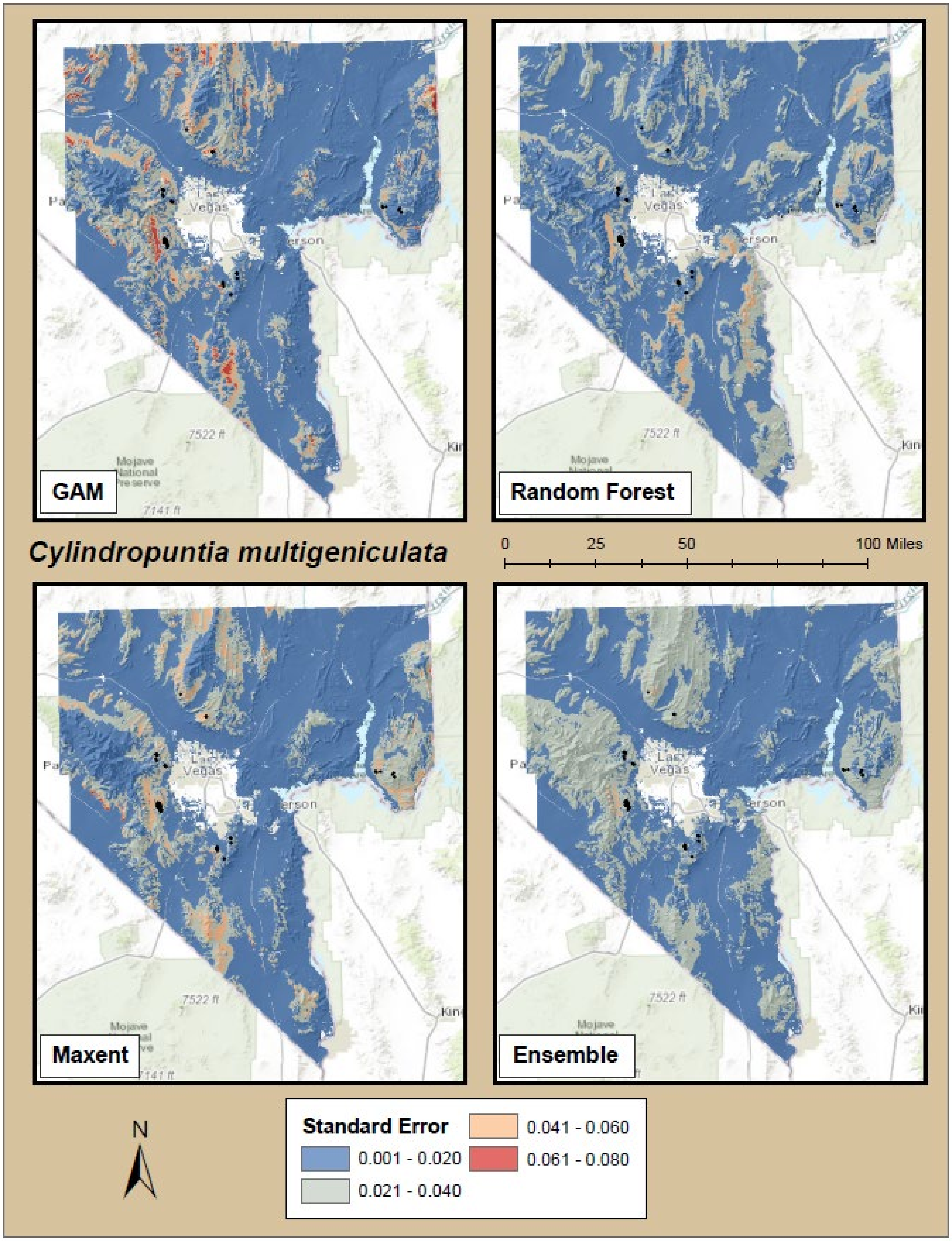


Figure A.5-2. Standard error maps for Blue Diamond cholla models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

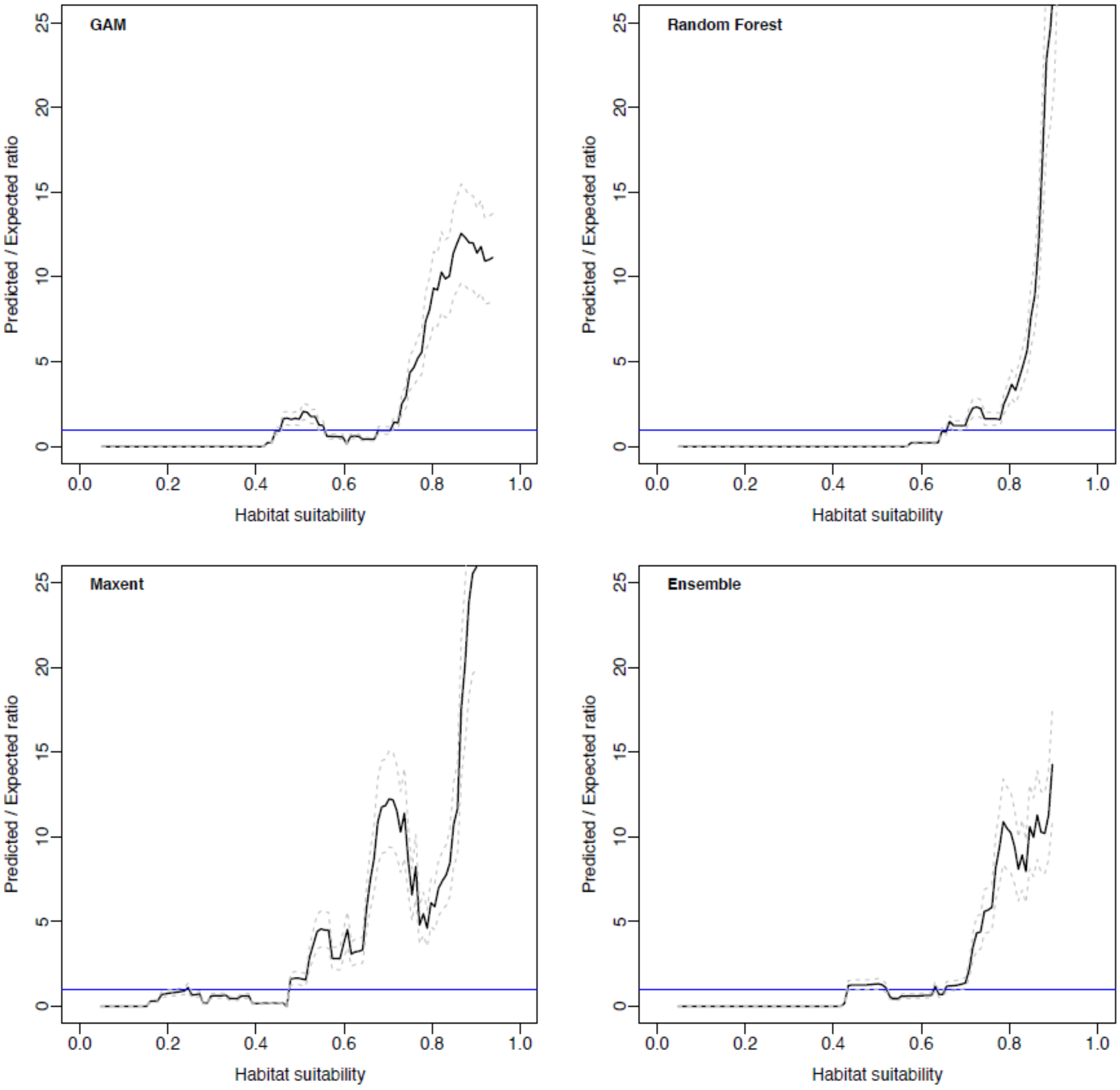


Figure A.5-3. Continuous Boyce Indices for Blue Diamond cholla models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

A.5.4.1 GAM model

The GAM model ensemble identified 3 contributing variables with more than 10% contribution toward the model representing 85% of the model contribution (Table A.5-2). The summer heat/moisture index had 35% contribution and was negatively related to predicted habitat suitability. Surface Roughness was the second highest contributor with 32% influence with a partial response curve indicating higher habitat values at intermediated levels of Roughness. NDVI Maximum also predicted higher values at lower levels that were near the most common values for this indicator in the study area, as the response curve matched the peak histogram most closely (Figure A.5-4). Lower contributions were from Winter Minimum Temperature, Surface Texture, and Summer Maximum Temperature, with higher predictions of suitability positively related to both temperature measures, and at moderate levels of surface temperatures, indicating rockier slopes at lower elevations (Figure A.5-4). None of the remaining variables Summer Precipitation, Winter Precipitation, Topographic Position (TPI), NDVI Maximum, Roughness (TRI), Surface Texture (ATI), Winter Min Temp, Temperature Range, Slope provided input to the model (Table A.5-2).

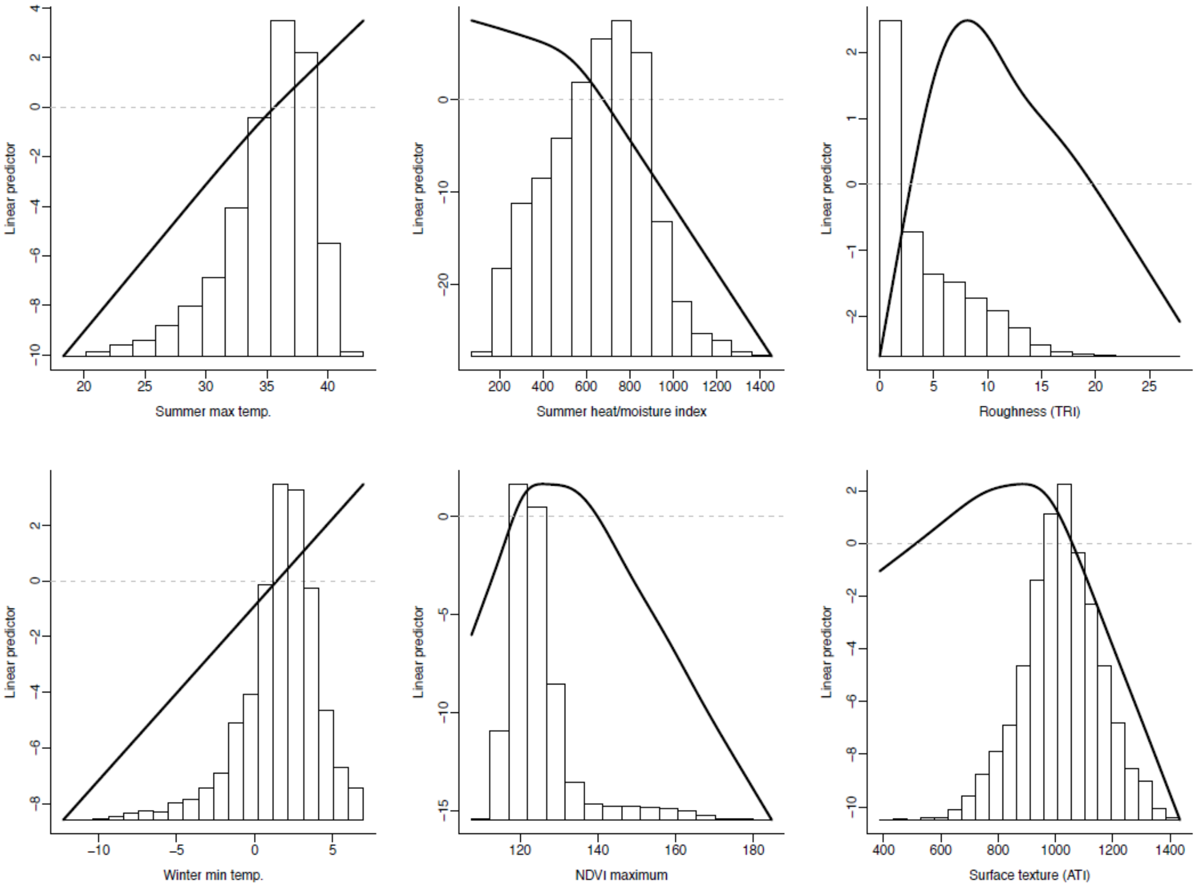


Figure A.5-4. GAM partial response curves for the Blue Diamond cholla model overlaid over distribution of environmental variable inputs in the study area.

A.5.4.2 MaxEnt Model

The MaxEnt model had four variables contributing 10% or more each, accounting for 70% of model contribution, with an additional four contributing 5-7% (Table A.5-2). The Summer Heat/Moisture index was the highest contributing covariate (30%) with higher suitability in areas with a lower index falling sharply above values of 400. This corresponds to high suitability in areas that tended to have higher temperatures and lower amounts of summer rains. Summer Maximum Temperature and Summer and Winter Precipitation were also strong contributors, with higher habitat suitability in areas of lower Summer Precipitation, higher Summer Maximum temperatures, and higher Winter Precipitation (Figure A.5-5).

The standard error map for this algorithm showed areas of moderate uncertainty among the models (SE of 0.04 to 0.06) in what appear to be lower slopes and bajadas throughout the county (Figure A.5-2). Of particular note regarding high standard error among the four models, are the bajada habitats in Red Rock Canyon NCA, and south- facing slopes at the southern end of Sheep Peak, in the Sheep Range. MaxEnt model performed third among the four models, with strong performance overall and a Continuous Boyce Index indicating strong performance (Table A.5-1, Figure A.5-3).

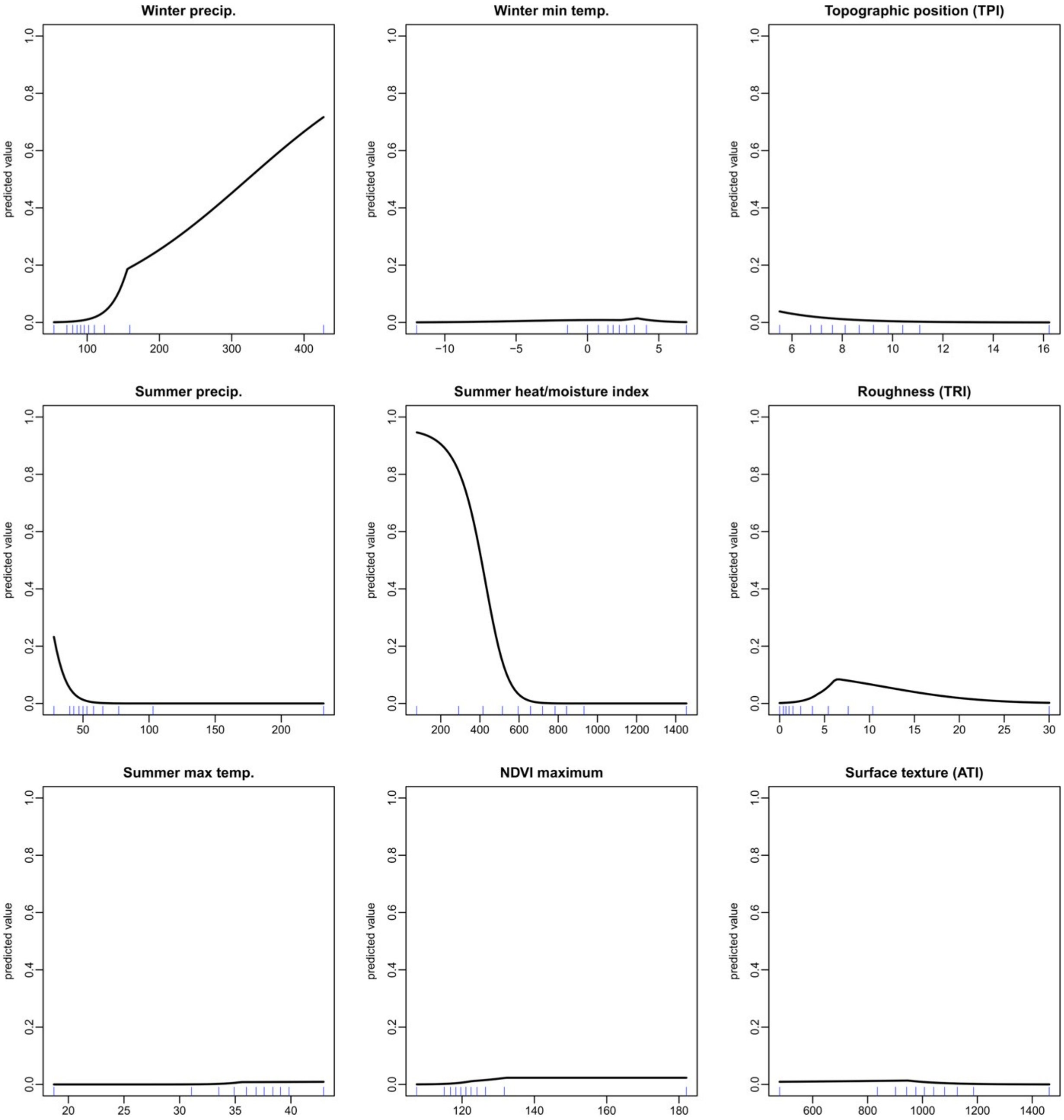


Figure A.5-5. Response surfaces for the top 9 environmental variables included in the MaxEnt ensemble model for Blue Diamond cholla.

A.5.4.3 Random Forest Model

The RF models had seven environmental variables contributing 9% or more totaling 80% of total model influence, but had relatively even contribution across all variables. The seven highest contributing variables were: Roughness (TRI), Summer Heat/Moisture Index, Topographic Position (TPI), Summer Precipitation, Surface Texture (ATI), NDVI Maximum, and Winter Precipitation (Table A.5-2). Habitat suitability was predicted by the RF model to be greatest in areas of higher surface roughness, with a lower Summer Heat/Moisture Index, with somewhat elevated levels of summer precipitation (Figure A.5-6) – in contrast to the results of the MaxEnt partial response (Figure A.5-5). Predicted habitat tended to be higher in the local watershed, with a peak in Surface Texture, possibly indicating an affinity for the surficial geology corresponding with that value, tending toward rockier habitats likely moderate sized rocky surfaces, with a lack of habitat predicted on sandier surfaces.

Standard error maps for this model were similar to those for the GAM model with low levels of error spread throughout the county largely in lowland areas, but with moderate levels of uncertainty near the type location, in the Newberry Mountains, on the eastern slopes of the Highland range, and in lower elevation slopes throughout Gold Butte (Figure A.5-2). This was the second best performing model overall among all models, with the exception of the Boyce Index which was the lowest among the four (Table A.5-1), and the CBI which had little response below values of 0.6 (Figure A.5-2).

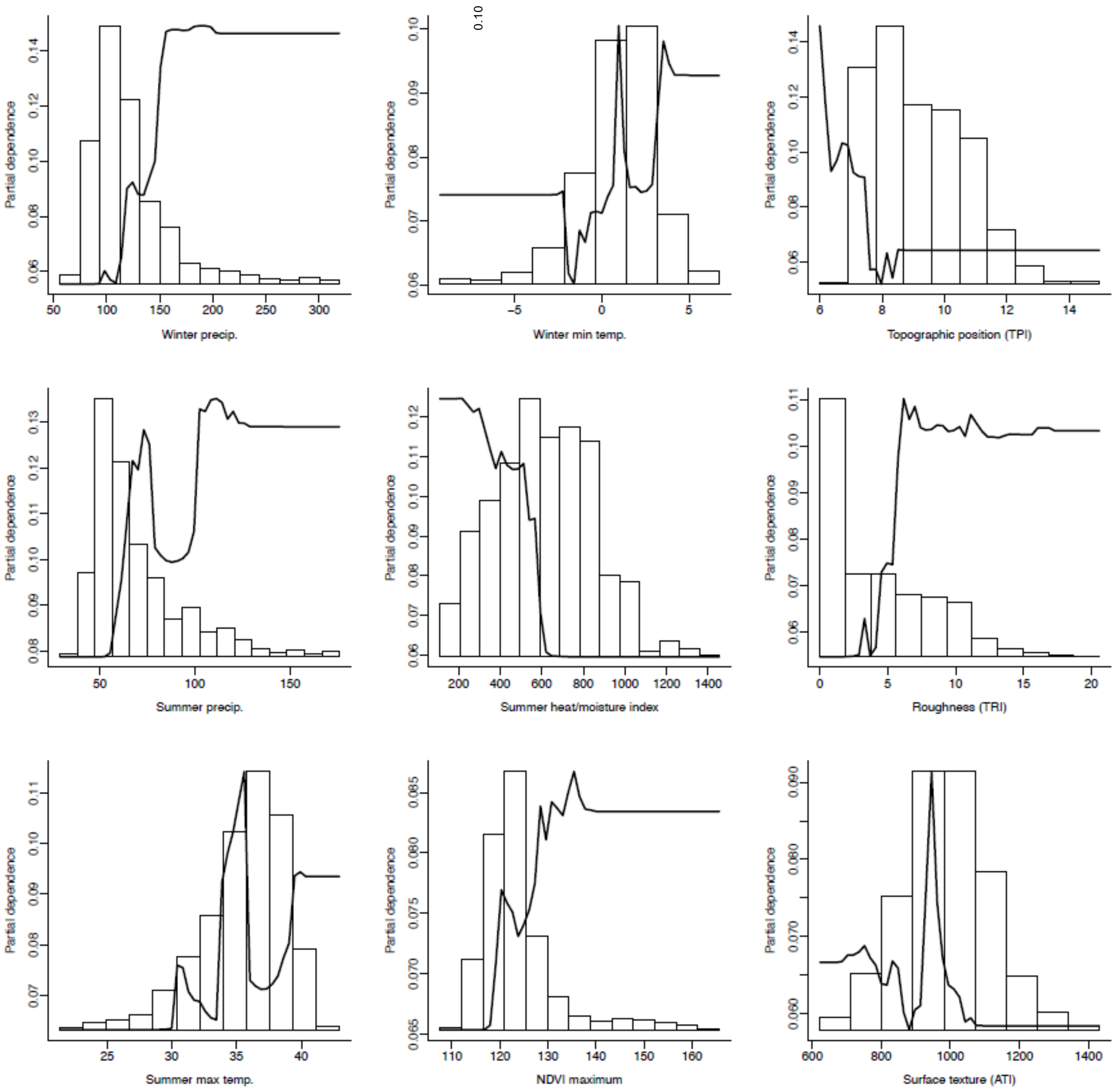
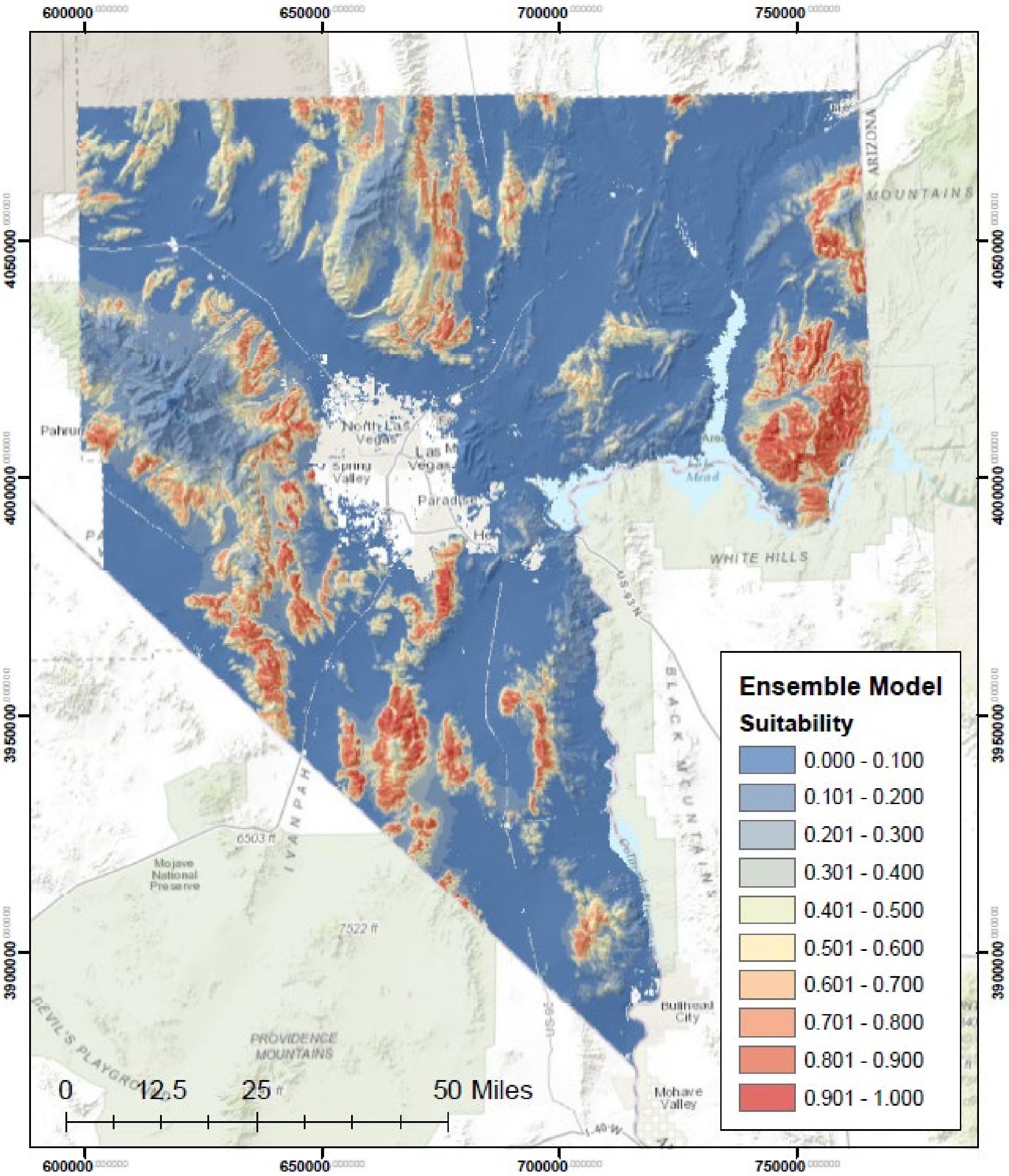


Figure A.5-6. Response surfaces for the environmental variables included in the RF ensemble model for Blue Diamond cholla. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis



N

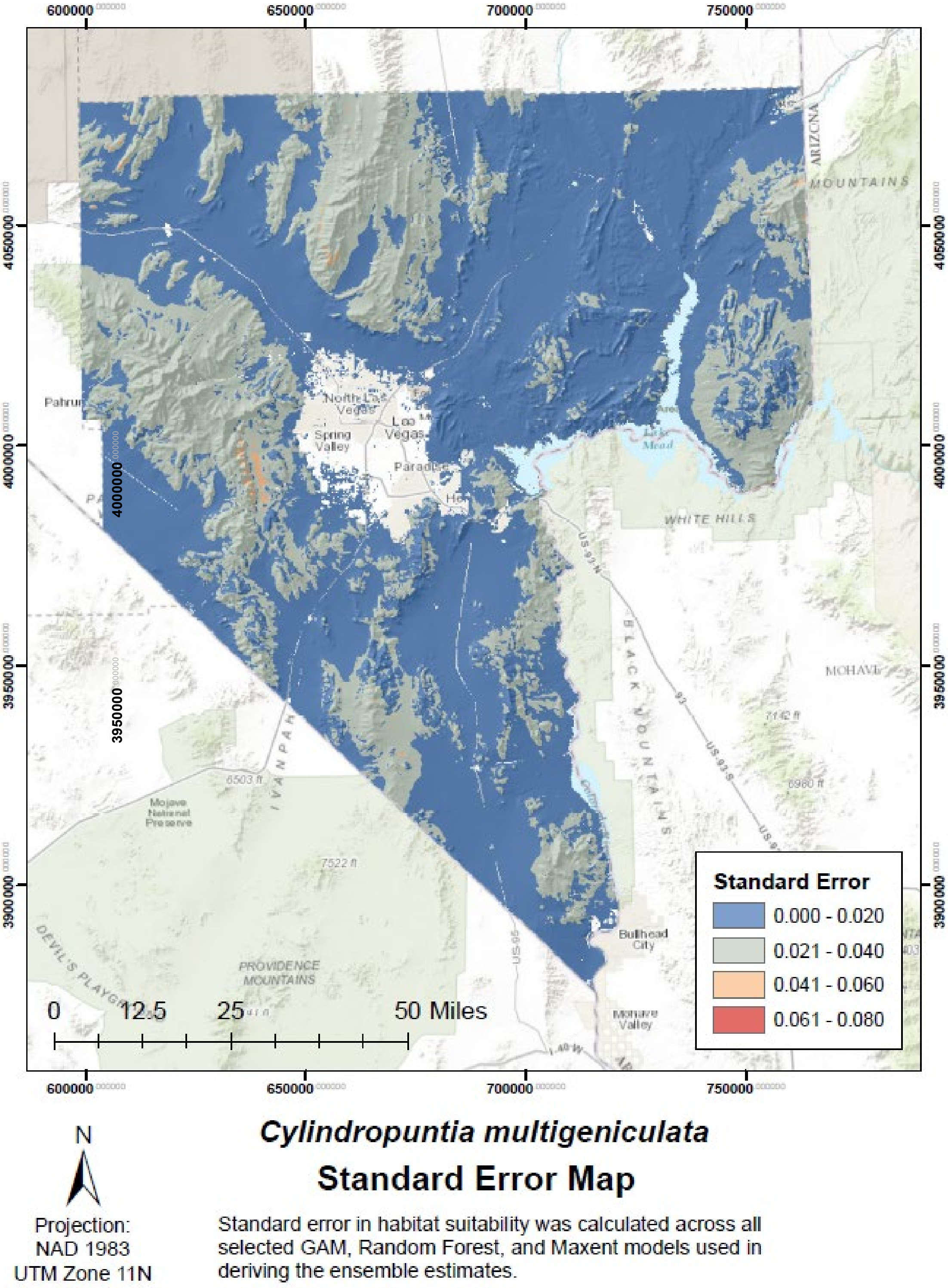
Cylindropuntia multigeniculata

Habitat Suitability Map

Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and MaxEnt.

Figure A.5-7. SDM map for the Blue Diamond cholla ensemble model.



Cylindropuntia multigeniculata

Standard Error Map

Projection:
NAD 1983
UTM Zone 11N

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

Figure A.5-8. Standard Error map for the *Blue Diamond cholla* ensemble model.

A.5.4.4 Distribution of Localities

Localities for Blue Diamond cholla are locally distributed in Clark County with only 162 observations. Most of the localities are distributed in clusters surrounding the Las Vegas valley with the exception of the northeast corridor (southern end of the Sheep Range). Two additional clusters occur in the mountains near the Gold Butte town site. (Figure A.5-1).

A.5.4.5 Standard Error

The standard error for the habitat suitability model for Blue Diamond cholla indicates low to generally low error throughout the majority of the mountainous areas in Clark County, with a SE of 0.02 – 0.04. One patch of moderate error (SE 0.04 to 0.06) occurs in the valley just east of the Spring Mountains on the bajadas in Red Rock NCA north of Blue Diamond – where the species was first described (Figure A.5-8).

A.5.5 Distribution and Habitat Use within Clark County

Within Clark County this species has been reported north of Blue Diamond, Nevada (type locality), in Sloan Canyon, near Gass Peak, and in Gold Butte near Bonelli Peak (Baker 2005, Nussear et al. 2011, Baker and Cloud-Hughes 2014).

Individuals of this cactus occur on limestone soils near the type locality west of Las Vegas as well as volcanic soils derived from basalt and granite for other populations. Aspect varies across known sites, and plants are typically associated with steep, dry, rocky slopes or washes with large rocks or boulders and with minimal vegetation cover (Baker 2005). Individuals of this species may be associated with overlying gypsum beds located up-slope, and typically co-occur with succulents and shrubs associated with vegetation dominated by creosote bush or blackbrush (NNHP 2001). Nussear et al. (2011) modeled this species in the Gold Butte area and found positive associations with proximity to volcanic and metamorphic, carbonate and sedimentary rock deposits, and in areas of moderate surface roughness with low flow accumulation. A broad elevational range for Blue Diamond cholla has been noted as 610 – 915 m (Baker 2005) and 1093-1295 m (NNHP 2001b), while Nussear et al. (2011) reported a range of 790 – 1420 m in their habitat suitability modeling. Habitat for this species is predominantly in Mojave Desert Scrub, Blackbrush and Pinyon Juniper ecosystems, with moderate habitat similarly distributed, but potentially including Salt Desert Scrub (Table A.5-3).

Modeled Habitat in the county is predicted to be high in middle elevation ranges surrounding Las Vegas, especially so in the southern extent of the Spring Range, Jean, and Goodsprings. The rockier portions of the McCullough range near Sloan Canyon, the slopes surrounding the Lucy Gray mountains, the low portions of the Virgin Mountains and in the middle elevation mountains in the southern portion of Gold Butte also are predicted to be good habitat (Figure A.5-7).

Among predictors for the Blue Diamond cholla habitat suitability model areas of high temperatures and low precipitation were identified. This is consistent with habitat descriptions discussed by Baker (2005). While previous work considered low winter temperatures to be a likely habitat-limiting factor for the distribution of the Blue Diamond cholla (Baker 2005), habitat suitability models found minimum winter temperatures to be of relatively low value among predictors, although it was quantifiable.

Table A.5-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	129312	137234	147979
Bristlecone Pine	7564	0	0
Desert Riparian	10468	162	0
Mesquite Acacia	17660	1290	751
Mixed Conifer	27262	73	0
Mojave Desert Scrub	1119667	102011	58028
Pinyon Juniper	72702	32753	10161
Sagebrush	3608	942	152
Salt Desert Scrub	63636	13693	1437

A.5.6 Ecosystem Level Threats

Desert fires have previously influenced the Blue Diamond cholla, and will continue to be an ecosystem threat. However, the steep, rocky terrain occupied by this species also provides some inherent level of protection due to the sparseness of vegetation. The lack of fuel continuity makes fires patchier in such habitats, and thus less prone to widespread damage.

A.5.7 Threats to Species

This species has been threatened directly by wildfire, and habitat loss (e.g. due to gypsum mining and road building, Baker 2005). Due to the rocky and steep terrain, this species is unlikely to be impacted significantly by OHV activity.

A.5.8 Existing Conservation Areas/Management Actions

Within the Red Rock Canyon NCA, multi-agency and stakeholder agreements have been put in place to protect habitat for this species by limiting mining development, and by implementing fire prevention and suppression plans (BLM 2005). This species also inhabits the Sloan Canyon NCA and wilderness, and would be similarly protected (BLM 2009).

A.6 SILVERLEAF SUNRAY (*ENCELIOPSIS ARGOPHYLLA*)

Silverleaf sunray (*Enceliopsis argophylla*) is a silvery gray plant that grows in sparsely vegetated, low elevation country on soils where few other plants grow. They have relatively large leaves, a thick tap root, and the flowers rise on leafless stalks with a large yellow sunflower-like inflorescence. They are spectacular to see thriving in such a hot environment. The silvery leaf surfaces of silverleaf sunray stems result from small plant hairs known as trichomes that occur on the surface of the leaves (Ehleringer 1984) and protect the plants from over-exposure to the strong desert sunlight in the very sparse environments they inhabit. The dense, straight-haired trichomes (Cronquist et al. 1994) reduce incidental solar radiation and are known to reduce temperature, thus influencing photosynthetic and transpiration rates (Ehleringer 1984). This species was formerly known as *Tithonia argophylla* (Cronquist 1994). The type locality for this species is reportedly near St. Thomas, Nevada and has been mostly under the surface of Lake Mead for almost 80 years (Cronquist 1994). This species has been found on gypsum deposits and sandy soils, and even in roadsides where the correct soils exist (i.e. along a roadside in Lake Mead National Park).

Researchers sampled pollinators of Silverleaf sunray on either side of Lake Mead in Mohave County, California and Clark County, Nevada. One bee species that visited the plants included an obligate specialist *Andrena balsamorhizae* to this *Enceliopsis* (Griswold et al. 2006). Other bees that visited silverleaf sunray but do not specialize on it included: *Xeralictus bicuspiadariae, Perdita meconis, P. mohavensis, Lasioglossum sisymbrii,* and an undetermined species of *Lasioglossum.* (Griswold et al. 2006).

As with some other ground-nesting bees (Cane 1992), the Mojave Gypsum Bee (*Andrena balsamorhizae)* has a restricted distribution by its need for gypsum soils, and also limited by its dependence on silverleaf sunray as a floral host. The young of *Andrena* are provisioned with pollen only from silverleaf sunray (Griswold et al. 2006). While nurturing the young requires *Enceliopsis* pollen, the adults may nectar on a variety of other flower species. *Andrena* is a MSHCP listed Species of Concern. *Andrena* go through one generation during the active season and adults have been collected from 12 March to 7 May (Griswold et al. 2006).

The Mohave Poppy Bee (*Perdita meconis*) also uses silverleaf sunray. It is a Species of Concern in the MSHCP, and limited in distribution by its floral host (Griswold et al. 2006). This endemic species to the eastern Mojave Desert is known primarily from Clark County, Nevada, but also known at several sites within five miles of Kelso, in San Bernardino County, California, and a single site southeast of St. George, Utah (Griswold et al. 2006). The Mojave Poppy Bee occupies creosote bush/mixed shrub communities (Griswold et al. 2006). This species' activity period is limited to a single annual generation whose adult phase is active from mid-April to early June. It is presumed that this species is a ground nester as all other congeners are (Griswold et al. 2006). As their name implies, these rare bees are specialists on large poppy species including *Arctomecon californica* (endemic to Clark County, Nevada), *A. humilis* (endemic to southwest Utah, near St. George), and a widespread *Argemone* sp. (prickly poppy) found extensively in roadsides across the desert – well beyond the range of this bee. *Perdita meconis* has not yet been found on *Arctomecon merriami* in Death Valley or elsewhere. Much is still not known about this bee species. For example, the nesting substrate is unknown. More work is required to understand the ecology of this bee and how important it is to the silverleaf sunray. *Perdita mohavensis* was found on silverleaf sunrays, but is generally known as a floral specialist on *Arctomecon* (Griswold et al. 2006). Thus it uses *Enceliopsis* (e.g. for nectar), but requires *Arctomecon* for some aspect of its life history for survival.

A.6.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): No Status

US Forest Service (Region 4): No Status

State of Nevada (NAC 527): No Status

NV Natural Heritage Program: Global Rank G2G3 State Rank S1?

IUCN Red List (v 3.1): No status

CITES: No status

A.6.2 Range

Silverleaf sunray is a rare plant reportedly found in Clark County, Nevada; Washington County, Utah (Cronquist 1994); and Mohave County, Arizona (McDougall 1973, Morefield 2001, Griswold 2006). McDougall (1973) erroneously reported silverleaf sunray for San Bernardino Co., California (explorer.natureserve.org accessed on internet 19 Nov 2016).

A.6.3 Population Trends

No information on population trends is available for this species.

A.6.4 Habitat Model

Silverleaf sunray localities used for modeling (N=230) were generally distributed within the Lake Mead National Park and surrounding BLM lands to the east of the Las Vegas Valley. Habitat predictions for this species from the three modeling algorithms differ somewhat in their extent, with both the GAM and RF models including some predicted habitat outside the general perimeter of the known localities. Suitable habitat is predicted along the eastern Lake Mead shore lines in Gold Butte National Monument, and the Eldorado Valley area south of Boulder City, with additional patches predicted along the Colorado River (Figure A.6-1). The MaxEnt model predicted a very restricted habitat, with only a few sparse areas of moderate habitat suitability predicted outside the extent of the known localities (Figure A.6-1).

Model performance was highest for the RF models, with the exception of the fixed Boyce Index, which was highest in the Ensemble Model (Table A.6-1). The Ensemble model was the second highest ranked model, with the GAM and MaxEnt models ranking similarly. Relative to the MaxEnt model, the GAM had higher correlation and BI scores, while MaxEnt had the higher AUC and TSS (Table A.6-1). Continuous Boyce Indices (CBI) for the GAM and RF models indicated good predictive performance, however the MaxEnt model had a much earlier peak, with erratic performance at habitat suitability values from ~ 0.4 to 0.6 (Figure A.6-3). The Ensemble CBI indicated good performance with a couple fluctuations, and a threshold value near 0.43, which was similar to the PRBE Cutoff score (Table A.6-1). Standard errors for the GAM model was largely limited to moderate levels (SE 0.04 - 0.06) in the Eldorado Valley and the southern boundary of Gold Butte (Figure A.6-2). The MaxEnt model had low error along the eastern Overton Arm of the Lake Mead shoreline in Gold Butte, with few other areas indicated. The RF model had moderately higher error near Echo Bay, and the southernmost boundary of Gold Butte.

The Ensemble model had broader expanses of low/moderate error throughout the predicted habitat area (Standard Error map for the silverleaf sunray ensemble model.).

These patterns may indicate true error in the models, however, they may also indicate habitat that could be, but has not yet been exploited by this species. Alternatively, the absence of Silverleaf sunray in the habitats where the models indicate suitability may indicate that the species once existed in some of the areas, but has since been extirpated by incompatible land uses. It is also likely that the species once occupied some of the areas that were inundated by the creation of Lake Mead. However, this does not explain the predicted suitable habitat further downriver and below the dam. And it is seems unlikely that Silverleaf sunray occur in the Eldorado Valley at present given the extensive biological surveys that have been completed in relation to the Clark County MSHCP and recent construction projects in that area. Similarly, it appears likely that this species' former habitat potentially extended further west from current known localities – an area now occupied by mostly impermeable surfaces of the municipalities within the Las Vegas Valley.

Table A.6-1. Model performance values for silverleaf sunray models

Performance	**GAM**	**RF**	**MaxEnt**	**Ensemble**
AUC	0.973	0.987	0.98	0.987
BI	0.698	0.74	0.596	0.766
TSS	0.89	0.948	0.911	0.935
Correlation*	0.877	0.921	0.824	0.906
Cut-off**	0.6	0.56	0.165	0.45

*point bi-serial correlation

**threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.6-2. Percent contributions for input variables for silverleaf sunray for ensemble models using GAM, MaxEnt, and RF algorithms

Term	**GAM**	**RF**	**Max**	**Avg**
Winter Min Temperature	44.2	21.2	37.4	45.3
Summer Max Temperature	13.2	16.6	44.8	33.5
Gypsum potential	27.9	13.7	7.0	23.3
NDVI Maximum	6.6	11.0	3.0	12.6
Temperature Range	8.0	8.9	3.1	11.3
Annual Heat/Moisture Index	0	9.1	1.0	8.1
Surface Texture (ATI)	0	6.6	3.6	6.8
Winter Precipitation	0	6.2	0.1	5.4
Slope	0	4.5	0	3.9
Heat Load Index (HLI)	0	2.2	0.1	2.0
Roughness (TRI)	0	0.0	0	0

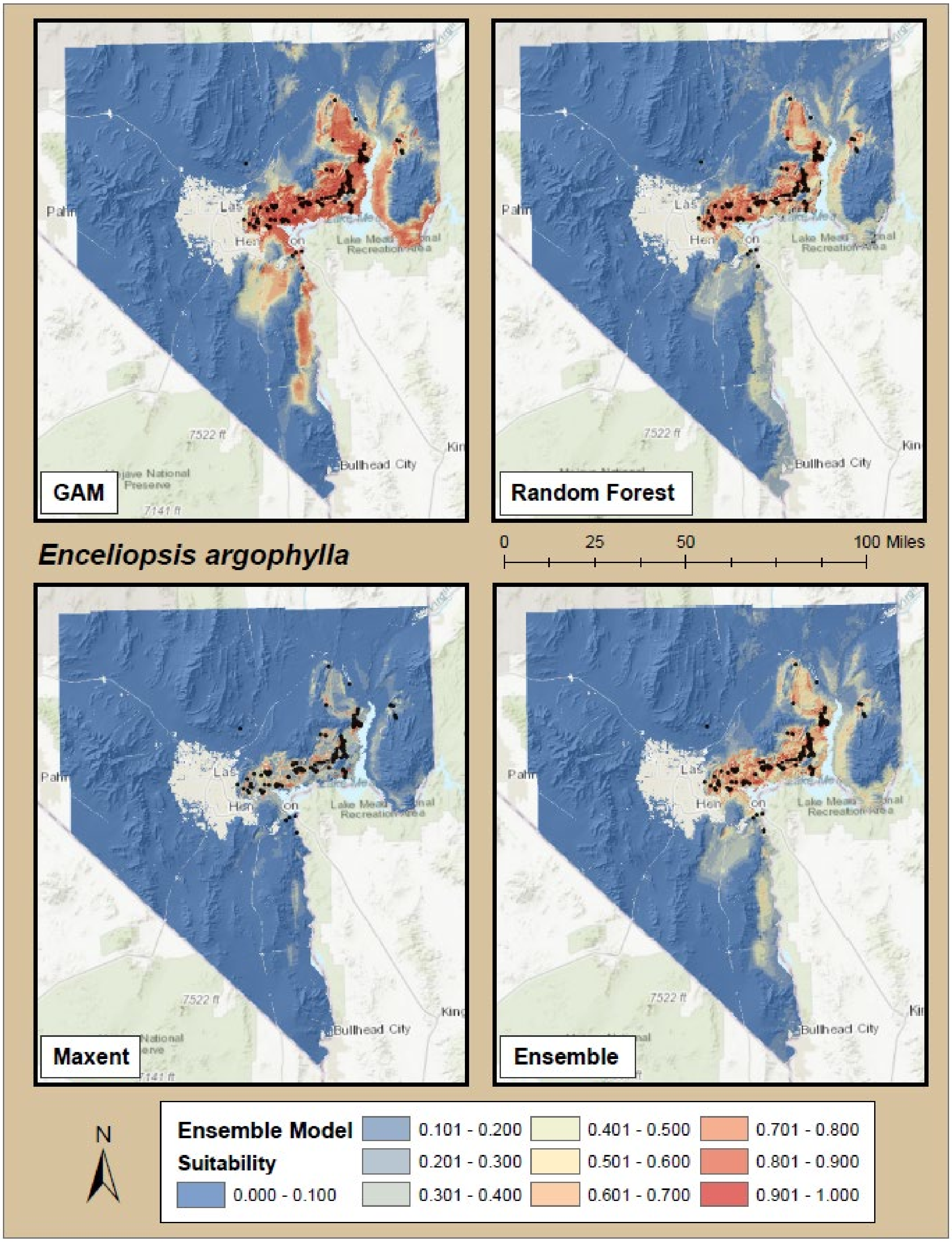


Figure A.6-1. SDM maps for silverleaf sunray for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right). Black dots indicate presence points.

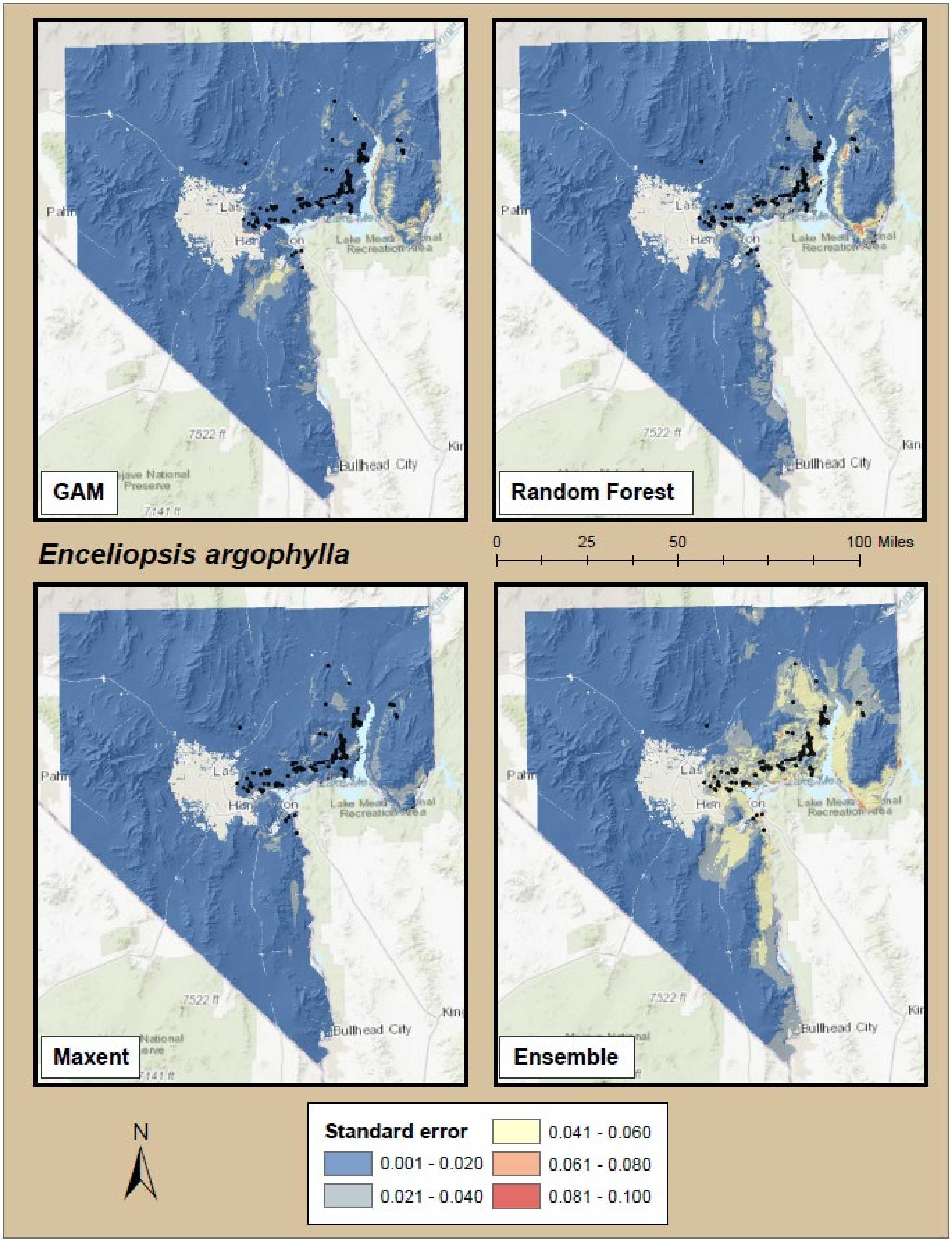


Figure A.6-2. Standard error maps for silverleaf sunray models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an Ensemble model averaging the three (Lower Right).

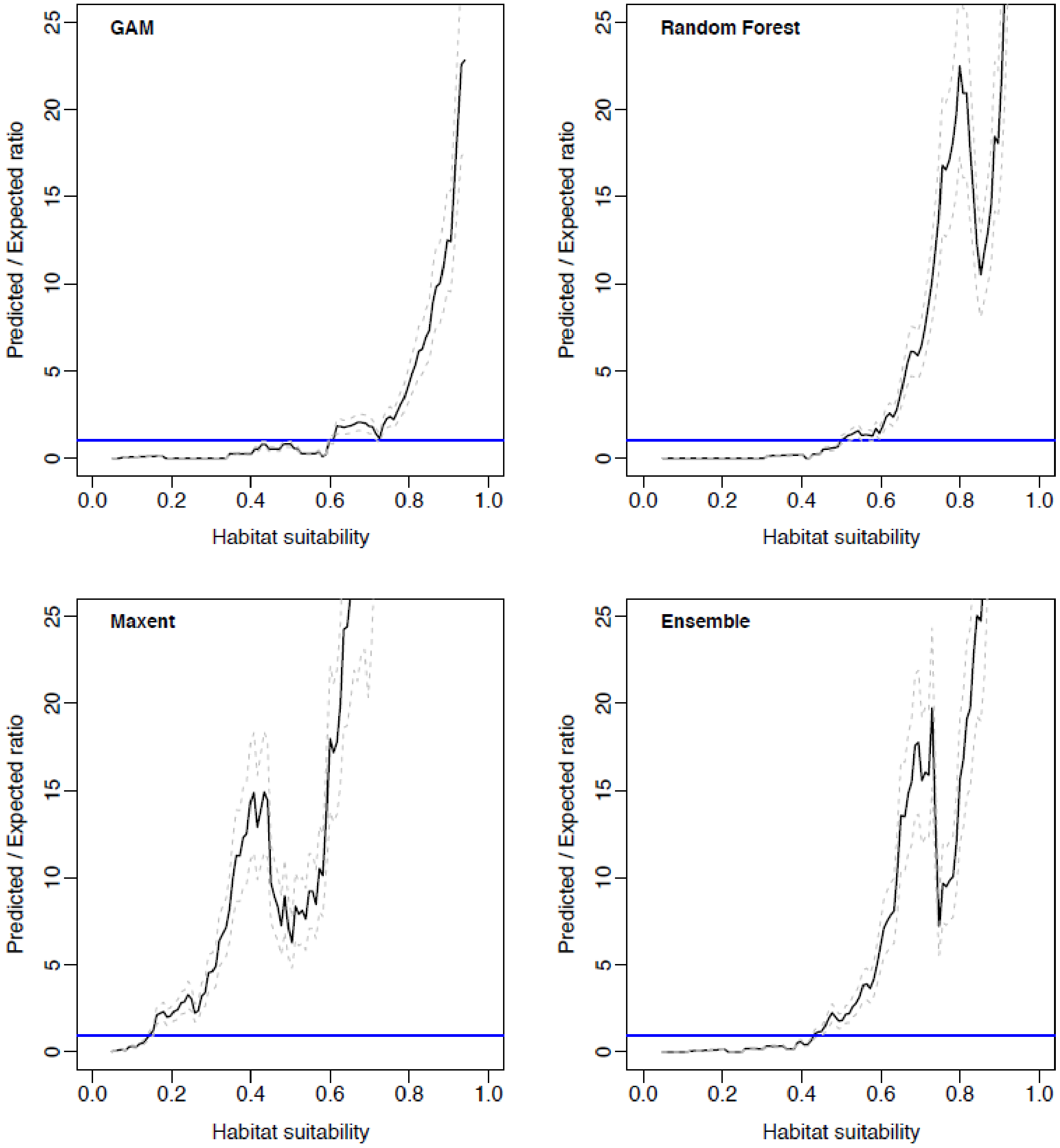


Figure A.6-3. Continuous Boyce Indices for silverleaf sunray models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an Ensemble model averaging the three (Lower Right).

A.6.4.1 GAM Model

Five of the 11 environmental layers contributed ~ 8% or more to the model, collectively accounting for 99% of model contributions (Table A.6-2. Winter Minimum Temperature was by far the largest contributor to the model, with 44% explained variance. Winter Minimum Temperature was positively related to predicted habitat suitability, with the association becoming positive in areas where temperatures were above ~1ºC. Gypsum Potential contributed 27%, and was positively associated with suitability at all levels (Figure A.6-4). Summer Maximum Temperature accounted for 13% of the model, predicting positive habitat with a peaked response above 35 ºC and peaking near 39 ºC. Temperature Range was also positively associated with predicted habitat suitability, while increases in NDVI Maximum were negatively associated with habitat suitability (Figure A.6-3).

Habitat for the species as predicted in the GAM models was high (> 0.8) and contiguous through the northern shoreline of Lake Mead and in the adjoining BLM lands, and throughout Valley of Fire State Park up to Logandale and Glendale.

Moderately high values (> 0.7) were predicted along the eastern shoreline of the Overton Arm of Lake Mead in the Gold Butte National Monument. Moderate habitat (~ 0.5) was also predicted in Eldorado Valley, and along the western shoreline of the Colorado River southward through Cottonwood Cove and Lake Mohave (Figure A.6-1). The GAM model SE was moderate (0.04 - 0.06) in a patch in the Valley of Fire State Park area, and on the southern border of Gold Butte National Monument, with a few patches of lower habitat suitability in Eldorado Valley (0.02 - 0.04), and the northern Lake Mojave shoreline (Figure A.6-2).

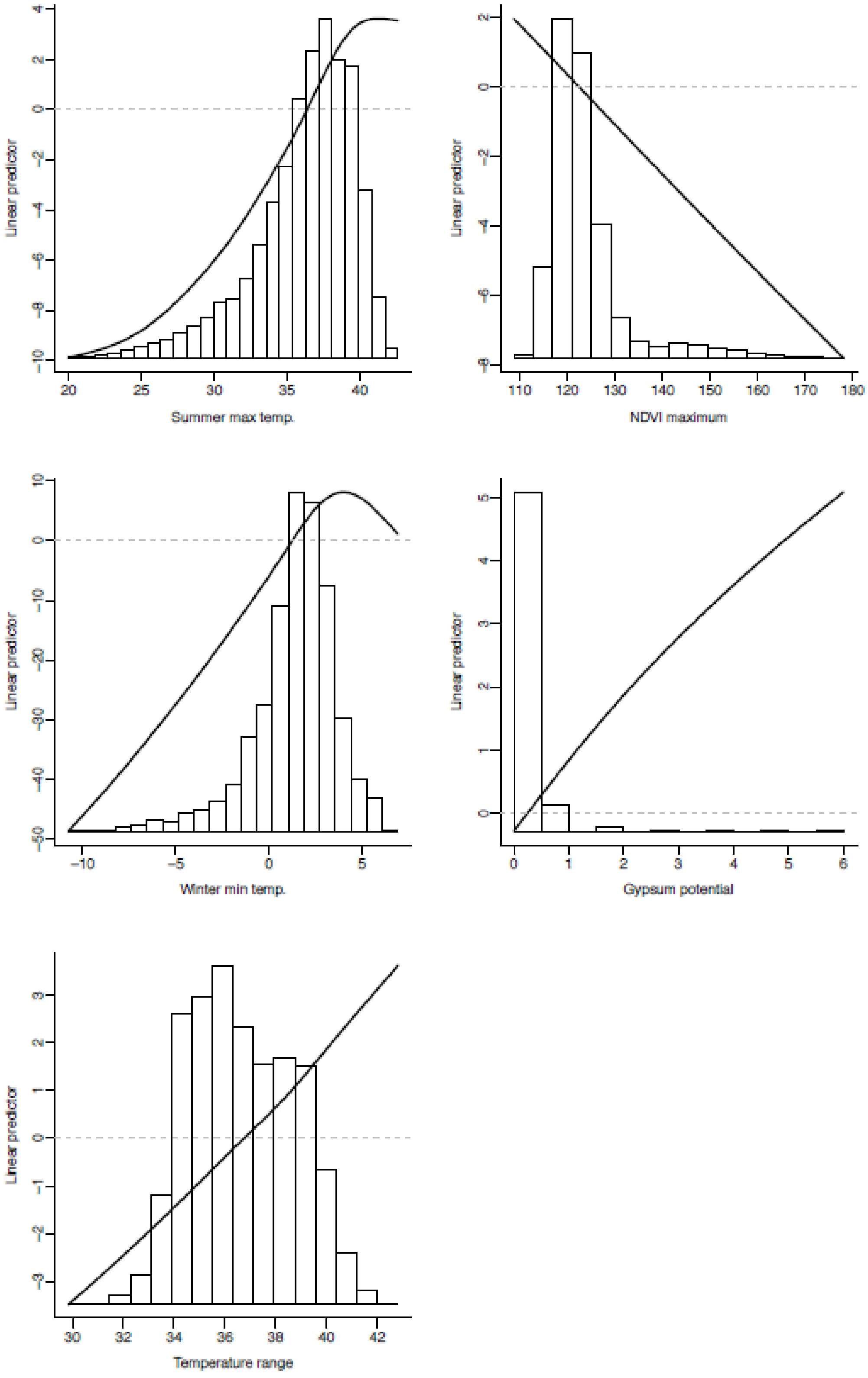


Figure A.6-4. GAM partial response curves for the silverleaf sunray model illustrated over the distribution of environmental variable inputs in the study area.

A.6.4.2 MaxEnt Model

There were only two variables contributing 10% or more to the model, accounting for 82% of total model contribution (Table A.6-2). Winter Minimum Temperature (37%) and Summer Maximum Temperature (44%) were by far the largest drivers in the model, and both had nearly the same relative response with habitat showing a peaked response relative to Maximum Winter Temperature at 5 ºC, and for Maximum Summer Temperature at 40 ºC. Each had low probabilities of habitat suitability below peak values. NDVI Maximum (9% contribution) was negatively associated with predicted habitat suitability (Figure A.6-5).

Predicted habitat suitability area for the MaxEnt model was extremely limited, with higher levels of habitat suitability predicted only near the modeling localities, and with little continuity of habitat within the habitat area (Figure A.6-5). The standard error map for this algorithm indicated minimal error near Valley of Fire, southern Gold Butte, near Eldorado Valley and one area near the Colorado River corridor (Figure A.6-2).

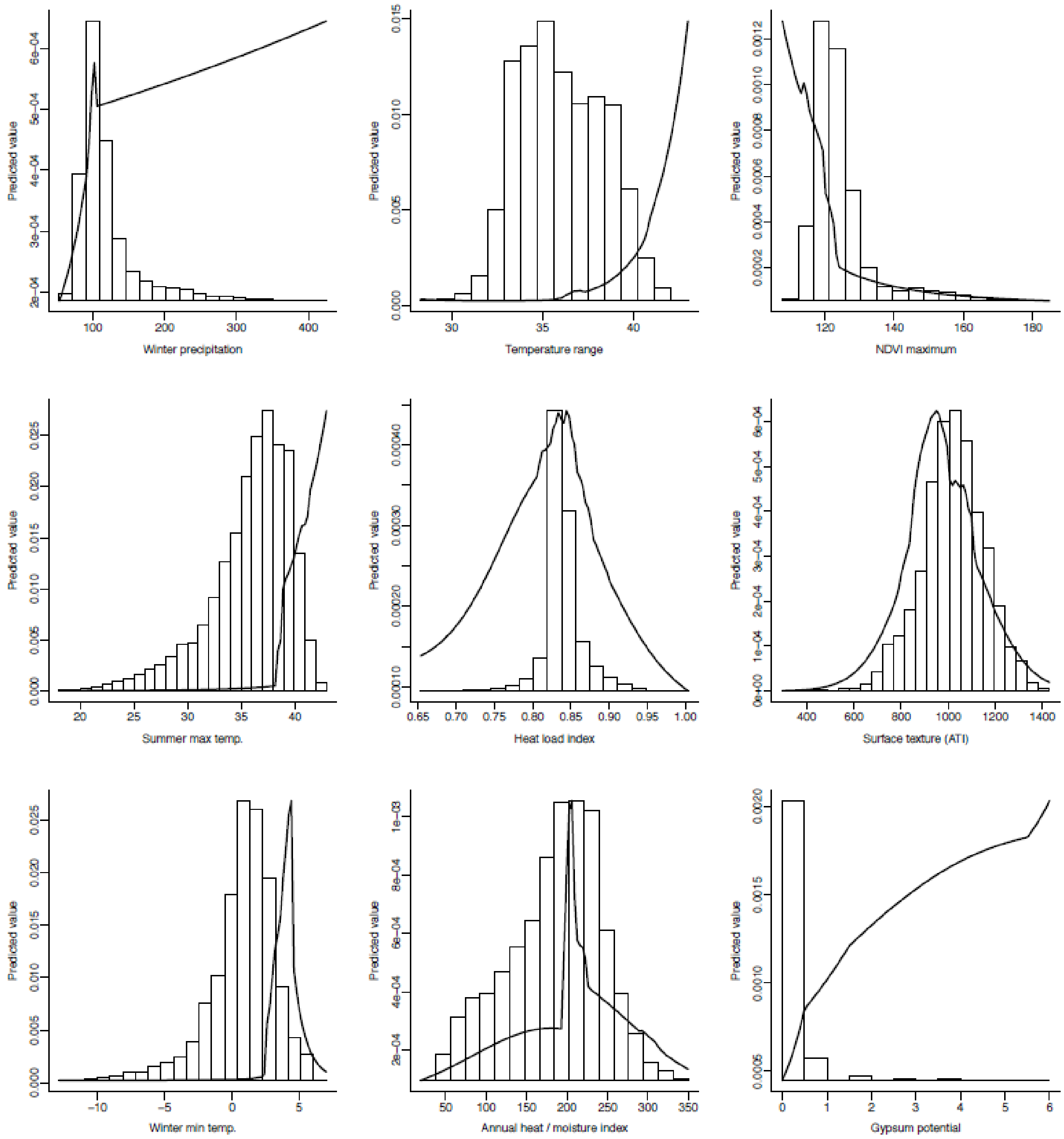


Figure A.6-5. Response surfaces for the top 9 environmental variables included in the MaxEnt ensemble model for silverleaf sunray.

A.6.4.3 Random Forest Model

The RF models had six environmental variables contributing ~ 9% or more totaling 80% of total model influence. Winter Minimum Temperature and Summer Maximum Temperature had similar partial curves to that seen in the MaxEnt model, with a sharp peaked response at higher values of both Winter Minimum and Summer Maximum temperatures reflecting the apparent preference for warmer habitats for this species (Figure A.6-6), NDVI Maximum was negatively associated with predicted habitat occurring only at the lowest NDVI levels, indicating low vegetation density where habitat for this species was predicted. Gypsum Potential was strongly and positively associated with predicted habitat suitability as was the Annual Heat/Moisture Index (Figure A.6-6).

Standard error had low (0.02 – 0.04) to moderate (0.04 – 0.06) values broadly in Eldorado Valley, along the shoreline on the east side of the Overton Arm of Lake Mead, southern Gold Butte, and the lower Colorado River (Figure A.6-2). There were patches of higher error values (0.06 – 0.08) near Echo Bay, and Southern Gold Butte.

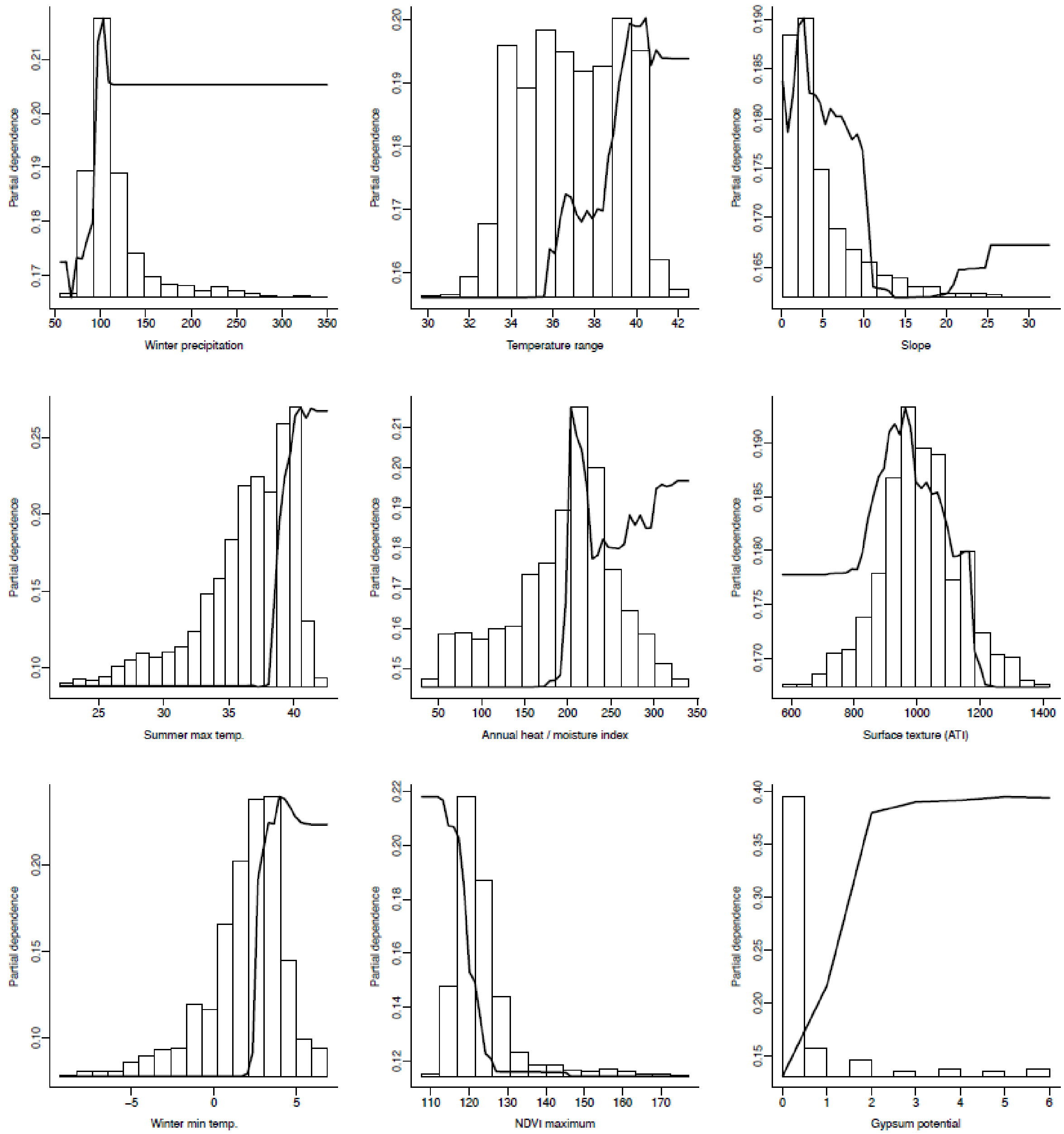


Figure A.6-6. Response surfaces for the environmental variables included in the RF ensemble model for silverleaf sunray. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

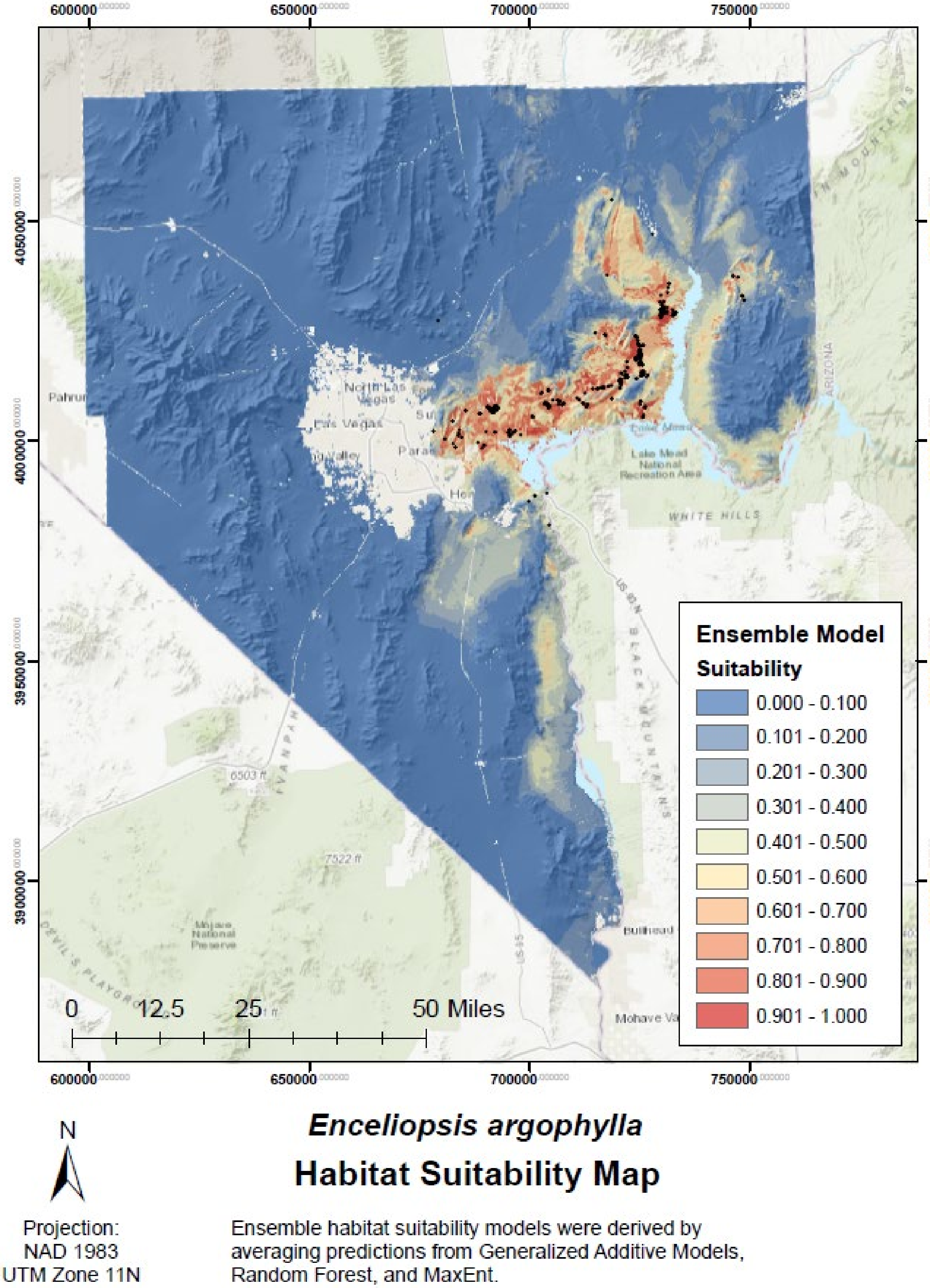


Figure A.6-7. SDM map for the silverleaf sunray ensemble model.

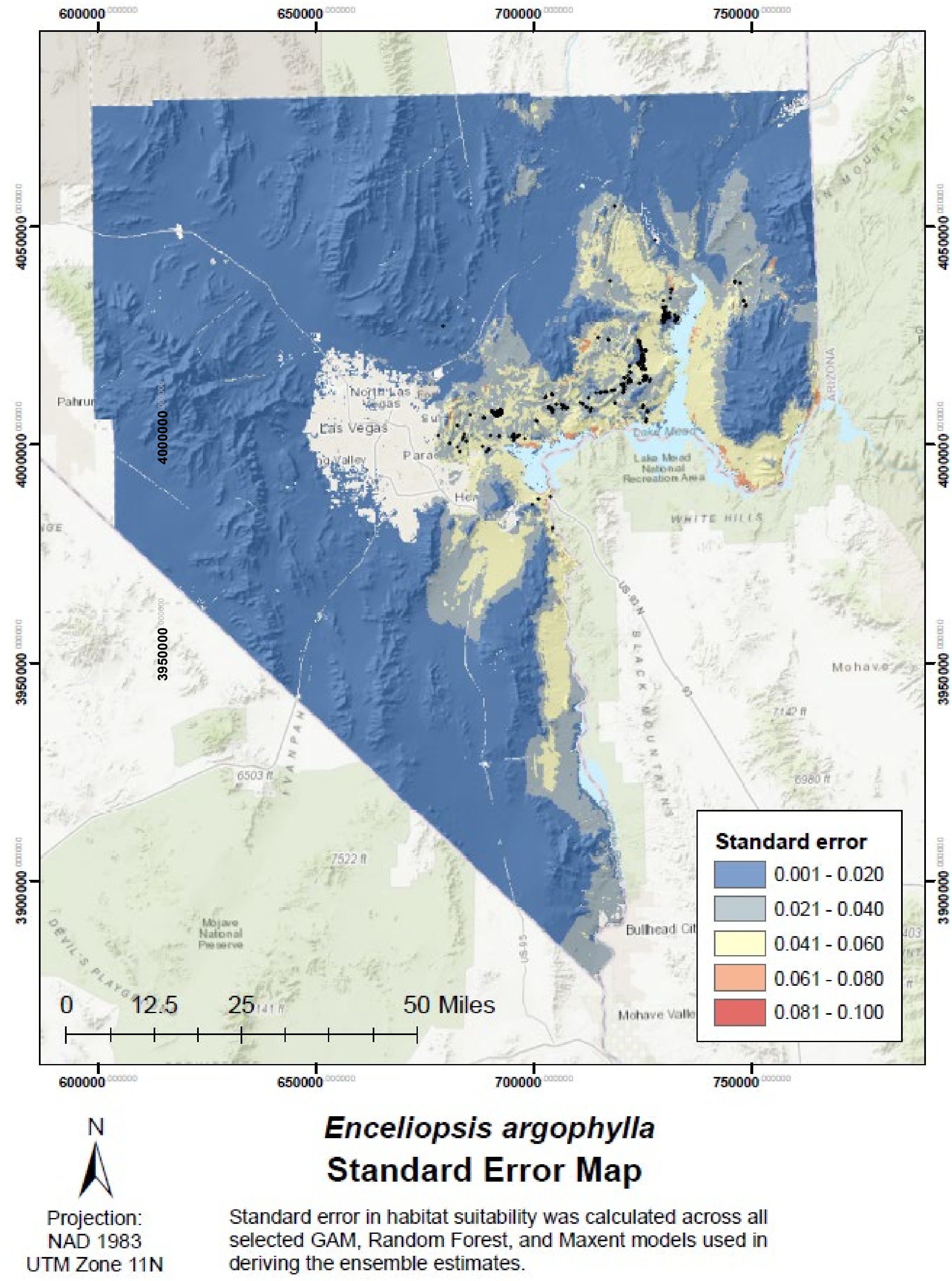


Figure A.6-8. Standard Error map for the silverleaf sunray ensemble model.

A.6.4.4 Distribution of Localities

Silverleaf sunray habitat was modeled using 230 localities within the county, which were clustered within the North Shore and Overton areas of Lake Mead (Figure A.6-7). There were few points outside this area, including northern Gold Butte National Monument, and in the upper extents of the Muddy River valley (Figure A.6-7). Geographic thinning to reduce influences of spatial bias reduced this to 148 localities for modeling runs.

A.6.4.5 Standard Error

Moderate levels of SE (0.04 – 0.06) are in larger expanses in Eldorado Valley, Valley of Fire, the Gold Butte and Lake Mead shore lines, and in the predicted habitat areas immediately north of the bulk of the localities (Figure A.6-8).

A.6.5 Distribution and Habitat Use within Clark County

The species is rare and known only to occur in Clark County in southern Nevada, from the River Mountains east of Henderson to Echo Bay and the Las Vegas Wash within the Lake Mead National Recreation Area (Kartesz 1988). It occurs on clay and gypsum cliffs and on gravelly slopes. It is very similar in appearance to *Enceliopsis covillei,* which occurs west of Boulder Dam, and extends up to Valley of Fire State Park within Clark County, but lives on gravel and clay banks and cliffs and has longer flowers (Kartesz 1988). The highest suitability habitat for this species is predicted to be within the Mojave Desert Scrub ecosystem, with very little habitat in any other ecosystem, even for moderate habitat (Table A.6-3). Some, but limited moderate habitat is also predicted for areas in lower Salt Desert Scrub ecosystems.

Modeled Habitat in the county is predicted to be high in the areas generally surrounding the localities, with extensions of predicted habitat (without confirmed localities) in the area around Valley of Fire, extending to Glendale. and up to the Logandale area. Pockets of lower level habitat (0.5 – 0.6) are predicted in other areas in the county (e.g., Eldorado Valley, the Gold Butte shoreline, and lower valleys in the Colorado River corridor near Nelson's Landing and Lake Mojave) (Figure A.6-7).

Table A.6-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	**Low**	**Medium**	**High**
Alpine	124	0	0
Blackbrush	415465	0	0
Bristlecone Pine	7565	0	0
Desert Riparian	9775	591	158
Mesquite Acacia	17887	892	932
Mixed Conifer	27339	0	0
Mojave Desert Scrub	1025131	184137	72109
Pinyon Juniper	115902	0	0
Sagebrush	4705	0	0
Salt Desert Scrub	77055	1547	100

A.6.6 Ecosystem Level Threats

Silverleaf sunray only occur in the Mojave Desert Scrub ecosystem of Clark County (Cronquist 1994). Some of the land occupied by this species occurs within Lake Mead National Recreation Area and is therefore protected from development concerns. Interestingly, at least some of the habitat was lost due to inundation with the filling of Lake Mead (Cronquist 1994).

A.6.7 Threats to Species

Threats to the species include off-highway vehicle traffic in less-protected areas of Clark County such as Gold Butte. Urban development has also occurred within habitat for this species. Several of the known pollinators for this species are rare, local endemics and loss of pollinator diversity may threaten the long-term persistence of silverleaf sunray.

A.6.8 Existing Conservation Areas/Management Actions

Lake Mead National Recreation Area provides protection for some populations of Silverleaf sunray. The Gold Butte area was designated a National Monument in December of 2016, and thus now offers similar protection. Some new areas of habitat for this species have recently been protected by private conservation efforts in Washington County, Utah (Endangered plant species workshop, St. George, Utah 2016).

A.7 PAHRUMP VALLEY BUCKWHEAT (*ERIOGONUM BIFURCATUM*)

Pahrump Valley buckwheat (*Eriogonum bifurcatum*) is a winter annual in the buckwheat family (Polygonaceae) that blooms from late May to late June. The forked buckwheat was first described in Pahrump Valley in Nye County, NV near the California-Nevada state line. It is described as a low spreading annual plant that forms a flat-topped crown that can be more than a meter across (Reveal 1971, Mozingo and Williams 1980).

A.7.1 Species Status

This buckwheat is a former Category 2 candidate for threatened or endangered status under the ESA. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that the forked buckwheat proposal for listing may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (USFWS 1993).

US Fish and Wildlife Service Endangered Species Act: No status

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): No status

NV Natural Heritage Program: Global Rank G3, State Rank S2

IUCN Red List (v 3.1): No status

CITES: No status

A.7.2 Range

Pahrump Valley buckwheat was originally found at 2525 ft., near the Charles Brown Highway - NV 372- CA 178) in Nye County, NV. Forked (Pahrump Valley) buckwheat is a highly range-restricted plant, known only from the California-Nevada border area in the Mesquite and Pahrump valleys in NV, and Stewart Valley in California (Reveal 1971, Crampton et al. 2006). The border region is within Clark and Nye counties in Nevada, and Inyo and San Bernardino counties in California. The elevational range for this species is from 2297 – 2800 ft. (700 – 853 m, NNHP 2001).

There are at least 19 extant occurrences in Clark and Nye counties in Nevada, with most occurring within Nye County (NNHP 2001, NatureServe 2010), and four occurrences in Inyo and San Bernardino Counties in California (California Natural Diversity Database 2009), which can be grouped into four population groups (TNC 2007). Pahrump Valley buckwheat has also been found on Las Vegas Resource Management Plan lands near the town of Sandy Valley on the edge of the Mesquite dry lake (Crampton et al. 2006).

A.7.3 Population Trends

Germination of forked (Pahrump Valley) buckwheat is largely dependent on winter precipitation, and as a result, population size fluctuates greatly from year-to-year: very few or no plants may be present in a dry year and thousands may be counted in a wet year. This makes estimating population trends difficult (TNC 2007), and the trend of forked (Pahrump Valley) buckwheat is described as unknown by Nevada Natural Heritage Program (2001). However, the USFWS described the range-wide status as declining (USFWS 2000) based on recent occurrence records, and extirpations of populations have been reported on private lands near Sandy NV. Populations on public lands in Pahrump and Stewart valleys have remained intact (Crampton et al. 2006).

Based on the difficulty of quantifying the population trends for a species such as this, with highly fluctuating expression of adult plants, we suggest that seed bank assays may provide better insights into population status – if such methods are successful (Mayer and Poljakoff-Mayber 1982). Such assays have been widely used in the Great Basin (Young et al. 1976) and in other systems and also in the Mojave Desert (Esque 2004).

A.7.4 Habitat Model

The three model algorithms generally predicted similar habitat arrangements throughout the County, and indicated a relatively low area of predicted suitable habitat within the county, where much of the predicted area did not have supportive locality information. The Random Forest models generally predicted more habitat, while the MaxEnt models tended to retain moderate values where other models predicted higher values (Figure A.7-1). Key areas of similarity among models in the County include a high habitat suitability in a rather large area north Amargosa Valley. Additionally, there is predicted habitat in two smaller areas Goodsprings/Jean along the Roach Dry lake toward Ivanpah Valley (Figure A.7-1).

The Ensemble model and GAM models had slightly higher performance relative to the other models, with an equivalent score for AUC, and nearly equivalent scores for BI and TSS. The RF model (Table A.7-1) performed well but had a lower BI score than both the Ensemble and GAM models. Relative to the other models, the MaxEnt model had lower performance on the BI metric. Overall AUC performance was very high, with all models performing above 0.94, while BI scores were relatively high. All three models shared Clay content as one of the top four most influential variables. The GAM and RF, models shared two of the top four influential environmental variables, where the Average of Maximum temperature, and the Clay component of the soils were the largest contributors (Table A.7-2). The RF and MaxEnt model shared Winter Precipitation as a top influential variable. The standard error was relatively low throughout the County, where only the GAM model had values approaching 0.07 in most areas. All other model standard errors were very low (Figure A.7-2). The Continuous Boyce Indices showed good model performance with the exception of the MaxEnt model (Figure A.7-3). The MaxEnt curve indicated some values of lower performance where point density was higher, indicating less discrimination between high and low habitat (Figure A.7-3), this is likely due to the lack of lower suitability scores in areas with fewer points that retained moderate suitability scores (e.g. 0.5, Figure A.7-1).

Table A.7-1. Model performance values for Pahrump Valley buckwheat models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.88	0.88	0.39
GAM	0.99	0.84	0.92	
Random Forest	0.99	0.75	0.88	
MaxEnt	0.94	0.57	0.85	

Table A.7-2. Percent contributions for input variables for Pahrump Valley buckwheat for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	12.9	5.6	2.3
Average Spring Max Temp	11.8	1.2	7
Clay	15.3	3.3	19.9
CV Average Spring Max Temp	11.1	2.9	3.4
Extreme Max Temp	8.9	1.4	1.5
Extreme Min Temp	3.3	2	24.8
Sand	9.9	1.1	4.2
Silt	13.7	0.5	12.9
Slope	5.6	4.6	8
Winter Precip	7.4	77.5	15.9

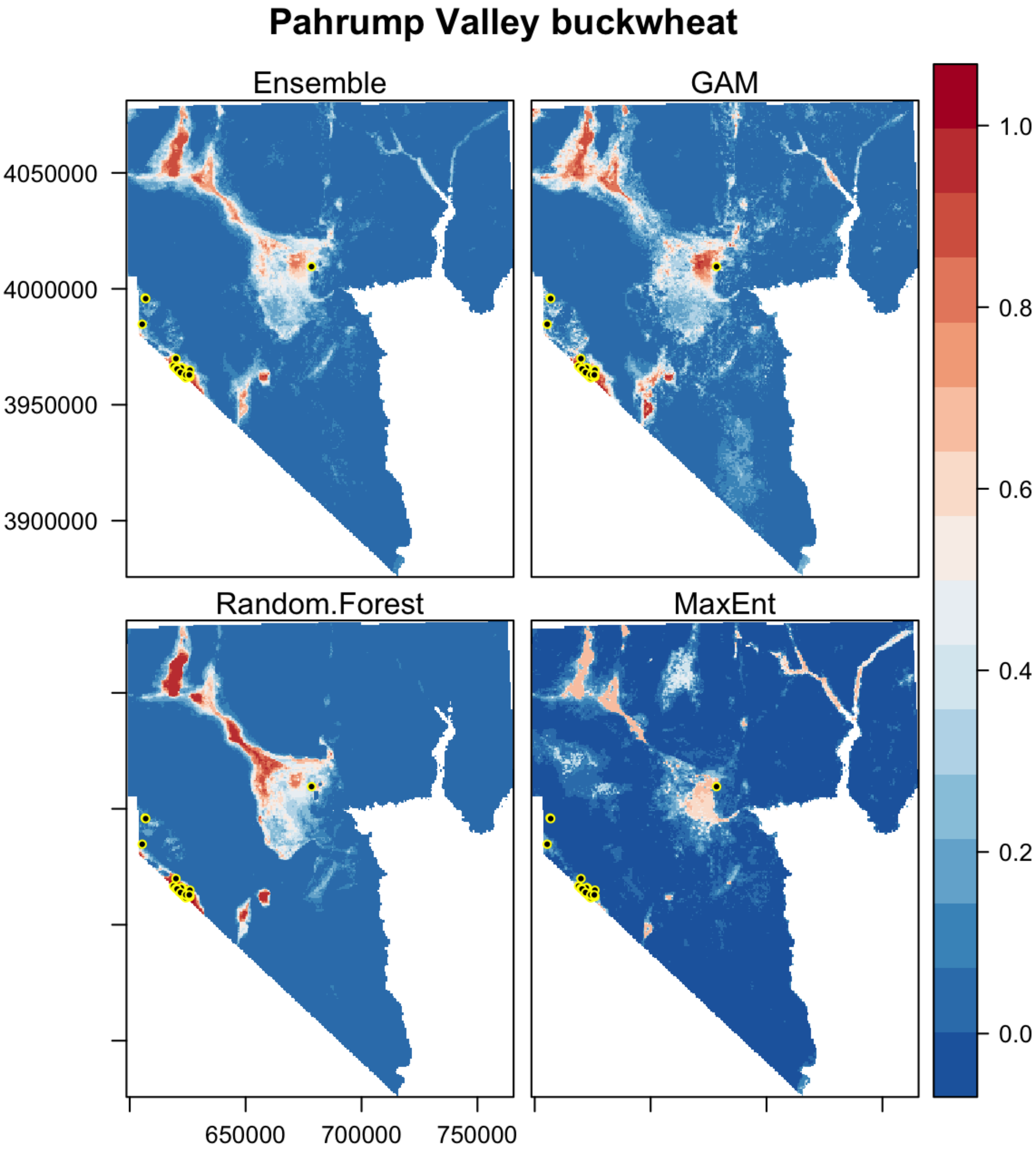


Figure A.7-1. SDM maps for Pahrump Valley buckwheat model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

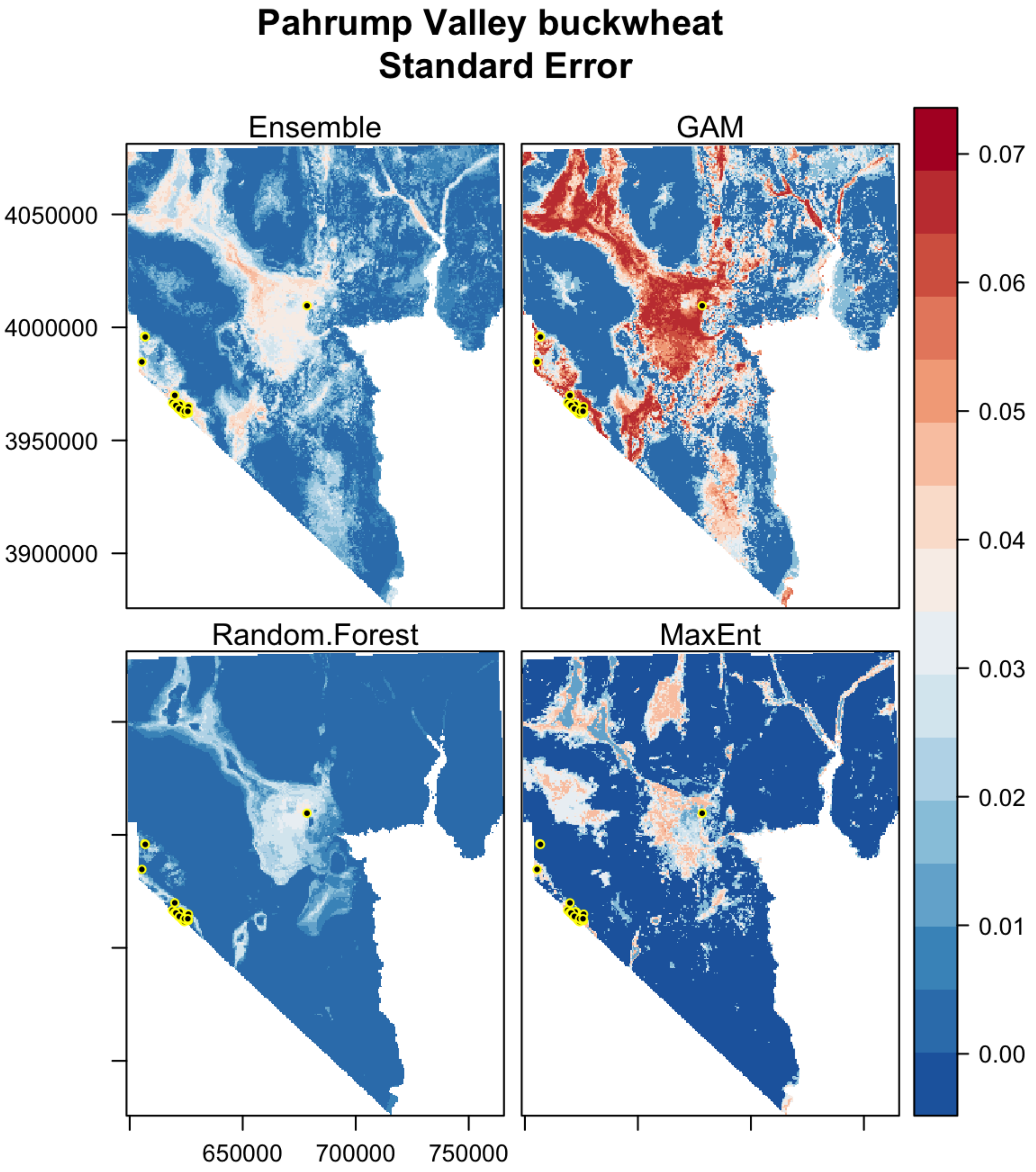


Figure A.7-2. Standard error maps for Pahrump Valley buckwheat models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

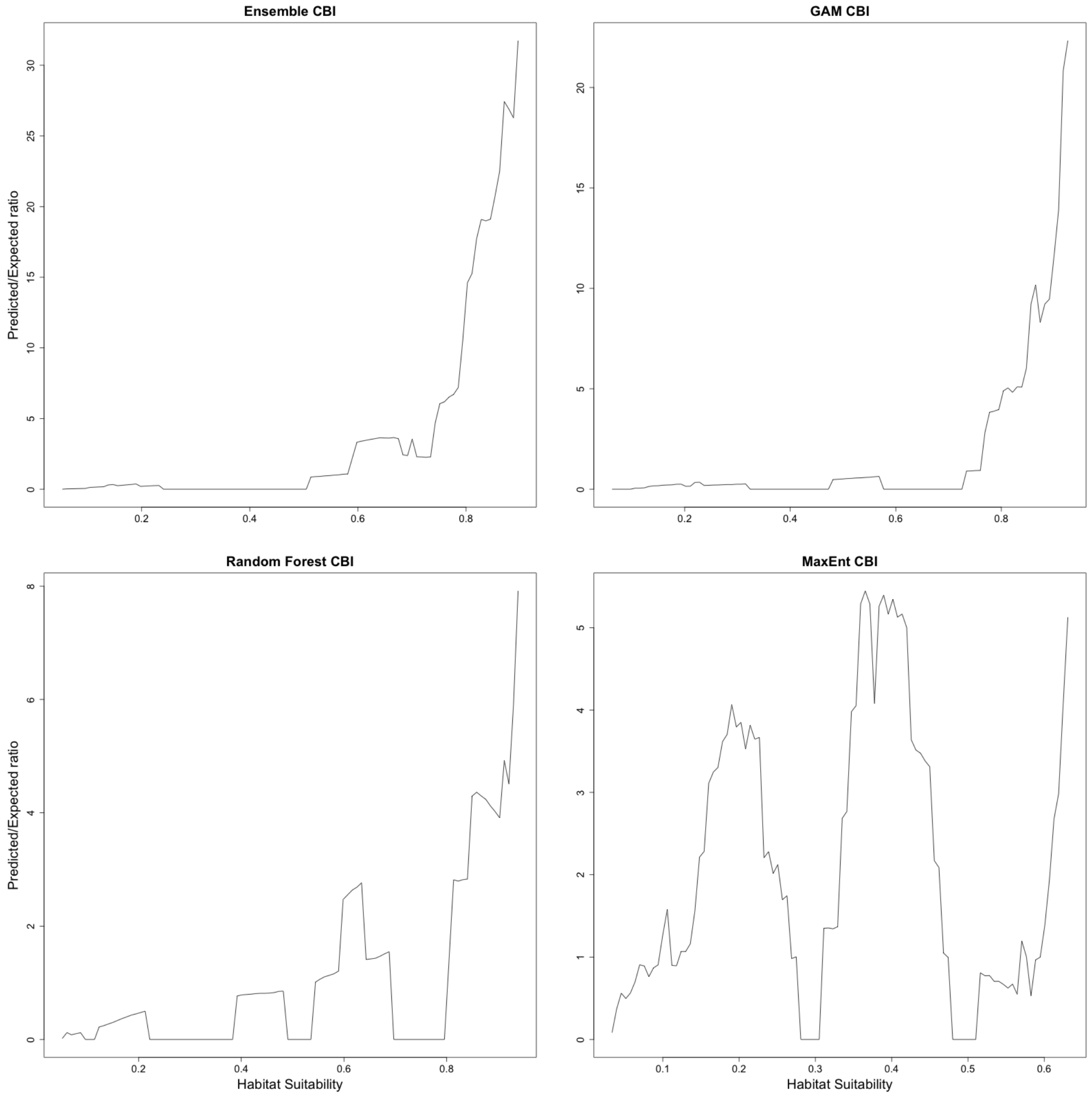


Figure A.7-3. Graphs of Continuous Boyce Indices [CBI] for Pahrump Valley buckwheat models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.7.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, Clay, and Silt components of the soil collectively accounting for 54% of total model contribution (Table A.7-2). Model scores were higher in areas with Extreme Maximum temperatures at 40 ºC, and lower at all other temperatures. Spring Maximum temperatures showed a peak response at 32 ºC, and were lower elsewhere. (Figure A.7-4). Model predictions were highest, and plateaued in areas with higher Clay Content, and with higher Silt Content than found in the County generally (Figure A.7-4). This algorithm had higher standard error values, indicating some dissimilar predictions among the 50 model cross-validation runs (Figure A.7-3).

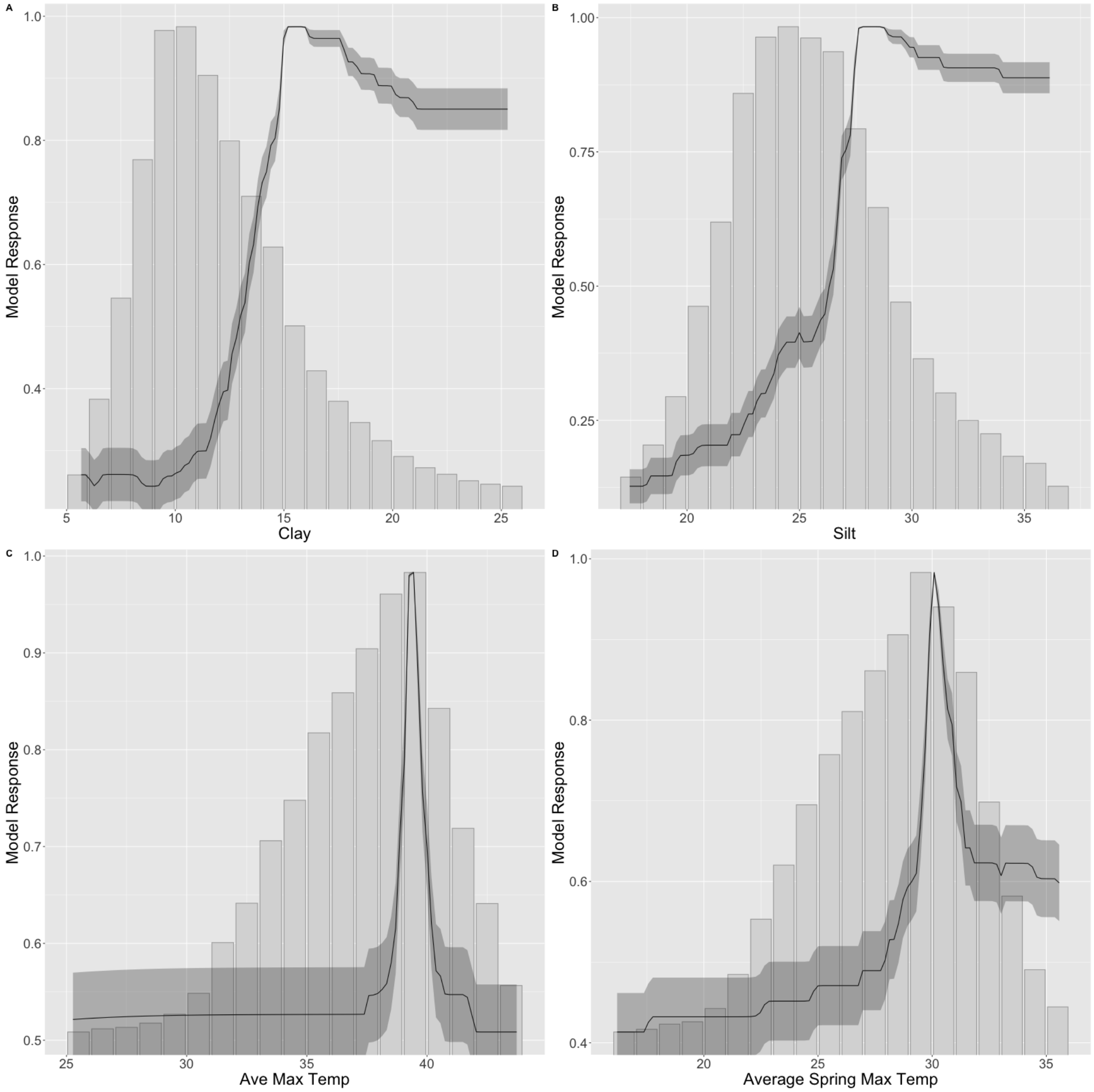


Figure A.7-4. GAM partial response curves for the top four variables in the Pahrump Valley buckwheat model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.7.4.2 MaxEnt Model

The MaxEnt models relied heavily on the one of the same four top variables as those in the GAM and RF models (Clay Content), shared Winter Precipitation as a variable with the RF models. Extreme Minimum temperature, and Winter Precipitation were also important contributors in the MaxEnt models. In total, these four variables accounted for 73.5% of total model contribution (Table A.7-2). This model also had very similar response curves among algorithms to the GAM model for the and RF models for the Clay Content variable, and a similar response curve as the RF model to the Winter Precipitation variable, indicating relatively robust model selection (Figure A.7-4, Figure A.7-5). The predicted response for the Extreme Minimum temperature showed a threshold response with suitability at high values when temperatures were lower than about 5 ºC. The model response for Winter Precipitation showed habitat suitability values that were similar to the distribution of that variable in the County, and were highest where Winter Precipitation was low (Figure A.7-5).

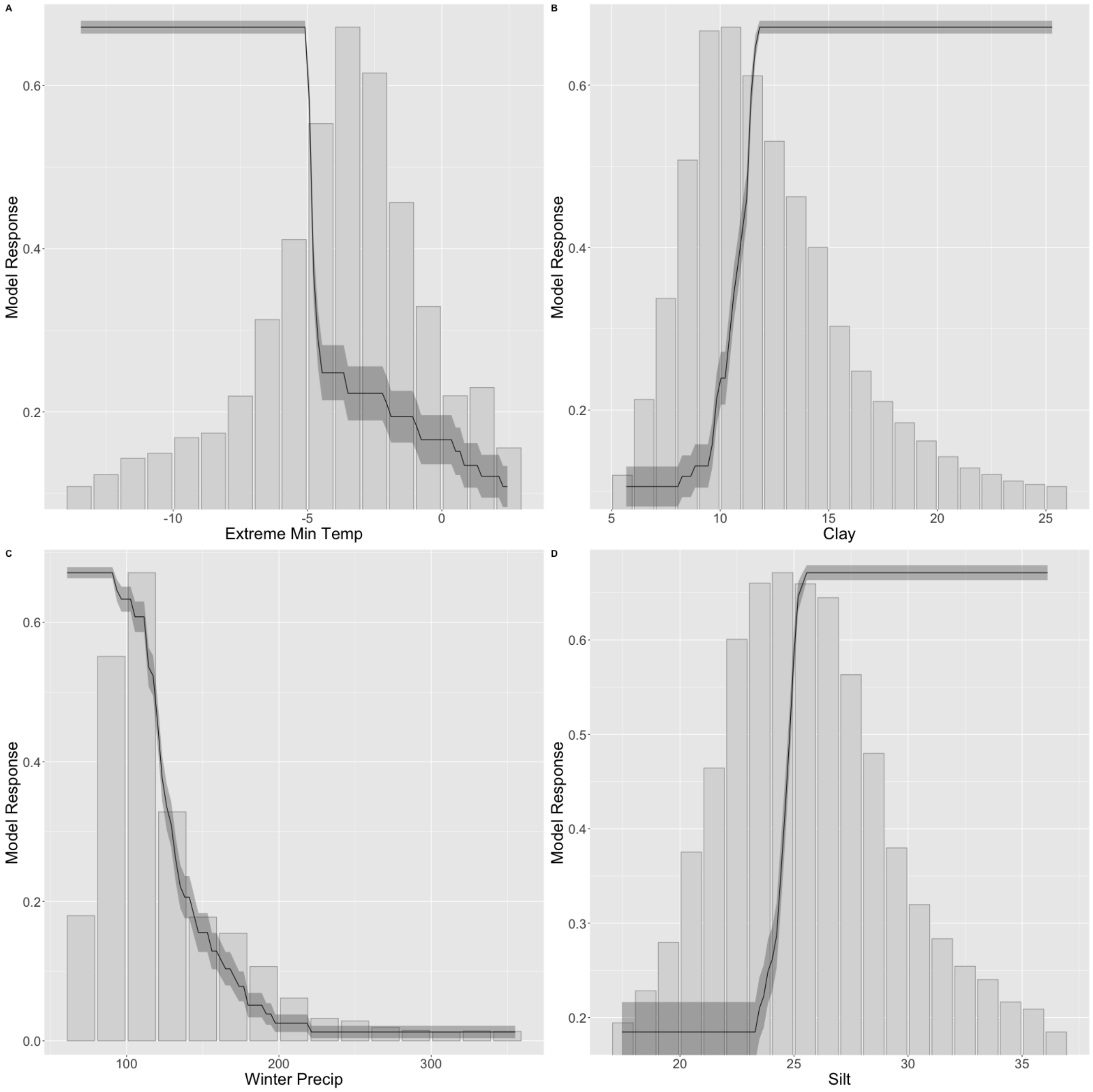


Figure A.7-5. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for Pahrump Valley buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.7.4.3 Random Forest Model

The Random Forest model was largely driven by Winter Precipitation (77.4%), Average Maximum temperature, Slope, and soil Clay Content (Table A.7-2). The collective model influence of these four variables was 91%, where very little additional influence was proved by several other input variables (Table A.7-2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (Figure A.7-6) and differed slightly from the response of the MaxEnt model, in that the RF model favors Winter Precipitation values that are slightly less than those found in the County generally. Average Maximum temperature indicated the highest habitat suitability at temperatures above 38 ºC, followed by a plateau. This differs slightly from the MaxEnt model which had a distinct peak at 40 ºC. The response curve for Clay Content is concordant with those of the GAM and MaxEnt models, with continued high habitat suitability at values above 10-15%. Slope indicated higher habitat in areas with low Slope, but did not differ dramatically from the distribution of Slope in the County (Figure A.7-6).

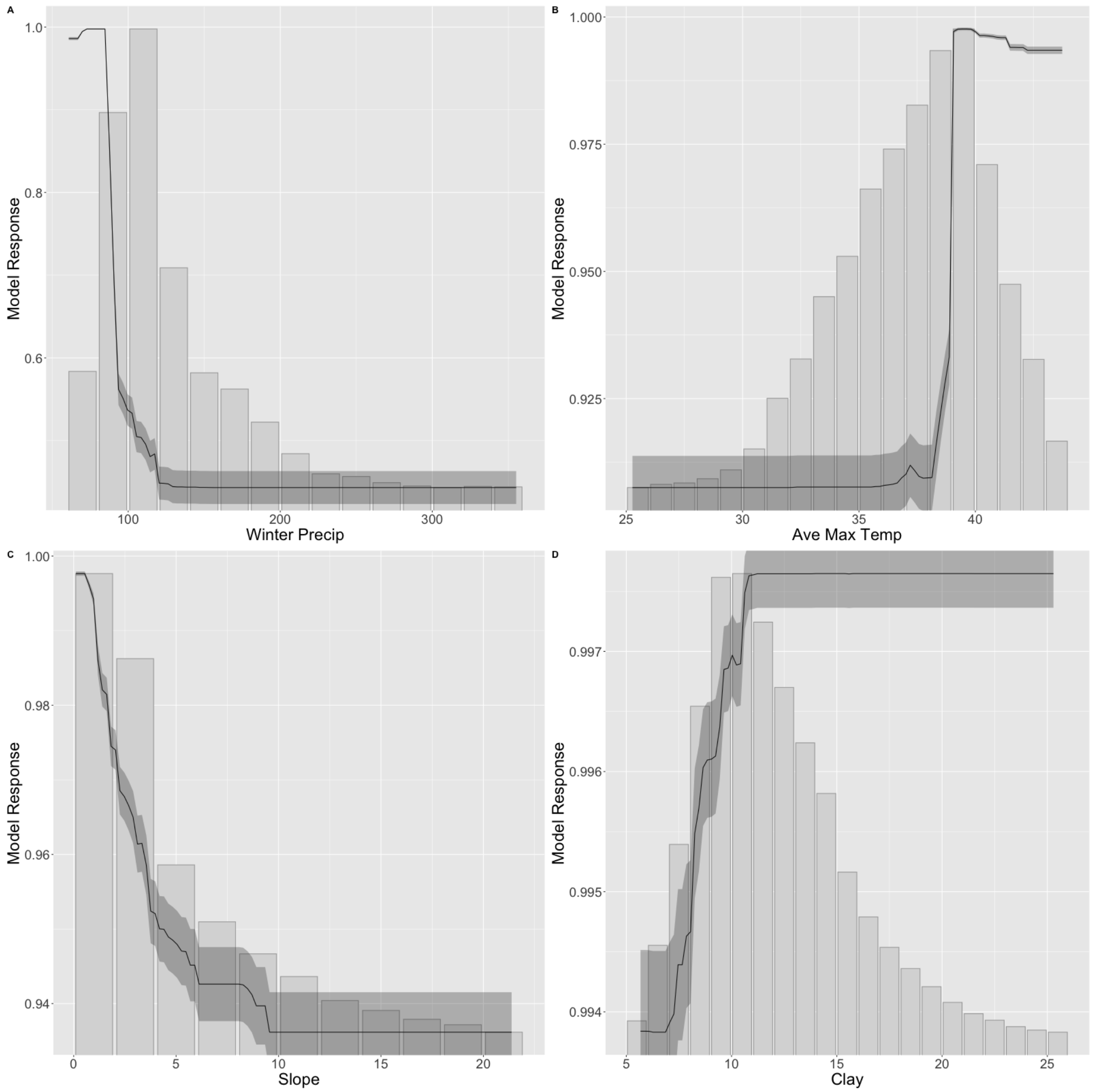


Figure A.7-6. Partial response curves for the environmental variables included in the Random Forest Ensemble model for Pahrump Valley buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.7.4.4 Model Discussion

Pahrump Valley buckwheat occurs almost exclusively along the Nevada state line in the area near Pahrump, NV. Records indicate its range in this area extends to the south to the Sandy Valley area, and to the north to Stewart Lake. However, the model indicates other areas of high habitat suitability. As discussed above there was a larger area of predicted suitable habitat along the US 95 corridor especially in the areas near Amargosa Valley and Mercury, and the periphery of the Las Vegas Valley. While these areas show predicted habitat, there is only 1 locality outside of the Pahrump Valley – on the east side of Las Vegas (Figure A.7-7). More habitat exists in the California side of the Pahrump valley, and in habitat extending into Nye County.

The locality data for this species consisted of 1384 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 128.

A.7.4.5 Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (Figure A.7-8), with moderate error, located in the areas that were predicted as high quality habitat that are outside of the species known range. Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

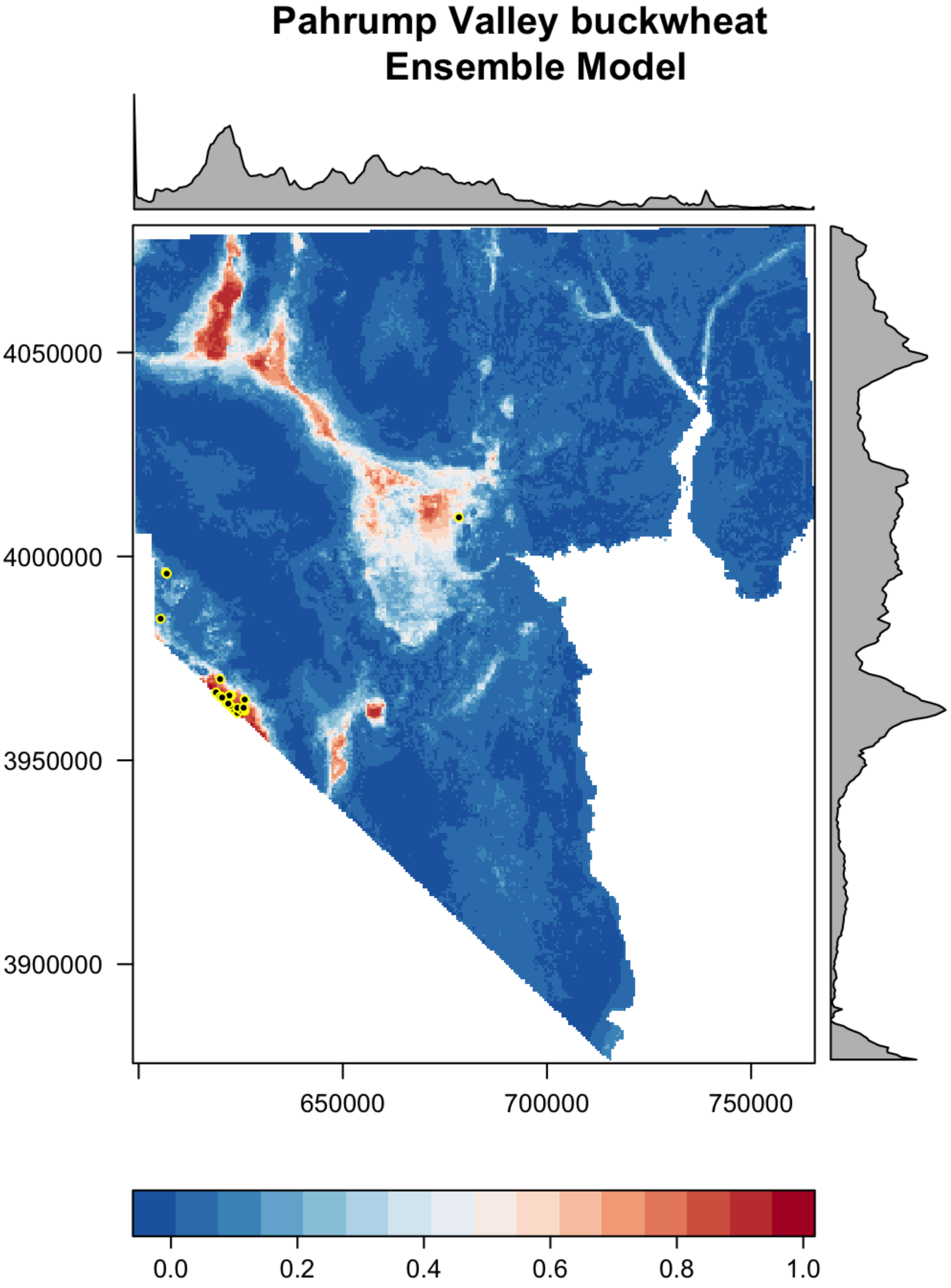
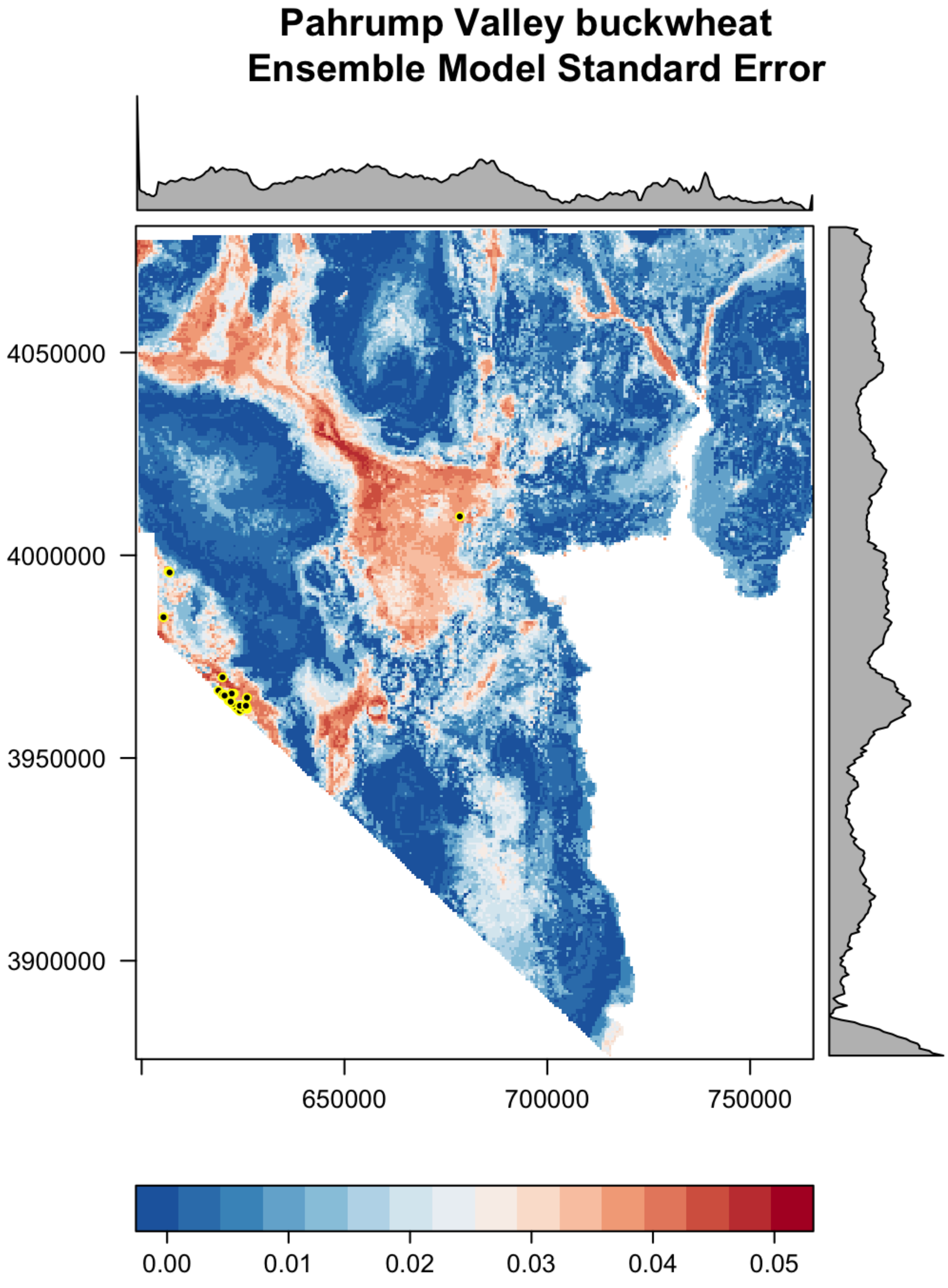


Figure A.7-7. SDM map for Pahrump Valley buckwheat Ensemble model for Clark County, NV.



Pahrump Valley buckwheat
Ensemble Model Standard Error

Figure A.7-8. Standard Error map for the Pahrump Valley buckwheat Ensemble model for Clark County, NV.

A.7.5 Distribution and Habitat Use within Clark County

In Clark County, forked (Pahrump Valley) buckwheat occurs only in Mesquite Valley in and around the town of Sandy Valley in the southwest region of the County, immediately adjacent to the Nye County border (Reveal 1971, Crampton et al. 2006, TNC 2007). This species occurs in valley bottoms, dry playa margins and adjacent shore terraces (Crampton et al. 2006) on barren heavy clays, silty hardpan soils, saline flats, and sandy hills (Reveal 1988, Nevada Natural Heritage Program 2001). Pahrump Valley buckwheat occurs on rolling hills, stabilized dunes, and alkaline flats around dry lake beds in association with *Atriplex* spp. Soil types where it occurs include clay soil soils (Reveal 1971, Mozingo and Williams 1980, Crampton et al. 2006). Major plant associates are mesquite (*Prosopis* spp.), shadscale (*Atriplex confertifolia,* Mozingo and Williams 1980). These habitats are characteristic of the areas around the Mesquite Dry Lake, and others in the region.

Habitat modeling for sand dependent species were conducted and provide estimates of the amount of area for species habitat categories within Clark County ecosystems. Estimated high suitability habitat was identified in Mojave Desert Scrub, and Salt Desert Scrub, and to a lesser extent in Mesquite Acacia (Table A.7-3). Moderate habitat includes some Desert Riparian areas as well (Table A.7-3).

Table A.7-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415209	54	5
Bristlecone Pine	7565	0	0
Desert Riparian	9336	829	0
Mesquite Acacia	16658	3023	540
Mixed Conifer	27339	0	0
Mojave Desert Scrub	1231732	102809	23431
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	49713	11711	21090

A.7.6 Ecosystem Level Threats

This species occurs in Salt Desert Scrub, and Mesquite/Acacia ecosystems. Threats include encroaching commercial or residential development, land conversion for agriculture, off-highway vehicles, development of trails, and dumping (Mozingo and Williams 1980, Nevada Natural Heritage Program 2001). USFWS (2009) list as threats: a proposed airport, urban/industrial development, public land disposal, utility corridors, and off-highway vehicles. This species can tolerate moderate transient disturbance (Nevada Natural Heritage Program 2001). These types of disturbance increase the risk of invasive plants and may alter surface and groundwater flows (TNC 2007).

A.7.7 Threats to Species

Specific threats to this species have not been identified (Reveal 1985, TNC 2007, USFWS 2009).

A.7.8 Existing Conservation Areas/Management Actions

A conservation strategy specific to this species was developed by TNC for the Clark County Desert Conservation Program. The recommended conservation actions for this species included the following:

- proactively protect and manage for long-term viability of all populations on federal lands;
- ensure that disposal of federal lands in Clark County will not significantly impact conservation of rare plant populations;
- ensure that long term viability of low elevation rare plants is not significantly impacted by rural development and sprawl;
- investigate opportunities to acquire land or conservation easements for Pahrump Valley buckwheat habitats in Clark County; and
- designate two population groups for proactive protection (TNC 2007).

The USFWS Spotlight Species Action Plan for the Pahrump Valley buckwheat (USFWS 2009) recommends acquiring precise acreage figures for occupied and potential habitats and developing a conservation strategy that avoids, minimizes, or mitigates loss of both occupied and potential habitat. Crampton et al. 2006 suggest that conservation measures targeting mesquite woodlands in southern Nevada will provide indirect protection for the Pahrump Valley buckwheat.

A.8 LAS VEGAS BUCKWHEAT (*ERIOGONUM CORYMBOSUM VAR. NILESII*)

The Las Vegas buckwheat (*Eriogonum corymbosum* var. *nilesii*) is a recently identified, genetically unique subspecies of crispleaf buckwheat in the Polygonaceae (*Eriogonum corymbosum* - Reveal 2004). This buckwheat is a woody shrub with yellow to pale yellow or, rarely, white flowers, blooming in August to November. The species is distinguished by dense hairs on the leaves and stems that are at least twice as long as they are wide (USFWS 2014).

A.8.1 Species Status

A petition to list the Las Vegas buckwheat for Endangered Species Act (ESA) protection was filed with the Secretary of the Interior on April 22, 2008 (Center for Biological Diversity 2008). In the 12 month review finding, the USFWS determined that listing of this species as threatened or endangered under the ESA was warranted, but is precluded by other, higher priority actions (USFWS 2008). The species remained in that status until September 24, 2014. That finding determined that listing the Las Vegas buckwheat for protection under the Endangered Species Act was unwarranted. New petitions for listing have not been submitted since that time.

US Fish and Wildlife Service Endangered Species Act: Sensitive

US Bureau of Land Management (Nevada): No status

US Forest Service (Region 4): No status

State of Nevada (NAC-527): No status

NV Natural Heritage Program: Global Rank G5T2, State Rank S1S2 (NNHP 2004)

IUCN Red List (v 3.1): No status

CITES: No status

A.8.2 Range

Initially Las Vegas buckwheat was believed to occur only in the Las Vegas Valley of Clark County, Nevada. Early examination of herbarium specimens suggested that Las Vegas buckwheat not only occurred in the Las Vegas Valley, but could be present in two additional locations outside of Nevada: Paria River in southern Kane County, Utah; and Pierce Wash near St. George Utah, in northern Mohave County, Arizona (Reveal 2004). However, further genetic investigations indicated that the extralimital locations are taxonomically distinct from those described in southern Nevada (Ellis et al. 2009). Populations of this species occur: north of Lake Mead in the Muddy Mountains of Lake Mead National Recreation Area of east Clark County; the north end of the Las Vegas Valley, Toquop Wash of Lincoln County and in the north and south of Coyote Springs Valley in both Clark and Lincoln counties. While somewhat widespread across the two counties, Las Vegas buckwheat habitat occupies only ~ 320 ha (~790 ac).

A.8.3 Population Trends

Caution must be used in the interpretation of population trend data for this species for a variety of reasons including: confusion about the use of terms such as site, location, subpopulation and population in the source materials; the wide variety of census and 'estimation' methods that have been employed by various groups tasked with measuring abundance of the species, and error involved in identifying polygons to define stand boundaries. These factors render the data for this species too variable for the data to be of technical use (USFWS 2014). These factors preclude population trend analysis in terms of a demographic analysis.

A broader interpretation including a spatial analysis was provided by USFWS (2014). Of the original 12 populations recognized by USFWS, three have already been extirpated by urban development and highways construction. Of the nine remaining extant populations, impacts to two more seems imminent (USFWS 2014a). Looking at it a different way, it is known to have been extirpated from ~527 ha (~1305 ac), Las Vegas buckwheat has lost nearly 62 % of its range (USFWS 2014a). Most of the lands from which the species has been extirpated are in private ownership (94.9 percent); the remaining lands where it was extirpated are owned or managed by the City of Las Vegas (1.95 percent), Clark County (2.24 percent), or the DOD (0.9 percent).

A.8.4 Habitat Model

While the three model algorithms generally predicted similar habitat arrangements throughout the County, the GAM and RF models generally predicted more habitat than did the MaxEnt models (Figure A.8-1). The MaxEnt model predicted the smallest area of habitat, and when it was predicted, habitat suitability values were low overall. Similarly, habitat suitability values for the Gam model were relatively low across the County, although it predicted a broader area than the RF or MaxEnt models. Key areas of similarity among models in the County included the City of Las Vegas, and areas to the East and North of there, including: Nellis Air Force Base, Muddy Mountains, Gale Hill, Valley of Fire and some areas at lower elevations between the Virgin and south Virgin Mountains of Gold Butte. A smaller area near the dry lake in Eldorado Valley is also moderately well supported. There is also an area of moderate suitability predicted along the US 95 corridor northwest of the Las Vegas Valley (Figure A.8-1).

The Ensemble model and GAM models had slightly higher performance relative to the other models, with an equivalent score for AUC and TSS (Table A.8-1). However, the Ensemble model had a noticeably lower BI score than any other model. The RF model performed well but had a lower BI score than both the GAM models (Table A.8-1). Relative to the other models, the MaxEnt model had lower performance on the BI metric than the GAM or RF models. Overall AUC performance was very high, with all models performing above 0.94, while BI scores were relatively high. The GAM and RF, models shared two of the top four influential environmental variables, where the Average Spring Maximum temperature, and the NDVI Amplitude were the largest contributors (Table A.8-2). The RF and MaxEnt model shared Winter Precipitation as a top influential variable. The GAM and MaxEnt shared the Silt Content of the soil variable as a top influential variable. The standard error was relatively low throughout the County, where only the GAM model had values approaching 0.07 in most areas (Figure A.8-2). All other model standard errors were very low (Figure A.8-2). The Continuous Boyce Indices showed good model performance for the Ensemble and GAM algorithms, while the RF, and to a lesser degree, the MaxEnt models' curves indicated some values of higher performance where point density was only moderate, indicating less discrimination between high and low habitat (Figure A.8-3). These lower scores were likely due to the lack of lower suitability scores in areas with fewer points that retained moderate suitability scores, and are typical when modeling with few localities.

Table A.8-1. Model performance values for Las Vegas buckwheat models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.7	0.95	0.39
GAM	0.99	0.98	0.95	
Random Forest	1	0.86	0.95	
MaxEnt	0.95	0.82	0.84	

Table A.8-2. Percent contributions for input variables for Las Vegas buckwheat for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	13.3	9.7	6
Average Spring Max Temp	13.5	18	1.2
Soil gypsum	2.6	5.3	3.2
NDVI Amplitude	18.9	15	1.9
NDVI Max	7.7	8.3	20
Sand	7	6.7	36.8
Silt	12.5	8.6	6.8
Start of Season (day)	6.2	11	4.6
Winter Precip	10.1	14.7	15
CV Winter Precip	8.2	2.6	4.6

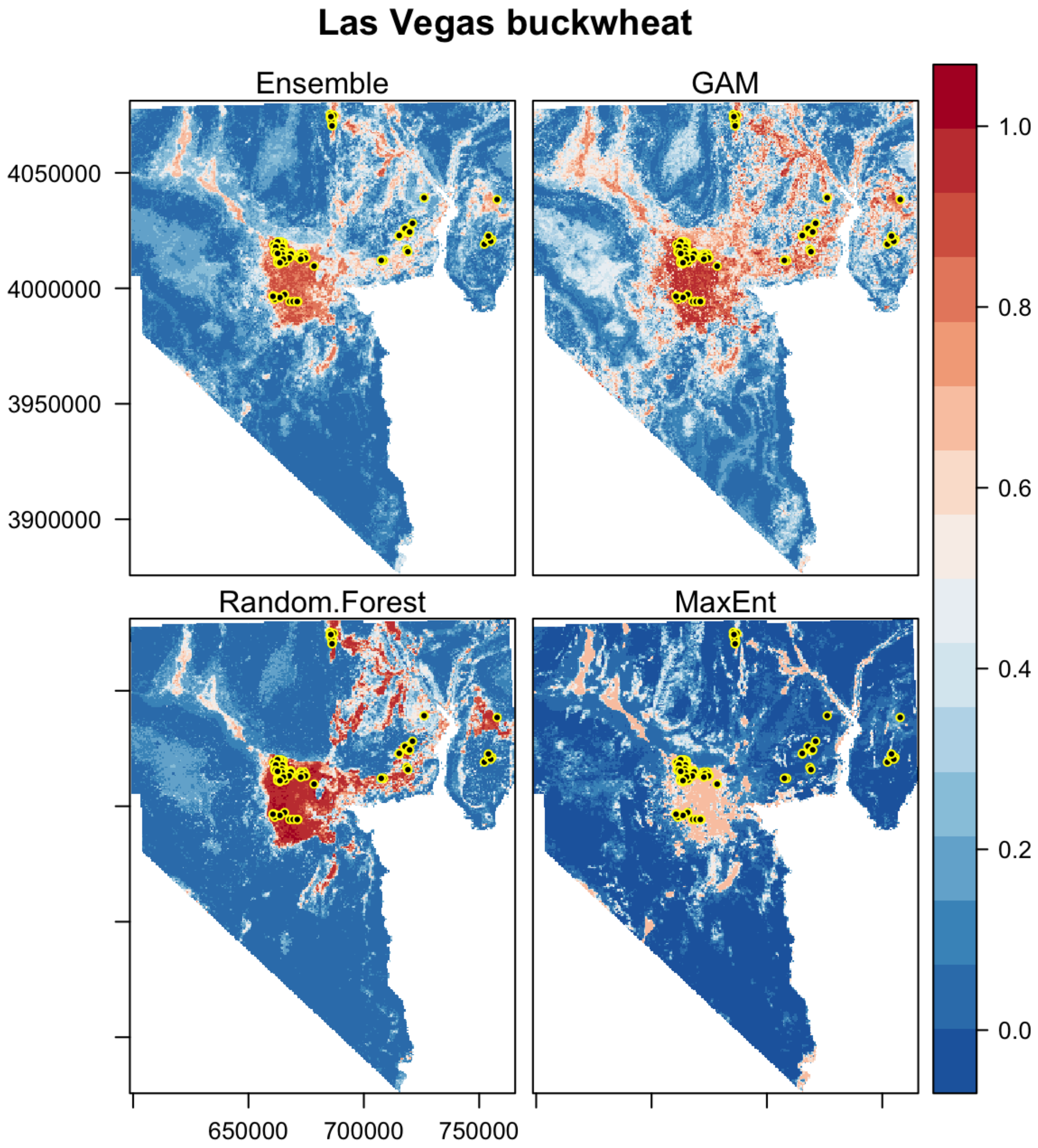


Figure A.8-1. SDM maps for Las Vegas buckwheat model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

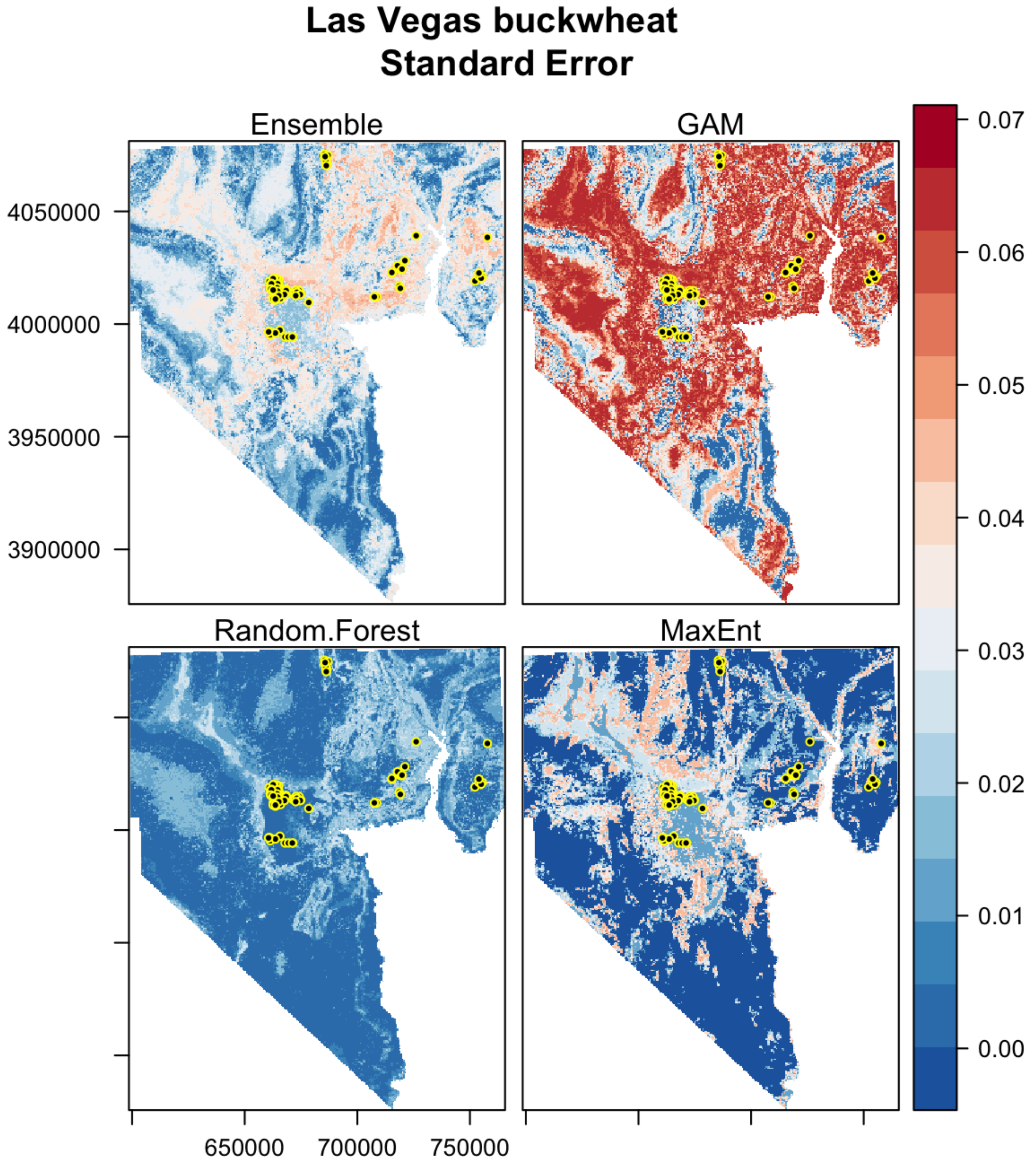


Figure A.8-2. Standard error maps for Las Vegas buckwheat models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

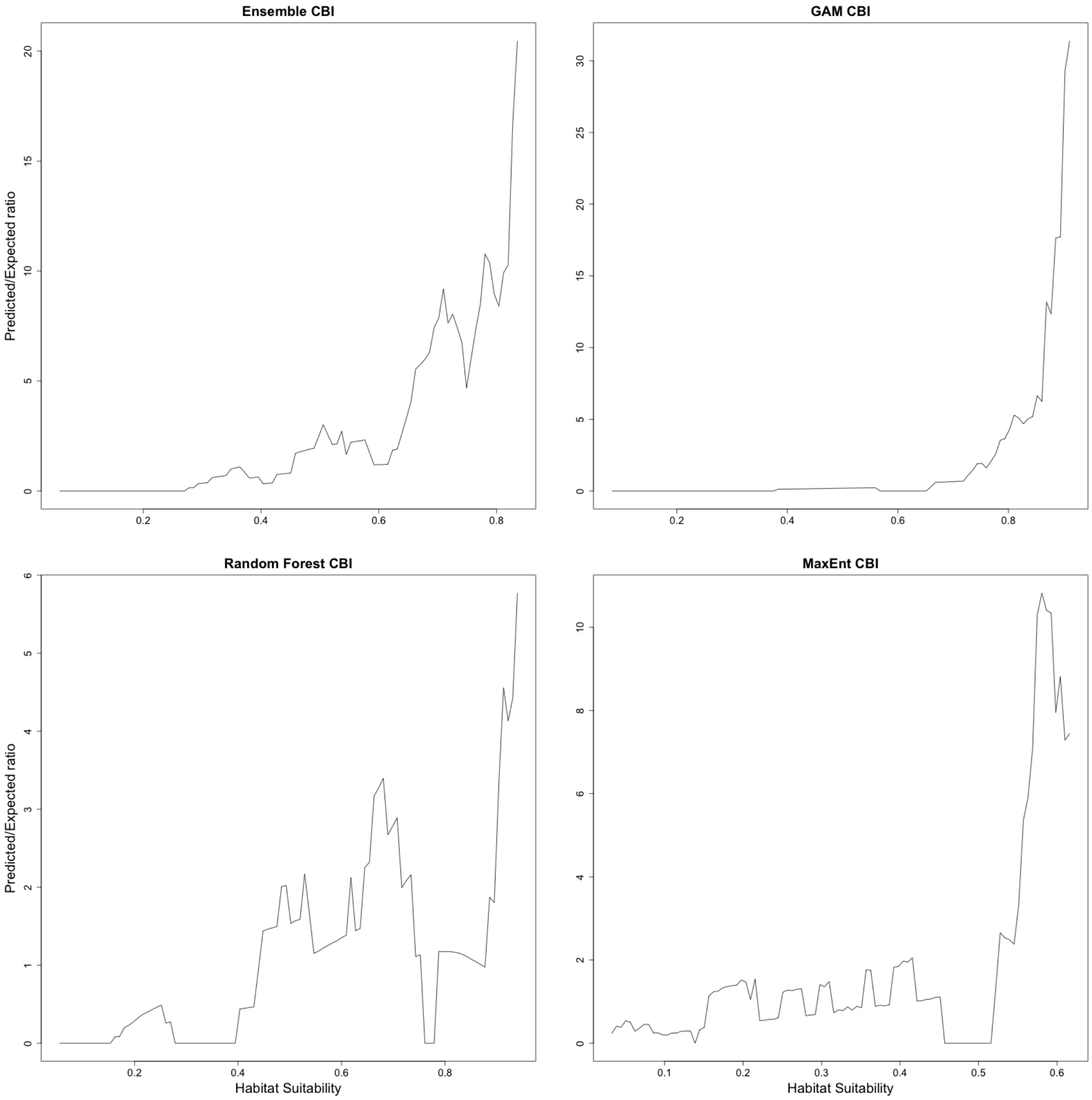


Figure A.8-3. Graphs of Continuous Boyce Indices [CBI] for Las Vegas buckwheat models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.8.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, NDVI Amplitude, and Silt component of the soil collectively accounting for 58.2% of total model contribution (Table A.8-2). Model scores were higher in areas with Average Maximum temperatures at 41.5 ºC, and lower at all other temperatures. Spring Maximum temperatures showed a peak response at 32 ºC, and were lower elsewhere (Figure A.8-4). This response is concordant with the RF models for Average Spring Maximum temperature, except that the RF model does not predict much lower values at temperatures above 32 ºC (Figure A.8-6). The GAM model predicts The highest habitat values for the variable NDVI Amplitude when NDVI Amplitude is low, and decreases nearly linearly as NDVI Amplitude increases (Figure A.8-4). This same response is evident in the RF model for NDVI Amplitude, except that the habitat values decrease more rapidly in the RF model as NDVI Amplitude increases. (Figure A.8-4, Figure A.8-6).

Habitat values for Silt Content were low when Silt Content was low, and increased to a point where they were highest, and plateaued at high values in areas with Silt Content of 31 % or higher (Figure A.8-4). These areas also represent areas with higher Silt Content than found in the County generally (Figure A.8-4). This prediction matches the prediction by the MaxEnt models for the Silt Content variable. This algorithm had higher standard error values, indicating some dissimilar predictions among the 50 model cross-validation runs (Figure A.8-3).

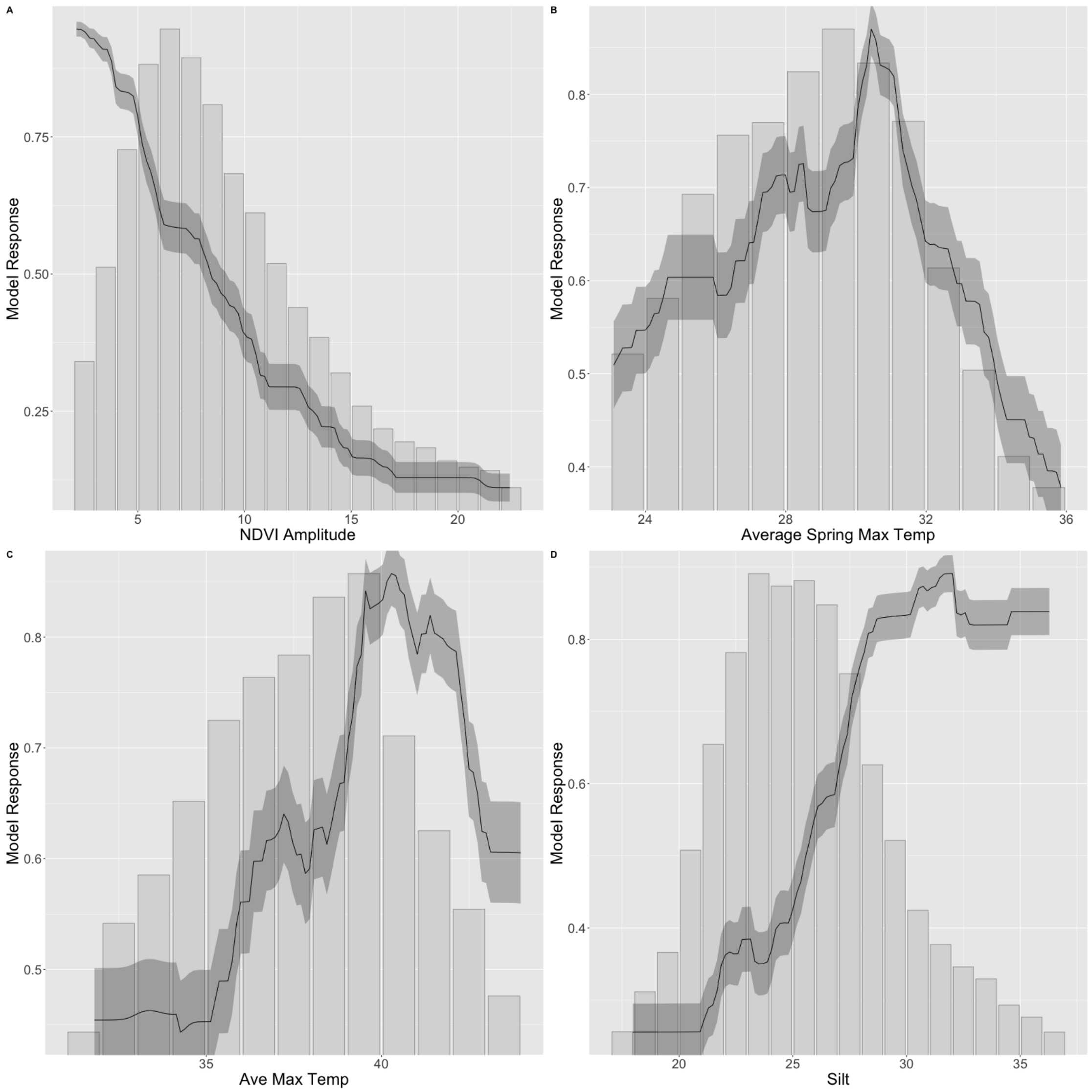


Figure A.8-4. GAM partial response curves for the top four variables in the Las Vegas buckwheat model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.8.4.2 MaxEnt Model

The MaxEnt models relied heavily on NDVI Maximum, Sand Content of the soil, Silt Content of the soil (shared with the GAM model), and Winter Precipitation (shared with the RF model). In total, these four variables accounted for 78.6% of total model contribution (Table A.8-2). The models indicated consistently high habitat values when NDVI Maximum was below 120, with a rapid decline thereafter (Figure A.8-5). The model predicts consistently low habit values when the Sand Content variable is low, and increases to a plateau at higher values when Sand Content reaches ca. 28% (Figure A.8-4). This model had very similar response curves to the GAM model for the Silt Content variable (Figure A.8-4. Figure A.8-5) as noted previously. The MaxEnt models show a similar response curve as the RF model to the Winter Precipitation variable, where habitat values are high when Winter Precipitation is below ca. 110, and decline thereafter.

This model had relatively low standard errors, indicating general agreement in the predictions among the 50 model cross-validation runs (Figure A.8-3).

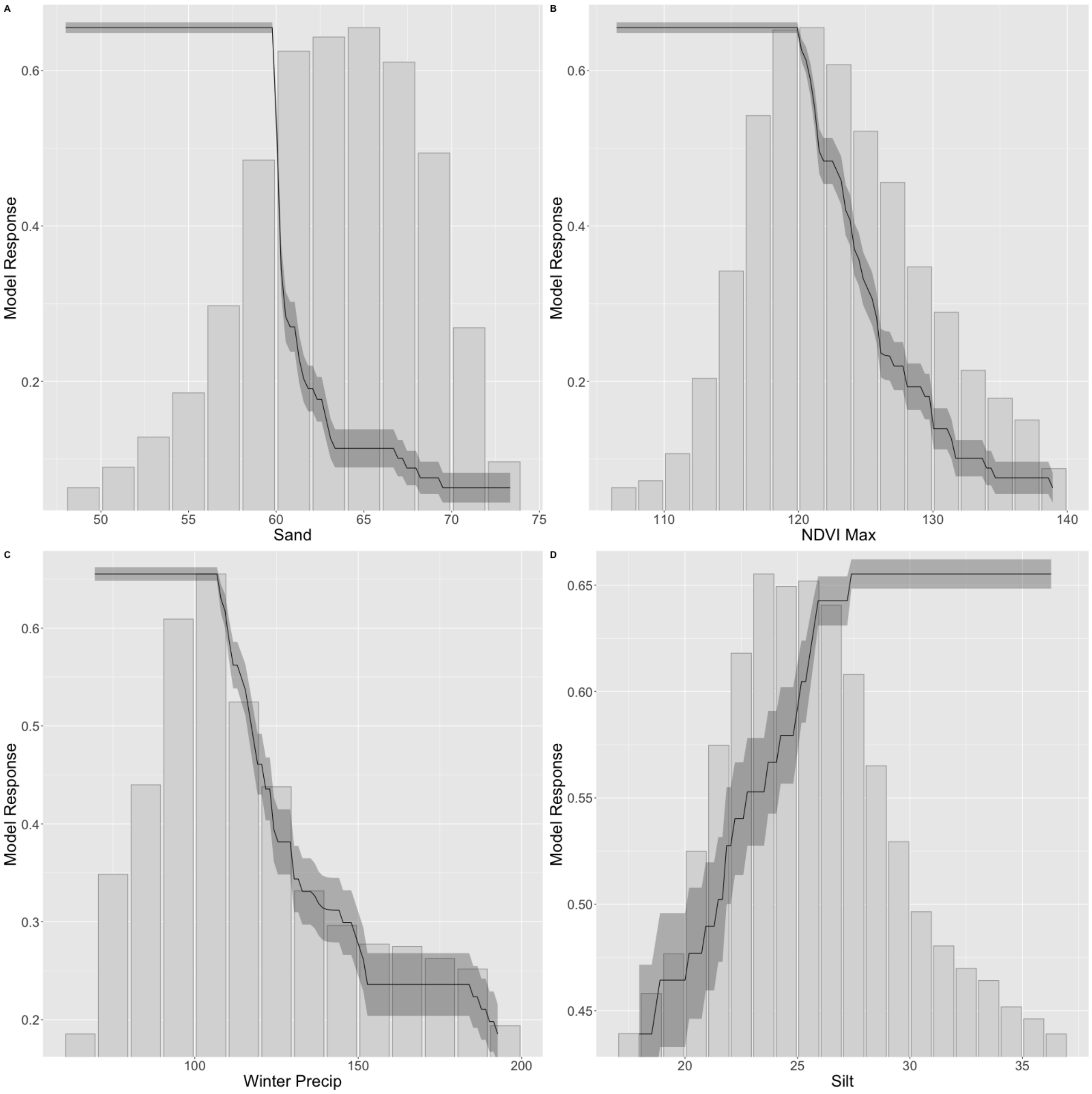


Figure A.8-5. Partial response curves for the top four environmental variables included in the MaxEnt Ensemble model for Las Vegas buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.8.4.3 Random Forest Model

The Random Forest model was largely driven by Average Spring Maximum temperature, NDVI Amplitude, Start of Season, and Winter Precipitation (Table A.8-2). The collective model influence of these four variables was 58.7%, where additional influence was proved by several other input variables (Table A.8-2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (Figure A.8-6) and differed slightly from the response of the MaxEnt model, in that the RF model favors Winter Precipitation values that are slightly less than those found in the County generally. Average Maximum temperature indicated the highest habitat suitability at temperatures above 38 ºC, followed by a plateau. This differs slightly from the MaxEnt model which had a distinct peak at 40 ºC. The response curve for Clay Content is concordant with those of the GAM and MaxEnt models, with continued high habitat suitability at values above 10-15%. Slope indicated higher habitat in areas with low slope, but did not differ dramatically from the distribution of slope in the County (Figure A.8-6).

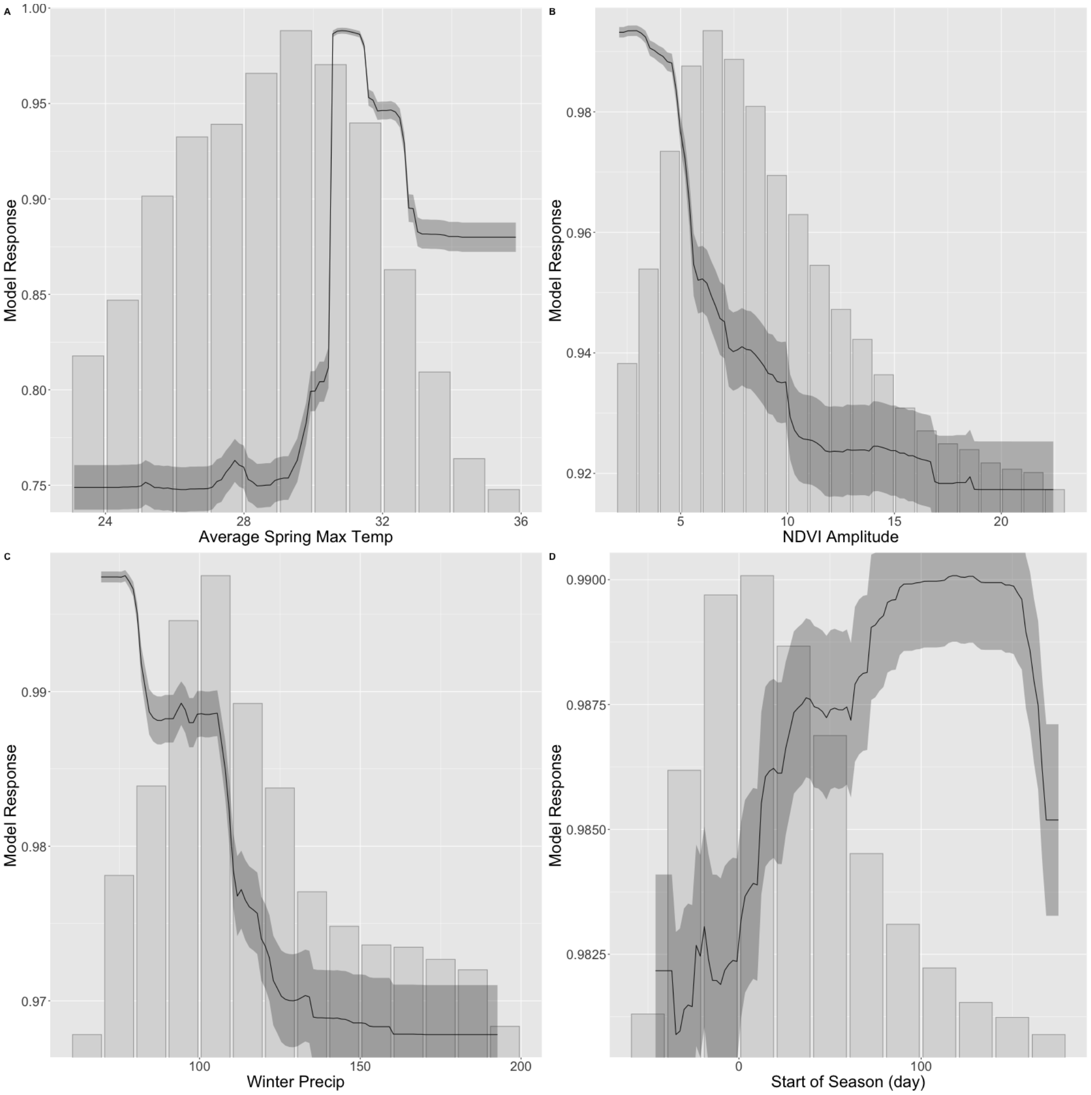


Figure A.8-6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for Las Vegas buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.8.4.4 Model Discussion

Las Vegas buckwheat primarily occurs in and near the City of Las Vegas, notably concentrated on both the North and South sides (Figure A.8-7). Disjunct populations also occur near the Muddy Mountains, the South Virgin Mountains / Gold Butte (although habitat is predicted to be low in the area of these localities), and the Coyote Springs Wash. However, the model indicates other areas of high habitat suitability. In particular all three models, predict high habitat suitability in a rather large area closest to the northern populations described above. The area near the Meadow Valley Wash, west of the North Muddy Mountains, and vicinity have pockets with rather high predicted habitat suitability. Another area near the dry lake in Eldorado Valley is also predicted to have high habitat suitably. Finally, a large area of moderately high habitat suitability is predicted along the northwestern US 95 corridor, extending north of Amargosa valley (Figure A.8-7)

The locality data for this species consisted of 936 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 96 records

A.8.4.5 Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (Figure A.8-8), with moderate error, located in some areas that were predicted as moderately high quality habitat. Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

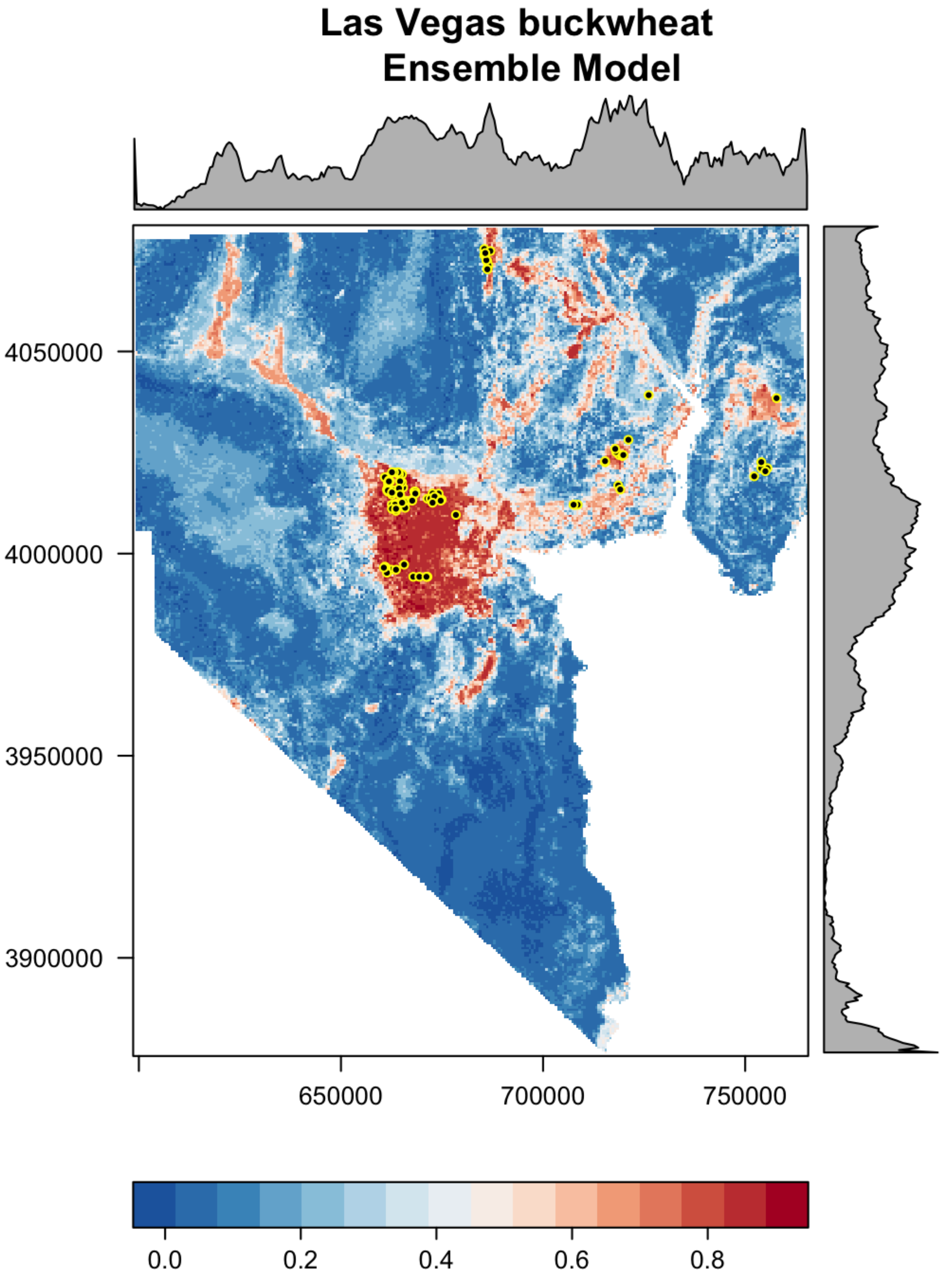


Figure A.8-7. SDM map for Las Vegas buckwheat Ensemble model for Clark County, NV.

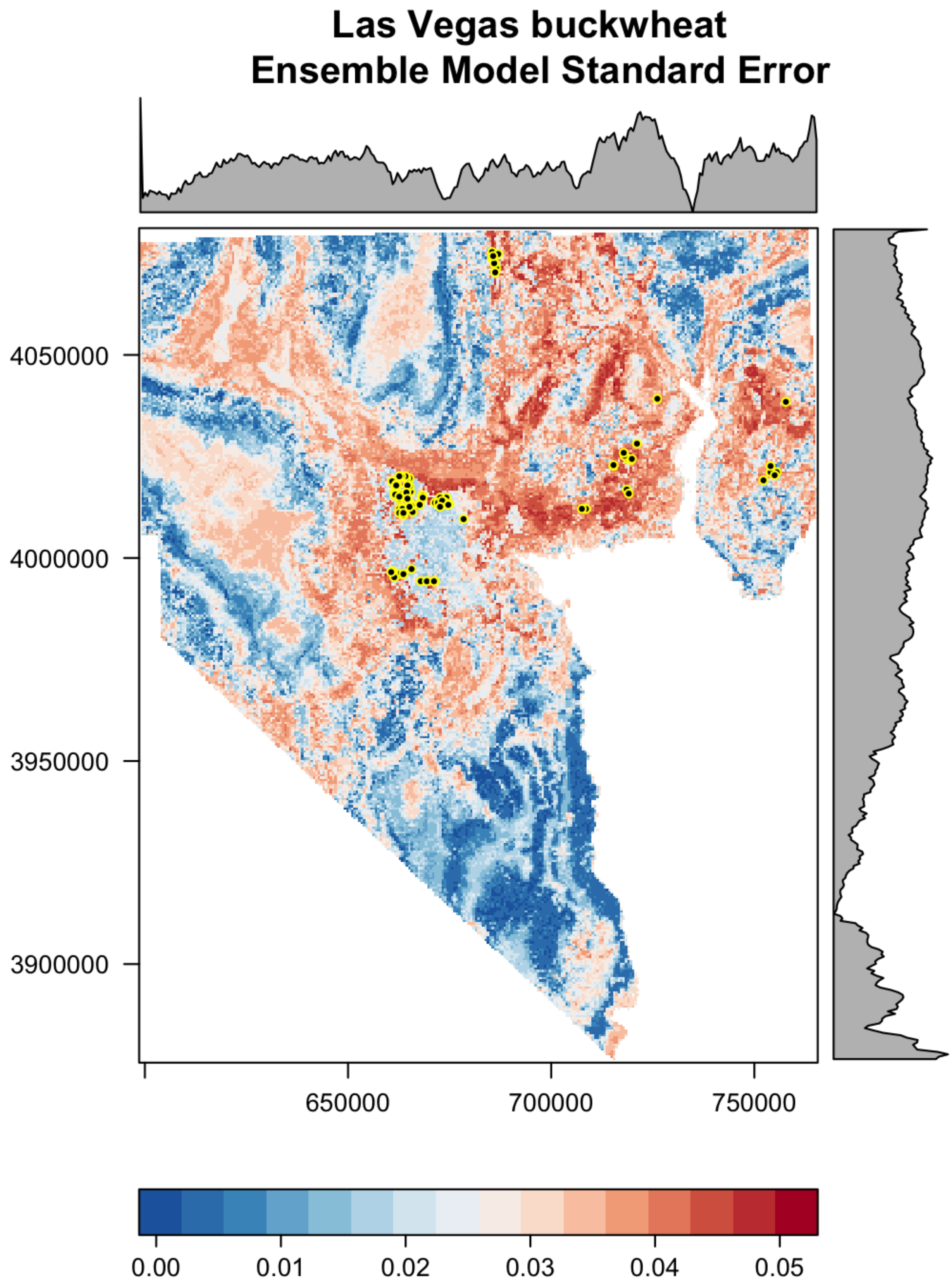


Figure A.8-8. Standard Error map for the Las Vegas buckwheat Ensemble model for Clark County, NV.

A.8.5 Distribution and Habitat Use within Clark County

Some of the largest populations of Las Vegas buckwheat are found in the upper Las Vegas Wash ecosystem, Nellis Air Force Base, and smaller populations in the Las Vegas Valley, Gold Butte, and Muddy Mountains (Morefield 2007). Historically, the largest concentration of this plant species and discrete localities has been in the Las Vegas Valley (USFWS 2008).

The elevational range of Las Vegas buckwheat is 200 to 850 m (656 to 2,789 feet ft). This species is strongly associated with soils with high gypsum content, clay beds, or high-boron content shales. Las Vegas buckwheat typically occurs with other gypsophylic species on sparsely-vegetated sites with cryptogamic soil crusts (Meyer 1986, Drohan and Merkler 2009, USFWS 2014). Pollinators of Las Vegas buckwheat have not been technically identified, however there have been 20 invertebrates observed on the flowers (Glenne 1999).

Estimated high suitability habitat for this species is predicted to be nearly exclusive to the Mojave Desert Scrub and Salt Desert Scrub ecosystems (Table A.8-3), while medium suitability habitat includes areas in Blackbrush, Mesquite Acacia, and Desert Riparian systems (Table A.8-3).

Table A.8-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	**Low**	**Medium**	**High**
Alpine	124	0	0
Blackbrush	406613	8521	7
Bristlecone Pine	7561	2	0
Desert Riparian	2046	7414	339
Mesquite Acacia	13302	5222	1692
Mixed Conifer	27337	1	0
Mojave Desert Scrub	961261	254208	139509
Pinyon Juniper	115444	403	0
Sagebrush	4705	1	0
Salt Desert Scrub	48171	16281	17991

A.8.6 Ecosystem Level Threats

This species occupies Mojave Desert Scrub and Salt Desert Scrub ecosystem types, and frequently on a subset of soils that support other sparse vegetation. Urbanization or infrastructure development (utility corridors and highways) of habitat is the primary threat to Las Vegas buckwheat (Center for Biological Diversity 2008, USFWS 2009). Other major threats that have been identified include off-highway vehicle use (including dirt-bikes), illegal dumping activities, transient migrant habitation, flood control development, plant invasions (*Halogeton glomeratus*, *Salsola tragus* L., and *Strigosella africana* (L.) Botsch (syn. *Malcolmia africana*; African mustard), recreational activities (equestrian, and pedestrians), and surface mining and mineral claims (particularly of gypsum) (Edwards 2007, USFWS 2009, BLM 2011, USFWS 2014). Another potential threat that has been named (USFWS 2014) includes fire that is dependent on nonnative invasive grasses. However, the most prevalent invasive grasses in this region (*Bromus madritensis* var. *rubens* and *Schismus* spp.) do not thrive on the gypsum soils, thus do not provide fuel sufficient to burn in most cases (T. Esque, Pers. Obs).

A.8.7 Threats to Species

Urbanization, utility and transportation corridor development, and OHV activity can cause wholesale losses of Las Vegas buckwheat populations. Other disturbance sources such as dumping, and recreation can damage or kill individual plants in addition to damaging habitat. Several remaining populations are at risk due to land ownership and the potential for urban development.

A.8.8 Existing Conservation Areas/Management Actions

Seven conservation measures have been completed that benefit the Las Vegas buckwheat (USFWS 2009):

- A conservation agreement with the City of North Las Vegas to establish the Eglington Preserve;
- Fencing installed by BLM to protect the Eglington Preserve and limit unauthorized off-highway vehicle impacts;
- Fencing installed by Nellis AFB to protect habitat within Nellis Area III;
- BLM purchase of 30 acres of the White Basin subpopulation; and
- BLM withdrawal of public minerals within some Las Vegas buckwheat habitat.
- Designation of the Muddy Mountains Wilderness
- Establishment of Tropicana and Decatur buckwheat Conservation Area
- During restoration efforts at Las Vegas Springs Preserve several Las Vegas Valley buckwheat plants were put in. While not significant for the population size it is important to note that they were placed there to educate the public on the Las Vegas buckwheat.

A.9 STICKY BUCKWHEAT (*ERIOGONUM VISCIDULUM*)

Sticky buckwheat (*Eriogonum viscidulum*) is a small, rare winter annual in the buckwheat family (Polygonaceae) (Holland et al. 1979). The elevational range for this species is 1200 to 2200 ft. (Swearingen 1981, NNHP 2001). The sticky buckwheat inhabits sandy soils and grows up to 40 cm tall with diffusely branched, thready stems rising from a basal rosette of leaves (NNHP 2001, ARPC – No Date). The tiny yellow flowers bloom in April and May (NNHP 2001).

This species exhibits the characteristic of entrapping sand particles onto its surfaces from the surrounding environment thus rendering it less palatable to herbivores. This adaptation in plants is known as psammophory meaning “sand armor” (Lopresti and Karban 2016).

Some native plants associated with sticky buckwheat include *Larrea tridentata*, *Ambrosia dumosa, Pleuraphis rigida, Krameria parvifolia, Dicoria canescens, Pediomelum sp., Croton californicus, Tiquilia sp.,* and *Abronia sp*. (NNHP 2001). The microhabitat of sticky buckwheat overlaps with another rare plant that is of concern in Clark County - *Astragalus geyeri var. triquetrus* (NNHP 2001).

A.9.1 Species Status

The sticky buckwheat is a former Category 2 candidate for threatened or endangered status under the Endangered Species Act of 1973. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that the sticky buckwheat proposal for listing may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (USFWS 1993).

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): Critically endangered

NV Natural Heritage Program: Global Rank G2, State Rank S2

IUCN Red List (v 3.1): No Status

CITES: No Status

A.9.2 Range

The first specimen of sticky buckwheat was found near the bridge over the Virgin River at Riverside, Clark County, Nevada (Howell, J.T., in Reveal 1985). Sticky buckwheat is nearly confined to Clark County, Nevada but some populations also occur in adjacent Lincoln County, Nevada and the extreme northwest corner of Mohave County, Arizona (TNC 2007). Eleven of the 13 known populations occur in northeast Clark County (TNC 2007). Three populations found on lands managed by BLM occur at least partly within designated ACECs.

A.9.3 Population Trends

Sticky buckwheat only appears sporadically due to the seasonal and inter-annual variability of available precipitation and appropriate temperatures. This must be considered in the evaluation of population trend data from monitoring plots. It will require several years of such data to understand population trends. The expression of this winter annual plant (i.e. germinating, growing, flower, going to seed and senescing between September and May) is dependent on seasonal precipitation with appropriate temperatures. However, if required germination conditions are met, several generations may germinate from the seed bank in a single season, or during droughts may not germinate at all. Niles et al. (1995) reported finding 20020 individual plants in an inventory of 22 localities where sticky buckwheat is known to occur. In 1997, an estimated 1500 plants were found at Lime Cove site, and 500 plants were found at the Glory Hole site in Lake Mead National Recreation Area (Powell 1999). In 2008, Bangle (2012) reported finding 4708 and 126 individuals at the Lime Cove and Glory Hole study plots; respectively, at the Overton Arm of Lake Mead. There are no systematic population assessments across the range of sticky buckwheat since the Niles' surveys (Bangle 2012). Extensive surveys have been conducted (Nevada Natural Heritage Program 2001), but populations fluctuate in response to variable rainfall, making long-term trends difficult to determine.

A.9.4 Habitat Model

The three model algorithms generally predicted similar core habitat arrangements throughout the County, but with different extents, and levels of suitability values. The Random Forest models generally predicted higher habitat values in a larger area than the other models. The MaxEnt models tended to retain lower habitat suitability values where other models predicted higher values, with a much smaller predicted area as well (Figure A.9-1). Key areas of similarity among models in the County included a large portion of the northeast of the county; including Moapa and Virgin Valleys, areas along the shore of Lake Mead, and - more weakly - a ring surrounding the lower elevations of Gold Butte, especially along the Lake Mead shoreline. The RF and GAM models also indicated an area of moderately high predicted habitat values near Eldorado valley in and around the dry lake, however the MaxEnt model does not (Figure A.9-1).

All three models had similarly high performance for AUC and TSS (Table A.9-1). The RF model had a *much* lower BI score than both the Ensemble and GAM models, likely due to the lack of moderate habitat predicted in areas with lower point densities. Overall, AUC performance was very high, with all models performing above 0.97, while BI scores were relatively high, with the exception of the MaxEnt model (Table A.9-1). The GAM and RF models shared Average of Maximum temperature as one of the top four influential environmental variables (Table A.9-2). The GAM and MaxEnt models shared Silt Content as one of the top four influential environmental variables (Table A.9-2). The RF and MaxEnt model shared CV Average Spring Maximum temperature, and CV Winter Precipitation as a top influential variables (Table A.9-2). The standard error was relatively low throughout the County for the RF and MaxEnt models, while the GAM model had values approaching 0.07 in many areas (Figure A.9-2). The Continuous Boyce Indices showed good model performance for the GAM models, with some irregularity in lower habitat values for the RF models (Figure A.9-3). The MaxEnt curve indicated some values of higher performance where point density was only moderate, indicating less discrimination between high and low habitat (Figure A.9-3), this is likely due to the lack of lower suitability scores in areas with fewer points that retained moderate suitability scores (e.g. 0.5, Figure A.9-1), and lack of high scores in areas of highest point density.

Table A.9-1. Model performance values for sticky buckwheat models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.77	0.9	0.41
GAM	0.97	0.93	0.86	
Random Forest	0.98	0.25	0.86	
MaxEnt	1	0.48	0.95	

Table A.9-2. Percent contributions for input variables for sticky buckwheat for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	15.9	9.2	1.1
Average Spring Max Temp	12.6	8.1	0.5
Depth to bedrock	4	1.7	5.8
Clay	11.1	0.4	15
Coarse frags	3.2	3.7	3.1
CV Average Spring Max Temp	8.3	16.9	39.6
Extreme Max Temp	11.2	49.9	6.9
Sand	13.6	0.4	0.6
Silt	12.4	0.9	9.2
CV Winter Precip	7.8	8.9	18.1

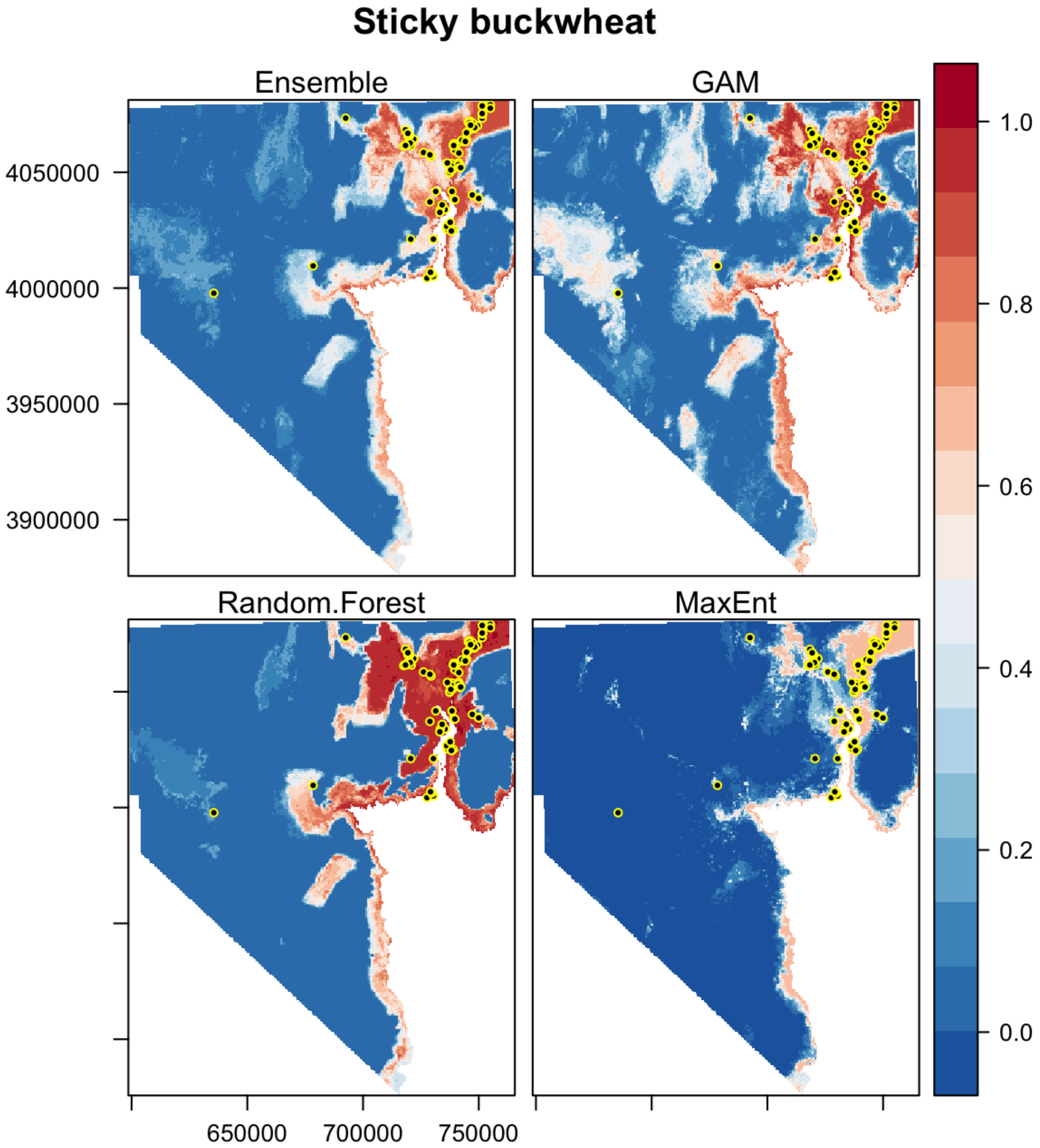


Figure A.9-1. SDM maps for sticky buckwheat model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

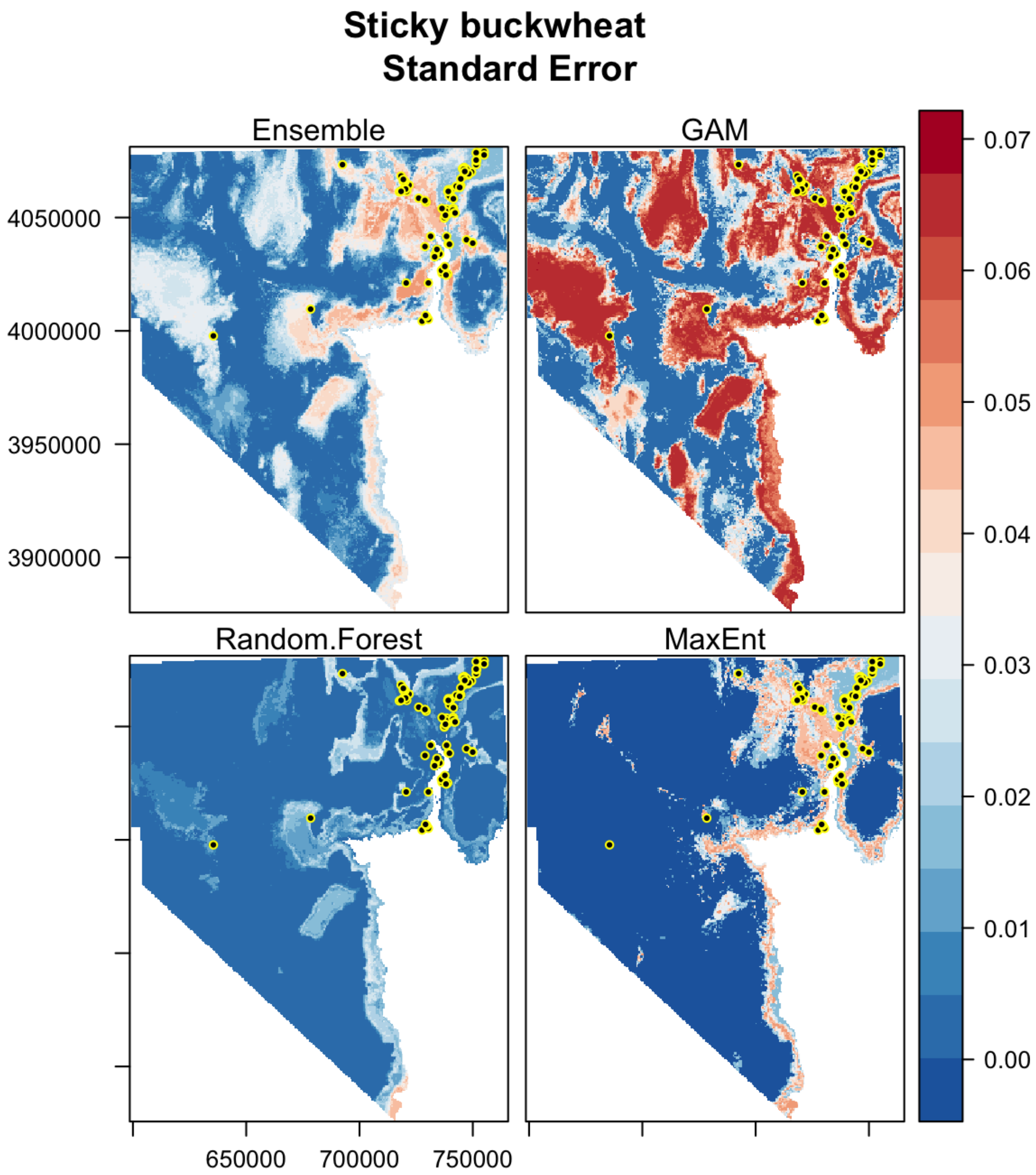


Figure A.9-2. Standard error maps for sticky buckwheat models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

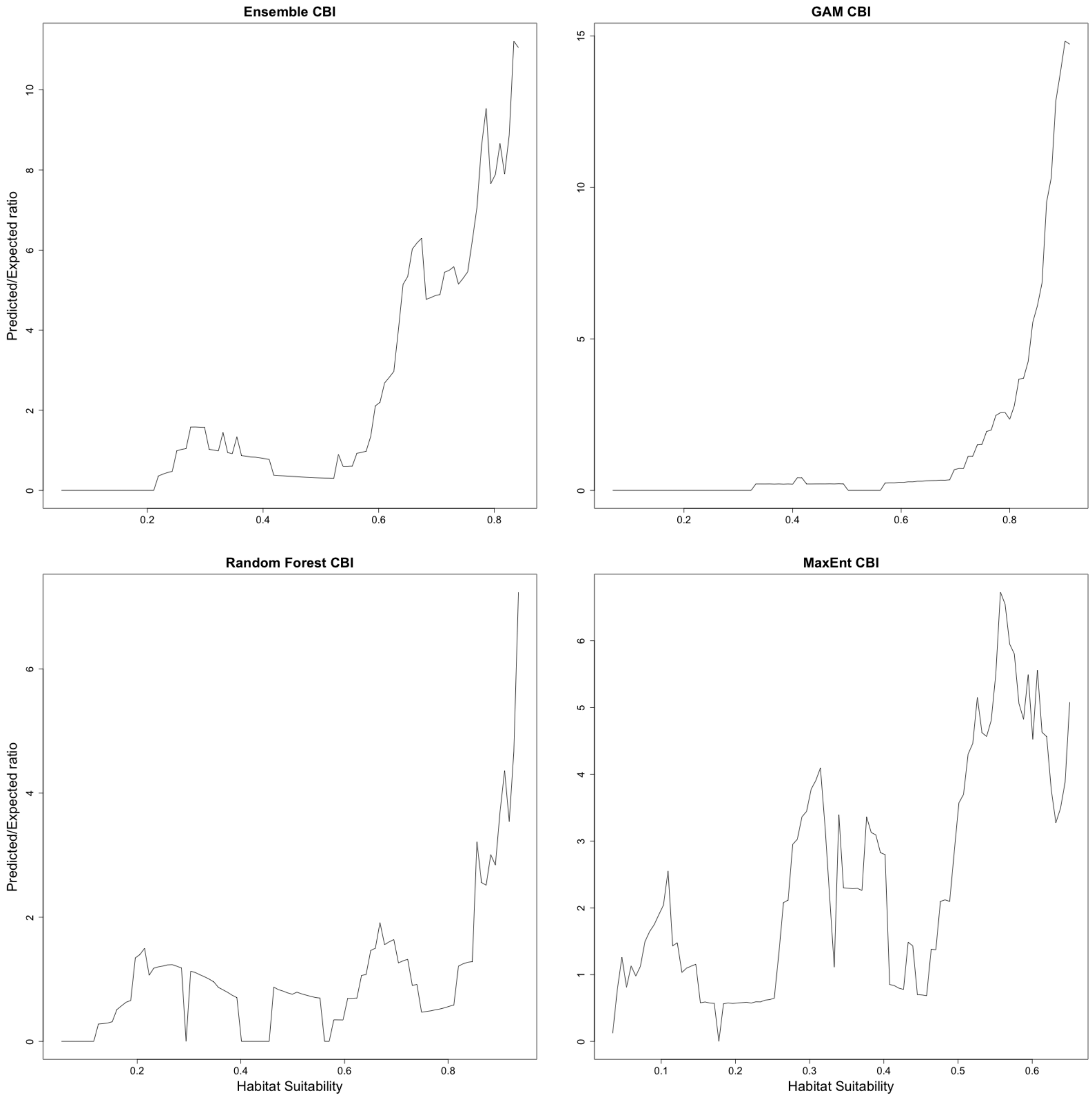


Figure A.9-3. Graphs of Continuous Boyce Indices [CBI] for sticky buckwheat models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.9.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, Sand, and Silt components of the soil collectively accounting for 54% of total model contribution (Table A.9-2). Model scores were higher in areas with Average Maximum temperatures at 44 ºC, and lower at all other temperatures. Spring Maximum temperatures showed a peak response at 33 ºC, and were lower elsewhere. (Figure A.9-4). Model predictions were highest, for areas with *ca*. 60% Sand Content, and were lower in areas with both higher and lower Sand Content. Areas with *ca*. 29% Silt Content had higher habitat values than found in the County generally (Figure A.9-4). This algorithm had higher standard error values (up to 0.07 – or 7% of potential model scores), indicating some dissimilar predictions among the 50 model cross-validation runs (Figure A.9-3).

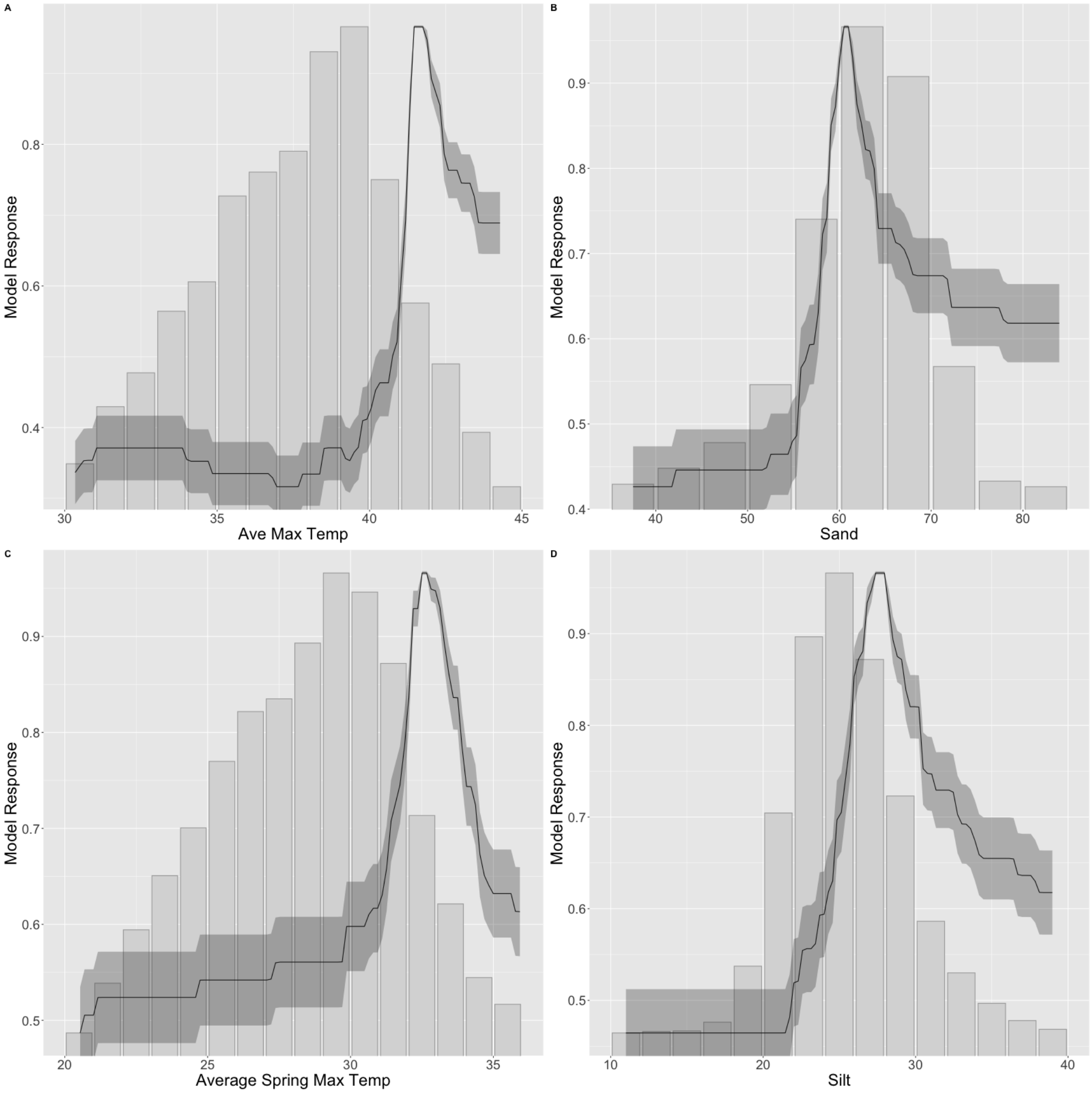


Figure A.9-4. GAM partial response curves for the top four variables in the sticky buckwheat model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.9.4.2 MaxEnt Model

The MaxEnt models relied heavily on the one of the same four top variables as those in the GAM models (Silt Content), and shared CV Winter Precipitation as a variable with the RF models. Clay Content, and CV Spring Maximum temperature were also important contributors in the MaxEnt models. In total, these four variables accounted for 72.7% of total model contribution, where CV of the Spring Maximum temperature was the largest overall contributor (40%. Table A.9-2). This model also had a dissimilar response curve for Silt Content than the GAM model. The MaxEnt model predicts high habitat values for low Silt Content until Silt Content reaches ca. 31%, and falls to nearly zero thereafter, whereas the GAM model did not have high habitat values for very low Silt Content (Figure A.9-4, Figure A.9-5). The predicted response for CV Winter Precipitation is nearly the same as the response seen in the RF model (Figure A.9-5, Figure A.9-6) where high habitat values are predicted when the CV Winter Precipitation is < 0.69, and then rapidly declines with higher CV values. The predicted response to Clay Content shows low habitat values with low Clay Content, until 11% Clay Content when the values dramatically increase and remain high for higher levels of Clay Content. The model response for CV Average Spring Maximum temperature shows higher habitat values when CV is low until ca. 0.07, and a rapid decline to near zero after that (Figure A.9-5). This is similar to the prediction of the RF model, which shows the same pattern of a rapid decline in habitat values at ca. 0.07, however, the RF model does not decline to near zero thereafter, with values plateauing at relatively higher habitat suitability (Figure A.9-5, Figure A.9-6).

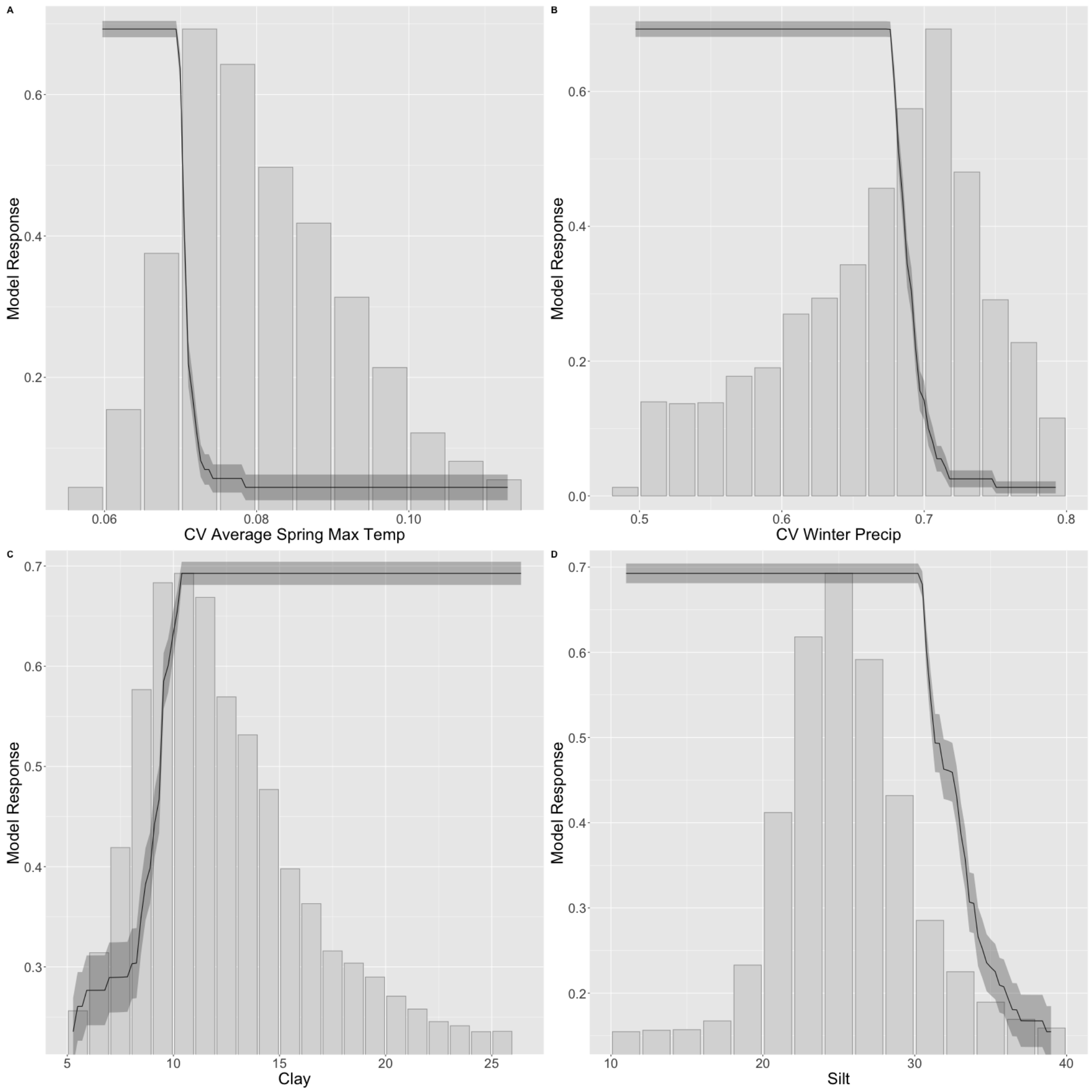


Figure A.9-5. Partial response curves for the top four environmental variables included in the MaxEnt Ensemble model for sticky buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.9.4.3 Random Forest Model

The largest contributor to the Random Forest model was Extreme Maximum temperature 50%). The response curve for Extreme Maximum temperature indicates higher habitat values for areas where the Extreme Maximum Temperature exceeds 42 ºC (Figure A.9-6). The CV of Average

Maximum temperatures was the second highest contributor (Table A.9-2). As described above, the response was similar to the MaxEnt model Figure A.9-5, Figure A.9-6) with low CV values indicated areas of higher suitability, combined with a rapid decline in values when CV rose above 0.07. Similarly, the model's response to the variable CV Winter Precipitation was concordant with the response seen in the MaxEnt model. In both cases, low CV indicated high habitat values, with a dramatic decrease, followed by a plateau, when CV values reached the 0.6 – 0.7 range. It should be noted that the habitat suitability values for the RF model dropped and plateaued at much higher values than the MaxEnt model (Figure A.9-5, Figure A.9-6). Average Maximum temperature indicated the highest habitat suitability at temperatures above 40 ºC, followed by a plateau. This differs only slightly from the GAM model which had a peak at 42 ºC and declined slightly thereafter (Figure A.9-4, Figure A.9-6). The RF model for this species tended to have a binary like prediction of habitat, with predictions of moderate habitat values being relatively absent. This model appears to over-predict some moderate habitat in the Moapa valley area relative to the GAM model (Figure A.9-1).

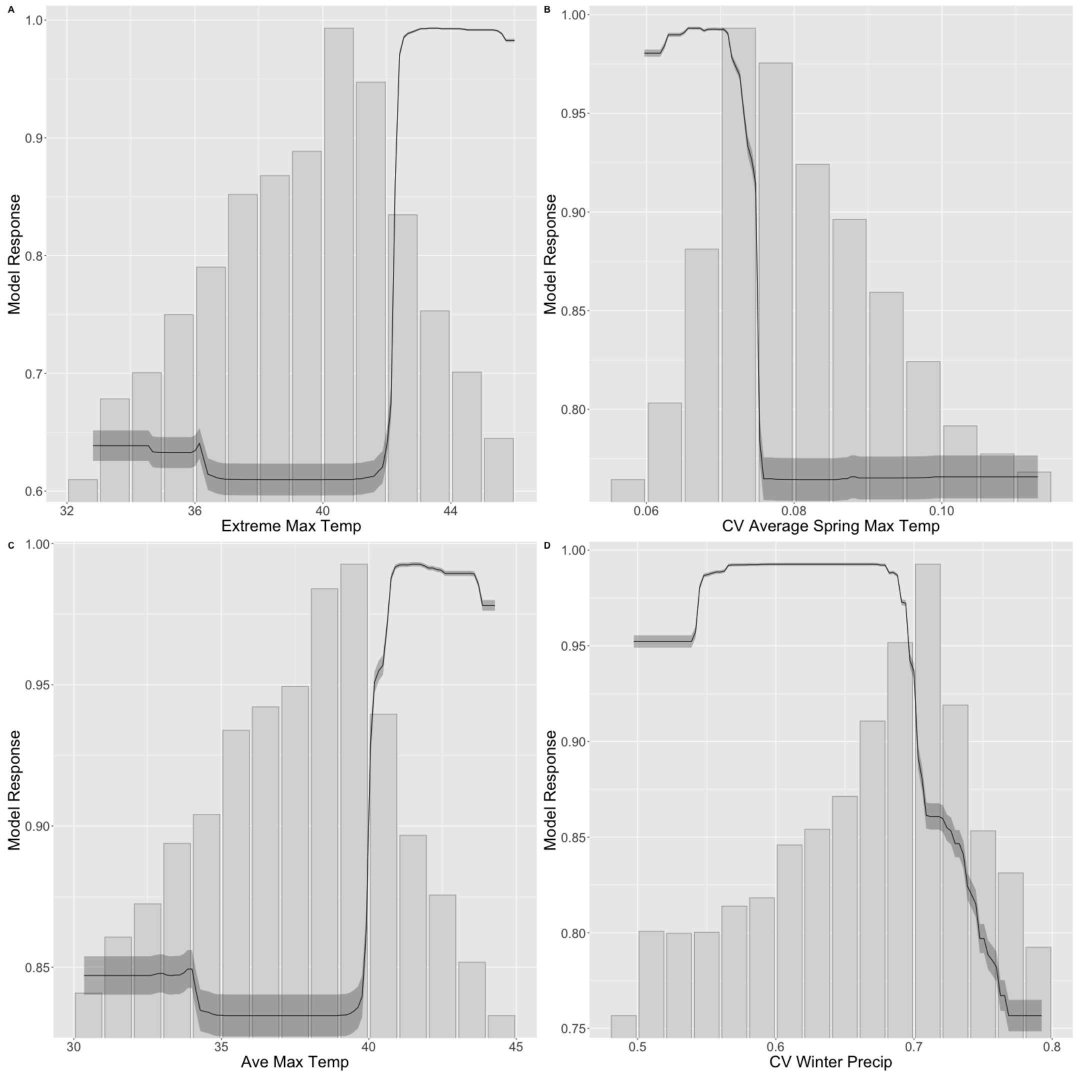


Figure A.9-6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for sticky buckwheat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.9.4.4 Model Discussion

Habitat for sticky buckwheat is predicted to occur primarily in the northeastern portion of the County, near the shores of Lake Mead, the Virgin River and Moapa Valley. The Ensemble model captures this distribution well, and is largely driven by the results of the GAM model. However, the model indicates other areas of high habitat suitability. In particular, areas around the lower elevations of Gold Butte, and the Colorado River south through the county (although there are no localities to support or confirm this prediction), and northwest along the Meadow Valley and Pahranagat washes near Bunker Hill (Figure A.9-7). There appears to be moderate habitat predicted near the Eldorado valley dry lake, but this is also not supported by any available locality data (Figure A.9-7).

The locality data for this species consisted of 603 records within the buffered modeling area. Spatial thinning of the data reduced the number of localities used for training and testing to 107, as there were many co-located records for this species.

A.9.4.5 Standard Error

The standard error map for the Ensemble model indicated relatively low error (ca. 0.05) throughout much of the study area (Figure A.9-8). Areas that were predicted as moderate to high quality habitat, and that are outside of the species known range did not necessarily have high standard error values. Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

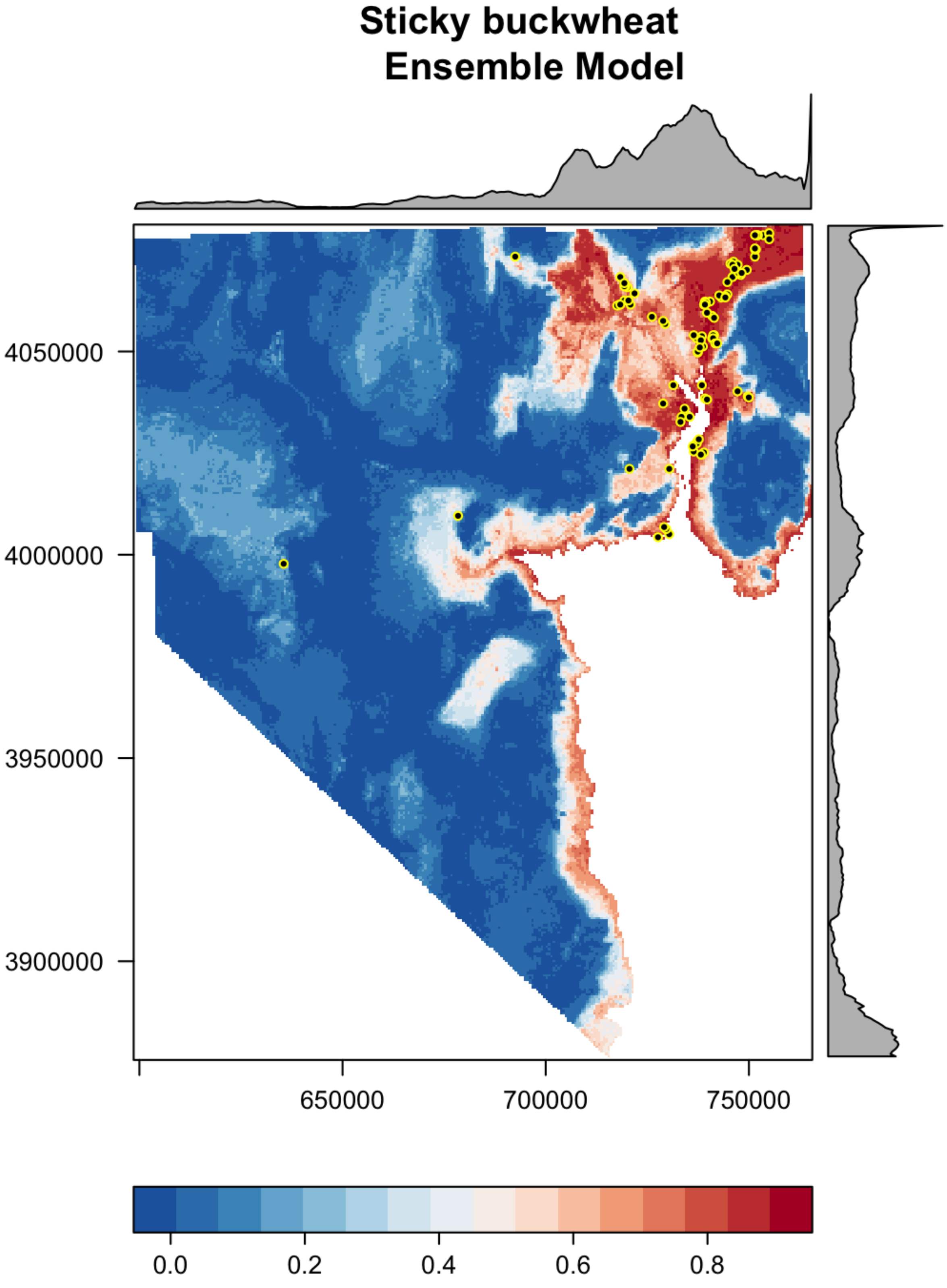


Figure A.9-7. SDM map for sticky buckwheat Ensemble model for Clark County, NV.

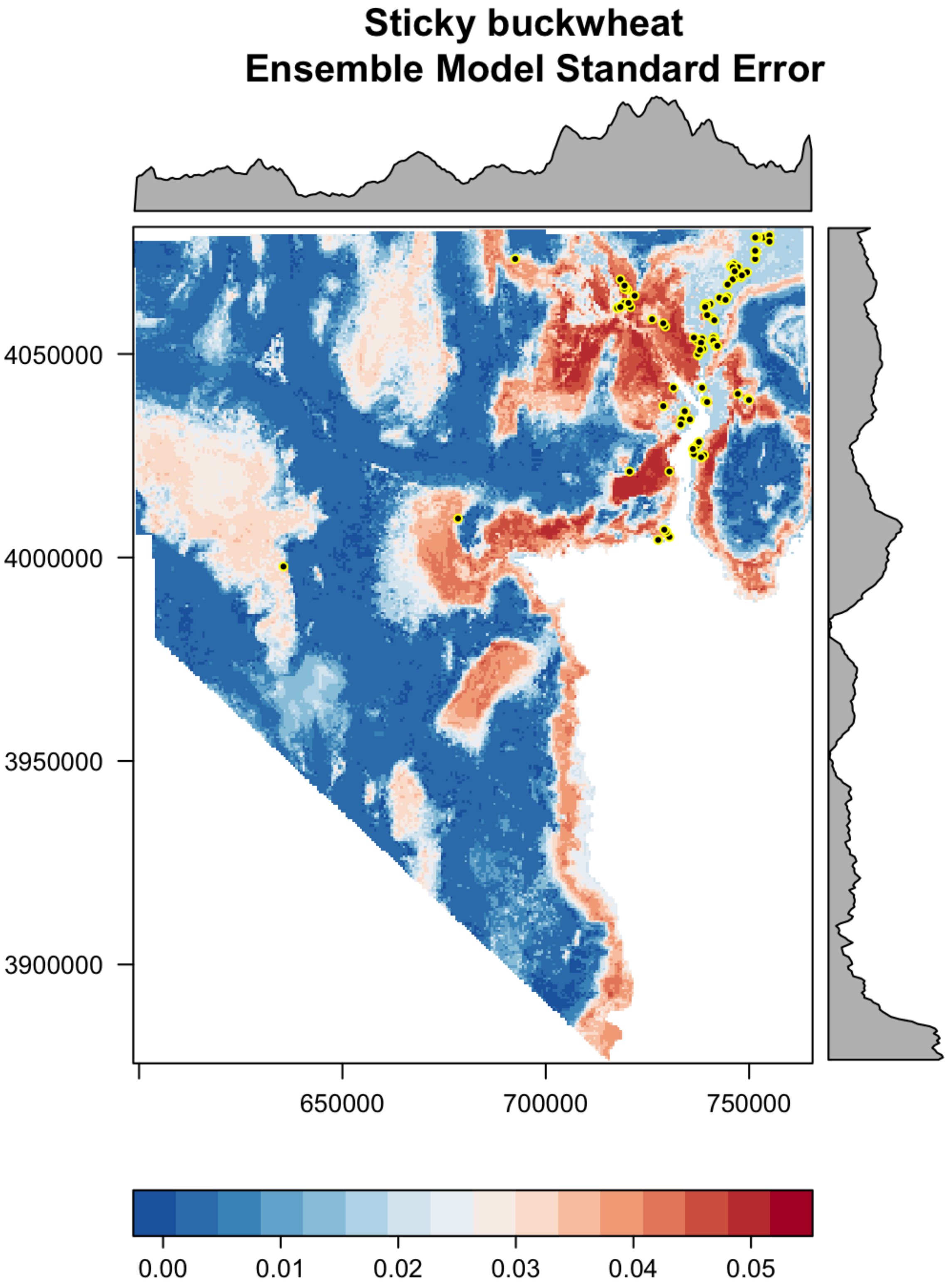


Figure A.9-8. Standard Error map for the sticky buckwheat Ensemble model for Clark County, NV.

A.9.4.5 Distribution and Habitat Use within Clark County

In Clark County, sticky buckwheat is confined to the eastern portion of the county, where it is centered on the confluence of the Muddy and Virgin rivers and ranges along the Muddy and Virgin rivers and the Overton Arm of Lake Mead (TNC 2007). Sticky buckwheat is associated with deep loose sandy soils, and occurs on dunes, open beach sand, and sandy slopes along the Lake Mead shoreline, sandy dry washes, roadsides, and sandy flats and slopes within shrub communities (Nevada Natural Heritage Program 2001, TNC 2007). The occurrence of sticky buckwheat is associated with a sedimentary deposit known as the Muddy Creek Formation (Niles et al. 1995). As this formation surfaces among hills around the Overton Arm, Virgin Basin, and Boulder Basin of Lake Mead National Recreation Area extending along the Virgin River Valley and Muddy River Valley and Meadow Valley Wash. As sand weathers from the Muddy Creek Formation, it is redistributed as aeolian or fluvial material providing habitat for sticky buckwheat (Niles et al. 1995). Ecosystems within Clark County that contain modeled habitat for this species in the high category include Mojave Desert Scrub and to a much lesser extent Mesquite Acacia, and Desert Riparian ecosystems (Table A.9-3). Salt Desert Scrub contains some moderate habitat for this species.

Table A.9-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415269	0	0
Bristlecone Pine	7565	0	0
Desert Riparian	0	2606	7568
Mesquite Acacia	13175	2817	4219
Mixed Conifer	27339	0	0
Mojave Desert Scrub	940130	197277	219875
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	79914	2628	59

A.9.4.6 Ecosystem Level Threats

Sticky buckwheat occupies a very small portion of the Mojave Desert Scrub ecosystem in Clark County, and would generally be associated with Desert Riparian habitat at a scale smaller than is used by the DCP ecosystem map. Historically, the largest loss of sticky buckwheat habitat was likely due to inundation by the impoundment of the Colorado River to create Lake Mead (Niles 1995, Powell 1999). During the high-stand of Lake Mead in 1998, several populations were temporarily inundated but apparently were not extirpated by short-term disturbance (Powell 1999). However, it is not known if the seeds survived short-term inundation or the area was re-populated by seed from nearby plants above the high water mark. It is possible that recent low water levels in Lake Mead have opened habitat where sandy shorelines exist, thus releasing previously unavailable potential habitat for use by this plant. Other identified threats to sticky buckwheat are habitat clearing for rural development, fire, energy development, invasive plant species, off-road vehicle use, surface water development, agriculture, utility corridor construction and maintenance, livestock grazing, sand and gravel mining, recreation use, and disturbance from wild burros and horses (TNC 2007). These factors can interact, resulting in changes in ecosystem functions that affect the sandy substrates that sticky buckwheat depends on, for example by increasing erosion or reducing fluvial sand deposition (TNC 2007). Invasive plant species such as Sahara mustard alter the fire regime, which can lead to increasing erosion and changes in habitat type. Other potentially important invaders include: *Tamarix* spp. (Saltcedar), *Salsola* spp. (Russian Thistle), and *Schismus* spp. (Mediterranean Grass; Bangle 2012).

A.9.4.7 Threats to Species

Sticky buckwheat may be trampled and grazed by cattle and feral burros (Bangle 2012). Natural predators of sticky buckwheat include the caterpillars of the white-lined sphinx moth (*Celerio lineata*) that are known to eat the plants (Bangle 2012).

Energy infrastructure – In 1989/90 sticky buckwheat plants were observed in the right-of-way of the Kern River Pipeline project, but project avoidance of the sensitive plants was preferred over disturbance thus, no further actions (e.g., re-seeding) were taken (Hiatt et al. 1995).

A.9.4.8 Existing Conservation Areas/Management Actions

The USFWS Spotlight Species Action Plan for the sticky buckwheat (2009) recommends conducting surveys and habitat modeling to acquire precise acreage figures for occupied and potential habitats and developing a conservation strategy that avoids, minimizes, or mitigates loss of both occupied and potential habitat.

A conservation strategy specific to this species was developed by The Nature Conservancy for the Clark County Desert Conservation Program (2007). The recommended conservation actions for this species include:

- proactively protect and manage for long-term viability of all populations on federal lands;
- manage viable populations by removing significant casual off-road vehicle use; control weeds in low elevation rare plant habitats;
- ensure that long term viability of low elevation rare plants is not significantly impacted by rural development and sprawl;
- ensure that disposal of federal lands in Clark County will not significantly impact conservation of rare plant populations;

- manage rare plants in sandy habitats for long term viability by addressing altered fire regimes (increased fire frequency and intensity) over the next century;
- manage viable populations of all covered rare plants in utility corridors and potential rights-of-way corridors; and management of viable populations on federal lands;
- protect sticky buckwheat populations along Muddy and Virgin rivers from significant agricultural impacts over the next fifty year;
- ensure conservation management for sticky buckwheat populations at LMNRA above high water line and manage populations below high water line during Lake Mead low water years;
- ensure construction of the Mesquite Airport does not significantly impact viability sticky wild buckwheat on public lands; and
- protect viable populations of sticky buckwheat in Gold Butte area (Lime Wash populations) and Virgin River Dunes from trespass grazing and exotic plant impacts (TNC 2007).

In addition, this species' habitat is included in the Nevada's Wildlife Action Plan within the Sand Dunes and Badlands Key Habitat type. The recommended conservation strategy for this habitat includes the objective of maintaining disturbance in sand dune and badland habitats within levels that do not compromise the sustainability of the vegetation and wildlife communities; conservation actions are focused on OHV use, minimizing disturbance, and developing conservation agreements that maintain biodiversity and multiple uses (Wildlife Action Plan Team 2012).

In addition to its inclusion in the Clark County MSHCP, sticky buckwheat is considered in the Lower Colorado River Multi-Species Conservation Plan (LCR MSCP) for the conservation of the species in and adjacent to the LCR MSCP planning area and populations are maintained or increased (Bangle 2012).

It is clear that actively managing landscapes for such rare species as the sticky buckwheat has high priority and many useful management recommendations are provided. However, in the absence of population monitoring there is no way of accurately determining the population status of these species. Furthermore, it is clear that monitoring plants as they are expressed in sample populations can yield volumes of highly variable data. Quantifying propagules in the seed bank is a relatively straightforward endeavor in very sandy soils – such as those where the sticky buckwheat occurs. While seedbank estimates are also notoriously variable it is possible that they may provide a more reliable and cost effective estimate of population status than monitoring plants on an annual basis. Furthermore, a seed bank investigation could also be used to determine the efficacy of invasive species control programs in these high-value habitats.

A.10 WHITE-MARGINED BEARDTONGUE (*PENSTEMON ALBOMARGINATUS*)

White-margined beardtongue (*Penstemon albomarginatus*) is an herbaceous perennial in the figwort family (Plantaginaceae, formerly Scrophulariaceae). As the name suggests, the leaves have a fine white margin around the edges. The bright pink to lavender or white corolla also has a white margin and flowers in March to May (Munz 1974). The tap root (30 to 120 cm long) can be more than double the height of the stems (15-35 cm tall) on this rare plant (Holmgren 1993, MacKay 2006). White-margined beardtongue is yet another psammophyte occurring in deep (>60 cm) stabilized sand deposits. Deep sandy soils accommodate the large taproot which stores resources such that growth and flowering may be less dependent on a given season's rainfall. Even so, the white-margined beardtongue is dependent on rainfall for seedling establishment (Scogin 1989).

Some insect pollination occurs, but there is speculation that self-pollination may be possible, and it is also hypothesized that vegetative reproduction occurs (MacKay 2006). A study of white-margined beardtongue pollinators found that pollinators visited this species infrequently, and this is considered unusual among *Penstemon* as a group (Griswold 2013). Furthermore, there are frequently specialist pollinators for *Penstemon* species, but this is not the case for the white-margined beardtongue, and Griswold et al. (2013) hypothesized that it may be due to the atypically small diameter of the flowers. The pollinators observed visiting white-margined beardtongue included wool carder bee (*Anthidium paroselae*), leafcutter bees (*Ashmeadiealla gillettei*), *A. holtii, A. xenomastax,* and sweat bee (*Lasioglossum sisymbrii*). Visitation rates of pollinators have not been quantified for this flower species, nor have experiments to determine pollination success under various scenarios. Seed dispersal that was measured at Hidden Valley in Clark County, Nevada ranged from 1 to 15 cm. This is in contrast to measurements of blackbrush and Joshua tree seed dispersal that were moved up to 30 m as facilitated by rodent dispersal (Vander Wall et al. 2006). If growth rings can be used to age white-margined beardtongue, then the range of ages for plants that were sampled is 5 to 35 years, but more work is required to validate those techniques (Etyemezian et al. 2010).

A.10.1 Species Status

The white-margined beardtongue is a former Category 2 candidate for threatened or endangered status under the Endangered Species Act of 1973. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that the proposal for listing may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (USFWS 1993).

In 2007, the Nevada Native Plant Society's Rare Plant Committee recommended the white-margined beardtongue be placed on Nevada's List of Fully Protected Species of Native Flora (Nevada Administrative Code 527.010). The Committee listed a number of threats including potential changes in sand transport and accumulation from proposed Ivanpah Airport, BLM's 90-mile OHV high speed races, mining, and development (Rare Plant Committee 2007, 2008) This petition was denied, and the plant was ultimately not listed by the state.

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): No status

NV Natural Heritage Program: Global Rank G2, State Rank S2

IUCN Red List (v 3.1): No Status

CITES: No Status

A.10.2 Range

The white-margined beardtongue occurs in Clark and Nye counties, Nevada; San Bernardino County, California; and in Mohave County, Arizona. They are found at elevations between 300 to 900 m (~2000 and 3000 ft.- Scogin 1989).

A.10.3 Population Trends

The populations in California were surveyed and found to have in excess of 650 individuals. The population on the western slope of the Hualapai Mountains in Mohave County, Arizona is thought to be the largest single population, but the 15 known populations in Nevada are thought to include 1000's of individuals (MacKay 2006). Twelve populations were estimated in Clark County, Nevada and in 1997/98, Smith (2001) estimated 25,964 white-margined beardtongue in Clark County, and 42,200 plants in Nye County. In 2008/09, estimates were nearly twice those of the previous decade with 125,825 white-margined beardtongue in Clark County and 78,954 in Nye County, however, these estimates cannot be directly compared due to differences in methods (Etyemezian et al. 2010).

Genetic diversity among 12 populations of white-margined beardtongue was evaluated and those studies indicated that most populations do not suffer from inbreeding (Wolfe et al. 2016). However, there was a geographic pattern of greater genetic diversity toward the south suggesting post-glacial dispersal of this species from north to south (Wolfe et al. 2016).

Range-wide, population trends are presumed stable, but may be declining in areas with intensive grazing (USFWS 2000). Trends in Nevada were described as unknown by Smith (2001), and Nevada Natural Heritage Program (2001). Populations in Clark County appear to be stable (TNC 2007).

A.10.4 Habitat Model

All of our SDM algorithms generally predicted habitat in a similar arrangements throughout the County, but with varying degrees of area surrounding the general pattern. The models followed a fairly consistent gradient, where GAM models generally predicted the most habitat, followed by Random Forest, while the MaxEnt models tended to have only moderate values of habitat suitability in smaller localized areas within the County (Figure A.10-1). Key areas of similarity among models in the County included Ivanpah Valley, Hidden Valley, and a stretch including Las Vegas through the northern Las Vegas Valley along the US 95 corridor to areas near Indian Springs. A smaller area near Pahrump Valley, south to Sandy Valley is also predicted to be of higher habitat suitability due to its similarity to the adjacent valley, but is not well supported by locality information (Figure A.10-1).

The Ensemble model outperformed the other models, with the highest scores for AUC and BI, but had a slightly lower TSS score than the RF models. Relative to other models, the MaxEnt model had a lower BI score than the others (Table A.10-1).

All three models shared Winter Precipitation content as one of the top four most influential variables. The GAM and RF, models shared two additional variables of the top four influential environmental variables, where the CV Winter Precipitation, and the CV Spring Maximum temperature were among the largest contributors (Table A.10-2). The RF and MaxEnt model shared Depth to Bedrock as a top influential variable (Table A.10-2). The standard error was relatively low throughout the County, where only the GAM model had values approaching 0.07 in many areas. All other model's standard errors were very low with the highest values of ca. 0.04 in the MaxEnt models (Figure A.10-2). The Continuous Boyce Indices showed good model performance in all algorithms, with a lack smoothing among the lower habitat values due to the relatively low numbers of points, and their clustered nature (Figure A.10-3, Figure A.10-1).

Table A.10-1. Model performance values for white-margined beardtongue models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.98	0.82	0.44
GAM	0.9	0.89	0.76	
Random Forest	0.93	0.68	0.88	
MaxEnt	0.94	0.7	0.76	

Table A.10-2. Percent contributions for input variables for white-margined beardtongue for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Average Spring Max Temp	15.1	1.3	13.1
Depth to bedrock	4.9	9.2	13.8
Clay	2.4	2.1	8.6
CV Average Spring Max Temp	19.7	13.8	1.5
CV Max Temp	9.8	5.5	6.3
Extreme Min Temp	8.6	2.7	10.3
NDVI Max	9.7	2.4	18
Slope	4.3	0.5	6.5
Winter Precip	12.5	33.3	11.9
CV Winter Precip	13	29.2	9.9

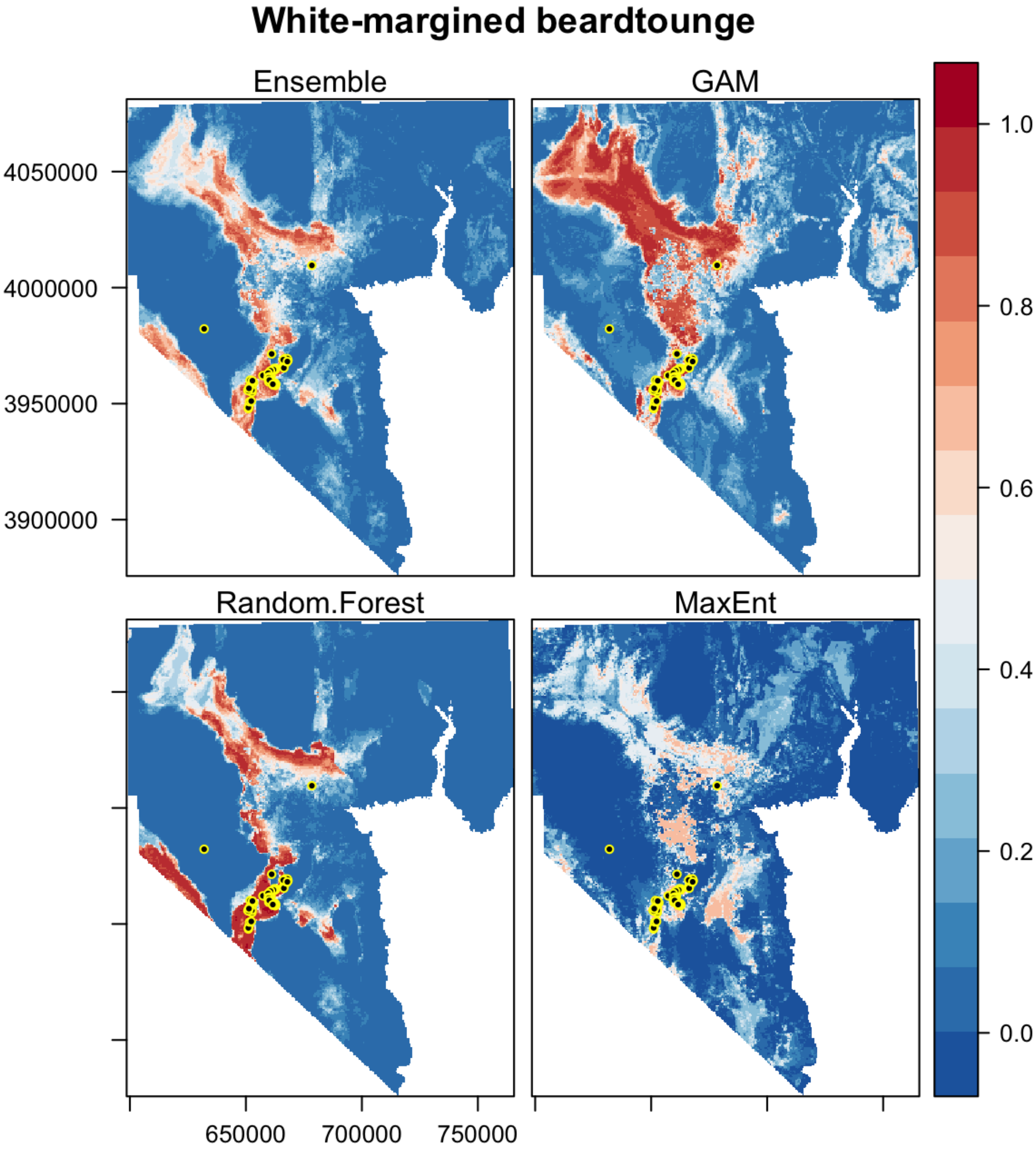


Figure A.10-1. SDM maps for white-margined beardtongue model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

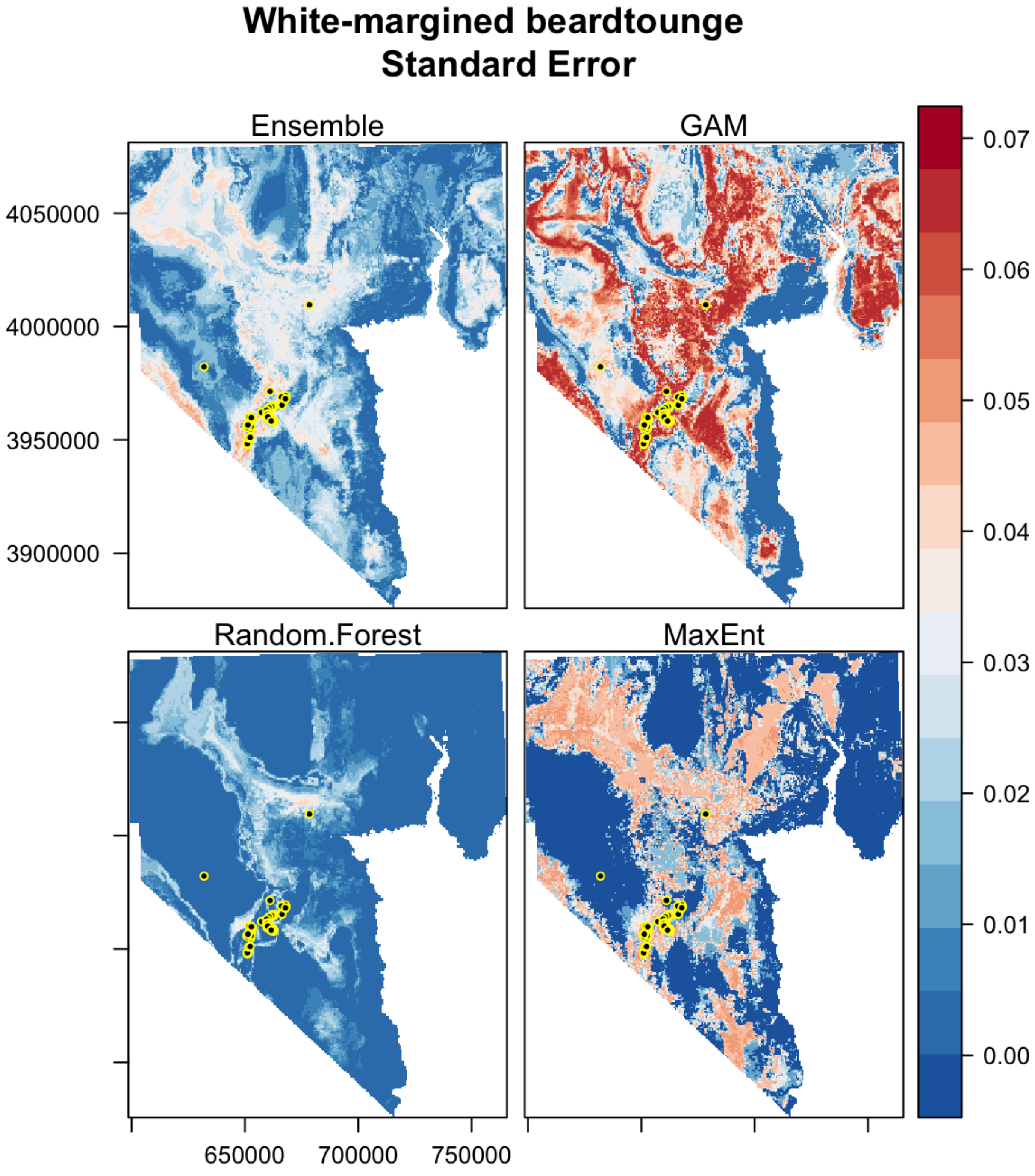


Figure A.10-2. Standard error maps for white-margined beardtongue models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

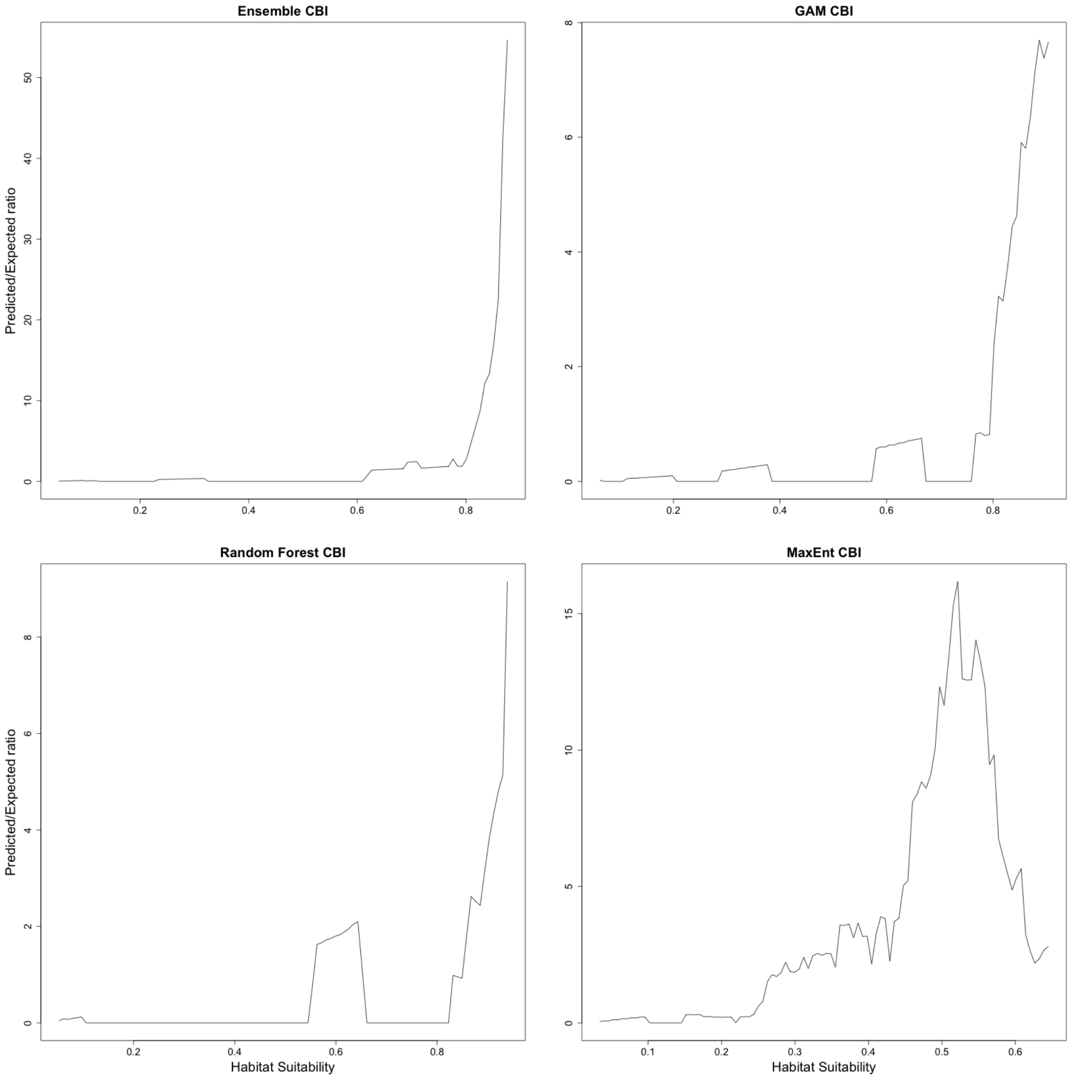


Figure A.10-3. Graphs of Continuous Boyce Indices [CBI] for white-margined beardtongue models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.10.4.1 General Additive Model

The top four contributing environmental layers were Average Spring Maximum temperature, CV Average Spring Maximum temperature, Winter Precipitation, and CV Winter Precipitation, collectively accounting for 60.3% of total model influence (Table A.10-2). Model scores were consistently high in areas with low Average Spring Maximum temperature, however at ca. 30 ºC habitat values decrease rapidly to near zero (Figure A.10-4). Similarly, CV Average Spring Maximum temperature indicates high habitat values when CV is low (< 0.08), but then decreases rapidly to near zero with higher CV values (Figure A.10-4). Model scores were highest with low Winter Precipitation, and declined when winter precipitation rose above 100 mm, but this generally follows the availability of habitat values and is thus unlikely to be an expressed preference. CV Winter Precipitation indicated lower habitat values when the CV was low, until CV reaches 0.6 – 0.7 when habitat values rise dramatically and plateau, suggested of a preference for more highly variable areas.

The GAM algorithm had higher standard error values, indicating some dissimilar predictions among the 50 model cross-validation runs (Figure A.10-3).

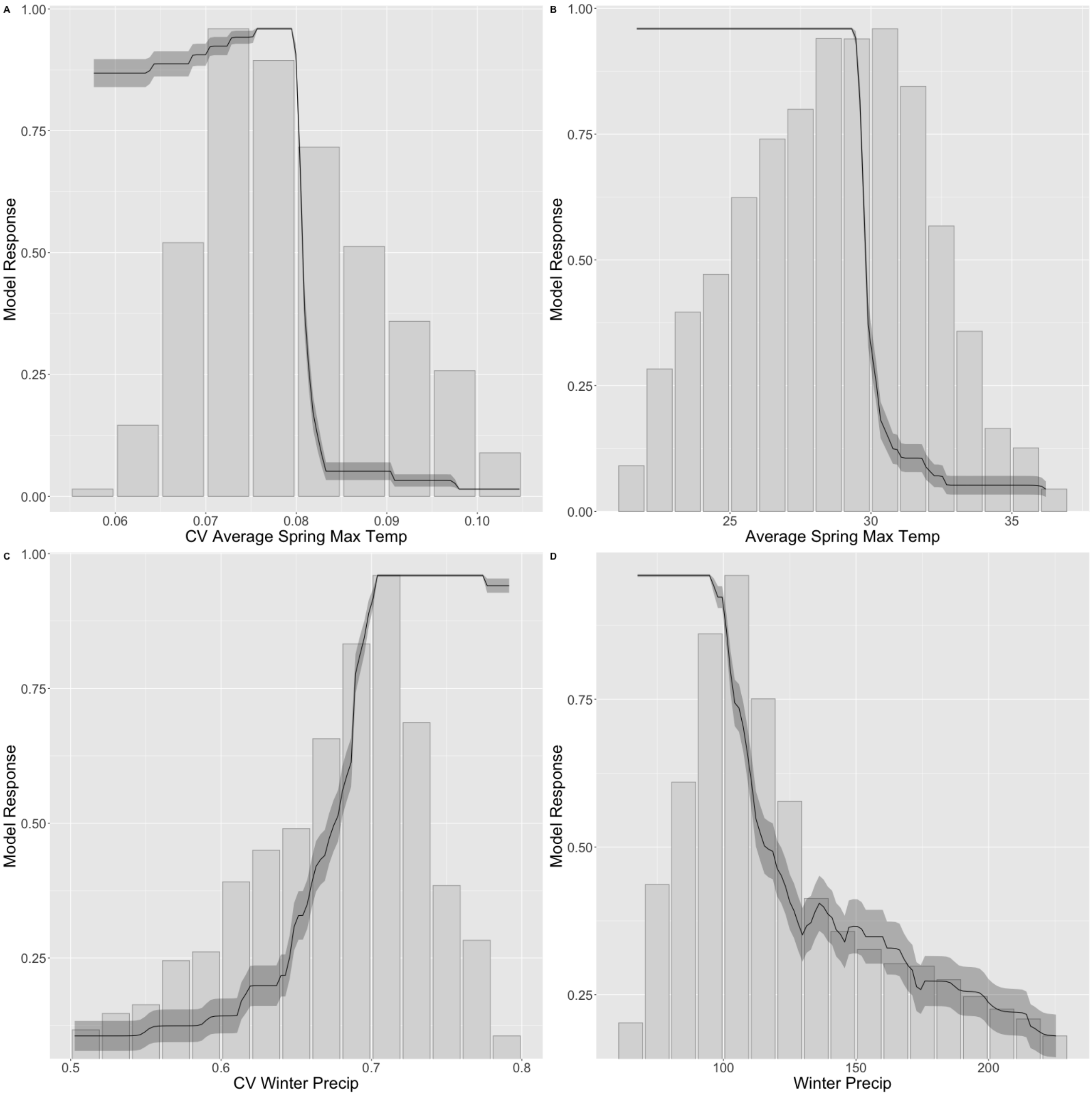


Figure A.10-4. GAM partial response curves for the top four variables in the white-margined beardtongue model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.10.4.2 MaxEnt Model

The MaxEnt models relied heavily on the two of the same four top variables as the GAM models (Winter Precipitation and Average Spring Maximum temperature). The MaxEnt model also shared one other top variable with the RF model (Depth to Bedrock). NDVI Maximum was also an important contributor in the MaxEnt models. In total, these four variables accounted for 49.1% of total model contribution (Table A.10-2). This model had very similar response curves among algorithms to the GAM model and RF models for the Winter Precipitation variable, where habitat values were lower with high Winter Precipitation (Figure A.10-4, Figure A.10-5, Figure A.10-6). The MaxEnt models also had a similar response curve as the RF model to the Depth to Bedrock variable, higher habitat values are indicated in areas with high Depth to Bedrock – indicating a preference for deeper soils (Figure A.10-5, Figure A.10-6). The similarity of these response curves in different algorithms indicates relatively robust model selection (Figure A.10-4, Figure A.10-5, Figure A.10-6). The predicted response for the NDVI Maximum showed a threshold response with suitability at high values only when NDVI Maximum was very low, indicating that this species prefers relatively less vegetated areas (Figure A.10-6).

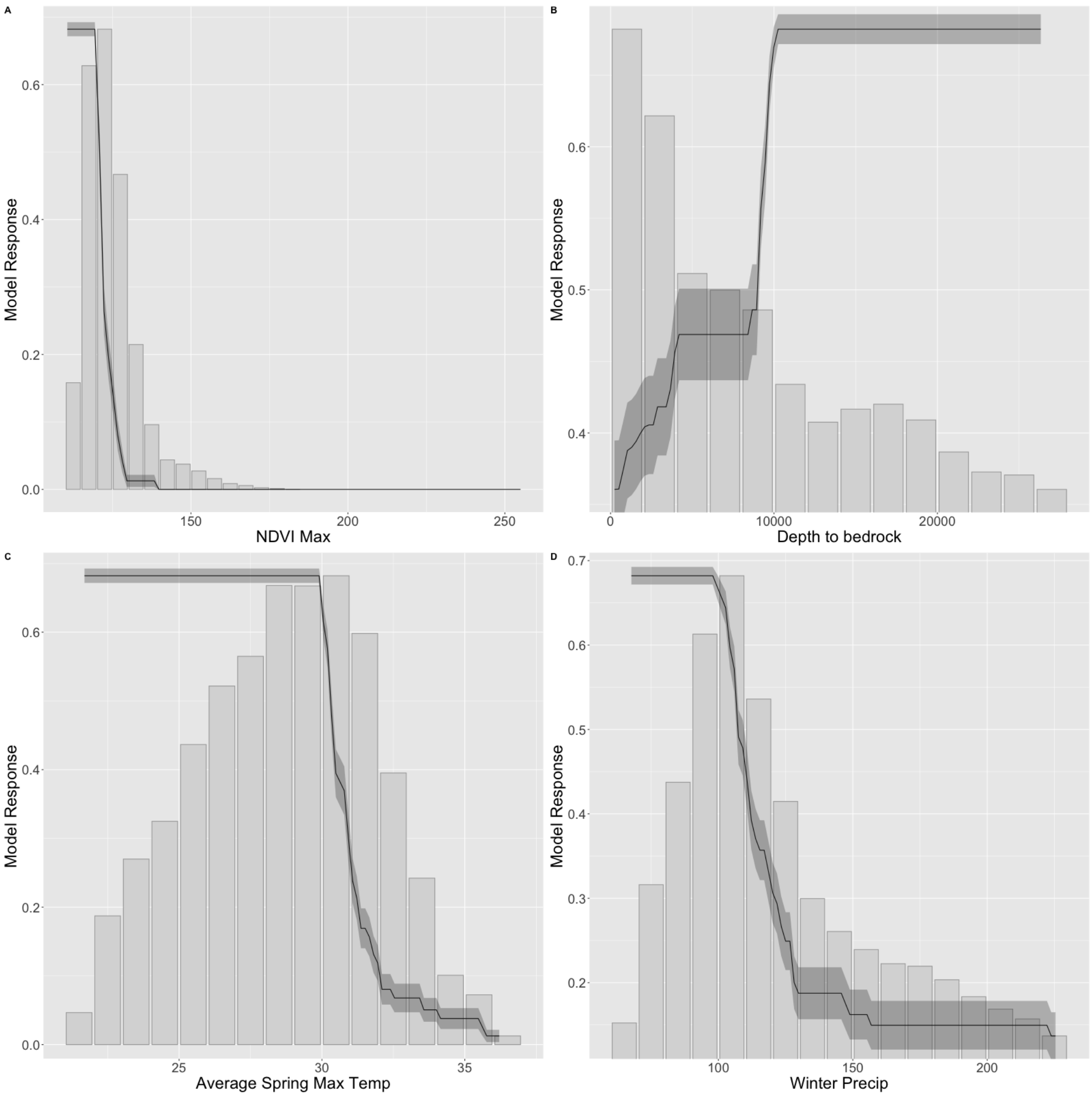


Figure A.10-5. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for white-margined beardtongue. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.10.4.3 Random Forest Model

The Random Forest model was largely driven by Winter Precipitation, and the CV of Winter Precipitation (collectively 62.5%). The variables CV Average Spring Maximum temperature, and Depth to Bedrock were also important (Table A.10-2). The collective model influence of these four variables was 85.5%, where very little additional influence was proved by several other input variables (Table A.10-2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (Figure A.10-6) and was concordant with the other algorithms for that variable. CV Winter Precipitation showed a similar response as the GAM models, with higher habitat values when the CV is above 0.7 (Figure A.10-4, Figure A.10-6). The RF models are also concordant with the MaxEnt models with respect to the Depth to Bedrock variable (Figure A.10-5, Figure A.10-6). In both cases, constant high habitat values are indicated when Depth to Bedrock exceeds 10000 mm.

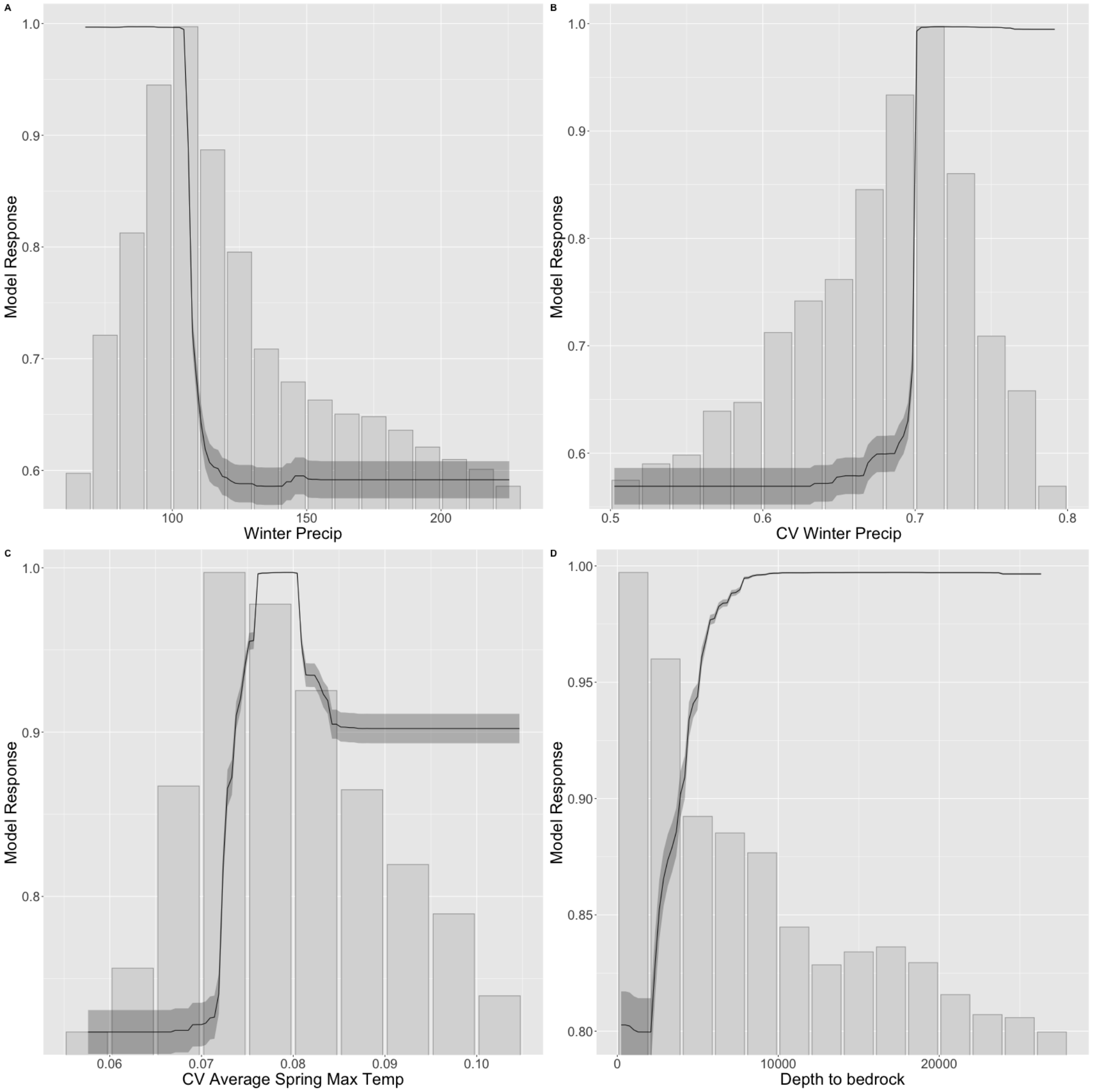


Figure A.10-6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for white-margined beardtongue. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.10.4.4 Model Discussion

Higher predicted habitat suitability for white-margined beardtongue occurs in Clark County in the areas near Hidden Valley, in and around the Jean Dry Lake, Ivanpah Valley and Sandy Valley. However, the model indicates other areas of high habitat suitability. In particular all three models, predict high habitat suitability in a rather large area including North Las Vegas, through the northern Las Vegas Valley to areas near Indian Springs, although there are no localities in this general region that support this prediction, and thus this result is largely driven by habitat similarity. A smaller area near Pahrump Valley is also predicted to have relatively high habitat suitability, and outside of the county this extends northwestward, where there are localities confirming the pattern.

The locality data for this species consisted of 15,915 records within the buffered modeling area, which had an *extremely* high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to only 85 records. Observations spread across a broader area, and true absence data in areas predicted with little to no locality support would be useful toward the modeling of this species.

A.10.4.5 Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (Figure A.10-8), with moderate error, located in the areas that were predicted as high quality habitat that are outside of the species known range. Overall errors were relatively low (despite the coloration much of the county is ~ a 3% error rate, indicating good agreement among the models used in the Ensemble.

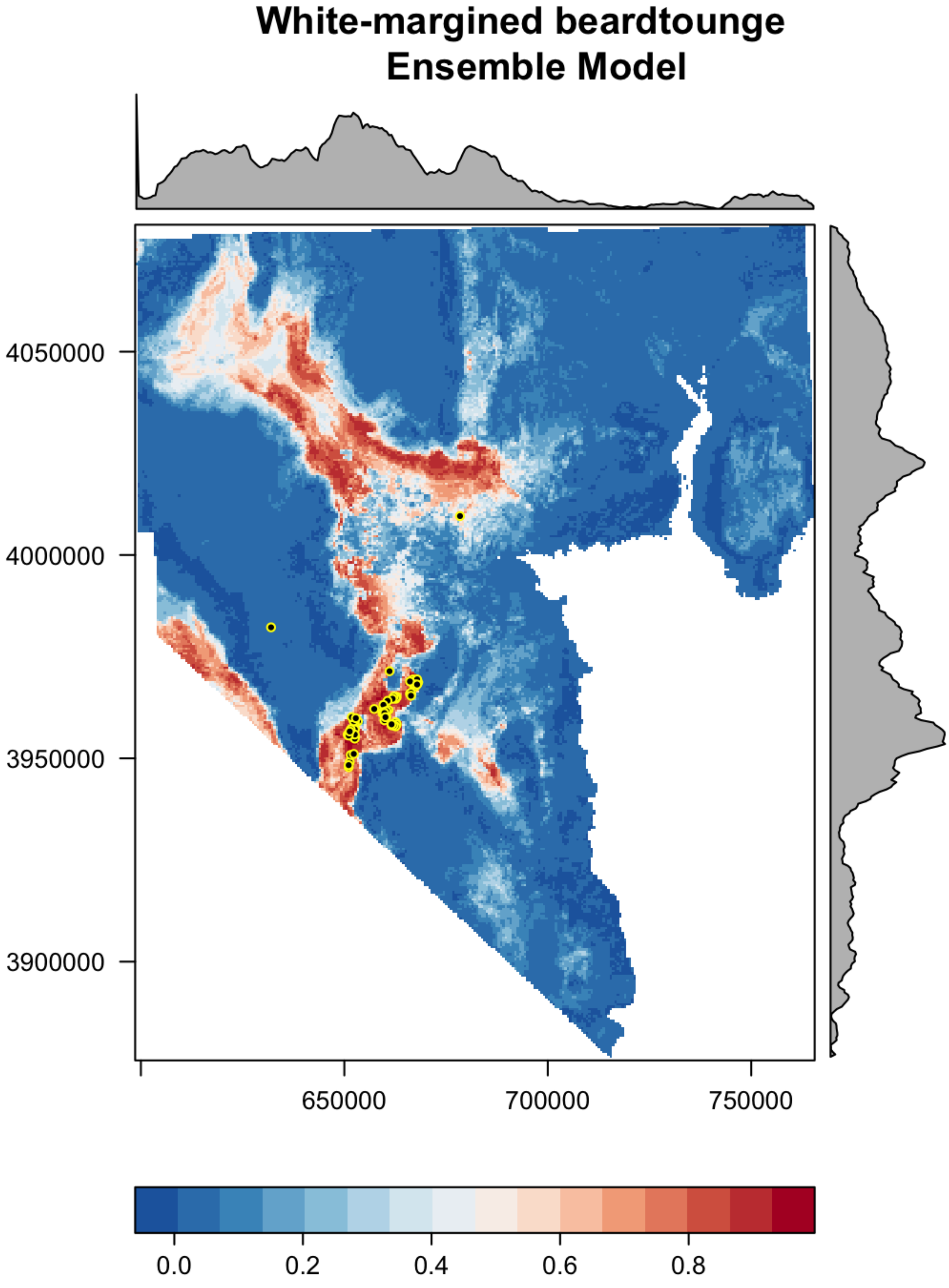


Figure A.10-7. SDM map for white-margined beardtongue Ensemble model for Clark County, NV.

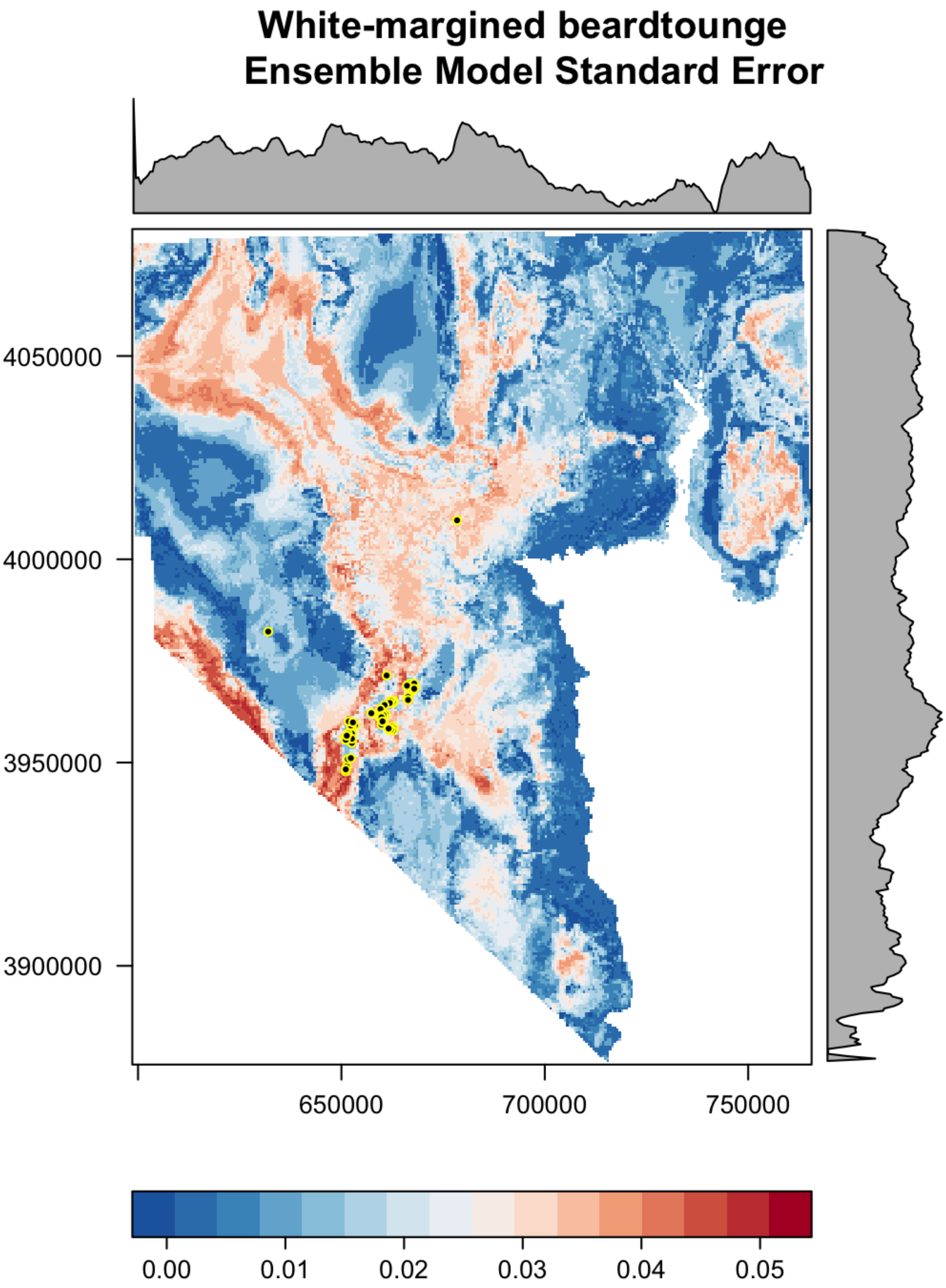


Figure A.10-8. Standard Error map for the white-margined beardtongue Ensemble model for Clark County, NV.

A.10.5 Distribution and Habitat Use within Clark County

White-margined beardtongue is found in southern Clark County in Hidden Valley, Jean Lake, Roach Lake, and Ivanpah Valley; these occurrences are centrally located within the global range for the species (TNC 2007). It grows on sand dunes and sand sheets at the base of mountain slopes, or deep sand (>60 cm) in washes and along roads, especially in washes, small dry drainages, foot-slopes, or alluvial terraces (Smith 2001). White-margined beardtongue is found on the on west-facing slopes where sand has accumulated over geologic time-scales (TNC 2007; Etyemezian et al. 2010). Ecosystems within Clark County projected to contain this species from the sand species habitat model (Hamilton and Kokos 2011) include Mojave Desert Scrub, Salt Desert Scrub, Mesquite Acacia, and Blackbrush to a lesser extent (Table A.10-3).

Comparison of white-margined beardtongue inhabited sites versus sites without the beardtongue indicate a strong correlation with soils consisting of alluvium covered by eolian sand in both Clark and Nye counties (Etyemezian et al. 2010).

White-margined beardtongue is found among creosote bush (*Larrea tridentata*), burrobush (*Ambrosia dumosa*), and big galleta (*Hilaria rigida*) associations. While the beardtongue may be found beneath creosote bush and big galleta, it is never found within the dripline of creosote bush (Etyemezian et al. 2010). Soil types possessing these characteristics in this region include Bluepoint and Arizo soil series (Etyemezian et al. 2010).

Table A.10-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	402608	12205	361
Bristlecone Pine	7565	0	0
Desert Riparian	10179	0	0
Mesquite Acacia	17914	1882	426
Mixed Conifer	27339	0	0
Mojave Desert Scrub	1052511	155667	149236
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	28159	39865	14404

A.10.6 Ecosystem Level Threats

White-margined beardtongue habitat occurs primarily in Mojave Desert Scrub and Salt Desert Scrub Ecosystems within Clark County, Nevada (Table A.10-3). The primary threats to white-margined beardtongue in Clark County are urban development, mineral exploration, utility corridor construction and maintenance, invasive plant species, OHV use, livestock grazing, highway and road construction and maintenance, legal and illegal off-highway events, federal land disposal to private ownership which may increase the probability of development, sand and gravel mining, and construction of the planned Ivanpah Airport (TNC 2007). Historical cattle grazing at the Hidden Valley population has disturbed the native vegetation and introduced several species of invasive plants (Sheldon 1994 *in* TNC 2007)

A.10.7 Threats to Species

Some habitat for the white-margined beardtongue has already been lost to pipelines, powerlines, transportation corridors, and their associated infrastructure (McKay 2006). These types of activities along with urban development and military training within habitats would also be detrimental to this species where it occurs. Heavy and persistent OHV use can damage or kill individual plants in addition to damaging habitat (McKay 2006). Increasing human population size in the Las Vegas metropolitan area will likely result in greater visitation and use to natural areas thus potentially increasing disturbances.

A.10.8 Existing Conservation Areas/Management Actions

A conservation strategy was developed particularly for this species by The Nature Conservancy for the Clark County Desert Conservation Program (TNC 2007). The nine recommended conservation actions for this species are:

- proactively protect and manage for long-term viability all populations on federal lands;
- manage viable populations by removing significant casual off-road vehicle use; control weeds in low elevation rare plant habitats;
- control weeds in low elevation rare plant habitats by 2020;
- ensure that long term viability of low elevation rare plants is not significantly impacted by rural development and sprawl;
- ensure that disposal of federal lands in Clark County will not significantly impact conservation of rare plant populations;
- manage rare plants in sandy habitats for long term viability by addressing altered fire regimes (increased fire frequency and intensity) over the next century;
- manage viable populations of all covered rare plants in utility corridors and potential rights-of-way corridors;
- manage viable populations of white-margined beardtongue along Federal highways and county roads; and
- ensure construction and maintenance of the Ivanpah Airport does not significantly impact the viability of four white-margined beardtongue populations on county land (TNC 2007).

In addition, this species' habitat is included in the Nevada's Wildlife Action Plan within the Sand Dunes and Badlands Key Habitat type. The recommended conservation strategy for this habitat includes the objective of maintaining disturbance in sand dune and badland habitats within levels that do not compromise the sustainability of the vegetation and wildlife communities; conservation actions are focused on OHV use, minimizing disturbance, and developing conservation agreements that maintain biodiversity and multiple uses (Wildlife Action Plan Team 2012).

Previous attempts to transplant white-margined beardtongue have failed, potentially because of the large and sensitive tap root. However, successful cultivation may provide restoration alternatives (e.g. potentially smaller plants could be out-planted), as well as increasing appreciation for the plant as more people come to know it.

An area on the western slope of the Hualapai Mountains in Mohave County, Arizona having the highest white-margined beardtongue densities was acquired by the Bureau of Land Management in a land exchange with the Santa Fe Pacific Railroad to benefit this species by expanding the lands in an ACEC (Anderson 2001).

Most of the white-margined beardtongue populations in Clark County are managed for multiple uses by the BLM; however, 10% of the Hidden Valley population is within the Sloan Canyon NCA. BLM has posted signs and conducts enforcement patrols to reduce illegal OHV use and actively manages legal OHV use (TNC 2007).

A.11 – PARISH'S PHACELIA (*PHACELIA PARISHII*)

Synonyms: *Phacelia salina* -M.E. Jones ex Brand (ambiguous synonym).

Parish's phacelia (*Phacelia parishii*) is a small herbaceous annual plant. A precise description of the adult life form is provided by Genevieve et al. (2013):

"**Habit:** Annual 5--15 cm, aromatic. **Stem:** ascending to erect, branched at base, short-stiff-hairy, minutely glandular. **Leaf:** +- basal, 8--30 mm; blade > petiole, +- widely elliptic to obovate, entire to +- toothed. **Flower:** calyx lobes 3--5 mm, 6--8 mm in fruit, not alike, especially in fruit, +- linear to ovate to oblanceolate to obovate, minutely glandular; corolla 4--6 mm, narrowly bell-shaped, tube yellow, lobes lavender, scales fused to filament bases, oblong to linear, occasionally not alike; stamens 2--4 mm, unequal, included, sparsely short-hairy proximally, filaments yellow; style 1--2 mm, included, cleft < 1/4. **Fruit:** 3--5 mm, +- oblong, short-stiff-hairy. **Seed:** 20--40, 1--1.5 mm, finely pitted."

The species inhabits clay or alkaline soils, especially along dry lake margins (Jepson 2019). In Nevada, Parish's phacelia has been found in "moist to superficially dry, open, flat to hummocky, mostly barren, often salt-crusted silty-clay soils on valley bottom flats, lake deposits, and playa edges, often near seepage areas, sometimes on gypsum deposits, surrounded by saltbush scrub vegetation but with few immediate associates such as *Atriplex confertifolia*, *A. canescens*, *A. argentea*, *Poa secunda*, *Monolepis nuttalliana*, *Phacelia fremontii*, *Lepidium flavum*, *Sarcobatus vermiculatus*, etc. Aquatic or wetland-dependent in Nevada."(Moorefield 2001).

The elevational range of the species in Nevada is ca. 668-1805 meters, and the plant is known to flower in late spring (Genevieve et al. 2013; Moorefield 2001).

A.11.1 Species Status

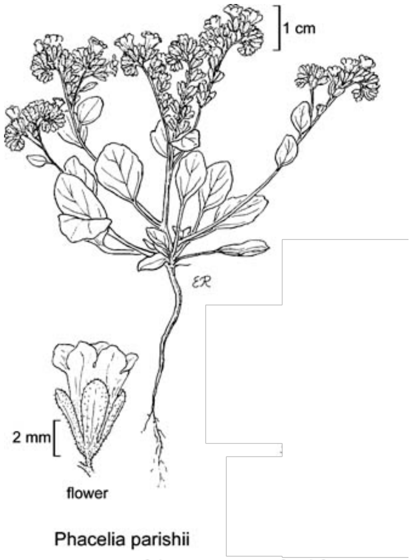


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Figure A.11-1. Parish's phacelia Parish's phacelia is a former Category 2 candidate for Threatened or Endangered status under the Endangered Species Act of 1973. The last ruling on the status of this species was published in the Federal Register on September 30, 1993 where it was determined that listing Parish's phacelia under the Act may be appropriate, but that insufficient data on biological vulnerability and threats were available to support the listing at that time (Federal Register 1993).

U.S. Fish and Wildlife Service Endangered Species Act: Not listed

U.S. Bureau of Land Management (Nevada): Sensitive (2010)

U.S. Forest Service (Region 4): No status

State of Nevada (NAC-527): Not listed

NV Natural Heritage Program: Global Rank G2G3, State Rank S3

IUCN Red List (v 3.1): No Status

CITES: No Status

A.11.2 Range

Parish's phacelia has a very limited global distribution. In Nevada, it occurs in Clark, Lincoln, White Pine, and Nye counties. Its global distribution also includes San Bernardino and Inyo Counties in California, and Mojave County in Arizona (NatureServe 2019).

A.11.3 Population Trends

Parish's phacelia is listed as declining by NNHP (Moorefield 2001) without any rationale for that categorization. While the species is rare in space, when found it can be super-abundant locally. For example, at one site in California there were as many as 200 million individual plants one year in a portion of one valley. Visits to the same site a few years later found no individuals (White 2006). The ephemeral nature of the species makes it extremely difficult not only for detecting the species in an area, but for determining any population trends.

A.11.4 Habitat Model

The three model algorithms predicted similar habitat arrangements throughout the County. The GAM and RF models generally predicted more habitat than did the MaxEnt models (Figure A. 11-2). The MaxEnt model predicted the smallest area of habitat, and when it was predicted, habitat suitability values were low overall. Habitat suitability values for the GAM model were relatively low across the County, and were scattered broadly with disparate small areas having higher habitat suitability (Figure A.11-2). Key areas of similarity among models in the County included some small areas North and East of Las Vegas, and areas of high suitability predicted along the US 95 corridor northeast of the Las Vegas Valley, extending into Indian Springs Valley and the Three Lakes Valley with some support for habitat in the north western portion of the USFWS Desert National Wildlife Refuge (Figure A.11-2). The Sheep Range and Spring Mountains show moderate habitat suitability. The Pahrump Valley and the southern extent of the I-15 corridor within Clark County near the Roach Dry lake each show small areas of relatively high habitat suitability (Figure A.11-2). Addition areas of potential habitat occur near the confluence of the Muddy and Virgin Rivers, and along the western shoreline of the Overton arm of Lake Mead.

The Ensemble model and MaxEnt models had slightly higher performance relative to the other models, with an equivalent score for AUC and TSS (Table A.11-1). However, the MaxEnt model had a noticeably lower BI score than any other model. The RF model performed well but had a lower BI score (Table A.11-1). Overall AUC performance was very high, with all models performing above 0.94, while BI scores were relatively high.

Due to a paucity of localities with which to model (43) we reduced the number of environmental variables considered to five, as many of the modeling algorithms were unable to produce models that converged. All three models shared Clay Content, and NDVI Maximum as the largest contributors (Table A.11-2). The RF and MaxEnt model shared Winter Precipitation as a top influential variable. The GAM and RF models shared NDVI Amplitude as a top influential variable (Table A.11-2). The GAM and MaxEnt also shared Average Minimum temperature as a top variable. The Soil Gypsum variable was among the top four most important variables in both the MaxEnt and RF models (Table A.11-2). The standard error was relatively low throughout the County, where only the GAM model had the highest error values (only approaching 0.07) in most areas (Figure A.11-3). All other models had standard errors that were very low (Figure A.11-3). The Continuous Boyce Indices showed fair model performance in all algorithms (Figure A.11-4). The RF and the MaxEnt models' curves indicated several areas of higher performance where point density was only moderate, indicating less discrimination between high and low habitat (Figure A.11-4), this is likely due to the lack of lower suitability scores in areas with fewer points (and thus lower point density) that retained moderate suitability scores, and the extremely small sample size for this species.

Table A.11-1. Model performance values for Parish's phacelia models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.94	0.94	0.78	0.34
GAM	0.9	0.72	0.67	
Random Forest	0.85	0.58	0.67	
MaxEnt	0.96	0.57	0.78	

Table A.11-2. Percent contributions for input variables for Parish's phacelia for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Clay	31.4	41.1	35.5
Extreme Min Temp	11.6	4	27.8
Soil gypsum	8.5	5.9	19.8
NDVI Amplitude	16.3	15.8	7.8
NDVI Max	32.2	33.2	9.1

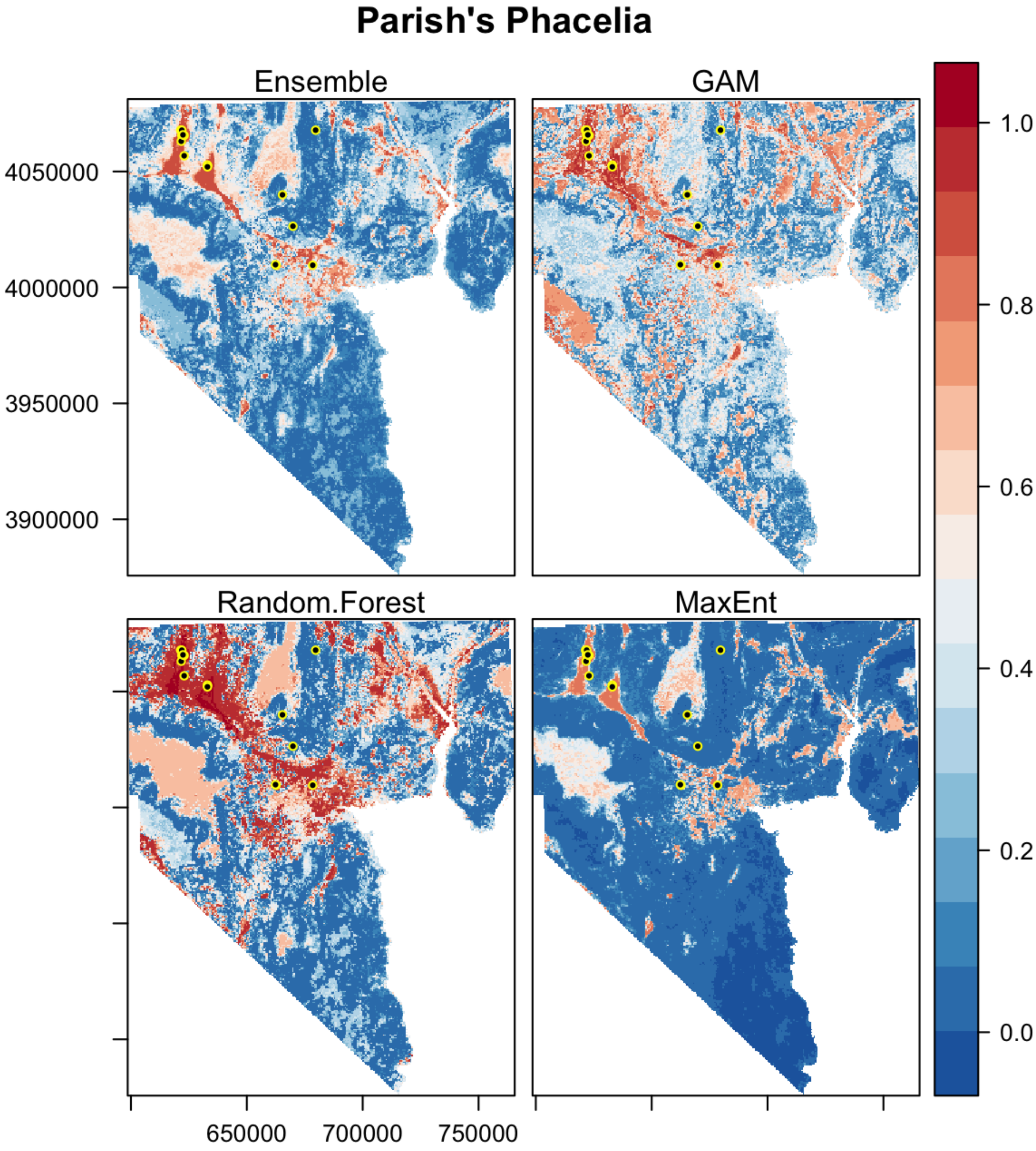


Figure A.11-2. SDM maps for Parish's phacelia model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

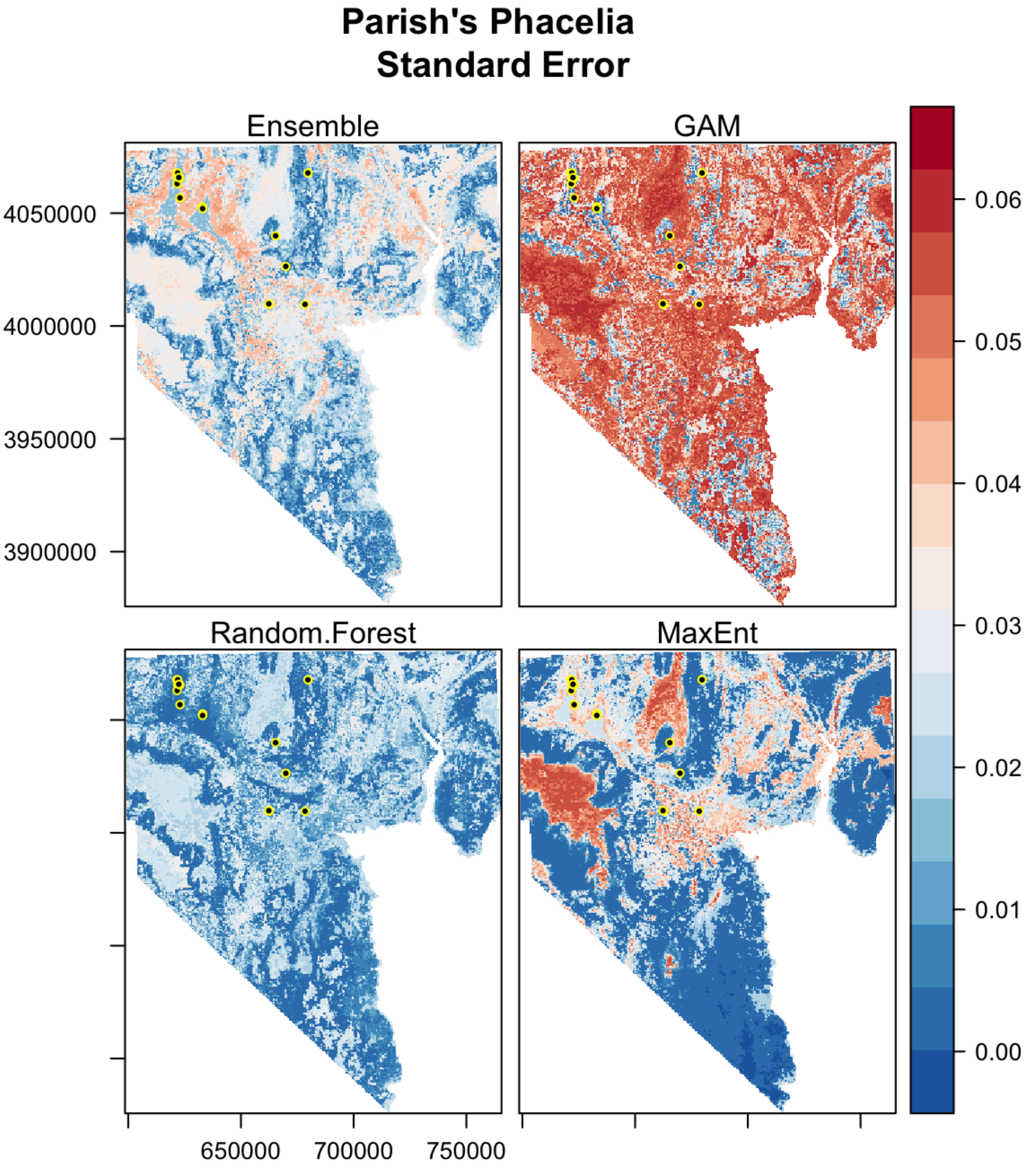


Figure A.11-3. Standard error maps for Parish's phacelia models for each of three modeling algorithms used (MaxEnt – lower right, GAM - upper right, Random Forest - lower left), and an Ensemble model averaging the three (upper left).

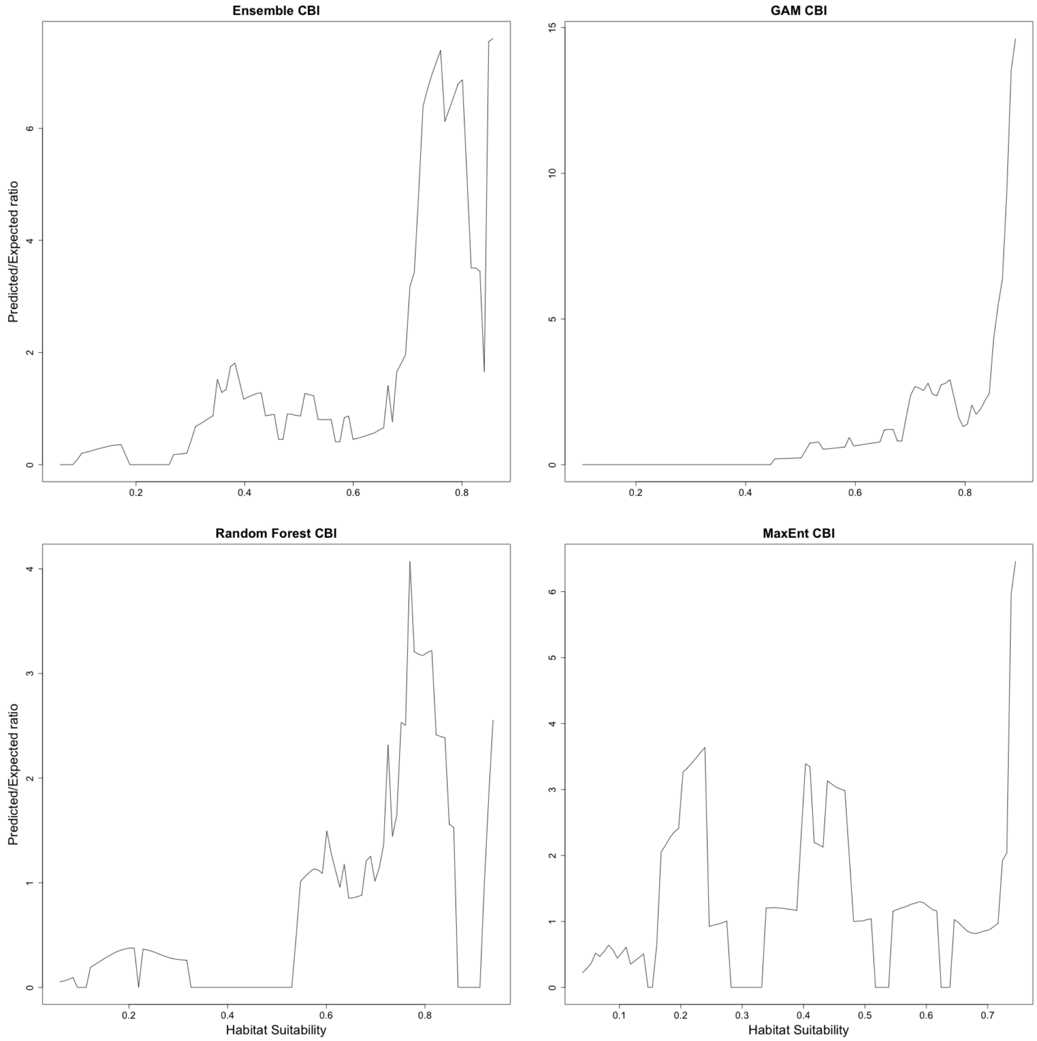


Figure A.11-4. Graphs of Continuous Boyce Indices [CBI] for Parish's phacelia models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.11.4.1 General Additive Model

The top four contributing environmental layers were Clay Content of soils, Extreme Minimum temperature, NDVI Amplitude, and NDVI Maximum, collectively accounting for 91.5% of total model contribution (Table A.11-2). Clay Content of the soils was a top variable for all three models and shows a similar pattern across the three models, where habitat values are generally low when Clay Content is low, followed by an abrupt increase in habitat values when Clay Content increases to ca. 10% (Figure A.11-5, Figure A.11-6, Figure A.11-7). The response curve for the GAM model for Clay Content differs from the other models' response, in that it briefly indicates high habitat values at low Clay Content, which may be an artifact of the smaller sample sizes for this species. Thereafter the response curve follows the other models, but decreases rapidly when Clay Content is higher (Figure A.11-5). NDVI Maximum was also an important variable for all three models. In all three models, habitat values are high, until NDVI maximum exceeds ca. 115, at which point habitat values decrease rapidly and remain low (Figure A.11-5, Figure A.11-6, Figure A.11-7). The GAM model shared NDVI Amplitude as an important variable with the RF models. Both models' response curves show a pattern where habitat values are high when NDVI Amplitude is low, with a rapid decrease as NDVI Amplitude increases (Figure A.11-5, Figure A.11-7). Habitat values for the GAM model are high when Extreme Minimum temperature is low, and habitat variables decrease abruptly when Extreme Minimum temperature reaches *ca.* – 4 ºC and is concordant with the results for this variable when the MaxEnt model is employed (Figure A.11-5, Figure A.11-7).

The concordant predictions and response curves across different models for the important variables indicates robust variable selection among models overall. However, the GAM algorithm had higher standard error values, indicating some dissimilar predictions among the 50-model cross-validation runs (Figure A.11-4).

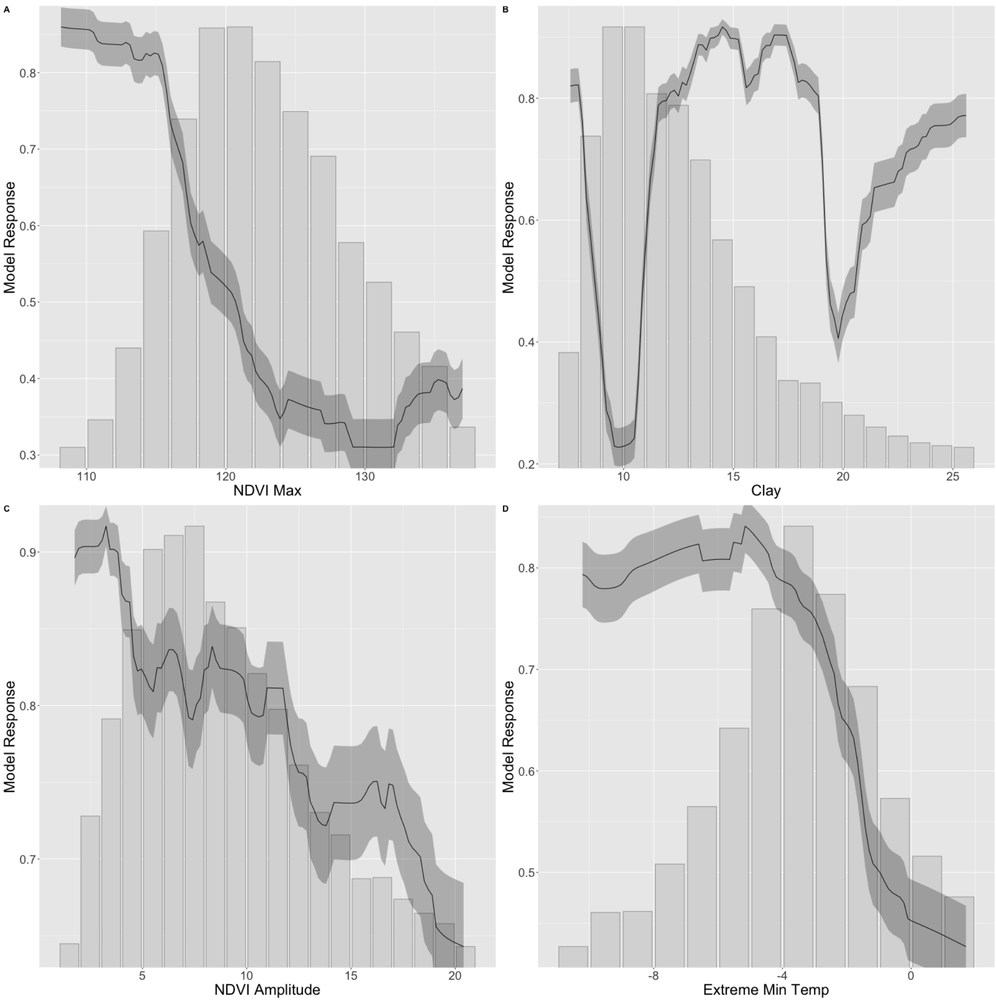


Figure A.11-5. GAM partial response curves for the top four variables in the Parish's phacelia model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.11.4.2 MaxEnt Model

The MaxEnt models relied heavily on Clay Content of the soil, Extreme Minimum temperature, Gypsum Content of the soil, and NDVI Maximum as the top four variables, collectively representing 92.2% of total model contribution (Table A.11-2).

The response curves for Clay Content of the soil and NDVI Maximum were similar among all three algorithms, and are described in detail above (Figure A.11-5, Figure A.11-6, Figure A.11-7). In general, habitat values are generally low when Clay Content is low, followed by an abrupt increase in habitat values when Clay Content increases to ca. 10% - 15% (Figure A.11-5, Figure A.11-6). Habitat values are high in all models, until NDVI Maximum exceeds ca. 115, at which point habitat values decrease rapidly and remain low (Figure A.11-5, Figure A.11-6, Figure A.11-7). The variable Gypsum Content of the soil was shared as a top variable with the RF model (Table A.11-2). Both the MaxEnt model and RF model show similar responses to this variable, where habitat values are low when Gypsum Content of the soil is low, followed by a rapid increase and plateau when Gypsum Content exceeds 3% (Figure A.11-6, Figure A.11-7). Similarly, the MaxEnt and GAM models shared Extreme Minimum temperature as an important variable (Table A.11-2). As noted previously, both the MaxEnt and GAM models show high habitat values when Extreme Minimum temperature is low, and habitat variables decrease abruptly when Extreme Minimum Temperature reaches *ca.* – 4 ºC (Figure A.11-5, Figure A.11-7).

This model had relatively low standard errors, indicating general agreement in the predictions among the 50 model cross-validation runs (Figure A.11-4).

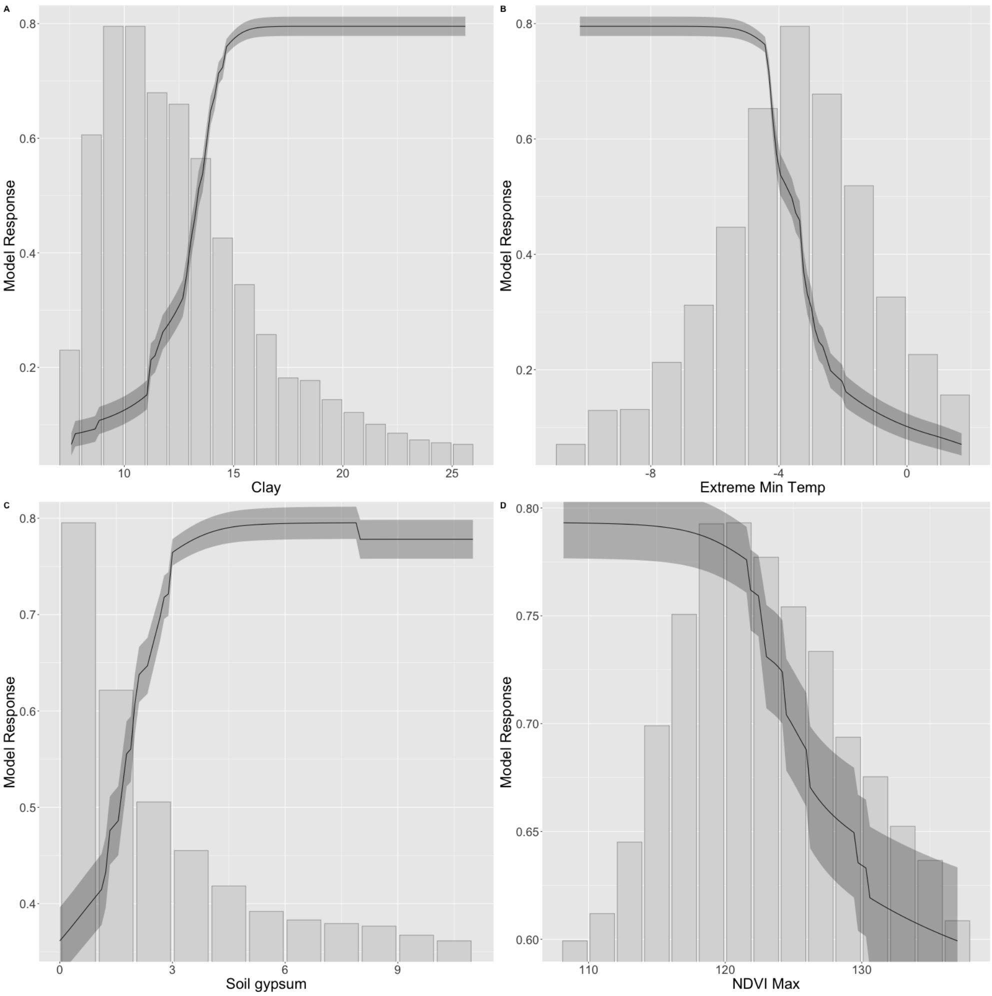


Figure A.11-6. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for Parish's phacelia. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.11.4.3 Random Forest Model

The Random Forest model was driven by Clay Content of soil, Gypsum Content of soil, NDVI Amplitude, and NDVI Maximum (Table A.11-2). The collective model influence of these four variables was 96% (Table A.11-2). All four variables are also important variables in either one or both of the other models (Table A.11-2). The RF model's predictions are concordant with the other models, and their responses are described in detail above. Only NDVI Maximum shows a slight departure from the other models, as habitat values for NDVI Maximum increase somewhat and fluctuate at higher NDVI Maximum values (Figure A.11-7). Habitat values are high when NDVI Amplitude is low, and rapidly decrease when NDVI Amplitude exceeds 5 (Figure A.11-7).

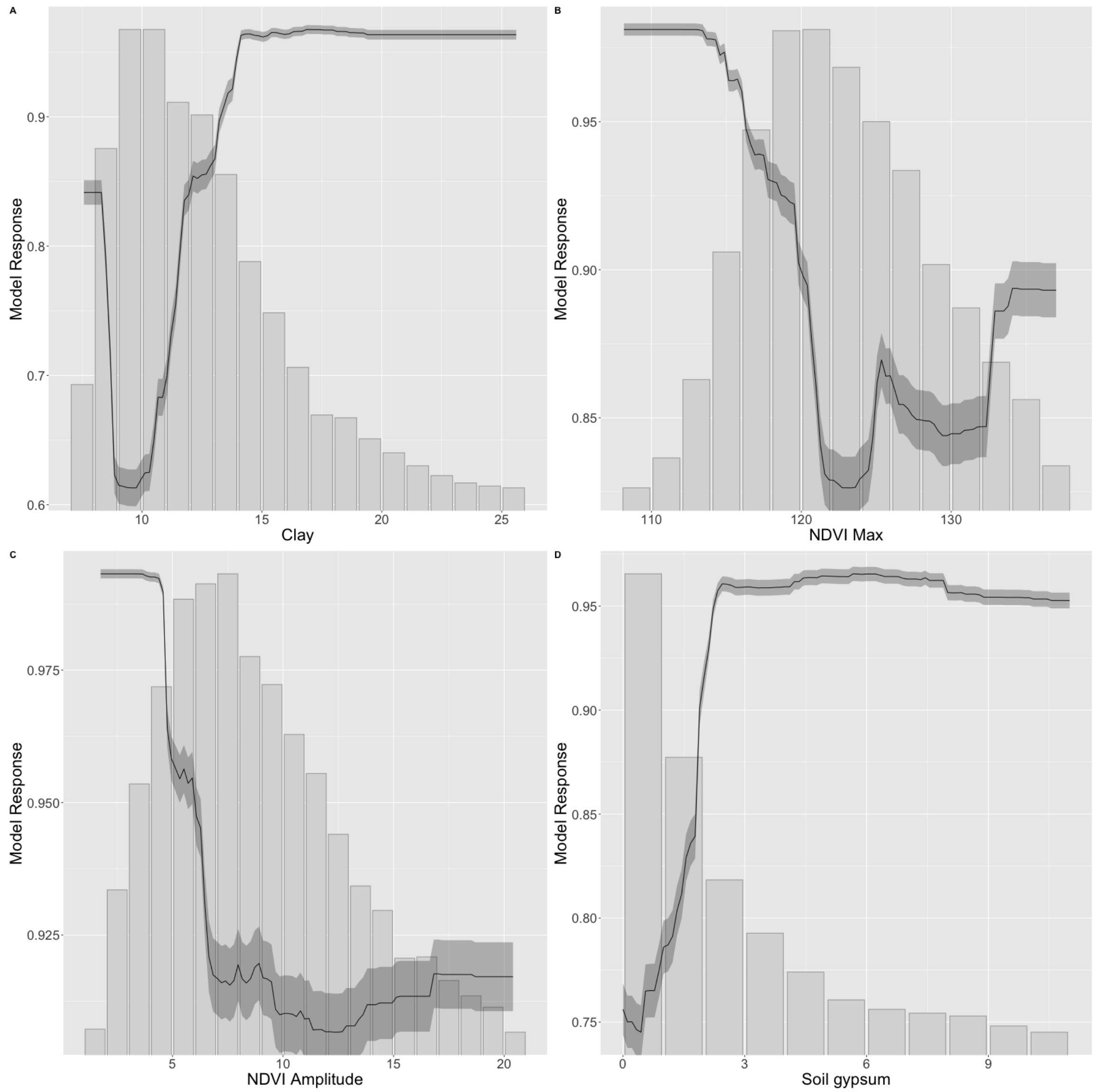


Figure A.11-7. Partial response curves for the environmental variables included in the Random Forest Ensemble model for Parish's phacelia. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.11.4.4 Model Discussion

Parish’s phacelia primarily occurs in the northern extent of the City of Las Vegas, and in areas in the northern Las Vegas Valley. Indian Springs Valley and the Three Lakes Valley. Disjunct records also report the species in the area near Coyote Springs Valley. The Ensemble model indicates other areas of high habitat suitability outside of this range. In particular all three models, predict high habitat suitability in a rather large area along the US 95 corridor, and other areas close to the northwestern populations described above (Indian Springs Valley and the Three Lakes Valley). The Sheep Range and the Spring Mountains show moderately high habitat values. Other areas along the Lake Mead shoreline, and areas near the Meadow Valley Wash, west of the North Muddy Mountains, and vicinity have pockets with rather high predicted habitat suitability. A portion of the center of Eldorado Valley (i.e. the dry lake) is also predicted to have high habitat suitably.

The locality data for this species consisted of 64 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 43 records.

A.11.4.5 Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05 – despite the indicated coloration) throughout much of the study area (Figure A.11-9), with moderate error, located in some areas that were predicted as moderately high quality habitat – especially in the northwestern US -95 corridor. Overall errors were relatively low, indicating good agreement among the models used in the Ensemble.

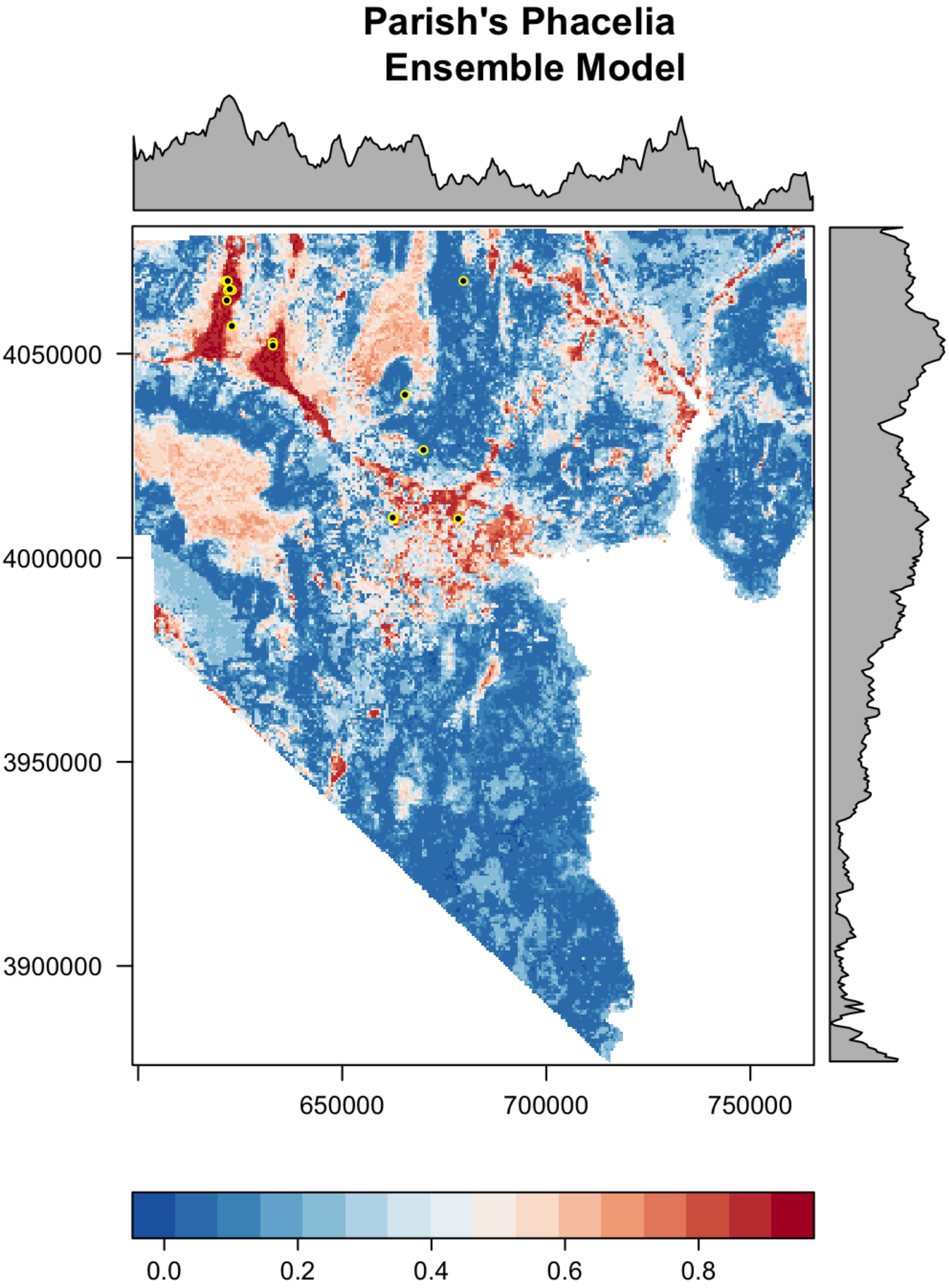


Figure A.11.8. SDM map for Parish’s phacelia Ensemble model for Clark County, NV.

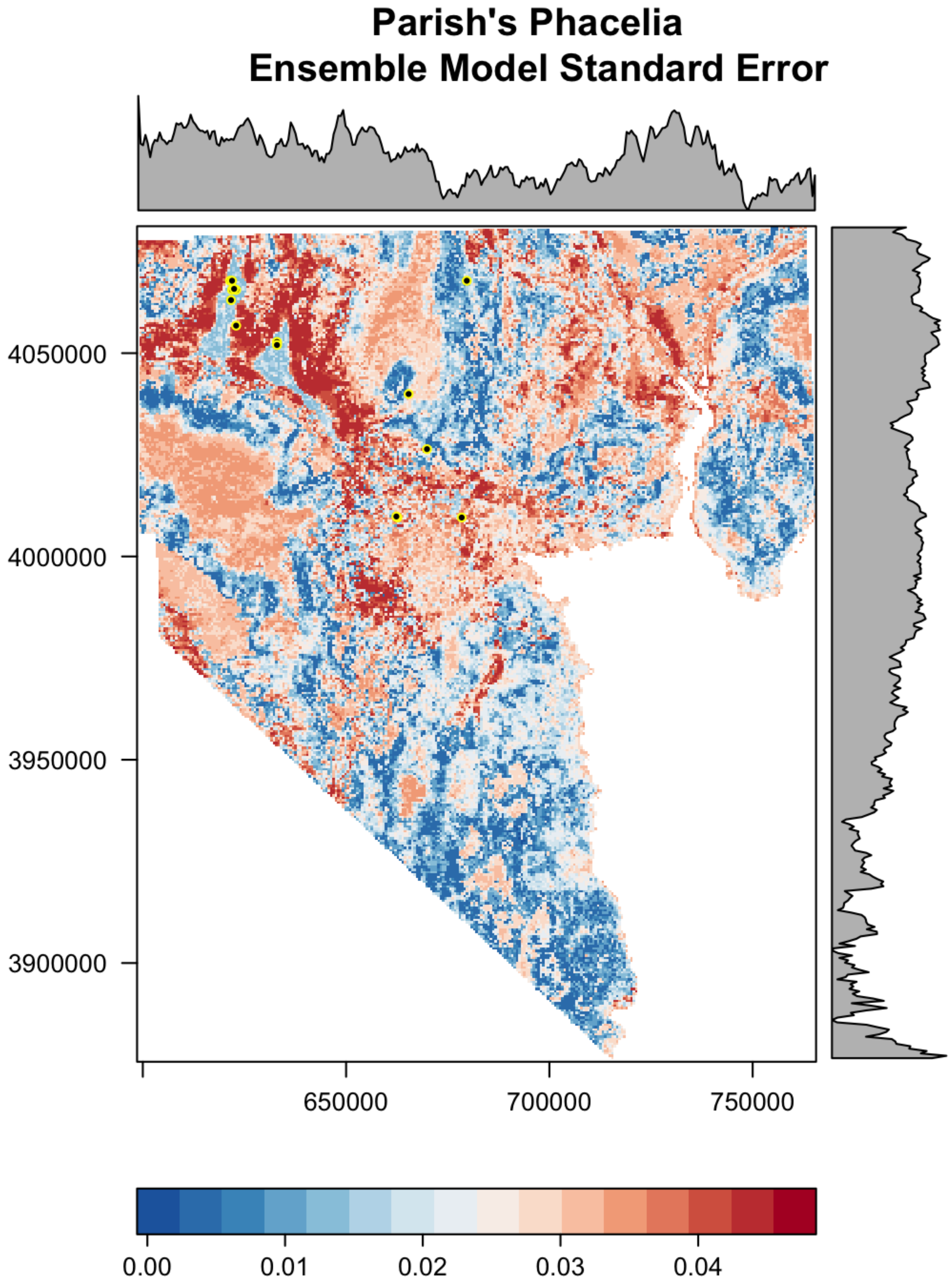


Figure A.11.9. Standard Error map for the Parish’s phacelia Ensemble model for Clark County, NV.

A.11.5 Distribution and habitat use within Clark County

In Clark County, the species is found Parish's phacelia primarily occurs in the northern extent of the City of Las Vegas, and in areas in the northern Las Vegas Valley. Indian Springs Valley and the Three Lakes Valley. Disjunct records also report the species in the area near Coyote Springs Valley. The Ensemble model indicates other areas of high habitat suitability outside of this range. In particular high habitat suitability is predicted in a rather large area along the US 95 corridor, and other areas close to the northwestern populations described above (Indian Springs Valley and the Three Lakes Valley). The Sheep Range and the Spring Mountains show moderately high predicted habitat values. Other areas along the Lake Mead shoreline, and areas near the Meadow Valley Wash, west of the North Muddy Mountains, and vicinity have pockets with rather high predicted habitat suitability. A portion of the center of Eldorado Valley (in and around the dry lake) is also predicted to have high habitat suitably.

Key relationships to habitat variables include: 1) increased habitat suitability when Clay Content is above 10%; 2) high habitat values for NDVI Maximum are high, until NDVI maximum exceeds ca. 115, at which point habitat values decrease rapidly and remain low; 3) habitat values are high when Extreme Minimum temperature is low, and habitat variables decrease abruptly when Extreme Minimum temperature reaches *ca.* – 4 ºC; 4) habitat values are low when Gypsum Content of the soil is low, followed by a rapid increase and plateau when Gypsum Content exceeds 3%; and 5) Habitat values are high when NDVI Amplitude is low, and rapidly decrease when NDVI Amplitude exceeds 5.

A.11.6 Ecosystem-level threats

This annual species occurs in flats, playas and dry lake beds that fill with rainwater in years with significant rainfall, at which time the species will germinate. Predicted is located in all ecosystems within the County (Table A.11-3). Its biology is very tightly linked with these flats and playas, and military activities threatened to damage the habitat where this species occurs (NatureServe, 2019). Likewise, solar energy development could threaten the species persistence (CNPS, 2019). Other possible threats include off-road vehicles, powerlines, road construction and similar disturbances (White 2006).

Table A.11-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	30	93
Blackbrush	342478	66752	5540
Bristlecone Pine	0	5921	1602
Desert Riparian	3027	6785	284
Mesquite Acacia	13312	5220	1688
Mixed Conifer	0	16739	10403
Mojave Desert Scrub	909867	346422	99408
Pinyon Juniper	13859	75413	25969
Sagebrush	1551	2723	419
Salt Desert Scrub	15299	38284	28853

A.11.7 Threats to Species

Direct mortality from the activities listed above could threaten the species. Furthermore, the species could face extinction if droughts increase in duration and last longer than the seeds remain viable (Smith, 1997, as cited in CNPS, 2019).

A.11.8 Existing Conservation Areas and Management Actions

Parish’s phacelia in California occurs largely on lands managed by BLM, and is a covered plant species (without specific actions for this species) under the BLM’s West Mojave Plan (Dudek 2012).

A.12 ST. GEORGE BLUE-EYED GRASS (*SISYRINCHIUM RADICATUM*)

St. George blue-eyed grass (*Sisyrinchium radicatum*) is a perennial forb in the Iridaceae family. The flowers consist of bluish violet tepals with yellow bases. The St. George blue-eyed grass flowers late spring to mid-summer. This species is predominately self-pollinating, which is a unique trait of the genus. The plant is able to achieve this because the anthers and stigmata mature concurrently. Self-pollination could also be a possibility by bees if the stigma maturation and anther dehiscence occur simultaneously, and if the elongation of the style results in the stigmata being close to the same height as the anthers, as is also believed to occur in St. George blue-eyed grass (Cholewa and Henderson 1984).

St. George blue-eyed grass looks much like, and is closely related to stiff blue-eyed grass (*Sisyrinchium demissum*), but can be distinguished by the white or cartilaginous margins on the stem and a broad apex to the hyaline margin of the inner spathe of St. George blue-eyed grass (Bicknell 1901a; Bicknell 1901b). Another distinguishing feature of St. George blue-eyed grass is branching stems (Ingram 1967; Henderson 1976).

As of 1977, Intermountain Flora classified St. George blue-eyed grass and stiff blue-eyed grass as the same species (Cronquist et al. 1977). Utah Flora (Welsh et al. 1987) also classifies the two as the same species. This species has been confused with stiff blue-eyed grass a result of these publications (Goodrich and Neese 1986). This should be considered when investigating distribution for management purposes.

A.12.1 Species Status

US Fish and Wildlife Service Endangered Species Act: No status

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No status

State of Nevada (NAC-527): No status

NV Natural Heritage Program: Global Rank G2?Q State Rank S1S2

IUCN Red List (v 3.1): No status

CITES: No status

A.12.2 Range

St. George Blue-eyed Grass is thought to be restricted to the northeast Mojave Desert between St. George Utah and Las Vegas, Nevada. The species is also expected to be in the adjacent northwest corner of Arizona (Bicknell 1901a). It has been reported in Duchesne, Kane, and Washington counties in Utah. Plants commonly associated with the species include *Poa pratensis*, *Juncus* spp., and *Glaux maritima*. In southern Utah it is thought to be sympatric with Stiff blue-eyed grass (Cholewa and Henderson 1984).

All SEINet occurrences recorded of the species are in southern Nevada with one occurrence in Lincoln County (Ash Springs), one in Nye County (Ash Meadows), and four in Clark County. The Clark County occurrences are in the Spring Mountains (one at Pine Creek and one at a seep in juniper habitat north of Mountain Springs), Warm Springs in Moapa (alkali meadow), and southeast of Riverside (alkali meadow). Three of these occurrences listed *Distichlis spicata* as an associated species. Other associated species included *Scirpus sp*. and *Muhlenbergia asperifolia* in Clark County occurrences. Other southern Nevada occurrences listed *Juncus balticus*, *Grindelia fraxinopratensis*, and *Spiranthes infernalis* as associated species (SEINet).

St. George blue-eyed grass has an occurrence count of six according to one source and has a distribution status of confident or certain within Nevada in Clark, Lincoln, and Nye counties (NNHP).

A.12.3 Population Trends

There are insufficient data on St. George blue-eyed grass to suggest any trends across populations. Historical discrepancies in accurate identification also obfuscate population information over time.

A.12.4 Qualitative Habitat Model

There were 14 localities for this species in Nevada, only 11 of which were within Clark County. Although few occurrence records exist for this species, it is clear that St. George blue-eyed grass requires moist or wetland soils for population establishment and persistence. The majority of known populations occur at desert springs (e.g., the Calico Basin in Red Rock Canyon National Conservation Area), alkaline meadows (e.g., Ash Meadows National Wildlife Refuge), or along riparian corridors (e.g., the Muddy River). However, the sample size (n = 14) of known occurrences is not sufficient to support development of a quantitative habitat model at this time. High variability in habitat characteristics of known occurrences also hamper such an effort: populations span an elevation range from 1760 to over 6000 ft. and include several different types of wetlands. For these reasons, and without further knowledge of the species distribution, we considered any riparian vegetation within Clark County to be potential habitat for St. George blue-eyed grass, including moist soils surrounding desert springs and their outflows, riparian vegetation along perennial or intermittent streams, and alkaline meadows.

To represent these riparian habitat types, we merged several existing sources of information. First, we selected the Desert Riparian and Mesquite acacia vegetation classes from the Clark County vegetation map developed by Heaton et al. (2011). This mapping project incorporated a broad range of remotely sensed data as well as a large sample size of field validation sites, and appears to be the most accurate vegetation map available for Clark County. Second, we compiled the locations of spring features from the National Hydrography dataset (https://nhd.usgs.gov/) as well as waypoints for springs from existing MSHCP project data. These point features were converted to a raster grid and merged with the Heaton et al. (2011) riparian vegetation classes at a unified spatial resolution of 90 m2, representing an initial model of riparian vegetation types that may be suitable for St. George blue-eyed grass.

Third, we developed a refined model of riparian vegetation within Clark County to supplement the riparian vegetation classes identified in Heaton et al. (2011). Visual examination of satellite imagery made it apparent that the Heaton et al. (2011) vegetation map underestimates riparian vegetation within Clark County, particularly where this type of vegetation occurs as narrow corridors within broader vegetation classes. For example, the Heaton et al. map does not include riparian vegetation within several creek channels where St. George blue-eyed grass occurs within the Red Rock Canyon National Conservation Area. In part, this may be because the vegetation map did not include ephemeral riparian vegetation within the riparian vegetation class, but rather dissolved such areas into the surrounding vegetation classes (Heaton et al. 2011). Therefore, we broadened the riparian vegetation classes from Heaton et al. (2011) to include a wider range of potential St. George blue-eyed grass habitat through a RF classification of riparian vegetation. The locations of known springs and riparian channels were treated as training points for the model, while background points were drawn randomly from non-riparian vegetation classes. The model was subjected to the same thinning and cross validation procedures described above (see Introduction- *Quantitative statistical models*). Covariates for this model included various vegetation indices calculated from a Landsat 8 mosaic (NOV 2016) of Clark County: Normalized Difference Vegetation Index (NDVI); Normalized Difference Moisture Index (NDMI); Normalized Difference Water Index (NDWI); and Tasseled Cap Greenness (coefficients in Baig et al. 2014). Additionally, we included the Maximum NDVI from the MODIS satellite averaged across 2001-2010 (https://phenology.cr.usgs.gov), along with Elevation and Topographic Position (TPI).

The final RF model (Figure A.12.1) had an *R2* of 0.72, with an average AUC of 0.91 and True Skill Statistic (TSS) of 0.84 across cross-validation runs. The Landsat-derived NDVI was the most influential term in the model, followed by TPI, Elevation, and NDMI, respectively. The Continuous Boyce Index also indicated strong performance (Figure A.12.2) with wetland delineation use as a proxy for habit in this species indicated above 0.5 to 0.6 range. From this model, we defined grid cells as riparian vegetation that had a probability score of at least 0.61 (the model's precision-recall break-even point) in addition to having an NDVI value of at least 0.1 in the Landsat 8 imagery. This latter criterion reduced the potential for commission error in our riparian vegetation designations. For our final qualitative model of potential riparian habitat for St. George blue-eyed grass, we then merged riparian grid cells identified through the RF model with the Heaton et al. (2011) riparian vegetation classes and the mapped spring locations.

The 11 localities within Clark County are distributed in two general areas. A single observation was made in the Moapa Valley area (Figure A.12.3), while the remaining 10 were west of Las Vegas in the general area of Red Rock National Conservation Area - in Calico basin and Pine Creek Canyon, and others. The resulting qualitative model shows habitat predictions along the Virgin and Muddy Rivers, in the lowland habitat of the Colorado River near Avi, and in various spring and ephemeral washes throughout the County, with most patches in and around the Spring Range, west of Las Vegas (Figure A.12.3).

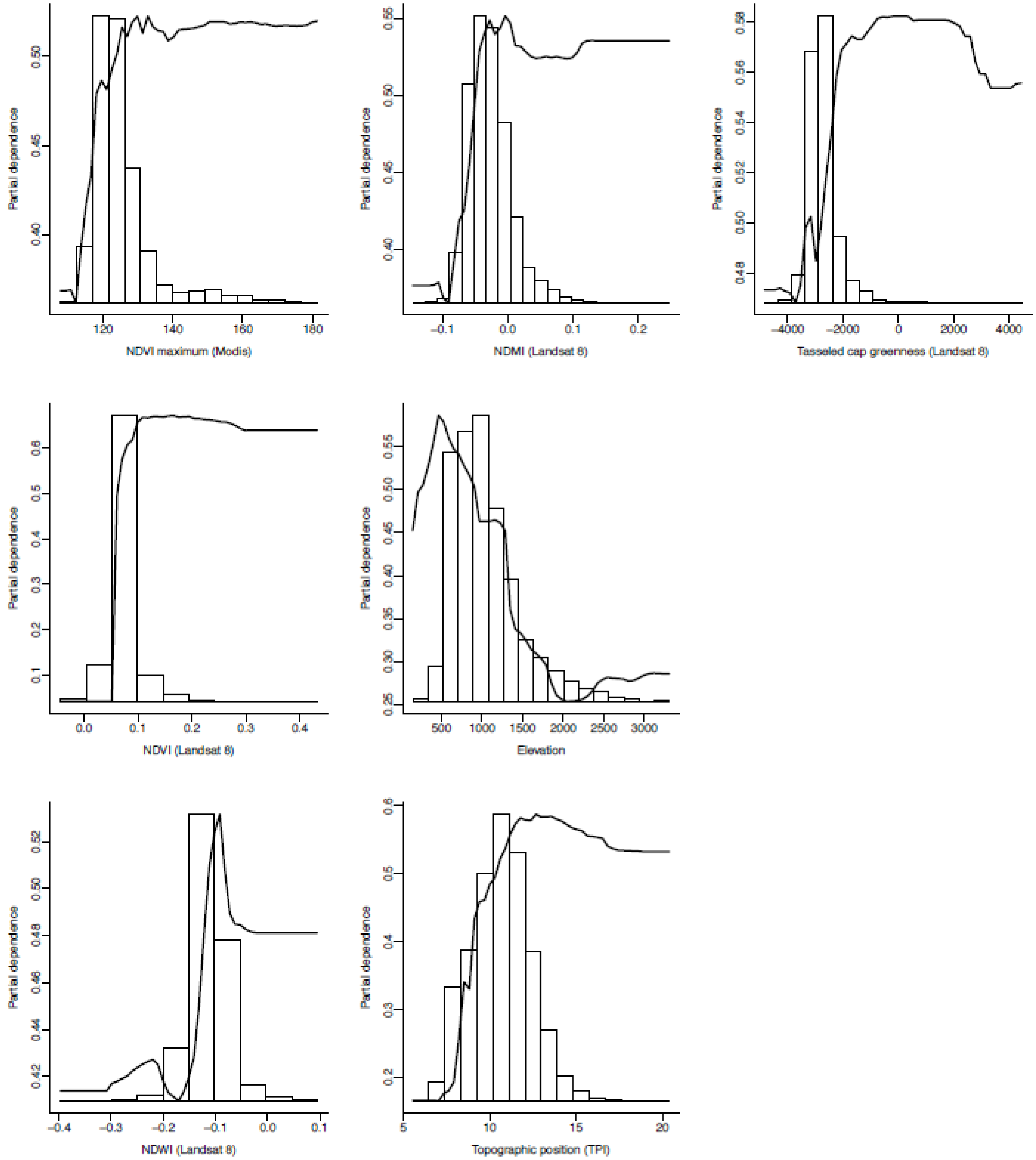


Figure A.12.1. RF partial response curves for the wetland soils and vegetation model to define qualitative habitat for St. George blue-eyed grass overlaid over distribution of environmental variable inputs in the study area.

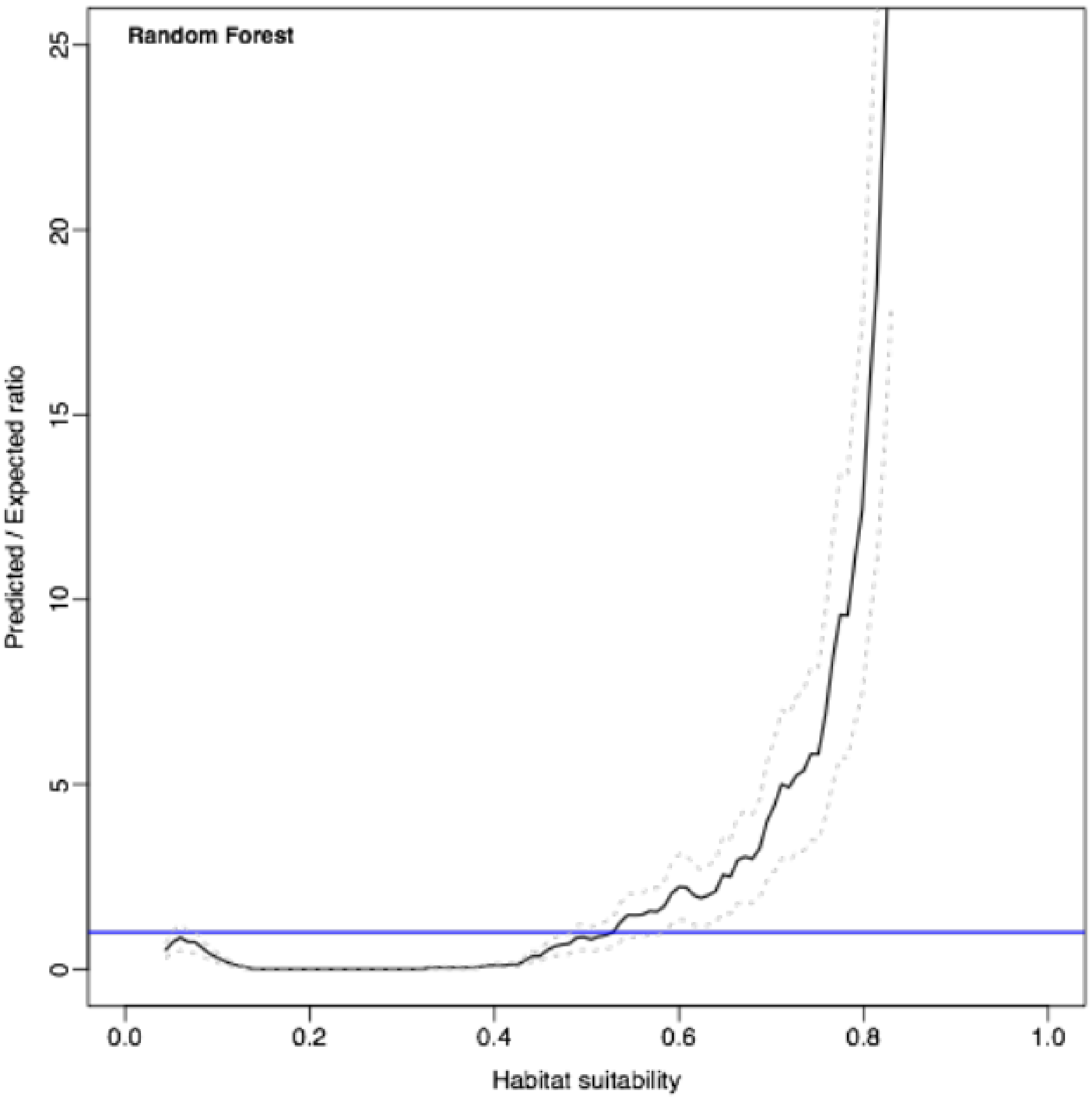
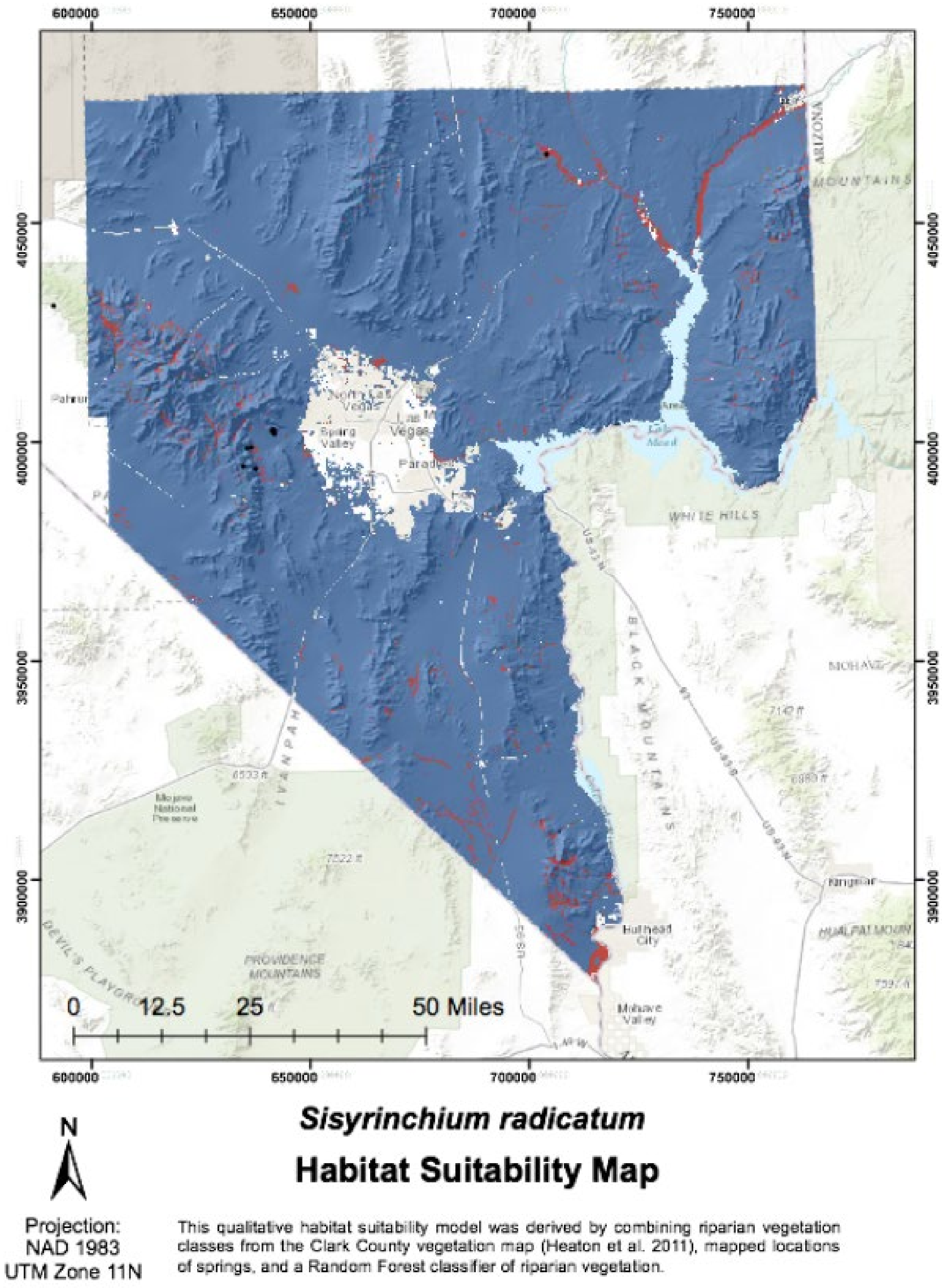


Figure A.12.2. Continuous Boyce Index plot for the GAM model defining wetland and riparian soils and vegetation for the qualitative St. George blue-eyed grass model.



Sisyrinchium radicatum

Habitat Suitability Map

This qualitative habitat suitability model was derived by combining riparian vegetation classes from the Clark County vegetation map (Heaton et al. 2011), mapped locations of springs, and a Random Forest classifier of riparian vegetation.

Figure A.12.3. Qualitative habitat suitability map for St. George blue-eyed grass.

A.12.5 Distribution and Habitat Use within Clark County

There may be only four SEINet locations that exist for this species in Clark County. This plant grows on moist, sometimes alkaline meadows, borders of springs, and on stream banks at 600 to 1300 m in Nevada and Utah (Bicknell 1901a). It is classified as a “wetland” species according to Nevada Natural Heritage Program (NNHP). The qualitative model for this species indicated limited areas of habitat among several ecosystems as the riparian and spring systems are widely dispersed throughout the county. The Mesquite Acacia had the largest area of habitat, while the areas within Desert Riparian ecosystems were nearly all considered habitat (Table A.12.1).

Table A.12.1. Ecosystems within Clark County, and the area (Ha) of Low and High predicted suitability within each ecosystem.

Ecosystem	Low	High
Alpine	124	0
Blackbrush	411497	2875
Bristlecone Pine	7533	32
Desert Riparian	767	7803
Mesquite Acacia	3997	15271
Mixed Conifer	25354	1968
Mojave Desert Scrub	1248522	9319
Pinyon Juniper	109456	6175
Sagebrush	4524	160
Salt Desert Scrub	77362	405

A.12.6 Ecosystem Level Threats

Alkaline meadow, springs, stream banks, and other wetland areas that are under threat could potentially inhabit St. George blue-eyed grass (Bicknell 1901a). Because the species flowers late spring to mid-summer (Bicknell 1901a), disturbances happening during those times could be especially harmful.

The two possible occurrences in the Spring Mountains (SEINet) are near Pinyon-Juniper woodlands and could be vulnerable to wildfire as a result. The two other occurrences from SEINet are located on alkali meadows. One of these is located on BLM land and one is located on private land.

Alkali mariposa lily (*Calochortus striatus*) occupies alkaline meadows, similar to St. George blue-eyed grass, presumably. Known threats to the lily may therefore be applicable to St. George blue-eyed grass. Threats of alkali mariposa lily that could be applicable to St. George blue-eyed grass include; lowering water tables, grazing, competition with weedy species, and land development (Green and Sanders 2006). Other threats to alkaline meadows include trampling and hydrological alterations such as water diversions that result in lowering the water table (Baldwin 2002; CNPS 2016).

A.12.7 Threats to Species

Direct threats to the St. George blue-eyed grass may include threats common to other rare plants including: illegal harvesting; livestock grazing; feral equids, and OHV impacts.

A.12.8 Existing Conservation Areas/Management Actions

St. George blue-eyed grass was listed as a sensitive species occurring in Ash Meadows in 2009 (USFWS 2009) and is thought to have hybridized with the other species on the Refuge, *S. funereum* (USFWS 2012).

Of the four locations listed within Clark County on SEINet, two occur in Red Rock National Recreation Area, managed by the Bureau of Land Management, one occurs on BLM land southeast of Riverside, and one occurs on private land outside of Moapa Valley National Wildlife Refuge (SEINet).

A.13 JOSHUA TREE (*YUCCA BREVIFOLIA BREVIFOLIA* AND *YUCCA BREVIFOLIA JAEGERIANA*)

Joshua trees (*Yucca brevifolia*) are large tree-like succulent plants occupying mid- to upper-elevational zones of Mojave Desert shrubland communities (McKelvey 1938, Rowlands 1978, Cole et al. 2011). These slow-growing, long-lived yuccas (Comanor and Clark 2000, Gilliland et al. 2006, Esque et al. 2015) can take a long time to recover from disturbances such as fire – depending on post-disturbance environmental conditions (DeFalco et al. 2010). Taxonomically, two species of Joshua trees are gaining acceptance in the literature (Lenz 2007) – *Yucca brevifolia* and *Y. jaegeriana* (see Distribution and Ecology section). Joshua trees are perhaps most famous for their symbiotic relationship with their small moth pollinators (Trelease 1893, Darwin 1874, Smith 2010). Each Joshua tree species requires its own species of *Tegeticula* moth for pollination (Pellmyr and Segreaves 2003), and the moths require the ripening seeds of the Joshua tree as sustenance for their developing larvae (Trelease 1893). Successful reproduction and growth to maturity of Joshua trees requires a remarkable coincidence of appropriate environmental and biological conditions (DeFalco et al. 2010). Joshua trees generally flower and seed unpredictably only every few years (Borchert and DeFalco 2016), a pattern called 'masting.' With sufficient precipitation, some seeds likely survive moth larvae predation, and develop in pithy fruits that do not open on their own (indehiscent), and require rodents or erosion to break up the fruit to free the seeds for dispersal (Waitman et al. 2012). Many of the seeds are consumed by seed-caching rodents and other granivores (Vander Wall et al. 2006). Caches that are forgotten or overlooked by rodents are perfectly placed for Joshua tree seed germination and establishment at about 2 cm deep in the soil (Waitman et al. 2012). Joshua tree seeds have very high germination rates when stored in dry conditions (e.g. >90 percent for several years), however, seeds in the ground deteriorate rapidly after about 18 months, thus there is not really a Joshua tree seed bank for future generations (Reynolds et al. 2012), meaning that the seeds that are present only occasionally are only good for a relatively short period of time. Seeds that germinate during summer rains have a better chance of survival than those germinating after spring rains (Reynolds et al. 2012), because the seedlings of summer germination avoid the harsh summer conditions for their first year of root and shoot development. Predation by herbivores can be as high as 50% in a single year for Joshua trees that are less than 1 m tall, and it may require 30 years for them to reach this stature (Esque et al. 2015). Small Joshua trees (e.g., <1 m tall) benefit by growing beneath other species of plants (e.g. white-bursage – *Ambrosia dumosa*, blackbrush – *Coleogyne ramossisima*) known as nurse plants (Brittingham and Walker 2000), and may be protected from herbivores in this way (Chameroy 2015). Joshua trees that are 1 m tall may flower, but it may take as long as 70 years for most Joshua trees to reach reproductive size (Esque et al. 2015). Mortality for adult Joshua trees is usually relatively low e.g., ~2-3% per year or less), but severe drought can cause increased mortality but is more severe on smaller Joshua trees (DeFalco et al. 2010). Drought can also increase herbivory and result in animals such as white-tailed antelope ground squirrels (*Ammospermophilus leucurus*), jackrabbits (*Lepus californicus*), woodrats (*Neotoma* spp.), and pocket gophers (*Thomomys bottae*) – apparently as a last resort, and result in high levels of mortality among Joshua trees over large areas (DeFalco et al. 2010). Joshua trees are important to many wildlife species across the Mojave Desert (Miller and Stebbins 1964) and may be considered an umbrella species in this region. Besides the yucca moth, a whole community of may invertebrate species feed on the flowers, fruit, and stems of Joshua trees. The seeds also provide forage for many rodents (e.g. Merriam's kangaroo rats – *Dipodomys merriami*, white-footed mice *Peromyscus leucopus*, and woodrats – *Neotoma* spp.), and insects such as harvester ants (e.g., the rough harvester ant – *Pogonomyrmex rugosus*). Raptors such as red-tailed hawks (*Buteo jamaicensis*), great horned owls (*Bubo virginianus*) use Joshua trees for hunting perches and nesting platforms. Western screech owls (*Otus kennicottii*), and American kestrel (*Falco sparverius*) use them as hunting perches or nesting cavities. Burrowing owls (*Athene cunicularia*) also perch on Joshua trees, but use ground-based burrows for nesting. Northern and gilded flickers (*Colaptes auratus* and *C. chrysoides*; respectively), and ladder-backed woodpeckers (*Picoides scalaris*) find Joshua trees among the only species they can use to excavate cavities for nesting in the Mojave Desert. Small owls, ash-throated flycatchers (*Myiarchis cinarescens*), and feral honeybees, secondarily use cavities created by woodpeckers. Perching birds such as the western kingbird (*Tyrannus verticalis*), loggerhead shrike (*Lanius ludovicianus*), and cactus wren (*Campylorhynchus brunneicappilus*) all perch and nest among the Joshua tree branches. The shrike pierces prey species such as lizards, snakes and scorpions on the tips of the sharp Joshua tree leaves as a larder to remove bits of food to feed their young.

A.13.1 Species Status

Joshua trees were petitioned for listing under the Endangered Species Act (1973) by WildEarth Guardians in September 2015 citing five potential listing factors. These factors document a wide array of threats. e.g. habitat loss, climate change, overutilization, and the inadequacy of existing regulating mechanisms to protect populations now and in the future. The petition cites their relatively short dispersal distances and low germination rates (due to limited seed dispersers that impart a large reproductive cost) under a shifting and shrinking habitat as cause for protection. The USFWS still has this petition under consideration with determination expected in FY 2018.[5]

U.S. Fish and Wildlife Service: Not Listed - currently under review/petition[5]

U.S. Bureau of Land Management (Nevada): None

U.S. Forest Service (Region 4): None

State of Nevada (NAC-527): None

NV Natural Heritage Program: Sensitive List: Global Rank G4G5, State Rank SNR (*Yucca brevifolia*); G4G5T3T5, State Rank S4 (*Yucca jaegeriana*)

IUCN Red List: Not listed

CITES: Not listed

A.13.2 Range

Joshua trees occur in the southern Mojave Desert of California, northwest Arizona, southwest Utah, and southern Nevada (Rowlands 1978, Cole 2011). Joshua trees are taxonomically subdivided into two distinct species (Lenz 2007), *Yucca brevifolia* – is found primarily in the western Mojave Desert of California; and Lincoln County, Nevada; Y. *jaegeriana* – primarily in Lincoln, Nye and Clark Counties, Nevada; Mohave County, Arizona; and Washington County, Utah. The two subspecies meet in a hybrid zone in Lincoln County, Nevada (Pellmyr and Segreaves 2003, Smith et al. 2010, Godsoe et al. 2009). *Yucca jaegeriana* is the only species known in Clark County, Nevada.

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[5] Editor note: In 2019, the USFWS completed its review of the petition in 2019, and concluded protection under the Endangered Species Act was not warranted (84 FR 41694). Joshua tree has no federal status. (April 10, 2020).

A.13.3 Population Trends

Joshua trees are abundant where they occur in many locations across the Mojave Desert (Cole et al. 2011), and including Clark County, Nevada. While population studies on Joshua trees are ongoing (Esque et al. 2010), there are currently no existing research projects of sufficient scale to determine the population status of either species of Joshua tree across Clark County, Nevada, or similar areas of this size. One previous 30-year demographic study quantified growth rates, but was of insufficient sample size to detect mortality or natality (Comanor and Clark 2000). However, there is concern that the species may be negatively affected by climate change (Cole et al. 2011, Barrows and Murphy-Mariscal 2012). For example, it has been demonstrated that Joshua tree stands in parts of Joshua Tree National Park are not reproducing rapidly enough to keep up with natural declines of the populations. Most concern is for Joshua tree stands occurring at lower elevations and most southerly latitudes. Generally, it has been predicted that species ranges may recede at the more southerly and low elevation trailing edges of their ranges in the northern hemisphere, and that formerly unavailable landscapes at the leading northern and higher elevation edges of their ranges are opened up (Svenning and Sander 2013). This prediction essentially describes how plant species have migrated in response to previous large scale climate change episodes (e.g., during multiple glacial periods). However, this hypothesis has not been demonstrated empirically for Joshua trees and more research is needed on this topic. It has also been hypothesized that as Joshua trees migrate to keep up with the pace of future climate change across the landscape that they will not be able to move fast enough and may perish (Cole et al. 2011). Thus, the current ecological discussion about Joshua trees is being debated vigorously.

A.13.4 Habitat Model

Joshua trees were modeled using three species distribution modeling algorithms, and an ensemble model was created to integrates these models into a single model less influenced by the shortcomings of any one of the methods. Similar patterns of predicted suitability were produced by the three modeling algorithms with a similar range for all three models, but with higher suitability scores predicted by the General Additive Model (GAM) followed by the Random Forest (RF) model, while the MaxEnt model tended to have lower predictive scores, but in the same general areas. The consensus model predicted areas of higher habitat suitability in western half of the county on upper bajada slopes and Gold Butte, and the upper Mormon Mesa area (Figure A.13.1).

Performance was high in all models (where AUC scores were in the high 80’s and 90’s), with the highest overall for the Ensemble and Random Forest models. The Random Forest had the highest performance in all metrics but the Boyce Index, followed by MaxEnt and then GAM models (Table A.13.1). AUC was highest in the RF and Ensemble models, but the Ensemble model had higher BI, than the others, and the second highest in all other scores (Table A.13.1).

The Continuous Boyce Index [CBI] indicated good performance among all but the GAM model, where the rise in values for predicted values had a much lower peak (Figure A.13.3). Standard Errors were generally low among the three modeling algorithms, with low to moderately low error in the Ensemble model throughout the predicted area. Approximated bins for the ensemble model based on the CBI were 0-0.5 unsuitable, 0.5-0.55 marginal, 0.5 to 0.7 suitable, and > 0.7 optimal habitat; with a suggested cutoff threshold near 0.55 (Figure A.13.3), and the threshold value calculated from the AUC analysis for the ensemble model was 0.55 (Table A.13.1).

Table A.13.1. Model performance values for Joshua tree models.

Performance	GAM	RF	MaxEnt	Ensemble
AUC	0.87	0.98	0.88	0.92
BI	0.89	0.88	0.89	0.91
TSS	0.61	0.88	0.64	0.74
Correlation	0.64	0.86	0.67	0.74
Cut-off*	0.59	0.55	0.42	0.55

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.13.2. Percent contributions for input variables for an ensemble model combining GAM, MaxEnt, and Random Forest algorithms.

Term	GAM	RF	Max	Average
Winter min temperature	21.9	13.0	17.3	17.4
Summer precipitation	11.9	13.6	18.6	14.7
Summer max temperature	14.8	14.2	7.5	12.2
NDVI maximum	17.5	10.2	12.1	13.3
Temperature range	11.6	9.4	13.7	11.6
Surface texture (ATI)	3.1	9.5	4.9	5.8
Slope	5.9	7.3	7.6	6.9
Roughness (TRI)	0.0	7.7	10.8	6.2
Soil rockiness index	3.2	6.1	7.5	5.6
Winter precipitation	0	8.9	0	3.0
Terrain wetness index (TWI)	10.1	0	0	3.4
Topographic position index (TPI)	0	0	0	0

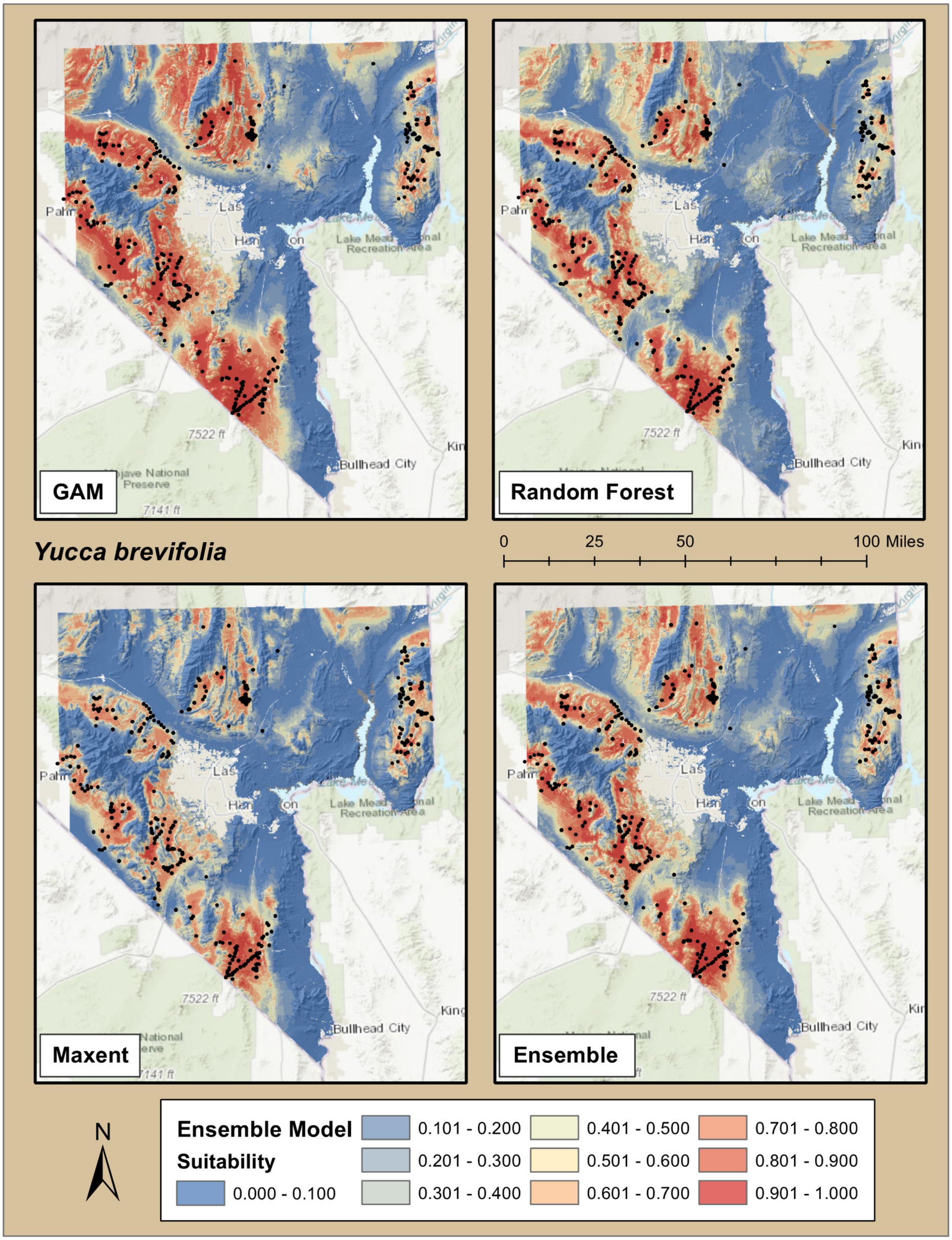


Figure A.13.1. SDM maps for Joshua tree for each of three modeling algorithms used (GAM - upper left, Random Forest - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

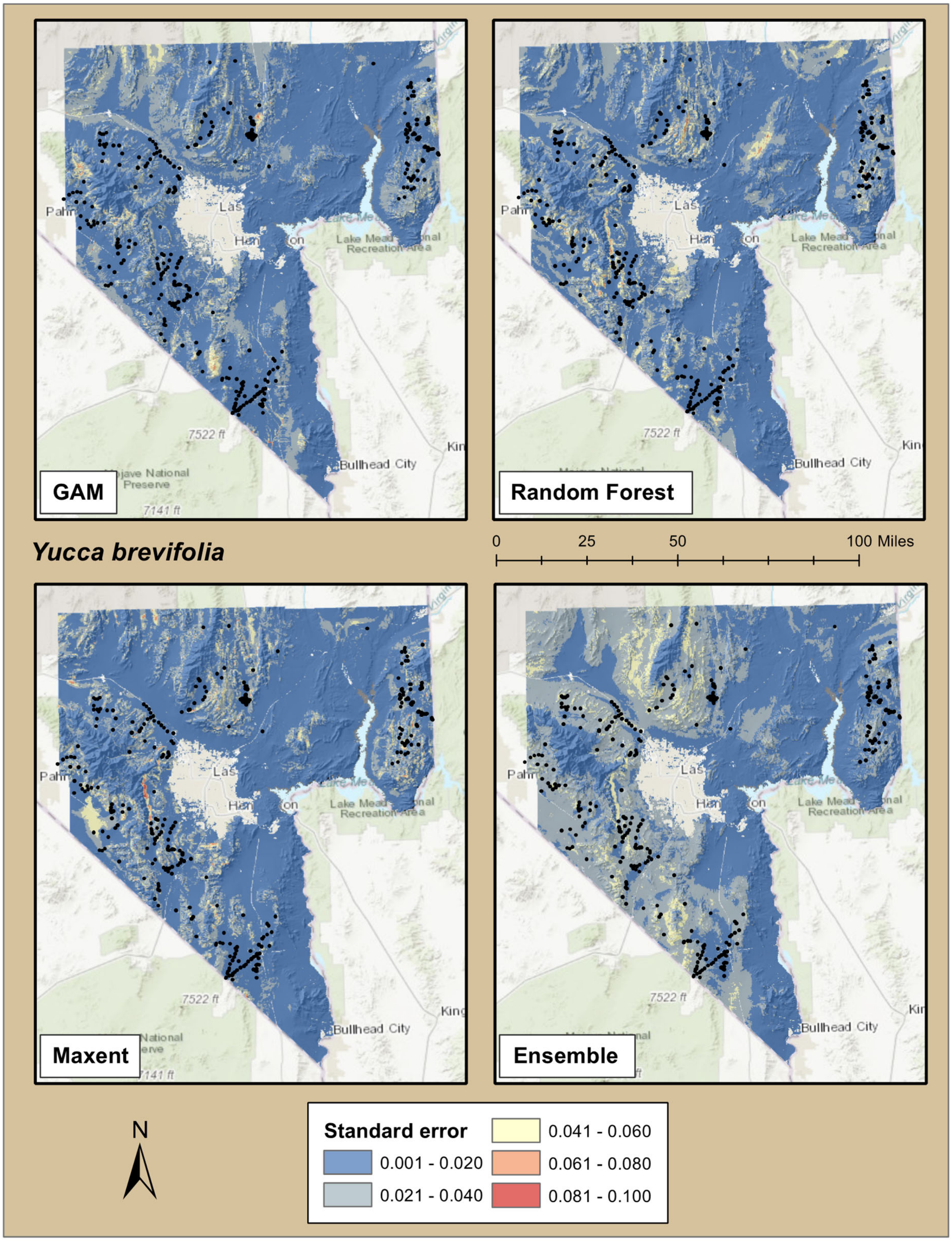


Figure A.13.2. Standard error maps for Joshua tree models for each of three modeling algorithms used (GAM - upper left, Random Forest - upper right, MaxEnt - lower left), and an Ensemble model averaging the previous three (Lower Right).

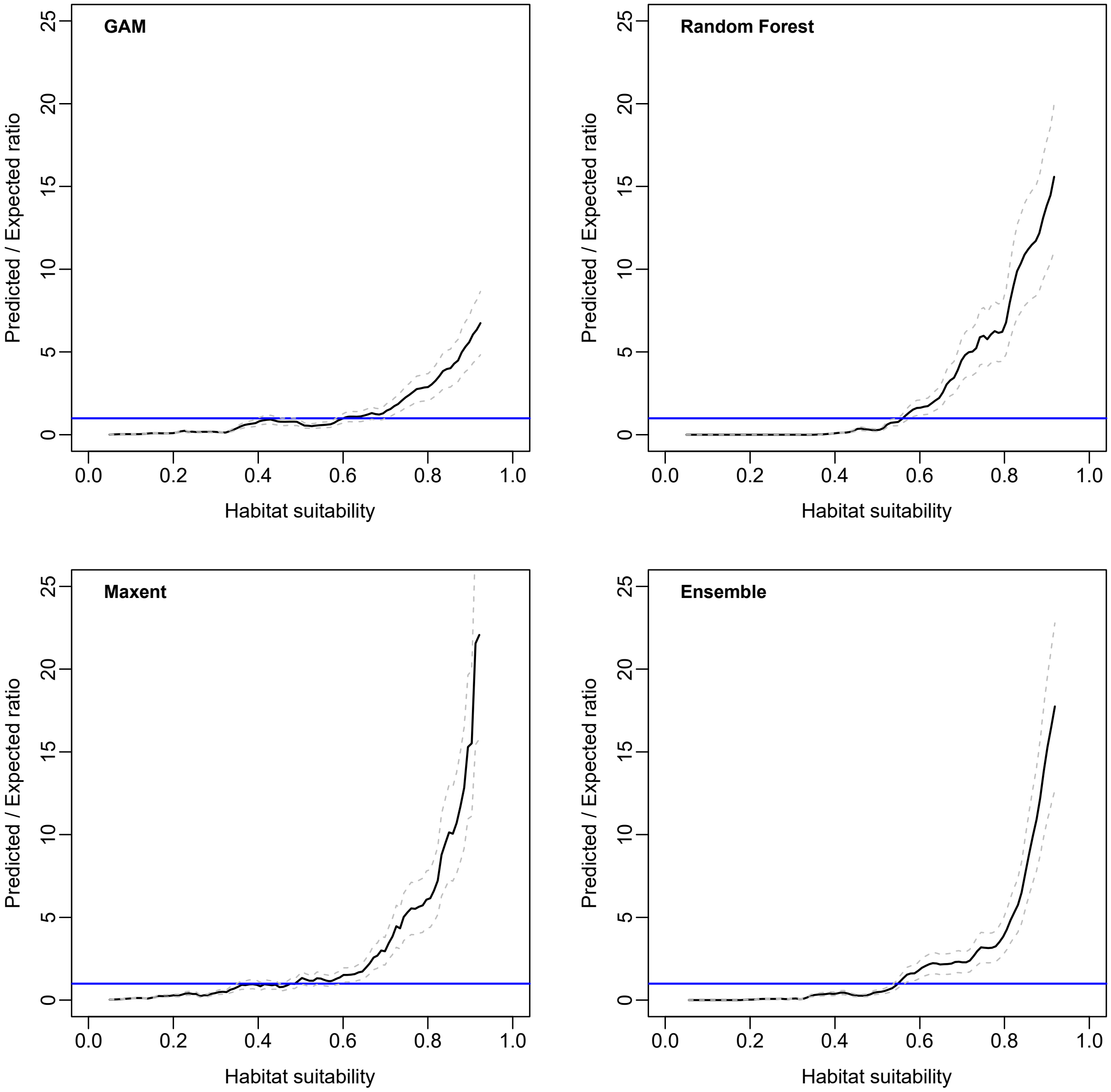


Figure A.13.3. Graphs of Continuous Boyce Indices [CBI] for Joshua tree models for each of three modeling algorithms used (GAM - upper left, Random Forest - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

A.13.4.1 General Additive Model

Six variables contributed 10% or more from the GAM model ensemble totaling 88% of model contribution (Table A.13.2). Winter minimum temperature was the strongest contributor with 21% model contribution, and peaked relationship, where habitat suitability was higher in areas that had relatively warmer minimum temperatures (0-3 ºC), but decreasing above 4 ºC (Figure A.13.4). NDVI maximum (17.5%) was also a peaked response with highest habitat values at just above the average for the study area. (Figure A.13.4). Habitat suitability was predicted to be higher in areas with lower Summer maximum temperature (12%) with predictions becoming negative above 37 ºC (Figure A.13.4). Summer precipitation and temperature range (~ 12% contribution each) both had peaked responses, both predicting positive habitat contribution near the mean values for the study area (Figure A.13.4). The terrain wetness index (10%), which indicates topographic position – indicated higher suitability in areas with higher values – which correspond to lower areas that have the potential for greater runoff in the watershed (Figure A.13.4).

The GAM model predicted the largest extent of highly suitable habitat for this species (Figure A.13.1). Highest habitat predictions were in western half of the county on upper bajadas surrounding the Spring, western McCullough and Sheep mountain ranges. Additional habitat was predicted in Gold Butte – where there were many localities, and in the northwestern corner of the county – where very few localities were available for confirmation (Figure A.13.1). Standard Error was estimated to be generally low throughout the county for this model, with very small areas of moderate error near Coyote Springs, and near the Lucy Gray mountains (Figure A.13.2).

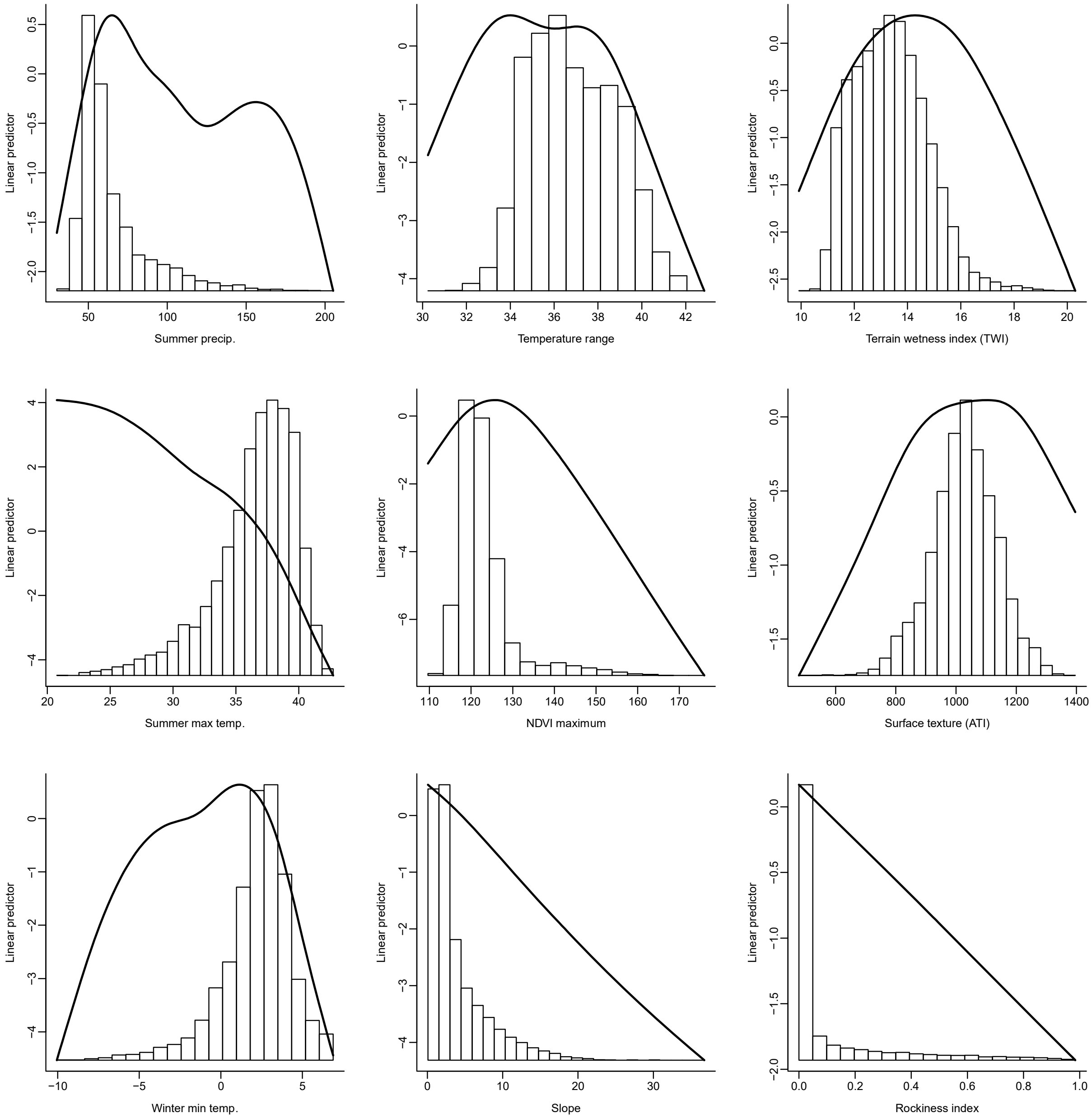


Figure A.13.4. GAM partial response curves for the Joshua tree model overlaid over distribution of environmental variable inputs in the study area.

A.13.4.2 MaxEnt Model

The MaxEnt model had five variables contributing more than 10% each, and four of these were top variables as the GAM model (Table A.13.2). The collective contribution of the top 5 variables was 72%. Summer precipitation (18.6) and winter minimum temperature (17.3) were the top 2 contributors. Habitat suitability was predicted to be higher in areas with greater summer precipitation, and winter minimum temperature had a peaked suitability response between 0 ºC and 4 ºC falling sharply above that range (Figure A.13.5). Temperature range was also a peaked response, and largely followed the range within the study area. NDVI maximum had a peaked response at lower values, but slightly above the study area average. Surface roughness contributed 10.8%, and had a peaked response at lower values, and was also generally similar to the roughness distribution within the study area (Figure A.13.5).

Habitat prediction for this model was concordant with the point locations for the species, and tended to remain tightly around them (Figure A.13.2). Exceptions were the upper Mormon Mesa, western slopes of the Sheep range, and the northwestern corner of the county, where habitat was predicted, but few localities were available. However, predicted habitat was in similar areas relative to the other models overall (Figure A.13.2).

Standard Error was low (0.02 – 0.04) overall, with some pockets of moderately low error in the Pahrump valley, and with higher error (0.08 – 0.01) near the western edge of the Red Rock area (Figure A.13.2).

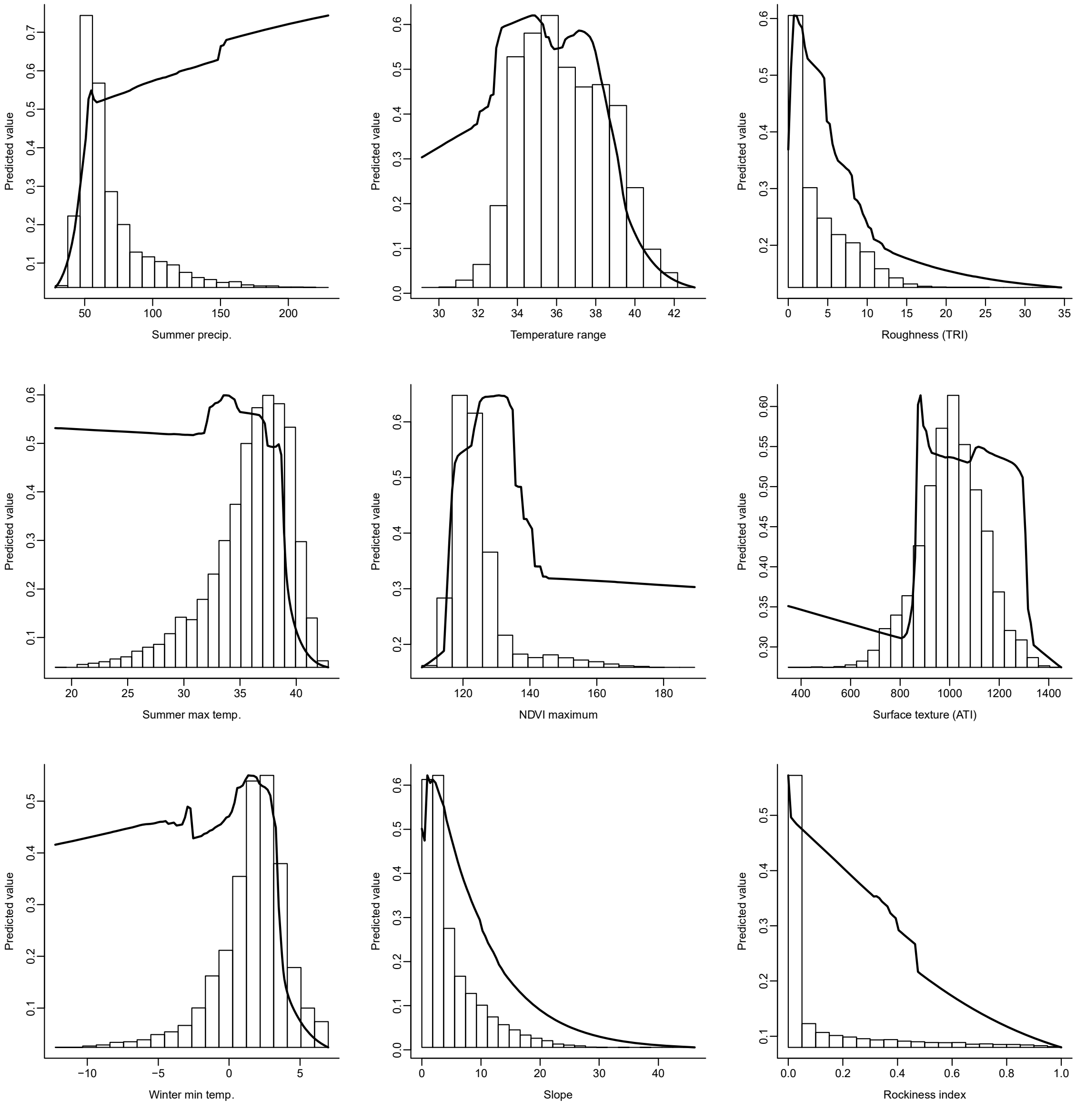


Figure A.13.5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for Joshua tree.

A.13.4.3 Random Forest Model

The Random Forest models had four environmental variables contributing ~ 10% or more collectively accounting for 51% of the total model influence, with six additional variables contributing lesser, but not minimal amounts (Table A.13.2). Four of these top five variables were consistent with the MaxEnt and GAM model selections. Summer maximum temperature was the highest contributing variable (14.2%), and the response curves indicated a thresholded response, favoring cooler areas, with habitat suitability falling sharply in areas above 37 ºC (Figure A.13.6). Summer precipitation also contributed strongly (13.6%) where predicted habitat suitability was very low in areas with below 60mm, and increased sharply above that level. Winter minimum temperature was also an important contributor (13%), and had a similar thresholded response to summer precipitation, with predicted suitability rising sharply in areas receiving more than 100m winter precipitation. NDVI maximum contributed 10.2%, and suitability tended to occur in areas that were slightly above the average for the study area (Figure A.13.6).

Standard error maps for this model indicated low (0.02 to 0.04) error rates generally surrounding areas of predicted habitat (Figure A.13.2, Figure A.13.1). There were a few small areas of higher standard error (0.06 – 1.0) in Hidden valley west of Apex, in the mountains East of Apex, and on the western side of the Red Rock area (Figure A.13.2).

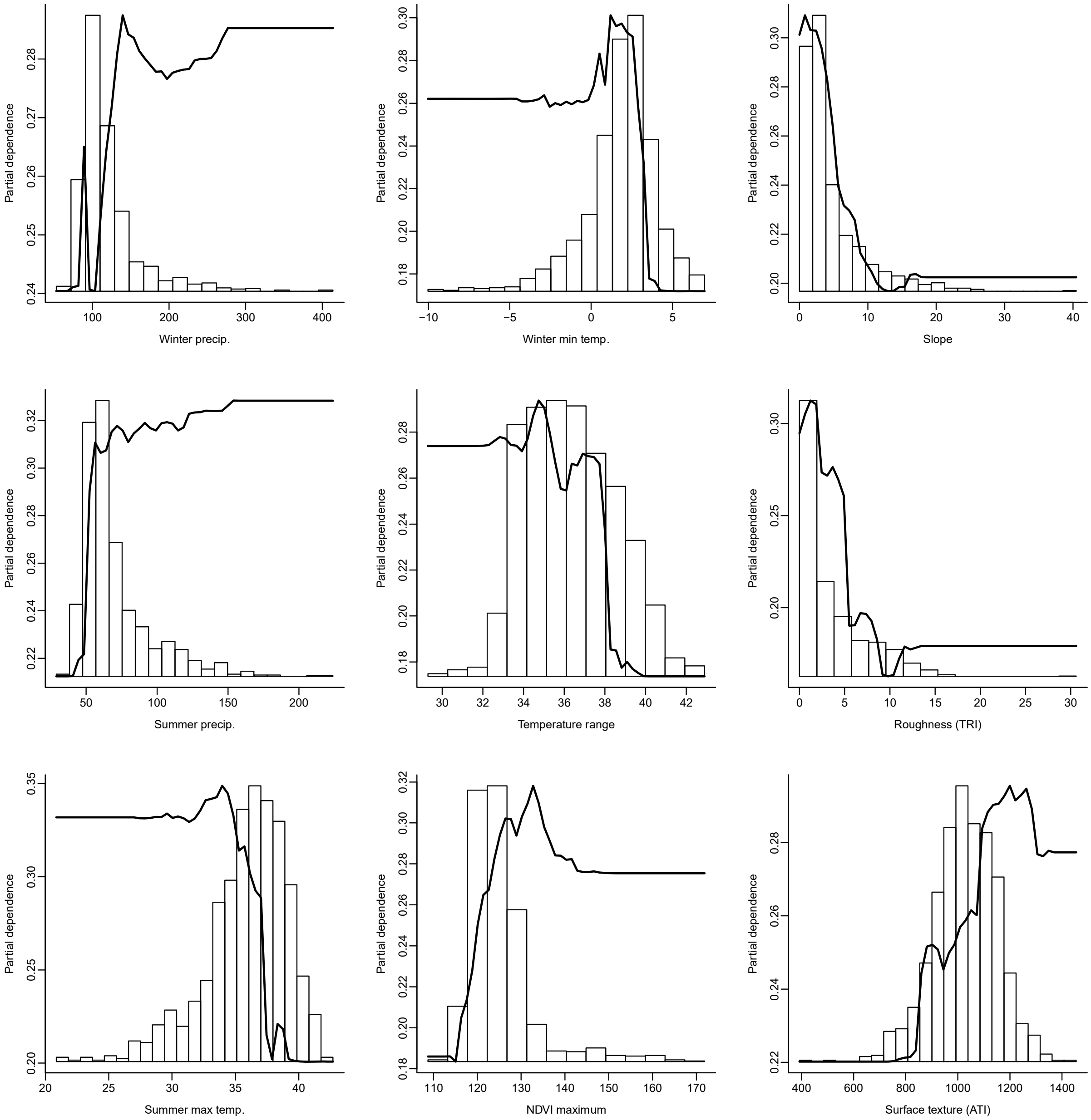
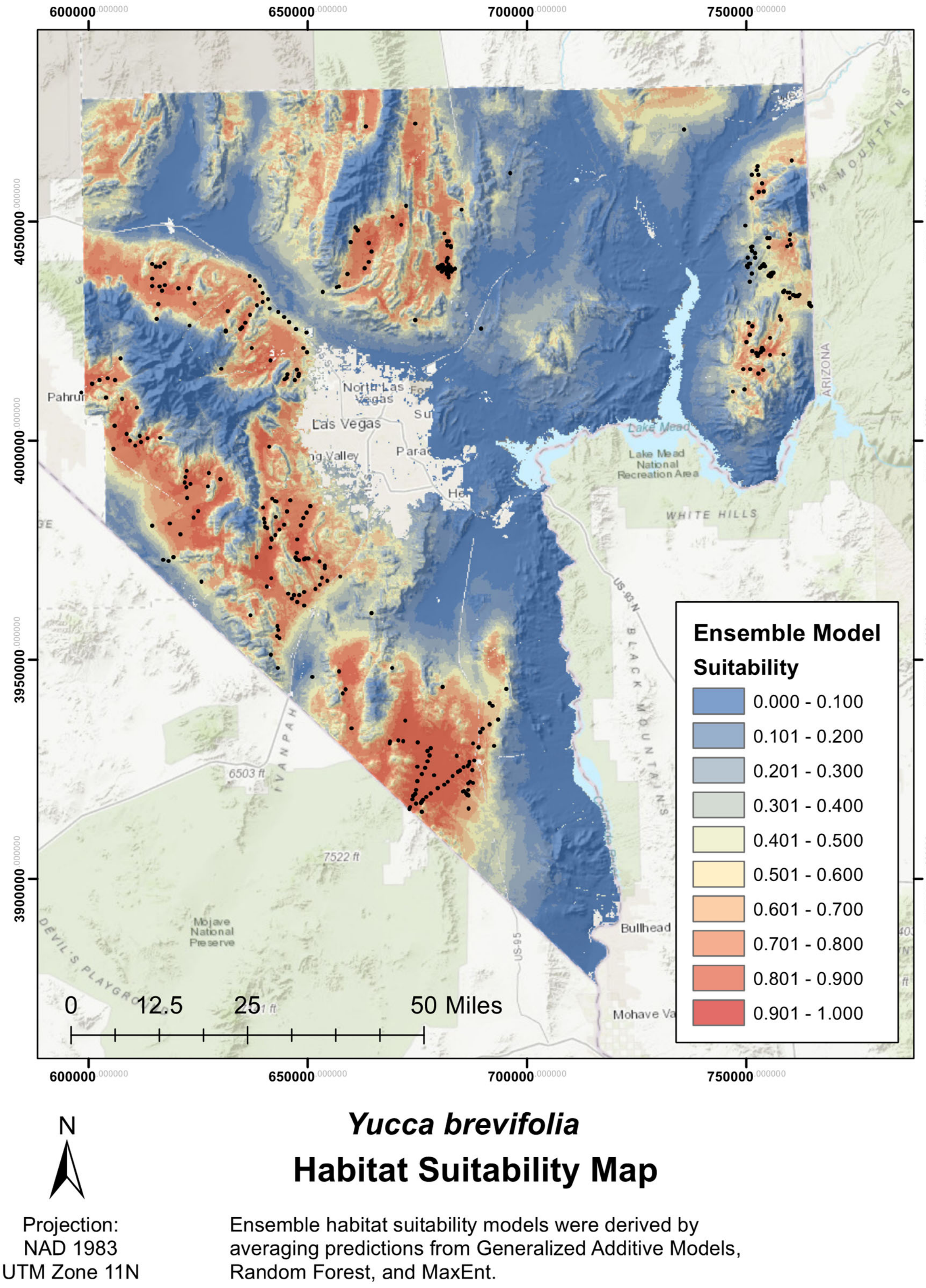


Figure A.13.6. Partial response surfaces for the environmental variables included in the Random Forest ensemble model for Joshua tree. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

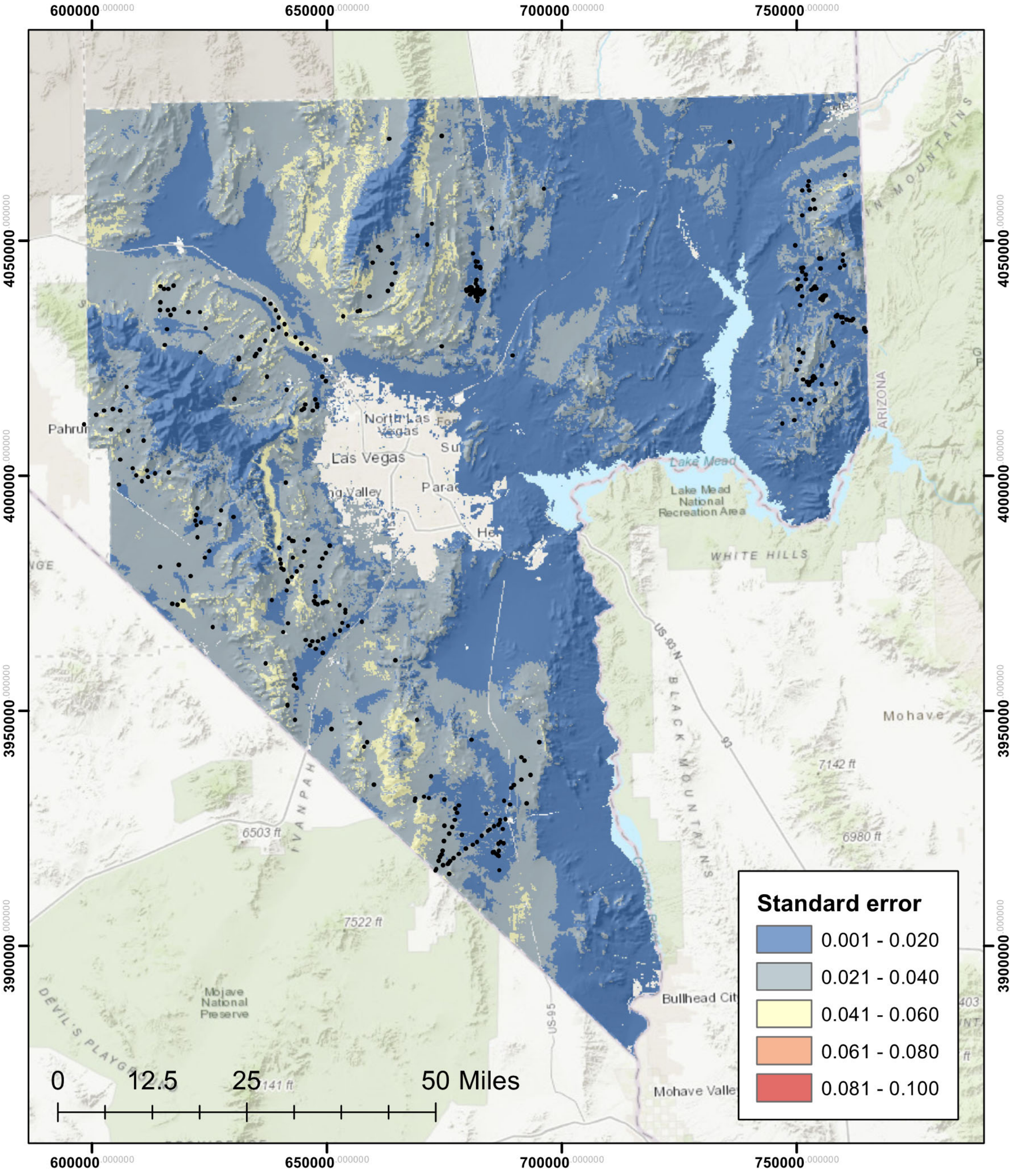


Yucca brevifolia
Habitat Suitability Map

Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and MaxEnt.

Figure A.13.7. SDM map for Joshua tree Ensemble model.



N

Yucca brevifolia

Standard Error Map

Projection:
NAD 1983
UTM Zone 11N

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

Figure A.13.8. Standard Error map for Joshua tree Ensemble model.

A.13.4.4 Model Discussion

Distribution of Localities – Localities (N= 363 unique presence points at 250 m2 grid intervals – and 313 after geographic thinning) for Joshua tree are distributed throughout Clark County especially on upper portions bajadas surrounding the McCullough, Spring, and Sheep ranges in the western half of the county, and in the mountainous areas of Gold Butte – which tend to be lower in elevation. There are several areas of predicted habitat that lack locality information (e.g. Upper Mormon mesa north of I-15) but on visual inspection using aerial imagery do indeed have Joshua trees (Figure A.13.7). However other areas, such as the northeastern extent of the county near Beatty, and on the Nevada National Test Site do not have imagery of sufficient quality for inspection.

A.13.4.5 Standard Error

There is generally low Standard error throughout the study area, but a few areas of moderate Standard Error (0.04 – 0.06) are indicated in Figure A.13.8 near the Sheep Range, on the western extent of the Red Rock area, and sporadically in the western McCollough range (Figure A.13.8). The western extent of the Red Rock area has a sharp transitional habitat with steep slopes, and thus the zone for this species may be narrow there, and indeed absent in many areas.

A.13.5 Distribution and Habitat Use within Clark County

Joshua trees are widespread in Clark County, Nevada. Geomorphically Joshua trees occupy some higher elevation valley bottoms, bajadas, and lower mountain slopes. They are found in all types of soil origins including: granite, volcanic, sandstone, and various limestone species including dolomite. They generally do not occur in very fine soil textures of playas in lower valley bottoms.

Joshua tree stands occur around the western base of the Virgin Mountains and other areas of similar elevation in the Gold Butte National Monument. There are also stands further to the north on the Mormon Mesa in shallow sandy hollows on top of mudstones. The valleys, bajadas, and lower mountain slopes between the Arrow Canyon Range and the Desert Range have extensive Joshua tree habitat of high quality – although some large portions of those areas were damaged by wildfire during the past 15 years. There are also extensive stands on the west side of the Desert Range and in some of the valleys currently occupied by the Nellis Bombing Range. Much of the desert habitats on the north side of the Spring Range and south of State Highway 95 are occupied by sparse to moderately Joshua tree stands. Joshua tree stands almost entirely encompass the Spring Range, Mt. Potosi (except for areas burned multiple times), and the State Line Mountains, except for a small area that was developed on the east side. However, the most extensive and robust Joshua tree populations occur along State Highway 93 to the north and south of Searchlight, and westward to the California state line from there. This area includes Clark County's very scenic Joshua Tree Highway. This population extends across low passes in the McCollough Mountains and into the next valley over to Sheep Mountain. Habitat modeling indicated that the highest areas predicted to be highly suitable were located within Mojave desert scrub and Blackbrush ecosystems, indicative of mid and upper bajadas (Table A.13.3). Moderate suitability habitat was predicted to be within the same habitat, with inclusion of Pinyon Juniper ecosystems, and potentially some salt desert scrub, although this seems uncharacteristic for this species, and may reflect some inaccuracy in the ecosystem designation, or the model prediction (Table A.13.3).

Modeled Habitat suitability in the county is highest in the western McCullough range in a large area extending to the border, and northward to the Lucy Gray Mountains (Figure A.13.7). Modeled habitat for is low or absent in the I-15 corridor, but picks up again north of I-15 near the Goodsprings and Blue Diamond area, and continues on the upper bajadas - occurring on all sides of the Spring Range. (Figure A.13.7). Habitat is predicted in the upper bajadas north of US Highway 95 from Beatty, eastward to the Sheep Range, and in the valleys north of Las Vegas along US Highway 93, Upper Mormon Mesa, and throughout Gold Butte (Figure A.13.7).

Table A.13.3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	49078	131500	234060
Bristlecone Pine	7564	0	0
Desert Riparian	10712	0	0
Mesquite Acacia	13049	2294	4358
Mixed Conifer	26917	419	0
Mojave Desert Scrub	811609	275515	192295
Pinyon Juniper	86682	22606	6452
Sagebrush	1601	1333	1762
Salt Desert Scrub	44544	27529	6546

A.13.6 Ecosystem Level Threats

Joshua trees occur throughout the Blackbrush, Mesquite/Acacia, middle to upper Mojave Desert Scrub, lower Pinyon-Juniper, and lower Sagebrush Ecosystems of the Desert Conservation Plan area. Primary ecosystem threats to the Joshua tree are development, and wildfire associated with red brome (*Bromus madritensis*) invasions. Development is most evidently a threat to Joshua tree populations on the west side of the Las Vegas Valley. Perhaps an even greater threat to Joshua tree stands is wildfire fueled by invasive plant species. There are many old fire scars that have reduced Joshua tree populations around the base of the Spring Mountains, and a few around the McCollough Mountains. These older burned areas likely resulted from previous forest fires that dropped down from forests and woodlands into desert shrublands. More recently low elevation desert shrubland has burned as a result of red brome grass invasions during the past 15 years. During that period massive fires occurred in the Desert Range and Arrow Canyon area, as well as northern Mormon Mesa, and the new Gold Butte National Monument. Some of these areas will likely benefit from restoration programs that are ongoing with Federal, State and County agencies.

A.13.7 Threats to Species

Threats to this species within Clark County are reflected in the increased fire risk and incursion of development in to Joshua tree habitat. The landscape scale wildland fires that occurred in the Southern Nevada Fire Complex in 2005 are illustrative of the fire danger, as large expanses of desert habitat burned within Clark County, much of in Joshua tree habitat (e.g. in Hidden Valley, near Coyote Springs, and in Gold Butte). Increased presence of invasive grasses increases the inter-shrub fuels that increase fire risk (Van Linn et al. 2013). Loss of habitat due to urbanization, and expansion of anthropogenic infrastructure continues within the county, and while much of the predicted Joshua Tree habitat is within conserved areas, it is also the case that additional habitat loss and fragmentation will continue. Habitat fragmentation also leads to increased incursion of invasive grasses, and provides the potential for increased ignition sources, thereby increasing fire risk (Van Linn et al. 2013).

A.13.8 Existing Conservation Areas/Management Actions

Among the largest stands of protected Joshua trees are in the Gold Butte National Monument, and wilderness areas therein. Secondarily, Lake Mead National Recreation Area provides protection for some smaller areas of Joshua tree habitat in Clark County, but their most extensive habitats are in Arizona. Redrock National Conservation Area similarly provides conservation areas for Joshua trees existing there. The Desert National Wildlife Refuge also provides conservation lands for Joshua trees, especially around the lower elevation edges of the refuge area. BLM’s Wee Thump Wilderness that is east of Searchlight provides protection to the most robust Joshua tree stands in the county.

There are some preliminary active restoration projects that include outplantings of young Joshua trees and the distribution of Joshua tree seed along with other experimental treatments. That work is sponsored by Las Vegas BLM, with research and monitoring provided by USGS – Western Ecology Research Center.

A.14 MOJAVE DESERT TORTOISE (*GOPHERUS AGASSIZII*)

On April 2, 1990, the Mojave Desert population of Mojave Desert tortoise was placed on the federal list of Threatened species afforded protection under the Endangered Species Act. The protected Mojave population includes Mojave Desert tortoises occurring north and west of the Colorado River in Arizona, California, Nevada, and Utah (55 FR 12178). In 2011, Mojave Desert tortoises were re-defined taxonomically as two species: Mojave Desert tortoise (*Gopherus agassizii*), and Sonoran Desert Tortoise (*Gopherus morafkai*) (Murphy et al. 2011). Further research has identified some tortoises east and south of the Colorado River as Mojave Desert tortoise thus reducing the utility of the riverine boundary line and introducing ambiguity to the distribution of which tortoises should be protected in Arizona. Further analyses of tortoises on either side of the river will no doubt occur and perhaps clarify or obfuscate distributional limits for these species. The current ruling on the protections for the Mojave Desert tortoise have not changed. In Clark County, Nevada all the wild tortoises are considered to be Mojave Desert Tortoises with full protection under the Endangered Species Act and there is no confusion on that point. The remainder of this species account will focus on the Mojave Desert Tortoise.

A.14.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Threatened

US Bureau of Land Management (Nevada): Protected

US Forest Service (Region 4): Threatened

State of Nevada: Threatened

NV Natural Heritage Program: Global Rank G3, State Rank S2S3

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red list (v 2.3): Vulnerable

CITES: Appendix ii

A14.2 Range

The Mojave Desert tortoise occurs in the Mojave and Sonoran deserts in southern California, southern Nevada, Arizona, and the southwestern corner of Utah in the US (Germano et al. 1994, Nussear et al. 2009, Bramble and Hutchison 2014). The listed Mojave population of the Mojave Desert tortoise includes those animals living north and west of the Colorado River in the Mojave Desert of California, Nevada, Arizona, and southwestern Utah, and in the Sonoran (Colorado) Desert in California (USFWS 1994, USFWS 2011). The northern range limit for confirmed wild Mojave Desert tortoise sightings was verified by a photograph taken by a BLM employee near Hiko in Lincoln County, Nevada (BLM *unpublished data* 2015). The easternmost Mojave Desert tortoises live near the entrance to Zion National park in Iron County, Utah, the westernmost sighting for Mojave Desert tortoise is in the wind farms in Banner Pass, just northwest of Palm Springs, California, and the southernmost Mojave Desert Tortoises are found in the Cargo Muchacho Mountains, California north of Felicity in Imperial County, California (*data used in* Nussear et al. 2009). Elevational ranges for the species in the current climate are from below sea level to an elevation of 2,225 meters (7,300 feet), although they are more typically found below 1,677 meters (5,500 feet) (USFWS 2011).

A.14.2.1 Habitat Model

Desert tortoise habitat is predicted to occur in most of the lower bajadas in Clark county, with thinner habitat in the upper northwestern portion of the county (Figure A.14-1). The three model algorithms had very similar habitat predictions with different intensity, where the MaxEnt model had slightly reduced habitat prediction in a few isolated areas, and the Random Forest model predicted habitat strongly in core areas (Figure A.14-1).

Model performance is relatively high, with AUC scores ranging from 0.78 to 0.88, Boyce Indices near 1, and TSS scores ranged from (0.46 – 0.66), where the Ensemble and RF models had higher scores (Table A.14-1). The continuous Boyce indices all indicated very good performance, (Figure A.14-3).

The top four environmental variables among models (which explained 52 – 73 % of the influence), had different predictors among algorithms, with four variables shared among two of the three models (Average Minimum temperature, Average Maximum temperature, Depth to Bedrock, and Slope) (Table A.14-2).

The Standard error maps indicated relatively low standard error among all of the models, ranging from 0 to 0.02 throughout the study area (Figure A.14-2).

Table A.14-1. Model performance values for Mojave Desert tortoise models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.87	0.98	0.64	0.59
GAM	0.81	1	0.5	
Random Forest	0.88	0.98	0.66	
MaxEnt	0.78	1	0.46	

Table A.14-2. Percent contributions for input variables for Mojave Desert tortoise for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	**GAM**	**RF**	**MaxEnt**
Ave Min Temp	6.9	2.8	36.2
Ave Max Temp	26.8	15.8	0.1
Depth to Bedrock	5.6	18.2	13.5
PPT Sand	19.6	7.1	6
Slope	3.6	9.2	13.6
Extreme Max Temp	17	7.3	0
PPT Clay	2.4	5.3	7.9
Winter Precip	2.9	9	3.4
CV Winter Precip	1.2	3.2	9.7
PPT Silt	3.7	3.3	2.5

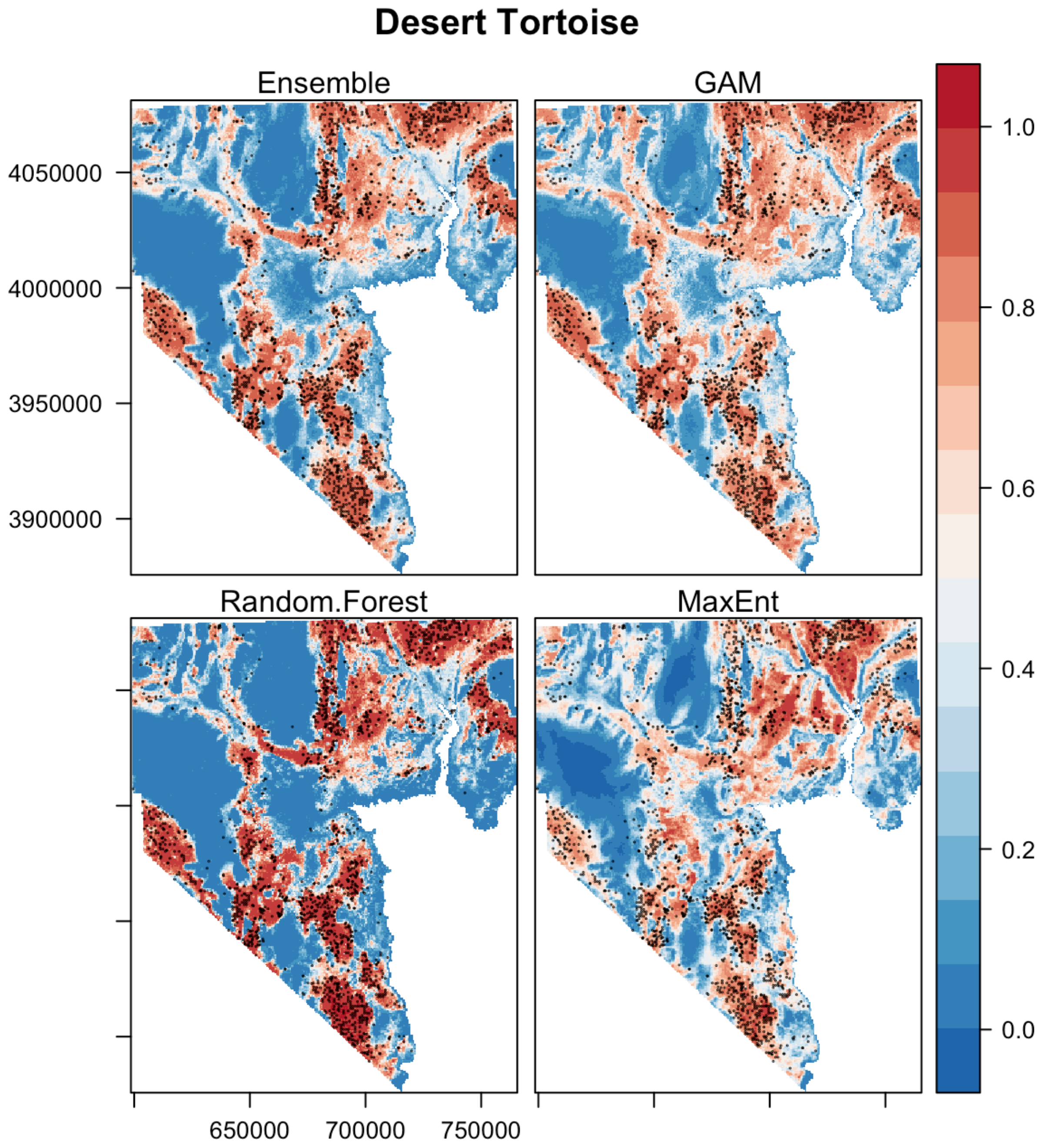


Figure A.14-1. SDM maps for Mojave Desert tortoise model - Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

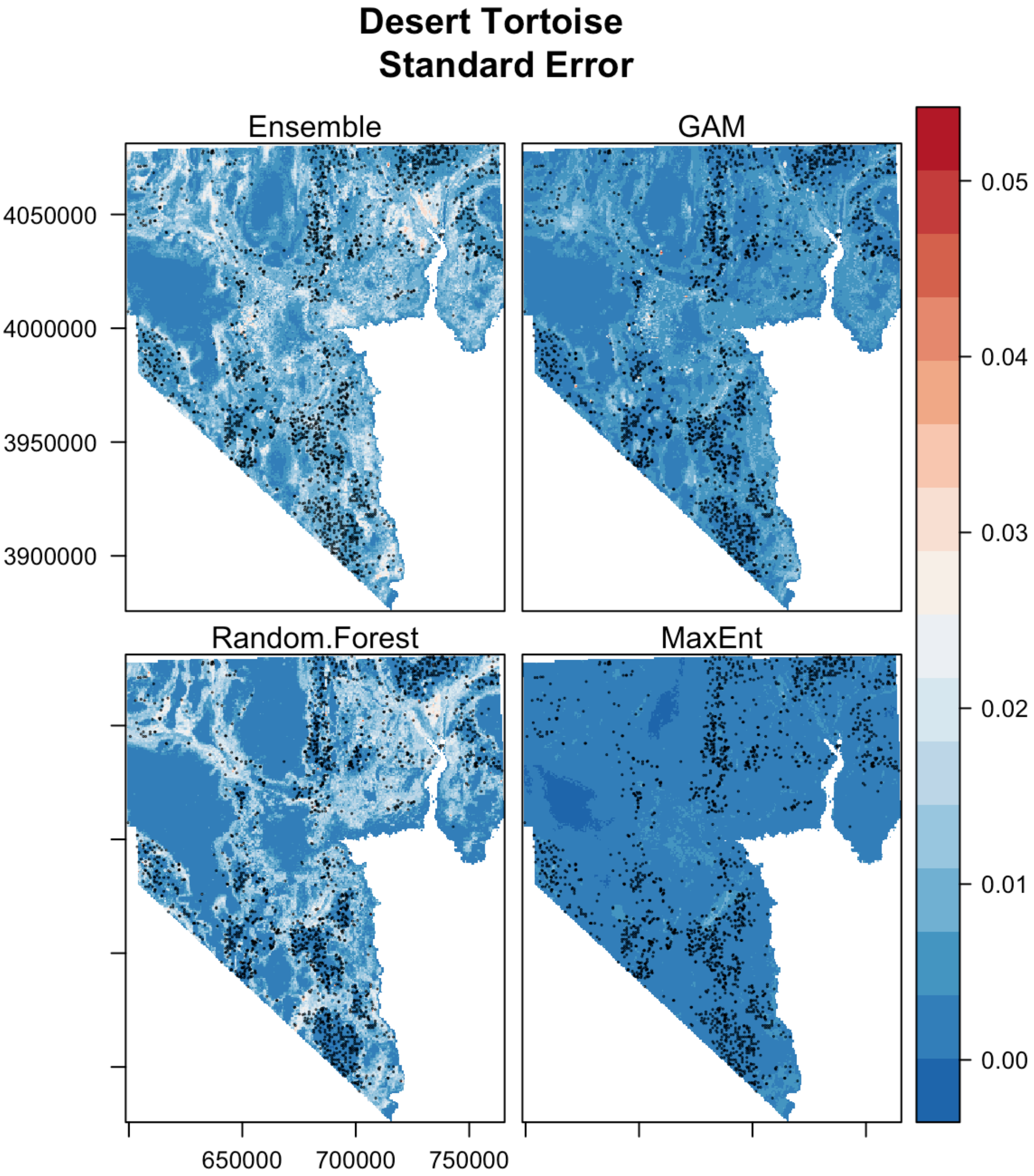


Figure A.14-2. Standard error maps for Mojave Desert tortoise models for each of three modeling algorithms used (GAM - upper right, Random Forest - lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

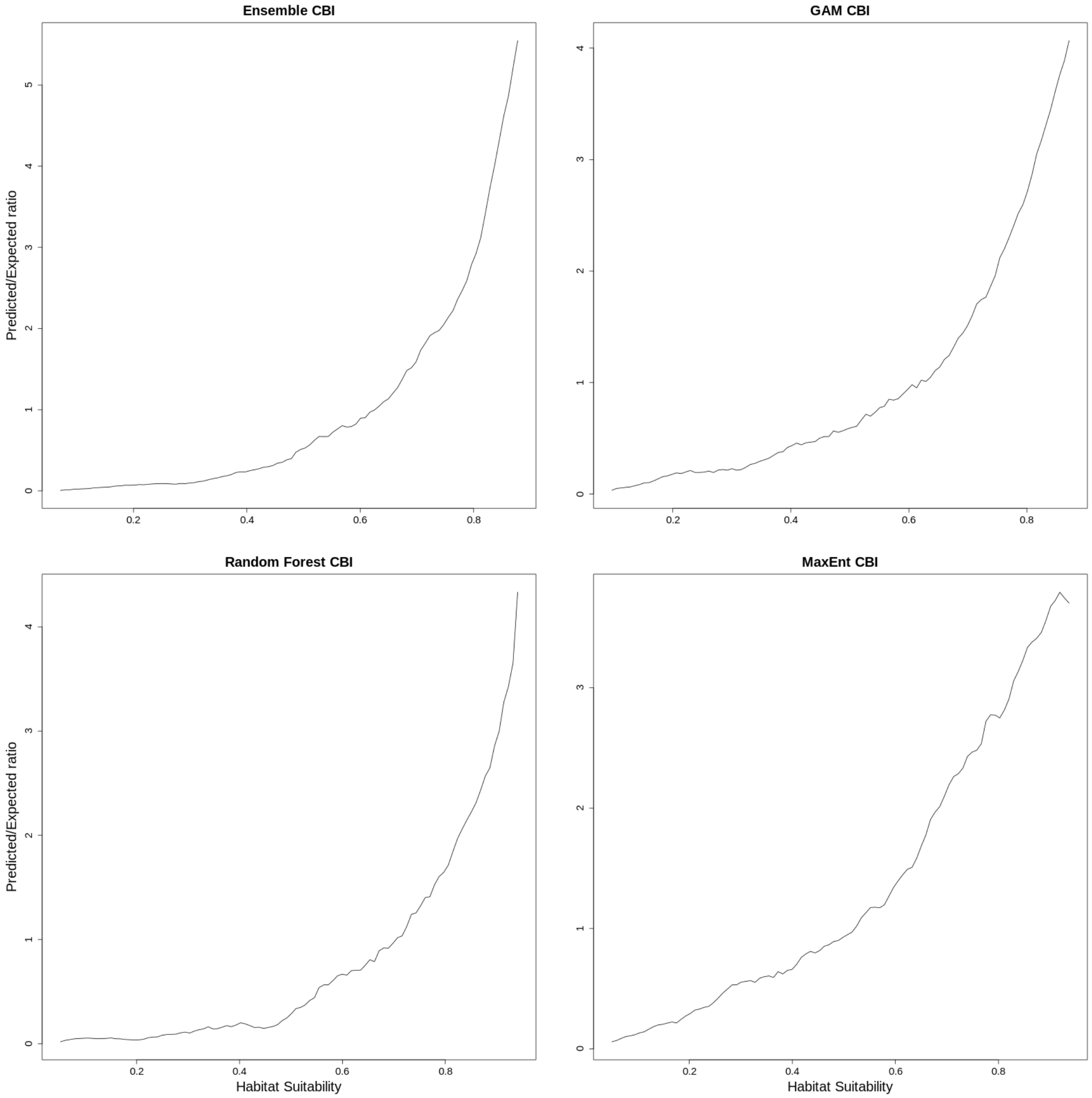


Figure A.14-3. Graphs of Continuous Boyce Indices [CBI] for Mojave Desert tortoise models for the Ensemble model prediction (upper left), and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.14.2.2 General Additive Model

This model was largely influenced by Average Spring Maximum temperatures, which comprised 27% of the explained variance in the model (Table A.14-2), and had a bimodal peaked response at temperatures lower than the study area average, and then following the average (Figure A.14-4). Soil Sand Content was the second most influential variable (20%), and had positive relationship where higher habitat values were in areas with higher soil Sand Content. Extreme Maximum temperatures contributed to 17% of model performance, and had a positive response following environmental prevalence and peaking at higher values (Figure A.14-4). The fourth most influential variable was Average Minimum temperatures (7%) where habitat peaked with environmental values, remaining high above that level (Figure A.14-4).

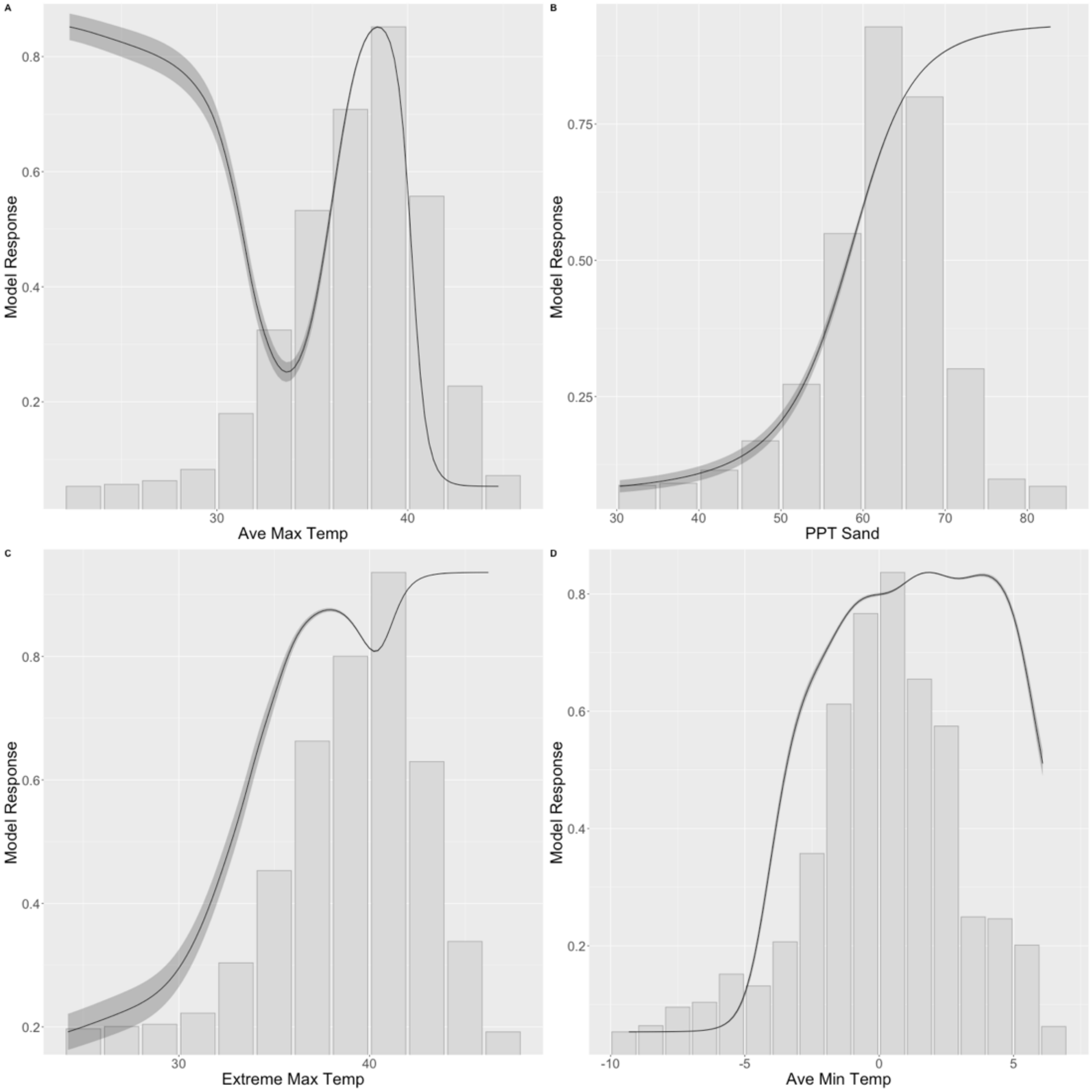


Figure A.14-4. GAM partial response curves for the top four variables in the Mojave Desert tortoise model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.14.2.3 MaxEnt Model

The top four influencing variables in the MaxEnt models were Average Minimum temperature, Depth to Bedrock, Slope, and the CV of Winter Precipitation (Table A.14-2). Average Minimum temperature, and Depth to Bedrock each had positive responses, peaking above average values in the study area (Figure A.14-5). Slope and CV of Winter Precipitation had negative responses, where tortoise habitat was higher in flatter slopes, and in areas with less variable Winter Precipitation (Table A.14-2).

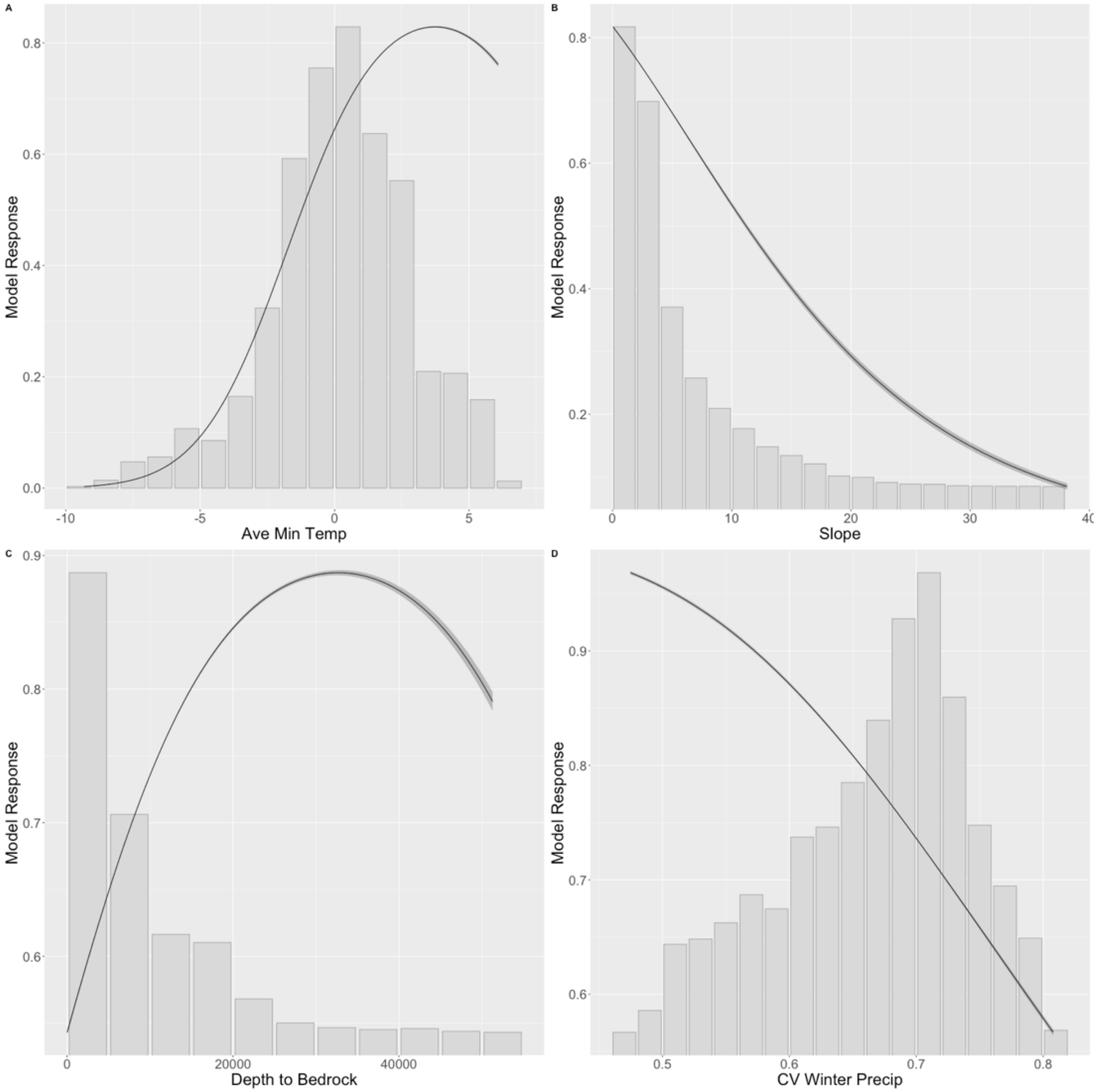


Figure A.14-5. Response surfaces for the top four environmental variables included in the MaxEnt Ensemble model for Mojave Desert tortoise. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.14.2.4 Random Forest Model

The top four variables in the Random Forest models were Average Maximum temperature, Depth to Bedrock, Slope, and Winter Precipitation (Table A.14-2). Average Maximum temperature had the highest influence (16%), where habitat was predicted to be higher in areas with temperature values similar to the environmental values (Figure A.14-6). Depth to Bedrock indicated higher habitat values in deeper soils, as was the case for the MaxEnt model (Figure A.14-5). Slope generally followed habitat prevalence, and habitat tended to be higher in areas at and above the area average (Figure A.14-6).

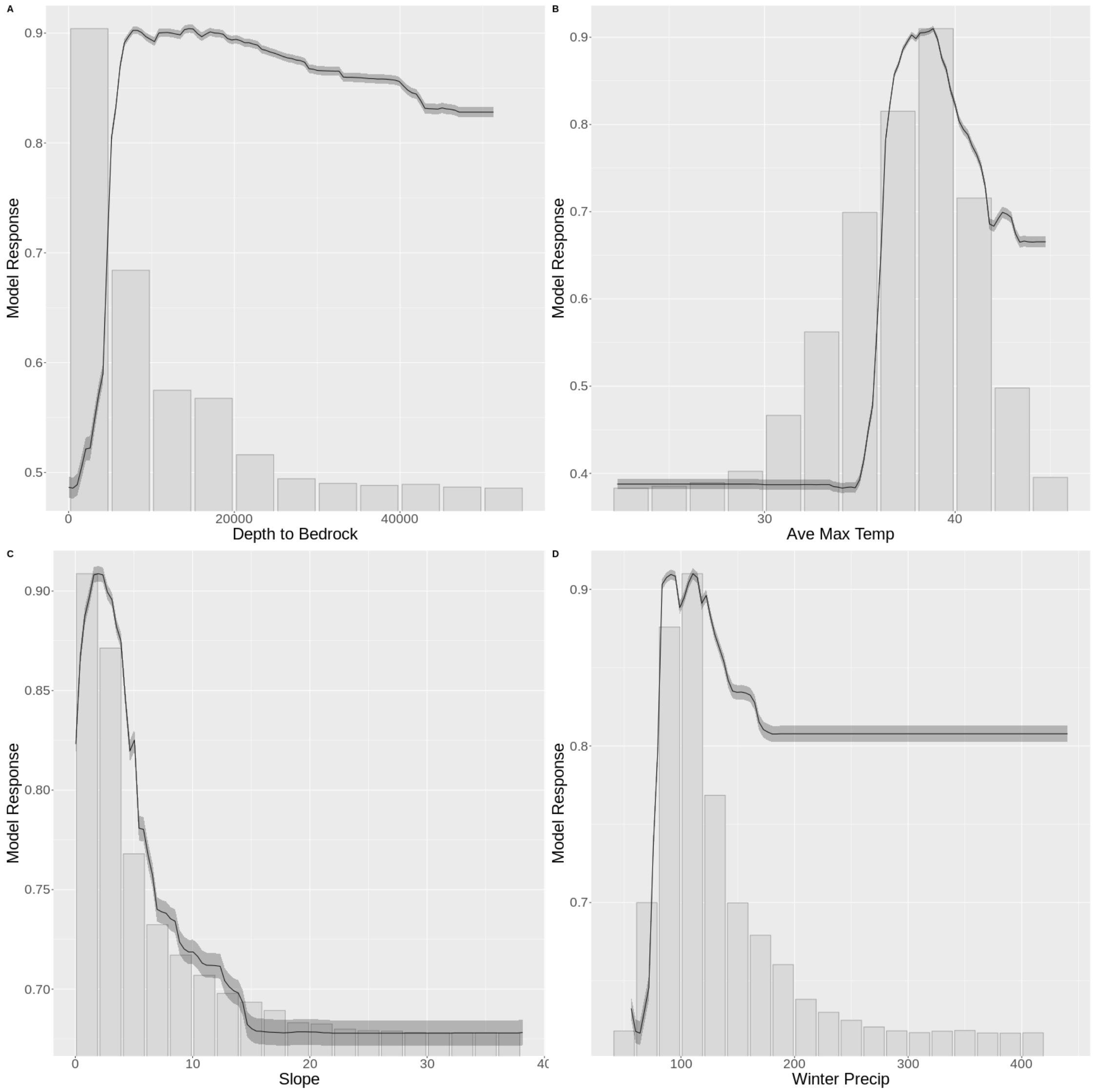


Figure A.14-6. Partial response surfaces for the top four environmental variables included in the Random Forest Ensemble model for Mojave Desert tortoise. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.14.2.5 Model Discussion

Mojave Desert tortoise habitat predictions for this model follow the localities for the species well, throughout the county, with similar habitat areas to that predicted by Nussear et al. (2009). Areas of lower habitat within the county are the mountainous areas in the Spring and Sheep ranges, Lucy Grey Mountains, Virgin Mountains, and southern Gold Butte. Habitat also becomes sparse in the northwestern extent of the county (Figure A.14-7). That area has been historically devoid of surveys, and additional information is needed to confirm whether this corridor provides more than lower grade, to moderate habitat for tortoises.

A.14.2.6 Standard Error

The Standard Error for the Ensemble model is quite low (0.025 or lower, Figure A.14-8). Small areas with higher error rates are in the area near Mormon Mesa.

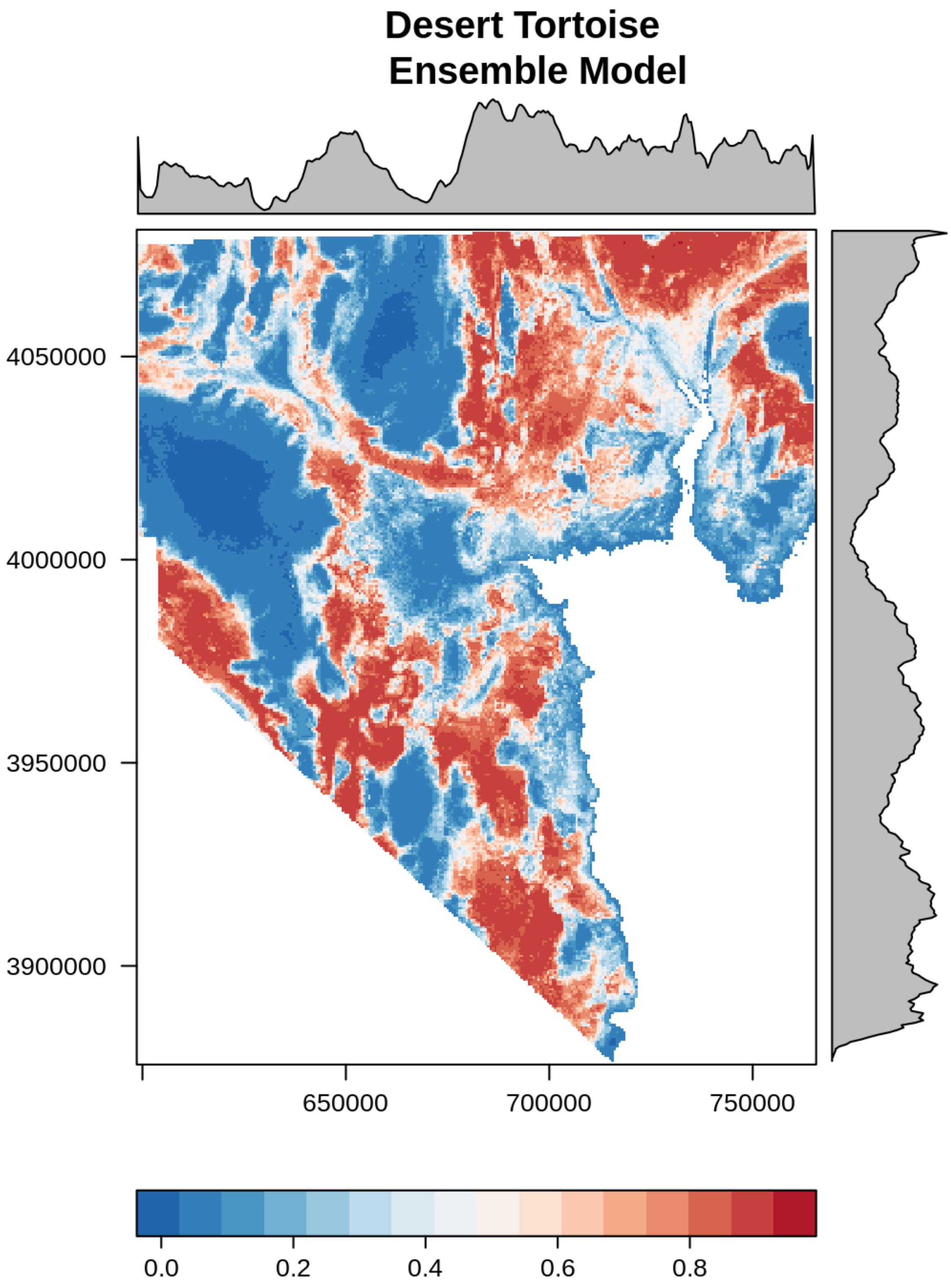


Figure A.14-7. SDM map for Mojave Desert tortoise Ensemble model for Clark County, NV.

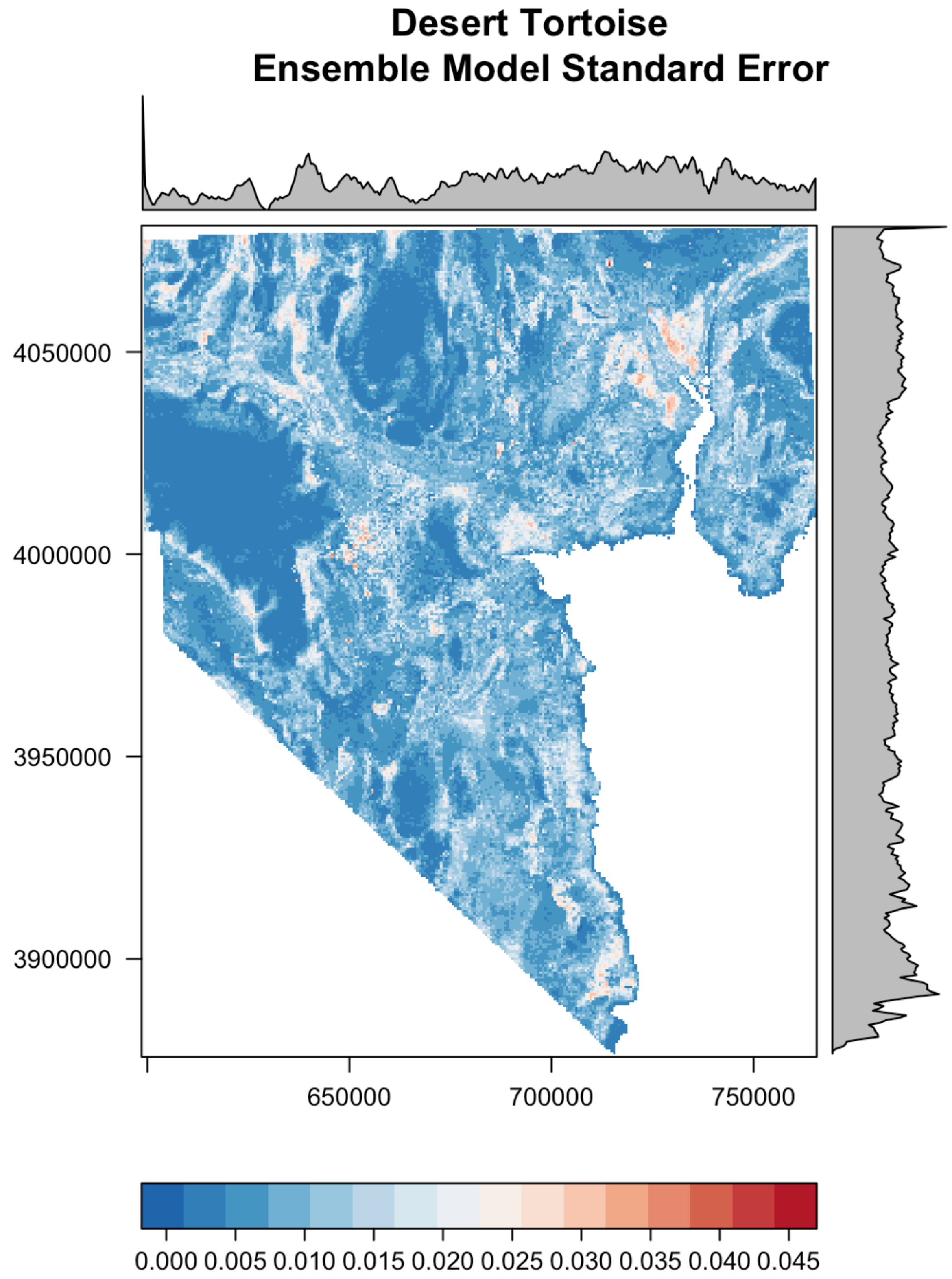


Figure A.14-8. Standard Error map for the Mojave Desert tortoise Ensemble model for Clark County, NV.

A.14.3 Distribution and Habitat Use within Clark County

Mojave Desert tortoise habitat occurs widely throughout Clark County. The types of habitats that Mojave Desert tortoises occupy in Clark County are diverse and can be characterized as valley bottoms, lower slopes, upper slopes, mountain slopes and mountain passes. Within the 10 terrestrial ecosystems defined for the county (Heaton et al. 2011) the highest categories of predicted suitable habitat for Mojave Desert tortoises are Mojave Desert Scrub, Blackbrush, Mesquite Acacia, and, Salt Desert Scrub, with a smaller amount of habitat in Desert Riparian ecosystems (Table A.14-3). Moderate habitat incudes an expansion of habitat in these ecosystems, with an increase of area in the Blackbrush ecosystem and the inclusion of a small area of the Pinyon Juniper ecosystem, where tortoises are found, but not typically in high densities (Nussear and Tuberville 2014).

Table A.14-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	360867	40209	13871
Bristlecone Pine	7565	0	0
Desert Riparian	7654	1900	609
Mesquite Acacia	7032	4404	8766
Mixed Conifer	27339	0	0
Mojave Desert Scrub	329966	341898	684399
Pinyon Juniper	115848	20	0
Sagebrush	4706	0	0
Salt Desert Scrub	51878	23156	7388

Optimal habitat has been characterized as creosote bush scrub in which precipitation ranges from 50 to 203 mm (2 to 8 inches), where a diversity of perennial plants is relatively high, and production of annual plants is high (Luckenbach 1982; Turner 1994; Turner and Brown 1994). Mojave Desert tortoises occupy habitat with a wide variety of geomorphic features from flat valley floors, and rolling hills of lower and upper outwash plains (i.e. bajadas), to rugged mountain slopes and passes (Nussear et al. 2009, Nussear and Tuberville 2014). Mojave Desert Tortoises are found in a variety of Mojave Desert scrub vegetation types (Turner 1994, Turner and Brown 1994, Keeler-Wolf 2007) variously dominated by perennial plants such as creosotebush (*Larrea tridentata*), white bursage (*Ambrosia dumosa*), saltbush (*Atriplex* spp.), galleta grass (*Hilaria rigida*), bush muhly (*Muhlenbergia porteri*), beavertail prickly pear cactus (*Opuntia basilaris*), cottontop cactus (*Echinocactus polycephalus*), cholla cactus (*Cylindropuntia* spp.) Joshua tree and Mojave Yucca (*Yucca brevifolia* and *Y. schidigera*; respectively), Mormon tea (*Ephedra* spp.), and blackbrush (*Coleogyne ramosissima*). The lower elevational limits to Mojave Desert tortoise range are dominated by saltbush species, and perennial grasses discussed above. The upper distributional limits of Mojave Desert tortoise habitat are characterized by pinyon-juniper (*Pinus-Juniperus*) woodlands interspersed by patches of blackbrush, banana yucca (*Yucca baccata*), sagebrush (*Artemisia* spp.), rabbitbrush (*Ericameria nauseosus*) and a variety of the Mojave Desert scrub species already discussed (Luckenbach 1982, Germano et al. 1994, Nussear and Tuberville 2014).

A.14.3.1 Valley Bottoms

Mojave Desert tortoises do not occupy the seasonally submerged playas such as the Jean, or Eldorado dry lakes. However, they are abundant in the broad valleys like those around Cal-Nev-Ari, Goodsprings, and Coyote Springs. Those areas have deep soils of fine sandy-loam and gravels where tortoises dig their burrows. Vegetation is creosotebush and white bursage shrublands where many other species of shrubs, grasses, cactus and a few trees occur. The open shrublands have approximately 10 to 25 percent plant cover. The shrubby flats are often interspersed by large patches of desert pavement characterized by interlocking gravel surfaces on top of thin layers of clay and very sparse (i.e. less than five percent cover) shrubs, cactus and yuccas. These surfaces can be very ancient, taking millions of years to develop as we see them today. Desert pavements are important places for Mojave Desert tortoises to get a drink during brief rains (Medica et al. 1980), and with adequate rainfall the pavements are thickly covered by desert annual plants that are important food for tortoises.

A.14.3.2 Lower and Upper Outwash Plains (Lower and Upper Bajadas)

Lower and upper outwash plains (lower and upper bajadas, respectively) are gentle slopes resulting from the alluvial rocks, gravels and sands that erode from mountains. Outwash plains are characteristic of tortoise habitats at Red Rock Canyon National Conservation Area (BLM) and Lake Mead National Recreation Area (NPS), the slopes around the base of the Spring Mountains, and the Desert National Wildlife Refuge. These large geomorphic features are also known regionally as bajadas. The lower outwash plains arise from the edges of valley bottoms and playas. The soils are usually very fine with a lot of sand and clay and they are dominated by plants like saltbush (e.g. shadscale - *Atriplex confertifolia*, quailbush - *A. canescens*), and in sandy areas galleta grass. Normally these areas do not support high densities of tortoises, but there are some areas in the Mojave Desert where robust populations inhabit these areas. Upper outwash plains are comprised of gravels, and larger cobbles and stones. These flat upland benches are incised by shallow washes and deeper arroyos that are also important to tortoises. The washes may expose layers of calcium carbonate deposits also known as caliche, or calcrete. Wherever caliche layers are exposed in washes, tortoises either dig caves between the layers in the walls of the arroyos or opportunistically use those that erode on their own. The caliche caves are often used as winter dens by tortoises when they can find them and also by many other desert animals like kit fox (*Vulpes macrotis*), burrowing owls (*Athene cunicularia*), gila monsters (*Heloderma suspectum*), and many snakes and invertebrates. The vegetation is frequently dominated by creosotebush and white bursage with many other associated shrubs, succulents, grasses, and a few trees such as catclaw acacia (*Acacia greggii*). A diversity of annual plants is also found on the benches. While caliche layers can be beneficial for Mojave Desert tortoises and other wildlife, large flat areas where unbroken caliche layers occur just inches below the soil surface create an impediment to plant growth and to tortoises digging. These areas are frequently dominated by cactus gardens and other shallow rooted plants. Creosote bushes growing on these layers are frequently much smaller than in surrounding areas with deeper soil – thus an indicator of this important habitat feature.

A.14.3.3 Mesa Tops and Slopes

Mesas are flat-topped geomorphic features with steep sides. Some are derived from sedimentary layers, while others are derived from volcanic layers. The sedimentary derived mesas often harbor tortoise populations. The volcanic mesas are often so stony on top as to provide few opportunities for tortoise cover, thus while tortoises may be found there, they are frequently sparser than other areas described here. Talus slopes, comprised of large unstable boulder piles on steep slopes are great habitat for rattlesnakes, but dangerous for tortoises, because it is difficult for them to move among the boulders, except around the edges where the large rocks can provide good cover. Mesas occur over less area than the valleys and outwash plains, yet they provide some important Mojave Desert tortoise habitat. Some of the best representative mesa habitat is on Mormon Mesa near Overton. Once considered too low and harsh for tortoises, after a tortoise research project was conducted there it was found to support a healthy population of tortoises at the confluence of the Virgin and Muddy rivers (Nussear 2004, Nussear et al. 2012). The northern section of Mormon Mesa, near the Mormon Mountains is also challenging to tortoises because of extremely deep caliche layers; however, where arroyos have cut into the caliche there are caves that provide good cover for tortoises inhabiting the area.

A.14.3.4 Mountain Slopes and Passes

Low elevation mountain slopes and passes between valleys have recently been shown to provide good habitat for Mojave Desert tortoises (Nussear et al. 2009). The mountain slopes and passes have expansive areas of exposed bedrock with caves, and boulder piles that provide tortoise cover around the edges, and a few areas of deep soil pockets that are probably important for reproduction. Examples of areas where tortoises occupy such areas occur throughout the McCullough Range, Spring Mountains, and the Arrow Canyon Range in north central Clark County. While most of the previously mentioned desert scrub species are found in these habitats, additional shrubby species include: buckwheats (*Eriogonum* spp.), barrel cactus (*Ferocactus* spp.), teddy bear cholla cactus (*Opuntia bigelovii*), catclaw acacia (*Acacia greggii*), and many others.

A.14.3.5 Life History and Ecology

Mojave Desert tortoises hatch from eggs that are buried by the females in April through June (Rostal 2014). Clutch sizes are 3 to 5 eggs and in the northeast Mojave Desert a female may lay up to three clutches in a season (Turner et al. 1986). The eggs take 70 to 90 days to hatch (Rostal and Wibbels 2015). In most cases, after depositing her eggs, the female goes on about her business and leaves her eggs, and the young to hatch and disperse on their own. Neonatal tortoises are less than 1 year old and approximately 45 mm maximum carapace length when they hatch. Either before they hatch or within 24 to 48 hours of hatching the tiny tortoises absorb a remaining portion of egg yolk through a gap in the shell near their abdomen (Ewert 1979, Mushinsky 2014). The yolk is attached to the small intestine and provisions the small tortoise that may not find edible vegetation to eat until the following spring (if they are fortunate). Very little is known about tortoises from when they hatch until they are subadults at about 180 mm maximum carapace length. Juvenile Mojave Desert tortoises that use rodent burrows or large rocks for cover from predators and harsh cold and hot environmental conditions (Esque and Duncan 1985, Nafus et al. 2015). The availability of abundant rodent burrows and small desert washes has been correlated with higher growth and survival of small tortoises (Nafus et al. 2017). As tortoises increase body size their ability to dig burrows increases substantially. Adult Mojave Desert Tortoises can increase burrow length more than a foot a day in friable soil. Soil that is too sandy (i.e., <8% clay) does not maintain the integrity for burrows to last very long. The shells of Mojave

Desert tortoises are not completely ossified until they are several years old. Mortality of tortoises smaller than adults is thought to be very high. Once they reach adult size, wild Mojave Desert tortoise life expectancy is 30 to 50 years (Germano 1992, Medica et al. 2012).

A.14.3.6 Home Range

Tortoise activities are concentrated in potentially overlapping core areas known as home ranges. Home ranges supply tortoises with shelter, food and water, and tortoises travel in these areas to find mates and lay eggs. The home range must provide for all the tortoises' needs throughout all life stages. Because tortoises do not defend a specific, exclusive area, they do not maintain territories. The size of Mojave Desert tortoise home ranges varies with respect to climatic factors, topographical features, burrowing substrate, forage availability, social interactions, anthropogenic disturbances, the physical structure of vegetation (Berish and Medica 2014), and the health of the individual tortoise. Annual home range sizes vary from 1 to 125 ha (Berish and Medica 2014). Female home ranges are approximately half that of the average male (Berry 1986). Over its lifetime, each Mojave Desert tortoise may require more than approximate 4 km^2 (1.5 square miles) of habitat and make forays of more than Approximately 11 km (7 miles, Berry 1986) at a time.

A.14.3.7 Diet and Drinking

If watched long enough, Mojave Desert tortoises sample everything that is in their environment (Esque 1994). Tortoises in Clark County are no different, but they mostly eat desert annual plants. Annual plants remain dormant, as seeds, for much of the year. There are winter/spring annual plant species and there are summer/fall annual species as well. Some studies on tortoise diets have been conducted in the Mojave Desert (Esque 1994, Oftedal 2002, Jennings and Berry 2015), but summer diets are mostly unknown. Tortoise diets are more diverse when lots variety of species are available. Individual tortoises have dietary preferences but the mechanism driving this selection has not been determined (Esque et al 2014). Mojave Desert tortoises eat fewer species of perennial plants than annual plant species. One of the shrubs they prefer is range ratany (*Krameria* spp.), and they particularly consume the flowers. Occasionally they will eat perennial grasses such as bush muhly or galletta grass. During years when there is very little to eat tortoises will consume beaver tail prickly pear cactus (Esque 1994). It is currently believed that sites having a diversity of plant species available represent good tortoise habitat. Diets of tortoises smaller than adults are mostly undocumented, but the small tortoises probably eat many of the same species as adults. They may be more selective in their diets to increase the value of their nutrition. Tortoises appear to benefit from acquiring mineral nutrition by sometimes consuming bones and stones. It is assumed that these materials provide calcium, phosphorus, and magnesium (Esque and Peters 1994, Walde et al. 2007).

Tortoises need to drink water, and they will drink whenever it rains. Tortoises have locations within their home ranges that they know water will pool and when storms are approaching they travel to those places in anticipation of getting a drink (Medica et al. 1980). As water pools or runs off of rocks, the tortoise positions itself so that the front of its face where it breathes (the nares) are in contact with the water or wet substrate and draw the water in through the nares. If the puddle is deep enough they may put their entire face into the water. Tortoises also wallow in mud, but it is not known whether this contributes to their water balance. Water intake is so important to tortoises that they will leave their winter dens to go and get a drink during winter storms.

A.14.4 Ecosystem Level Threats

Ecosystem level threats to tortoises and their habitats can be widespread in the environment and may be direct or indirect (Esque et al. 2003). Activities that create surface disturbances can damage vegetation, disturb seed banks, and increase surface erosion by water and wind (Sankey et al. 2011, Soulard et al. 2013,), which leads to further desertification by altering soil surfaces and the ability for water to infiltrate. Surface disturbances can be caused by urban and suburban development, renewable energy and infrastructure development, military training activities, transportation and communication corridors, and recreational activities (Tracy et al. 2004, USFWS 2011). Invasive species and related desert wildfires are other sources of disturbance that have been of concern by resource managers for the past 30 years (Brooks and Esque 2002, Brooks and Matchett 2006, Drake et al. 2015). Climate change has recently been acknowledged as an important consideration for the conservation of many species including Mojave Desert tortoise (Rostal and Wibbels 2014). Invasive grasses have recently been shown to be a direct threat to tortoises for their negative influence on the health of tortoises that eat the harmful grasses (Drake et al. 2016). The largest threat to this species' habitat is the loss and degradation of habitat through urban and suburban development, although the widespread effects of fire and climate change have yet to be ascertained. Additionally, development results in the fragmentation of large expanses of habitat and can reduce genetic flow between subpopulations (USFWS 2011). Off-road vehicular activity and the invasion of non-native plants contribute to the degradation of suitable habitat (Bury and Luckenbach 2002). Non-native plant invasions can cause increased incidence of wildfires, from which desert vegetation is very slow to recover (Brooks 1999, Brooks and Esque 2002, Webb et al. 2003, Drake et al. 2015). Often, native vegetation is replaced with invasive non-natives and habitat is at risk to permanent conversion through a series of wildfires and re-invasion of non-natives (Wildlife Action Plan Team 2006, USFWS 2011). Historically, livestock grazing has induced changes to Mojave Desert Tortoise habitats through pressure on vegetation, soil disturbances, and changes in nutrient distributions (USFWS 2011).

A.14.5 Population Trends

Population trends for Mojave Desert tortoises can be monitored in a variety of ways. In Clark County, there is a rich history of demographic and population trend monitoring. Beginning in 1976, a network of permanent population monitoring study plots that were sponsored by USDI-BLM and Nevada Department of Wildlife were established in southern Nevada. These plots were typically 1 sq. mile in area, were selected to be representative of the range of local habitat types, and were re-sampled on a roughly 5-year rotation (Tracy et al. 2004). Annual range-wide population monitoring of the Mojave Desert tortoise using line distance transects began in 2001, and the study plots were temporarily abandoned in about 2000 in favor of a new sampling framework.

Following the federal listing of the Mojave Desert tortoise there was a debate about the relative value of these demographic plots in comparison with transects randomly distributed throughout habitat areas. The benefit of the random transects is a stratified random sampling design could be used to select habitat types representative of a larger subset of all habitat available, and that they could statistically derive population estimates for large areas. While that is true, the random transects also had a very large error associated with the estimates and they required very large sample sizes over many years to yield statistically relevant results (Nussear and Tracy 2007). Fortunately, enough time has passed for the random transects to begin yielding relevant results. Population density estimates of adult tortoises resulting from these surveys varied among recovery units and years. These surveys show appreciable population declines at the local level in many areas without corresponding increases to offset declines in other areas (USFWS 2008). However, recent reports from the Mojave Desert Tortoise Recovery Office indicate increasing trends in the Northeast Mojave DWMA, which is largely composed of Clark County (USFWS 2015).

While the debate about demographic plots versus random transects has gone back and forth for an intervening 15 years, new opportunities provided the ability of resource agencies to adopt both types of surveys. The random transects allow for broad inference about population trends, while a return to intensively sampled demographic plots provide detailed information about changes in the demographic profile of local tortoise populations. The demographic profiles provide detailed information about reproduction and survival of tortoises at all of their life stages (e.g. juveniles, subadults, adults). While the plots have only recently been re-established, they are expected to provide new and rapid insights into the dynamics of population change in relation to habitat qualities for Mojave Desert tortoises in Clark County.

A.14.6 Threats to Species

The vast majority of threats to the Mojave Desert tortoise and its habitat are associated with human land uses. The threats identified in the 1994 *Mojave Desert Tortoise (Mojave Population) Recovery Plan* (USFWS 2011), the basis for listing the tortoise as a Threatened species, continue to affect the species (Tracy et al. 2004, USFWS 2011). Habitat loss, degradation, and fragmentation from urbanization, off-road vehicular activity, linear features such as roads and utility corridors, livestock grazing, mining, and military activities were cited as some of the primary reasons for the decline in Mojave Desert Tortoise populations (Tracy et al. 2004, USFWS 2011). Disease and increased frequency of wildfire resulting from non-native invasive plant species proliferation in the Mojave Desert have also been implicated in Mojave Desert tortoise population declines (Wildlife Action Plan Team 2006, USFWS 2008).

Atmospheric nitrogen is a by-product of internal combustion engines and other urban activities. This nitrogen can settle on plants and soils, which can then increase the abundance of certain invasive species (e.g., *Schismus barbatus, Erodium cicutarium, Bromus madritensis*), particularly non-native annual grasses and forbs (Allen et al. 2009), and cause a concomitant reduction in native forbs (Allen et al. 2009). The reduction in native annual plants can have a negative impact on Mojave Desert tortoise (Brooks and Esque 2002, Drake et al. 2016).

Increases in Mediterranean grasses have led to extensive wildfires throughout the range of the tortoise (Brooks and Matchett 2003). Desert wildfires are known to kill >10% of adult populations of Mojave Desert tortoise in a single event (Esque et al. 2002). While it is known that adult tortoises used burned habitat, and it has been found that their growth, behavior, reproduction and health in burned areas is not different from unburned areas (Drake et al. 2015), it is also known that diets high in brome grass result in slow growth, reduce survival, and present other health hazards for juvenile Mojave Desert tortoises (Drake et al. 2017).

The presence of high levels of sand in soils can be detrimental to Mojave Desert tortoises in a mostly indirect manner. Tortoises find it difficult to maintain burrows in sandy soils because they collapse easily, and areas of pure sand soils were found to support very little tortoise activity (Baxter 1987). Increases in sand can result from OHV disturbance of cryptobiotic crusts as the underlying soils become exposed and subject to wind effects blowing the sand into new areas downwind. This, in turn, results in a reduction of soils appropriate for burrowing.

Deliberate harassment by humans and over collection for commercial, recreational, scientific, educational, or dietary purposes, are threats to the species (USFWS 2011). Injury and death as a result of collisions with motor vehicles is perhaps the greatest known threat in this category. Areas near highways that previously did not have tortoise fencing usually have reduced tortoise population densities near roads (von Seckendorff Hoff and Marlow, 2002, Boarman and Sazaki 2006, USFWS 2011, Nafus et al. 2013, Hughson and Darby 2013).

Two bacterial organisms are known to infect wild Mojave Desert Tortoises in Clark County: Mycoplasma agassizii, and M. testudineum. The mycoplasmosis resulting from these infections can result in the signs of Upper Respiratory Tract Disease (URTD) that was important in the federal listing of the species (USFWS 2011). Other organisms known or suspected to infect Mojave Desert tortoises in Clark County include herpesvirus, shell and skin fungi, pneumonia, Cryptosporidium, and Chlamydia (Jacobson 2014). Diseases known to affect tortoises include, gout, urolithiasis, and oxalosis (Jacobson 2014). A noninfectious disease known as cutaneous dyskeratosis also has been found in Mojave Desert tortoise (Jacobson 2014). Disease-related mortality may be a result of multiple factors including drought, poor nutrition, environmental toxicants, or habitat degradation (Mojave Desert Tortoise Recovery Office 2009, Jacobson 2014).

Hatchling and juvenile tortoises are naturally preyed upon by several species of native mammals, reptiles, and birds (Grover and DeFalco 1995, Bjurlin and Bissonette 2004). However, in areas where human development and activity increase, human-derived food subsidies (e.g., open trash bins, pet food left outdoors, leaky watering systems) have allowed subsidized predators (common raven - *Corvus corax*, and coyote - *Canis latrans*) to colonize previously less suitable areas with unnaturally high population levels, which in turn have allowed them to opportunistically prey on juvenile Mojave Desert tortoises (Kristan and Boarman 2003, Esque et al, 2010). Thus, urban and suburban development pose both a direct (i.e., loss of habitat) and indirect (i.e., increase in predation) threat to some Mojave Desert tortoise populations. Common ravens (Ft Irwin Translocation Project – unpublished data), coyotes (Esque et al. 2010), and American badgers (*Taxidea taxus*; Emblidge et al. 2015), are now known to prey on Mojave Desert tortoises of all sizes. Mountain lions (*Felis concolor*) are known to prey on adult Mojave Desert tortoise (Medica et al. 2012 With increasing sizes of the wildland/urban interface, feral and free roaming pets (e.g., canines and felines) pose an increased risk of predation to the Mojave Desert tortoise (USFWS 2011).

Captive or pet tortoises released into the wild can introduce diseases into the wild population potentially result in genetic contamination (USFWS 2008).

A more detailed discussion of threats to the Mojave Desert tortoise and its habitat, including global climate change and regulatory mechanism inadequacies, is available in the *Revised Recovery Plan for the Mojave Population of the Mojave Desert Tortoise (*Gopherus agassizii*)* (USFWS 2011).

A.15 GILA MONSTER (*HELODERMA SUSPECTUM*)

Gila monsters (*Heloderma suspectum*) are large (350–500 millimeters total length), venomous lizards that range across portions of the Sonoran, Mojave, and Chihuahuan deserts in the US and Mexico. In the US, they are distributed in Arizona, southern Nevada, portions of southeastern California near the Nevada border, and southwest Utah. Gila monsters are brightly colored, yet cryptic. They may have a short activity period (e.g. approximately 90 days from April to mid-June), with limited activity (i.e. only 1/3 of days during their activity season; Beck 1990). However, nocturnal activity may be much greater than expected from June - August (Beck 1990), and there is also commonly an increase in activity in the fall. They are strongly associated with burrows and deep caves and are frequently found in rocky (e.g. sandstone) or mountainous terrain. They are a secretive, diurnal predators and feed largely on the eggs and young of desert vertebrates, and feed by widely searching sandy areas and bajadas in the desert scrub habitats surrounding their shelter sites.

A.15.1 Species Status

In 2010, the Gila monster was petitioned for listing under the federal Endangered Species Act (ESA) by WildEarth Guardians and Daniel Beck as a distinct population segment (DPS) in Utah. The petition cited the loss of habitat and associated habitat degradation as a result of urban development. Numbers there were estimated to be as many as 20 per square mile; however, like other secretive, ground dwelling species, Gila monster population estimates are notoriously difficult to establish. The DPS was considered to have sustained substantial losses of individuals based on reduction of habitat from landscape development because census data were not available (WildEarth and Beck 2010). The USFWS denied review and consideration for listing as they determined that there was insufficient scientific evidence presented in the petition to distinguish the Utah population as a DPS (USFWS 2011). In 1982 the USFWS considered the Gila monster as a Category 2 candidate. However, the Gila monster was later removed from this categorization because there was insufficient information to justify listing (USFWS 1996). The Gila monster has state protected status in Utah, Arizona, and Nevada. Nevada also prohibits collection for personal or commercial purposes (Nevada Department of Wildlife [NDOW] 2009). The Gila monster is evaluated by the IUCN Red List as a species "Near Threatened" (Hammerson et al. 2007).

US Fish and Wildlife Service Endangered Species Act: No Status

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No Status

State of Nevada: Protected

NV Natural Heritage Program: Global Rank G4T4, State Rank S2 - Imperiled

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Near Threatened

CITES: Appendix ii

A.15.2 Range

Within the United States, the Gila monster inhabits isolated locales within extreme southwestern Utah, southern Nevada (Clark, Lincoln, and Nye counties), southeastern California (San Bernardino County), southern and western Arizona (Stebbins 2003), and southwestern New Mexico (Degenhardt et al. 1996). Gila monsters can be found in many habitats between 2500 and 5000 feet, but most commonly frequent the lower slopes of mountains and adjoining canyon bottoms and arroyos, and are frequently associated with rocky terrain (Bogert and del Campo 1956, Funk 1966) in areas with natural shelters and caves (Beck and Jennings 2003, Gienger 2003). Common habitat for the Gila monster is characterized by complex rocky landscapes of upland desert scrub adjacent to suitable foraging sites harboring appropriate prey and nest sites (Beck 1990, Gienger 2003). Most localities are also associated with desert wash, spring, and riparian areas, including those along the lower Colorado River drainage (Funk 1966, Lovich and Beaman 2007, NDOW 2007). Gila monsters winter at more elevated locations (i.e., on rocky slopes, in rocky outcrops, or below cliffs) often with other reptiles such as rattlesnakes and Mojave Desert Tortoises. Summer ranges, however, are located in adjacent lower valleys or alluvial fans (Jennings and Hayes 1994) where the prey base is larger. Data are lacking on reproduction and nest sites for this species (Beck 2005, Jennings and Hayes 1994, WildEarth and Beck 2010).

Home ranges in one population studied in Nevada are larger than those of lizards studied in a geologically similar habitat in southwest Utah (Gienger 2003) although both studies were of limited sample size and geographic areas. WildEarth and Beck (2010) argued for recognition of a unique DPS in southwestern Utah, citing isolation and ecological distinction. However, recent genetic analysis did not support the division of the species into subspecies (Davidson Douglas et al. 2010), although the sample sizes were small in that analysis.

A.15.3 Population Trends

Gila monsters are rarely observed in nature, which makes it difficult to determine population trends. Their populations are thought to be in decline throughout their range (Campbell and Lamar 2004). The Gila monster is described as having decreasing population trends in the IUCN Red List (Hammerson et al. 2017). Populations have declined from thousands to hundreds in Washington County, Utah; however, these estimates are not based on quantitative field surveys (WildEarth and Beck 2010).

A.15.4 Habitat Model

Models created for Gila monsters appear to be similar for the GAM and MaxEnt algorithms, with the RF predicting a tighter distribution (Figure A.15-1). The RF model had the highest AUC and TSS scores, while the GAM model and the highest BI, although all models were similar in that metric (Table A.15-1). The variables NDVI Start of Season, Sandy Soils, Summer Maximum Temperature, Washes were not selected in any of the models, and Surface Texture was chosen only in the RF model, ranking highest (Table A.15-2). The GAM and MaxEnt models were comprised of the same covariates, while the RF models did not include Surface Roughness or Terrain Position. Standard error (SE) maps for each model yielded thin areas of elevated SE in the Muddy and Virgin River bottoms for the GAM model, and some areas of low to moderate SE in the Mormon Mesa area for the Ensemble model (Figure A.15-2).

Continuous Boyce Indices indicated good predictive abilities for each of the models (Figure A.15-3).

Table A.15-1. Model performance values for Gila monster models.

Model	Presences	AUC	BI	TSS
Ensemble	262	0.898	0.95	0.68
GAM		0.798	0.957	0.473
RF		0.959	0.942	0.79
MaxEnt		0.834	0.953	0.562

Table A.15-2. Percent contributions for input variables for Gila monster for ensemble models using GAM, MaxEnt and RF algorithms

Variable	GAM	MaxEnt	RF
Elevation	29.378	34.387	26.657
NDVI Amplitude	7.703	14.014	14.109
NDVI Maximum	22.062	9.407	10.408
NDVI Start of Season			
NDVI Total Integrated	3.838	3.686	13.633
Sandy Soils (TerraSpectra)			
Slope	13.209	3.621	14.725
Summer Maximum Temperature			
Surface Roughness	5.189	10.211	
Temperature Range (Annual Max - Min)	6.733	7.443	14.843
Terrain Position Index	4.708	4.031	
Texture (ATI)			41.268
Washes			
Winter Minimum Temperature	5.9	8.986	27.774
Winter Precipitation	1.28	4.213	16.466

Figure A.15-1. SDM maps for Gila monster model ensembles for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and ensemble model averaging the three (Lower Right).

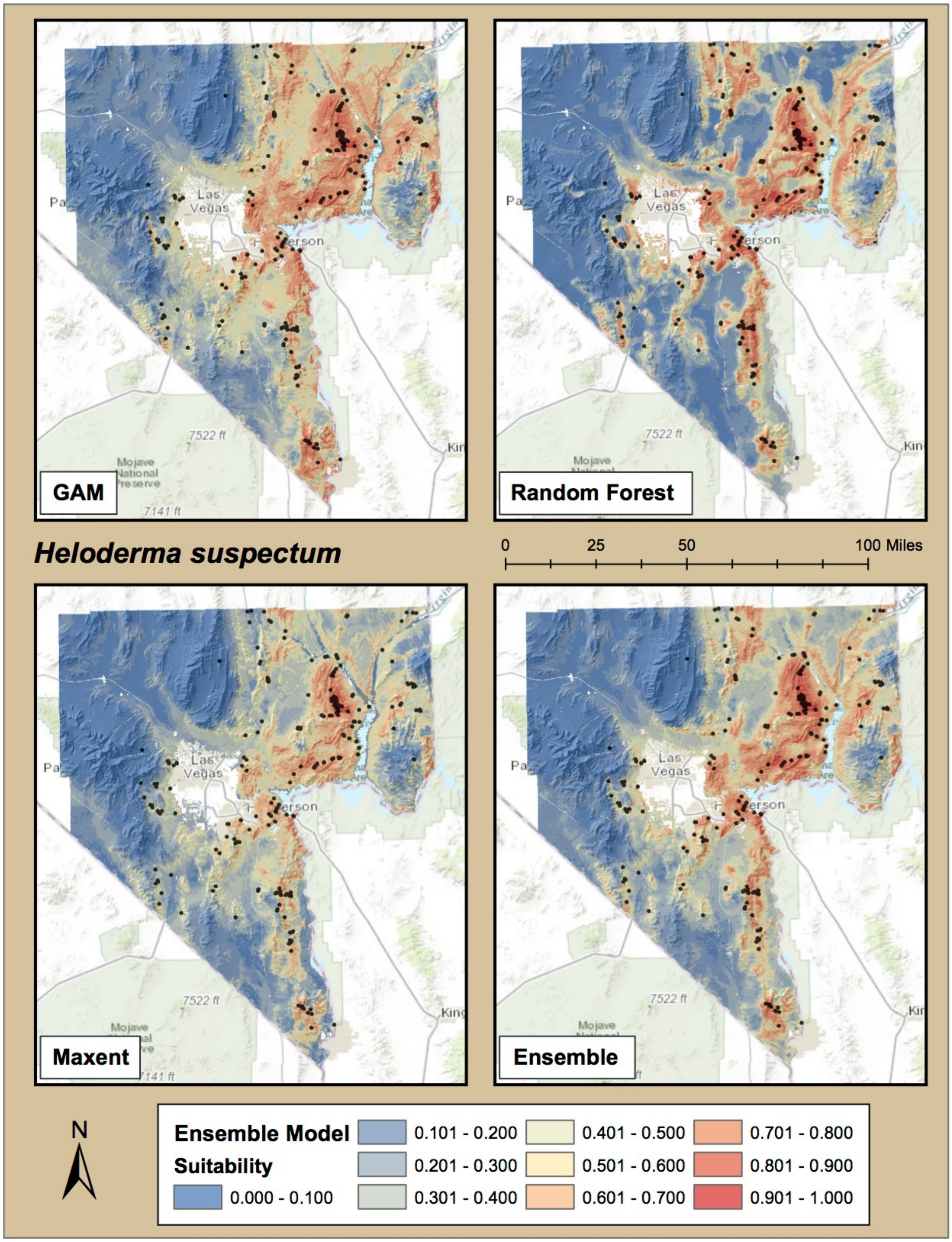


Figure A.15-2. Standard error maps for Gila monster models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

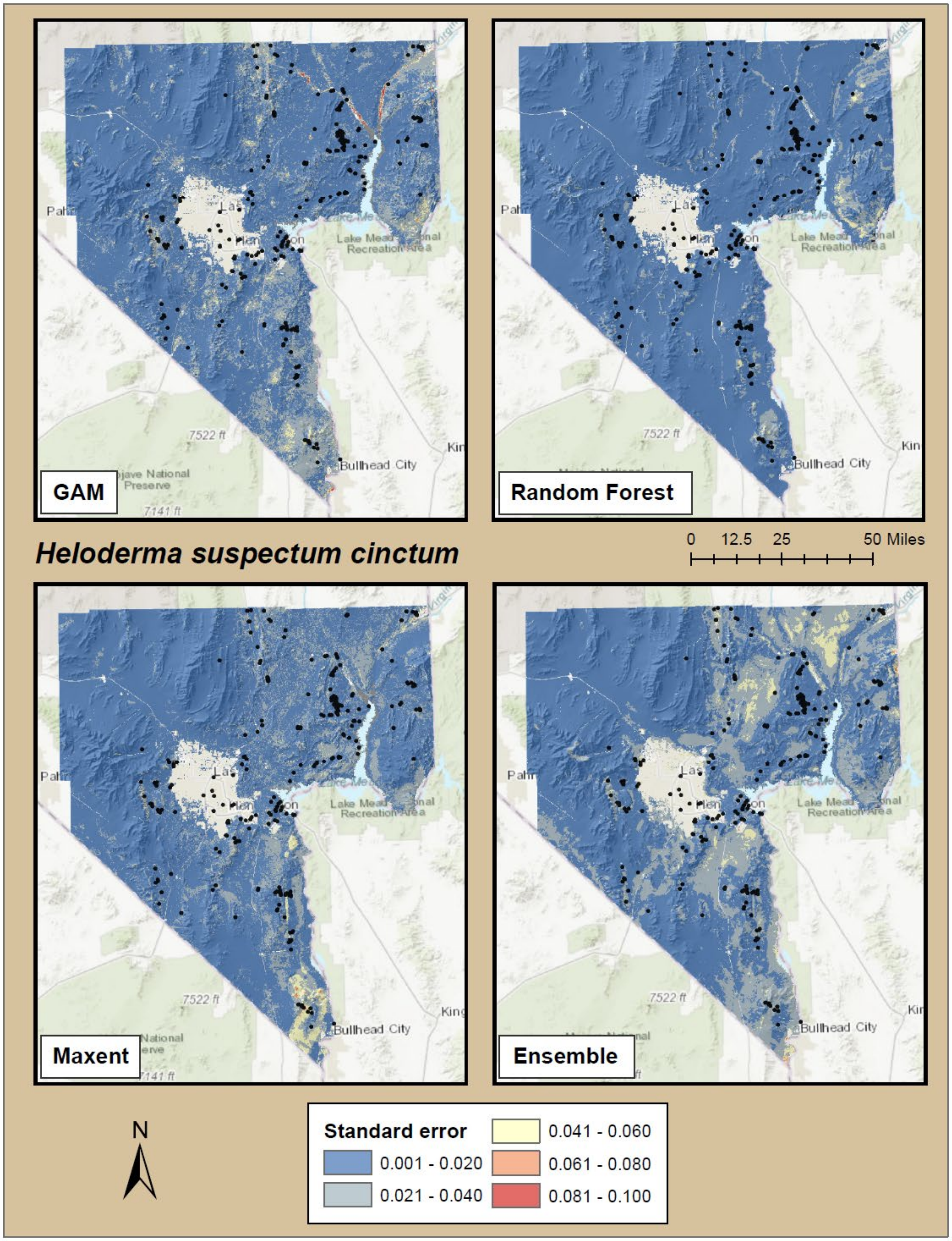
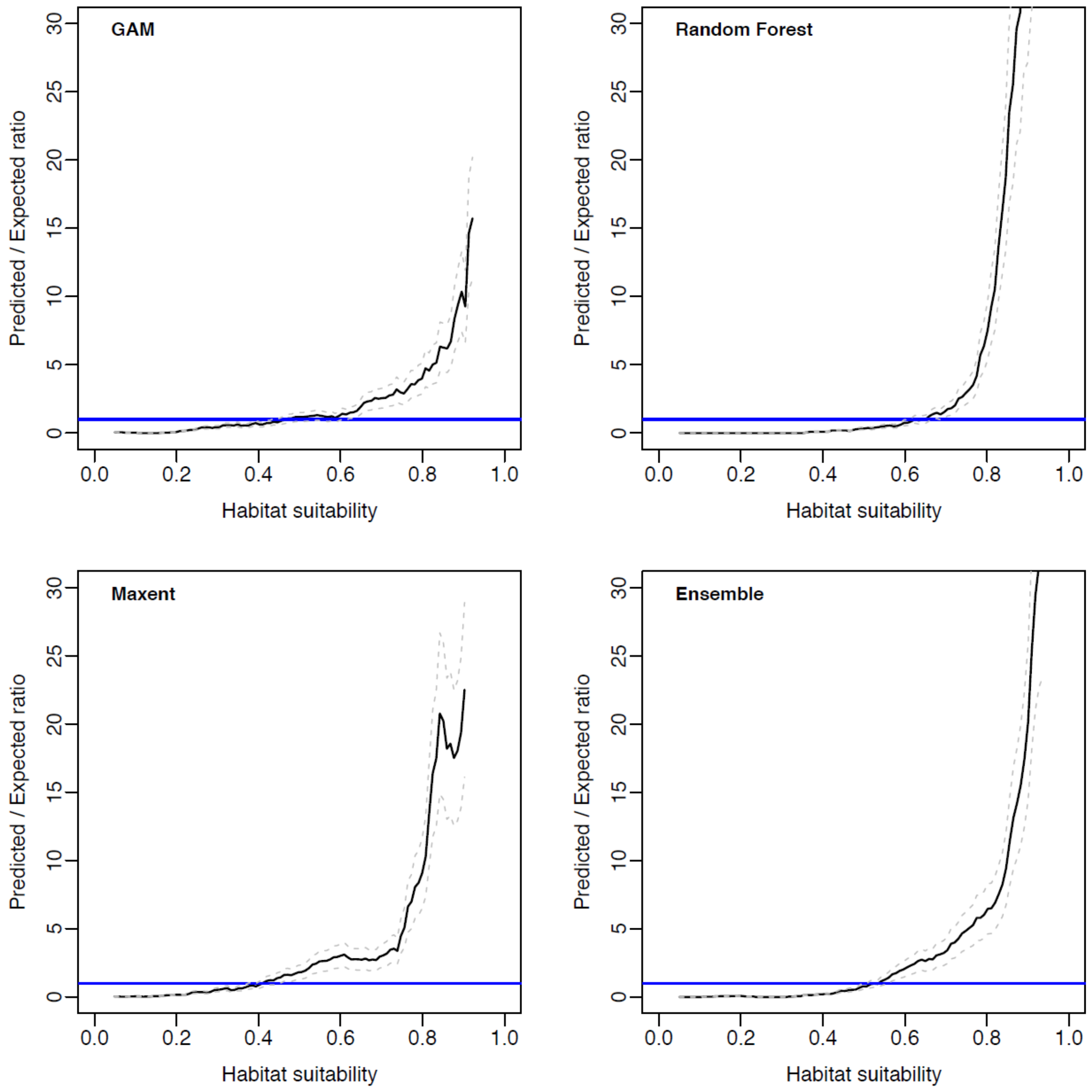


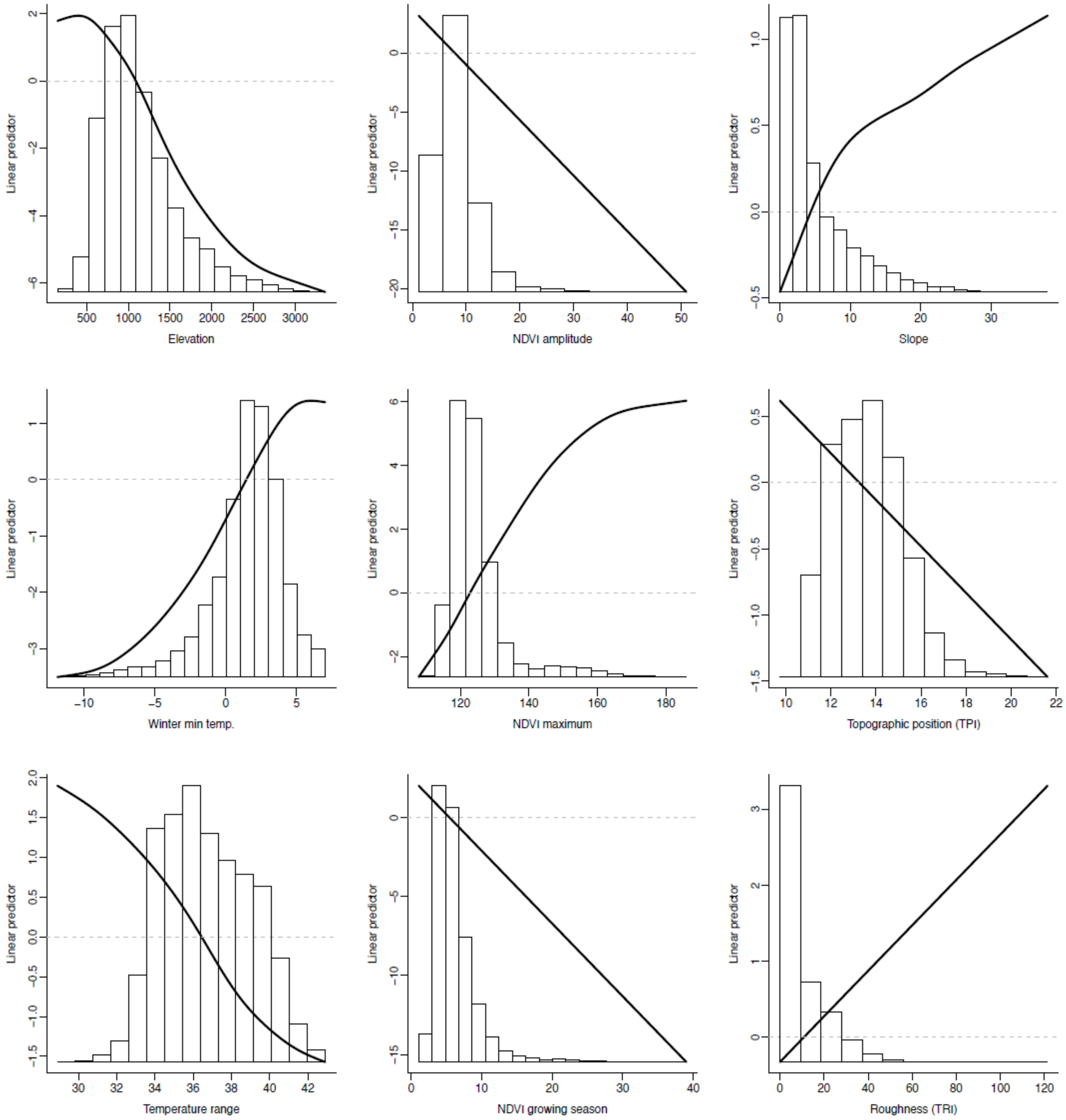
Figure A.15-3. Graphs of Continuous Boyce Indices [CBI] for Gila monster models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).



A.15.4.1 General Additive Model

Elevation, NDVI Maximum, and Slope were the highest contributing covariates in the GAM model, where Gila monster habitat was generally predicted at lower elevation and slope, and in areas with lower NDVI Maximum values, corresponding with lower vegetation found in the typically arid and rocky habitats (Table A.15-2, Figure A.15-4). NDVI Amplitude, Annual Temperature Range, Winter Minimum Temperature, Surface Roughness, Terrain Position Index, total integrated NDVI, and Winter Precipitation provided moderate contributions, were higher habitat was predicted for areas with warmer winter minimum temperatures with little greenup, and at a higher position relative to drainages, and decreased with surface roughness. These are characteristic responses that reflect the affinity of the species for rough, rocky terrain at lower elevations.

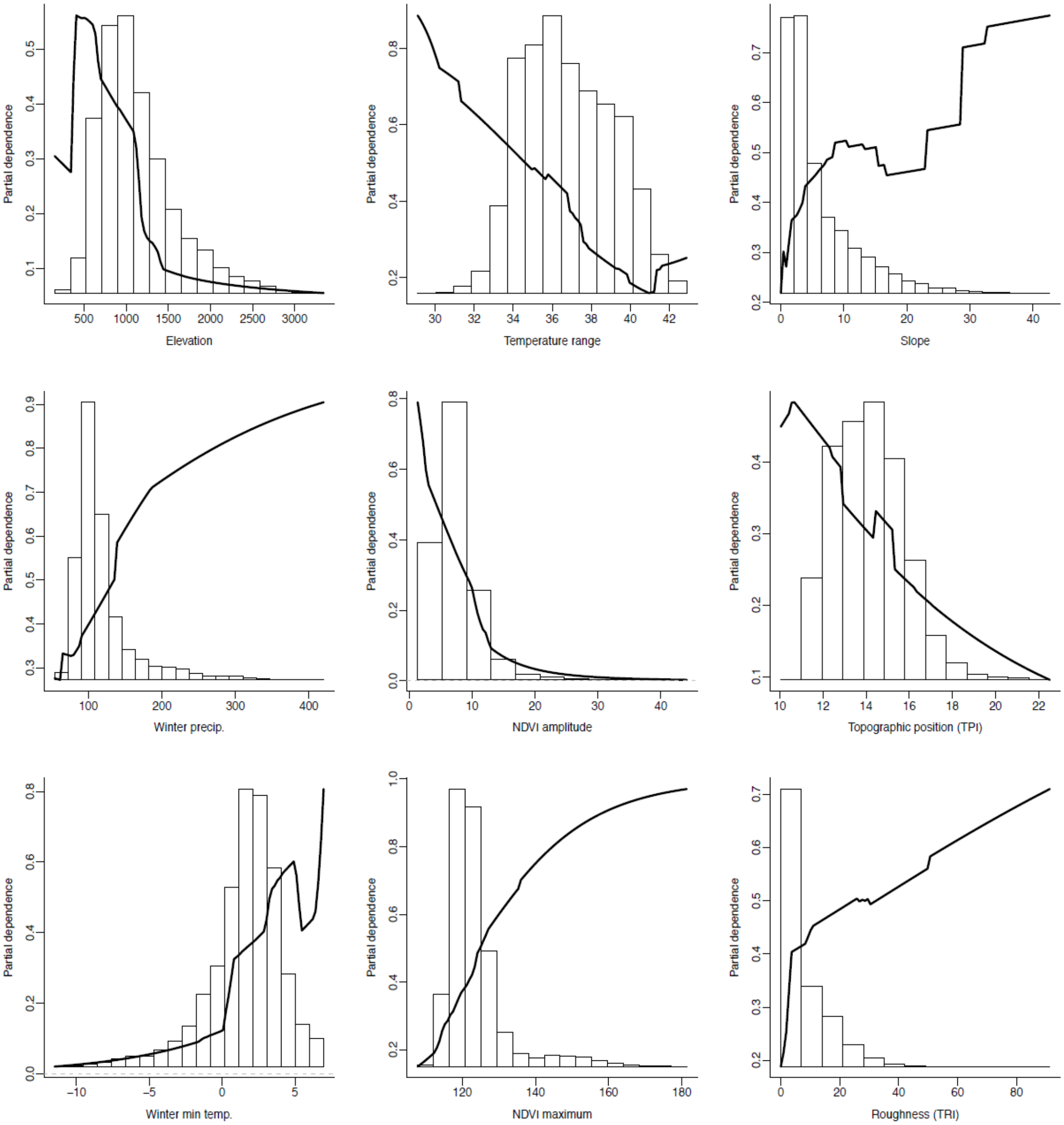
Figure A.15-4. GAM partial response curves for the Gila monster model overlaid over distribution of environmental variable inputs in the study area.



A.15.4.2 MaxEnt Model

The MaxEnt ensemble was most influenced by Elevation, followed by NDVI Amplitude, Surface Roughness. NDVI Maximum, Winter Minimum Temperature, Annual Temperature Range, Winter Precipitation, Terrain Position Index, Total Integrated NDVI, and Slope each contributed moderately, gently decreasing in contribution (Figure A.15-5). The predicted surfaces are qualitatively similar to those for the GAM model (Figure A.15-4, Figure A.15-5).

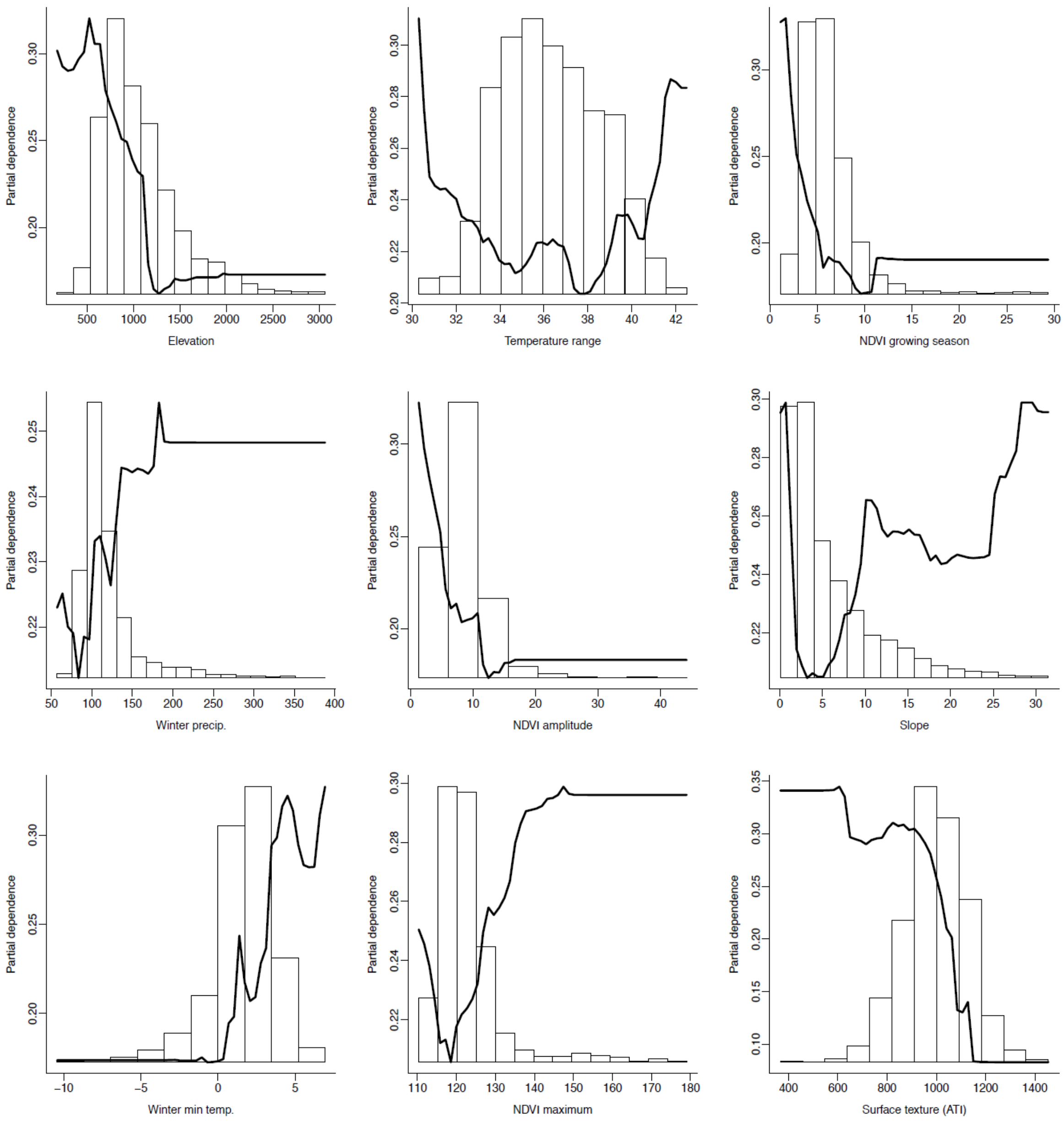
Figure A.15-5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for Gila monster.



A.15.4.3 Random Forest Model

RF models had quite different variable selection and contribution rankings. Surface Texture was by far the highest contributing covariate, replacing Elevation as the top contributor in the other two models. Winter Minimum Temperature, and Elevation were the next highest ranking, with lower but similarly ranked contributions from Winter Precipitation, Annual Temperature Range, Slope, NDVI Amplitude, total integrated NDVI, and NDVI Maximum (Table A.15-2). As for the MaxEnt models, the general trends indicated in the model response surfaces are conserved across algorithms for this species, although some additional complexity in the fitting functions is apparent in the RF surfaces relative to the others (Figure A.15-6, Figure A.15-4, Figure A.15-5).

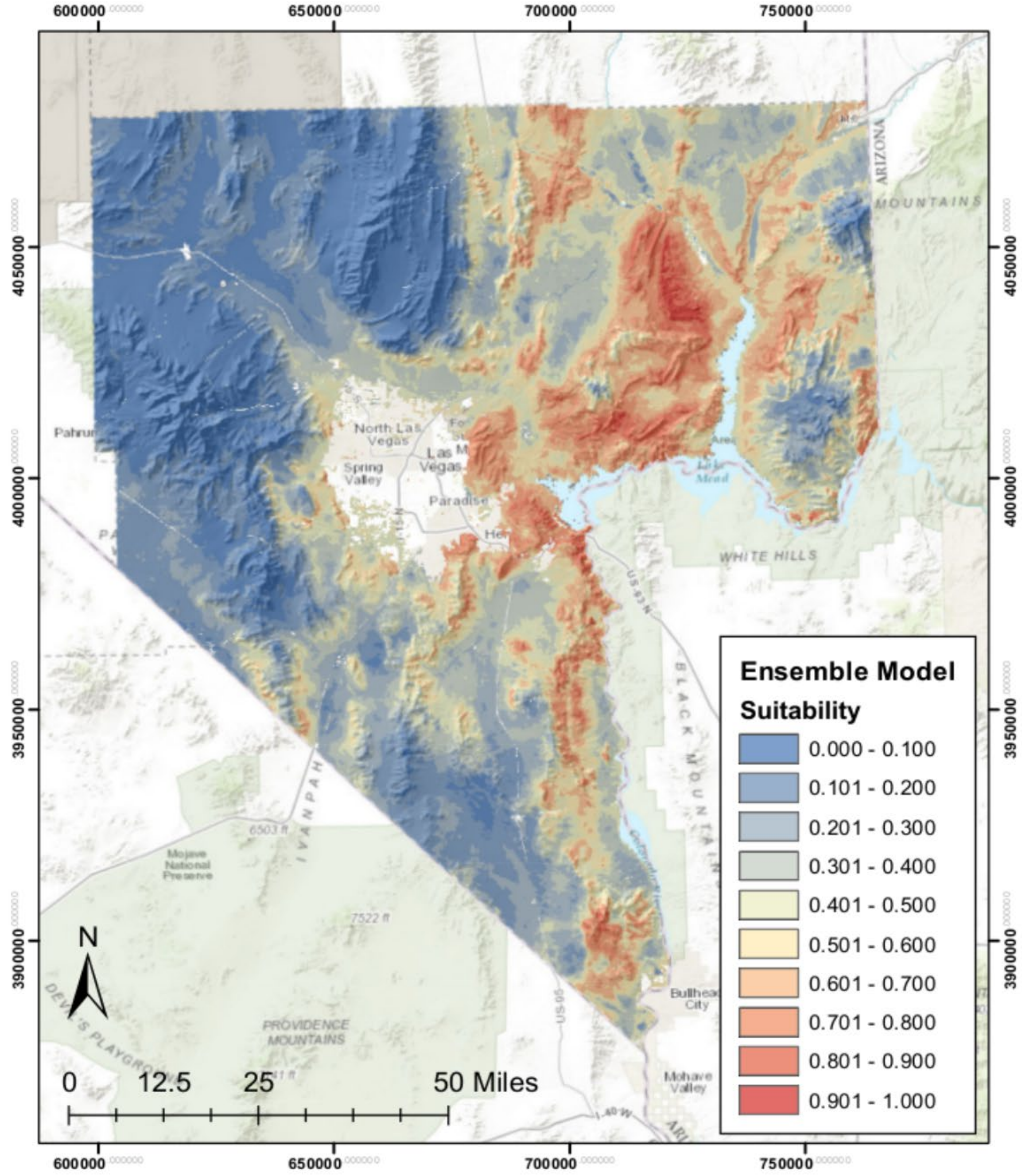
Figure A.15-6. Partial response surfaces for the environmental variables included in the RF ensemble model for Gila monster. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.15.4.4 Model Discussion

The Gila monster SDM predicts a range in Clark County where most locality points are concentrated along the main stem and primary tributaries of the Colorado River, although Gila monsters are found across the western and southern extent of Clark County. Gila monsters are also known to occur in Lincoln County, as well as southwest Utah, northwest Arizona (including on the north of the Colorado River in the Pakoon Basin), and in southern California just west of the Nevada border Figure A.15-7). The distribution of *Heloderma* in Clark County is geographically most similar to *Dipsosaurus*, however, *Heloderma* are found in substantially more heterogeneous sites with respect to soil substrate, frequenting areas of boulder piles and rocky outcrops surrounded by sand or loamy sands, where they travel to forage, mate, and seek cover sites. *Heloderma* are not frequently seen in broad open valleys unless there are abundant caliche caves to provide cover - which is why one of the areas of high modeling error in Eldorado Valley may occur (see below). There are five primary areas of elevated standard error in the model (Figure A.15-8). The first is a cluster of high error mostly concentrated along the Interstate Highway 15 corridor northeast of Las Vegas in the vicinity of California Wash, and the Moapa Indian Reservation. The second is mostly on top of the Mormon Mesa and west of there in the Muddy River Valley. The third area of increased modeling error is in the Eldorado Valley immediately southeast of Boulder City. A fourth area indicated to have somewhat higher error values is around the base of the Virgin Mountains and near St. Thomas Gap south of the Virgin Mountains. However, *Heloderma* have been observed just across the border from St. Thomas Gap in Arizona (T. Esque, *personal observation*), as well as the sightings in St. Thomas Gap. The final area of interest with respect to modeling error is at the extreme southern tip of Clark County, near Laughlin, which is another area of fairly high error. There are a few other isolated spots of error throughout the range. Most of the regions of high modeling error tend to be near sites where locality records exist, but do not have any locality records within their perimeters.

Figure A.15-7. SDM map for Gila monster Ensemble model.



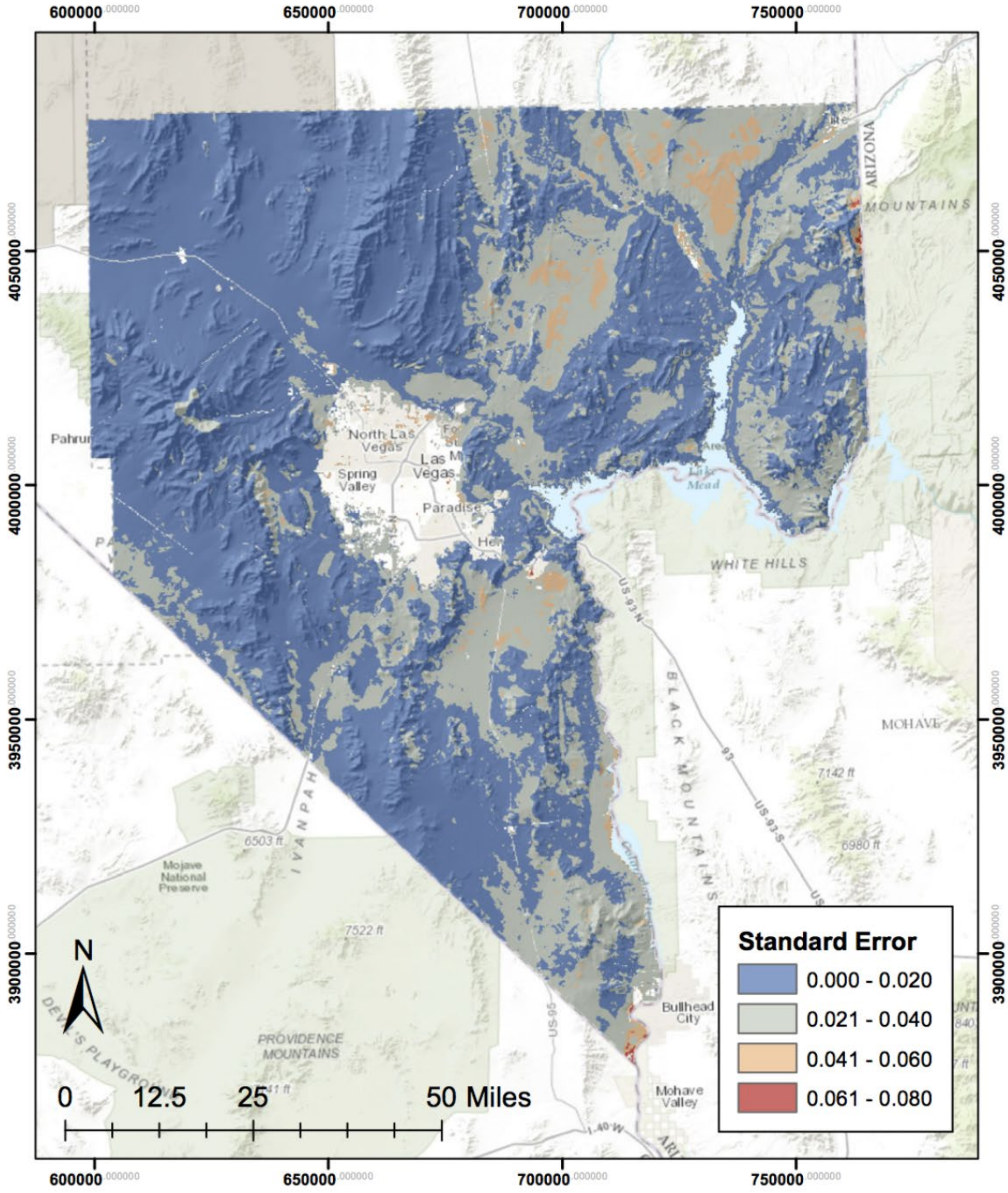
Heloderma suspectum

Habitat Suitability Map

Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and Maxent.

Figure A.15-8. Standard Error map for the ensemble Gila monster ensemble model for Clark County, Nevada.



Heloderma suspectum

Standard Error Map

Standard error in habitat suitability
was calculated across all selected
GAM, Random Forest, and Maxent
models used in deriving the
ensemble estimates.

Projection:
NAD 1983
UTM Zone 11N

A.15.5 Distribution and Habitat Use within Clark County

Distribution of the Gila monster within Clark County generally coincides with the distribution of Mojave Desert Tortoise and common chuckwalla (*Sauromalus ater*) however; little information exists on detailed distribution and relative abundance in Nevada (NDOW 2007). Recent research conducted by NDOW indicates that Gila monsters may be more common than previously expected in the McCullough Mountains. Predicted habitat for the Gila monster is nearly entirely contained within the Mojave Desert scrub ecosystem within Clark County.

Modeled habitat of additional habitat categories also predict limited high suitability habitat in Blackbrush, and Mesquite Acacia ecosystems, while moderate habitat is predicted in greater abundance among those three ecosystems (Table A.15-3).

Table A.15-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	339104	70156	5725
Bristlecone Pine	7565	0	0
Desert Riparian	1841	8272	484
Mesquite Acacia	6462	10179	3024
Mixed Conifer	27339	0	0
Mojave Desert Scrub	305583	645853	325393
Pinyon Juniper	113758	1895	180
Sagebrush	4707	0	0
Salt Desert Scrub	74986	3607	203

A.15.6 Ecosystem Level Threats

Threats to Gila monster habitat include loss and degradation of habitat associated, directly (e.g. bull-dozing landscapes, agriculture) and indirectly (e.g. feral pets, disturbances from increased recreation), with urban and suburban development.

Large-scale solar development, associated infrastructure, and the proliferation of power lines contribute to recent losses of habitat. Utility, transportation and water distribution infrastructure also contribute to habitat fragmentation (Brown and Carmony 1999). Off-road vehicular activity and the invasion of non-native plants contribute to the degradation of suitable habitat by fragmenting habitat, reducing vegetative cover used by prey species, and eliminating shelter used by Gila monsters. Illegal commercial collections are a source of population level losses throughout their range, because the species is highly valued by collectors globally (New Mexico Department of Fish and Game 1985). Native predator densities may increase in proximity to urban or suburban areas due to the increased availability of resources that are usually limiting in desert environments. These resources include food and water. Native predators gain access to increased refuse around human habitations, and prey species (rodents and cottontail rabbits) increase around parks and golf courses.

More water is available around human habitations from run-off, and water features throughout these areas. These subsidized predators continue to prey on native wildlife during drought years that would normally cause decreases of predators (Esque et al. 2010). Increased presence of feral predators (i.e. dogs and cats) also impact Gila monsters and their prey. Non-native plant invasions can cause increased frequency and intensity of wildfires, and desert vegetation is very slow to recover. Often native vegetation is replaced with invasive, non-natives and habitat is permanently converted through a series of wildfires and re-invasion of non-natives (Wildlife Action Plan Team 20012 USFWS 2008).

A.15.7 Threats to Species

Direct threats to the Gila monster, including those in Clark County, include mortality from habitat destruction, illegal collection for commercial and recreational purposes, and injury and mortality resulting from collisions with vehicles on paved and unpaved roads (AGFD 2002). Predation is also a threat to this species. As urbanization becomes more prevalent in previously uninhabited deserts, human and pet densities increase, as well as densities of subsidized predators (Esque et al. 2010). Pet encounters with wildlife are presumed to be a contributing factor in Gila monster declines (Jennings and Hayes 1994, WildEarth and Beck 2010). Additionally, the Gila monster has a poisonous bite and has therefore been the target of unwarranted destruction by humans (NDOW 2009, WildEarth and Beck 2010). Mitigation of these threats may be possible through enforcement of off road vehicle regulations, and public education programs to reduce direct persecution and subsidized and feral predators.

A.15.8 Existing Conservation Areas/Management Actions

The Gila monster is covered under the 1998 Conservation Agreement for the Spring Mountain Range. The goal of this conservation agreement is to provide long-term protection to the covered species and to preclude future listing of additional species under the ESA (USDA Forest Service, USFWS, and Department of Conservation and Natural Resources 1998).

In Nevada, the Gila monster is protected under the Nevada Administrative Code 503.080, wherein the species is listed as a State protected reptile and collection is controlled under section 503.093. An appropriate license, permit, or authorization must be obtained from NDOW to kill or possess an animal.

The Gila monster is considered a Species of Conservation Priority under the Nevada Wildlife Action Plan implemented by the NDOW. The banded Gila monster was identified in the conservation strategy as one of the highest priority reptilian species on which to conduct research studies (Wildlife Action Plan Team 2012).

Recommended conservation actions specific to this species and species habitat are also included in the Nevada Wildlife Action Plan. The Wildlife Action Plan recommended approach is to identify and describe suitable habitat for this species in Nevada, develop management guidelines based on suitable habitat parameters, and to maintain prohibitions against indiscriminate collection and unnecessary killing. Further, the recommended conservation strategies to conserve habitat for this species include: maintaining this species habitat at its current distribution in stable or increasing trend; sustaining stable or increasing populations of wildlife in key habitats; and, obtain no net unmitigated loss or fragmentation of habitat in areas designated by the 2000 MSHCP as "Intensive Management Areas" or "Less Intensive Management Areas," or in areas designated as "Multiple Use Management Areas" that represent the majority of habitat for a species (Wildlife Action Plan Team 2012).

The Gila monster is on the Nevada Natural Heritage Program (NNHP) Animal and Plant At-risk Tracking List, which directs the data acquisition priorities of the NNHP and provides current information on the status of these taxa. Taxa considered at risk and actively inventoried by NNHP typically include those with federal or other Nevada agency protection status and those with Global and/or State ranks 1 through 3 (NNHP 2012).

The banded Gila monster is included as a Covered Species in the Coyote Springs Investment Multiple-Species Habitat Conservation Plan published in July 2008 and the corresponding Endangered Species Act section 10(a)(1)(B) incidental take permit issued by the USFWS in October 2008 (Coyote Springs Investment Multiple-Species Habitat Conservation Plan 2008). The Coyote Springs Investment Multiple-Species Habitat Conservation Plan area covers portions of Clark and Lincoln counties, north of the Clark County MSHCP area.

A.16 GOLDEN EAGLE (*AQUILA CHRYSAETOS*)

As top avian predators, there is interest in golden eagles (*Aquila chrysaetos*) globally. Successful conservation and education efforts have formed around this iconic species since the time when they were shot for sport on their annual migrations in the eastern United States. While those types of losses have certainly been reduced, new threats have developed with the recent national thrust to create greater amounts of renewable energy. Since about 2010 there are re-doubled efforts to understand the status of golden eagle populations in North America and learn about their life histories and ecology on a continental basis. Golden eagles in the hot desert regions of the southwestern United States are among the least known populations in North America. The Desert Renewable Energy Conservation Plan (DRECP 2015) of southern California has invested some resources to improve our understanding of this species. Much more work will be required to better understand this far-ranging species.

A.16.1 Species Status

US Fish and Wildlife Service Endangered Species Act: No Status

Migratory Bird Treaty Act: Protected

Bald and Golden Eagle Protection Act: Protected

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No Status

State of Nevada: Protected (NAC 503.050.1)

NV Natural Heritage Program: Global Rank G5, State Rank S4

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red list (v 3.1): Least Concern

CITES: Appendix ii

A.16.2 Range

The distribution of golden eagles is circumpolar in the northern hemisphere (Bent 1961). They generally occupy relatively open areas that are not densely forested. Similarly, expansive grassland biomes are often suitable for establishing breeding territories where nesting substrate is present (e.g. cliffs or trees), and may be used by wintering eagles as well (Watson 2010). Currently, golden eagle populations are most robust west of the Great Plains with additional populations in northeastern Canada and isolated locations in the eastern US (Kochert et al. 2002, DeLong 2004). There are six subspecies of golden eagle worldwide, however only one (*A. c. Canadensis*) occurs in North America. Golden eagles occupy mostly remote open country that is isolated from human activities. Foraging habitats for nesting eagles include many North American habitat types including: the fringes of Arctic habitats; mountains of the Pacific northwest; the taiga of North America; foothills and shortgrass steppe east of the Rocky Mountains; cold deserts of the Great Basin and Colorado Plateau; the Mojave and Sonoran hot desert ecoregions, mountains and coastal areas of California and Mexico; and mountains of eastern North America (Watson 2010, Longshore In Prep., Daniel Driscoll – AERIE, personal communication). Wintering golden eagles use these above habitat types when prey is available year-round and climatic conditions allow. They may also parts of the Great Plains, but in that region nesting is limited by lack of appropriate nesting substrate. In North America nesting substrates usually include cliffs and trees.

A.16.3 Population Trends

The population trends for golden eagles in the west are no doubt reduced from Pre- Columbian levels due to three primary factors. First, organized and sustained predator and prey controls have been instituted in some parts of the region for nearly a century. Second, active hunting by shooting, as well as poisoned baits (e.g. carcasses laced with poison), and non-target poisoning with eagles consuming rodents laced with rodenticide have reduced eagle populations. And third, the endeavor of egg-collecting for the science of oology is considered to have detrimentally influenced golden eagle populations early in the last century. However, the greatest influence of previous egg collection was usually closer to heavily populated municipalities like San Diego or San Francisco, California in the past.

While there are several large scale efforts to determine population trends across the nation, the estimates tend to have wide margins of error. For example, a recent investigation of the golden eagle population in the western United Sates, based on the detection of 172 eagles in 148 aerial line transects across 12 western states, estimated a total population of 27,392, with a 90% confidence interval of 21,352 to 35,140, eagles (Good et al. 2007). However, this survey dealt primarily with the interior west; and large portions of the west, i.e. most of California, southern Nevada, southern Arizona, and southern New Mexico were not surveyed in this investigation, nor were coastal Oregon and Washington. Recent surveys by West Inc. reported low detections generally, and wide error on estimates of golden eagle density in the Mojave Desert of NV and California.

A.16.4 Habitat Model

While the three model algorithms generally predicted similar habitat arrangements throughout the County, the Random Forest (RF) models generally predicted more habitat, organized in less cohesive patches, than the other models, while the MaxEnt models tended to retain moderate values where other models predicted lower values (Figure A.16-1). Key areas of similarity among models in the County included the Sheep, Spring, Bird Spring, and Highland ranges, the McCullough and Lucy Gray mountains. Areas not well supported as habitat were large patches in the Mormon Mesa, Moapa Valley, Pahrump, lower elevation portions of Gold Butte, and the Lake Mead/Colorado river drainage (Figure A.16-1). Important differences in predicted habitat for this species occur in the Las Vegas valley, where the MaxEnt model predicts a patch of high suitability, while the others do not (Figure A.16-1).

The Ensemble model had high performance relative to other models, scoring the highest on all of the performance metrics AUC and BI, and with a similar TSS score (calculated on the blind testing dataset) as the RF model (Table A.16-1). Relative to the other models, the MaxEnt model had poor performance on the AUC and TSS metrics. Overall AUC performance was moderate, with no models performing above 0.8, while BI scores were relatively high. The GAM and MaxEnt models shared the top four influential environmental variables, where the CV and Average of Maximum temperature, Extreme Maximum temperature, and the sand component of the soils were the largest contributors (Table A.16-2). The RF model shared only the CV of Average of Maximum temperature in its top four contributing variables, and was more influenced by slope, minimum temperatures, and clay content. The standard error was relatively low throughout the County, where only the GAM model had values approaching (0.05 – which is not a value indicating large disagreement among models) which were located in small patches near Mt. Charleston (Figure A.16-2). The Continuous Boyce Indices showed good model performance in all algorithms (Figure A.16-3). The MaxEnt curve indicated some values of higher performance where point density was only moderate, indicating less discrimination between high and low habitat (Figure

A.16-3), this is likely due to the lack of lower suitability scores in areas with fewer points that retained moderate suitability scores (e.g. 0.5, Figure A.16-1).

Table A.16-1. Model performance values for golden eagle models giving Area Under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets. PRBE is given as the “precision recall break-even point” - threshold value for the ensemble model.

Model	AUC	BI	TSS	PRBE
Ensemble	0.77	0.98	0.43	0.52
GAM	0.75	0.98	0.39	
Random Forest	0.77	0.91	0.44	
MaxEnt	0.72	0.95	0.34	

Table A.16-2. Percent contributions for input variables for golden eagle for models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	12.6	6.7	0
Ave Min Temp	6.7	5.3	2.5
Average Spring Max Temp	12.7	3.5	21.7
CV Average Spring Max Temp	21	14.7	39.2
Clay	3.2	10	0
Extreme Max Temp	17.4	9	18.7
Extreme Min Temp	7.9	12.2	1
Sand	14.1	9	11.7
Silt	3.1	9.7	1.7
Slope	1.3	20	3.4

Figure A.16-1. SDM maps for golden eagle model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

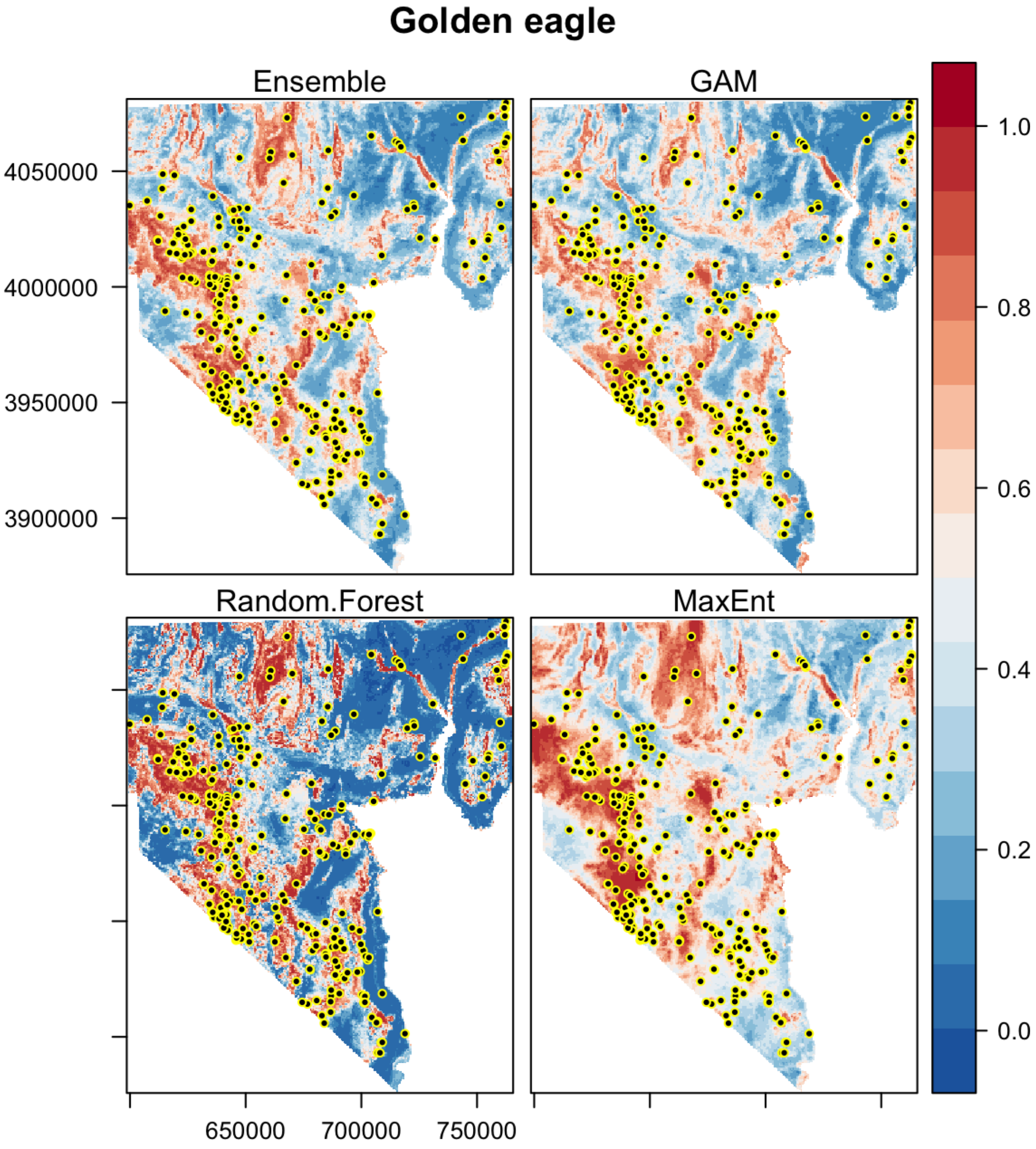


Figure A.16-2. Standard error maps for golden eagle models for each of three modeling algorithms used (GAM - upper left, Random Forest - upper right, Maxent - lower left), and an ensemble model averaging the three (Lower Right).

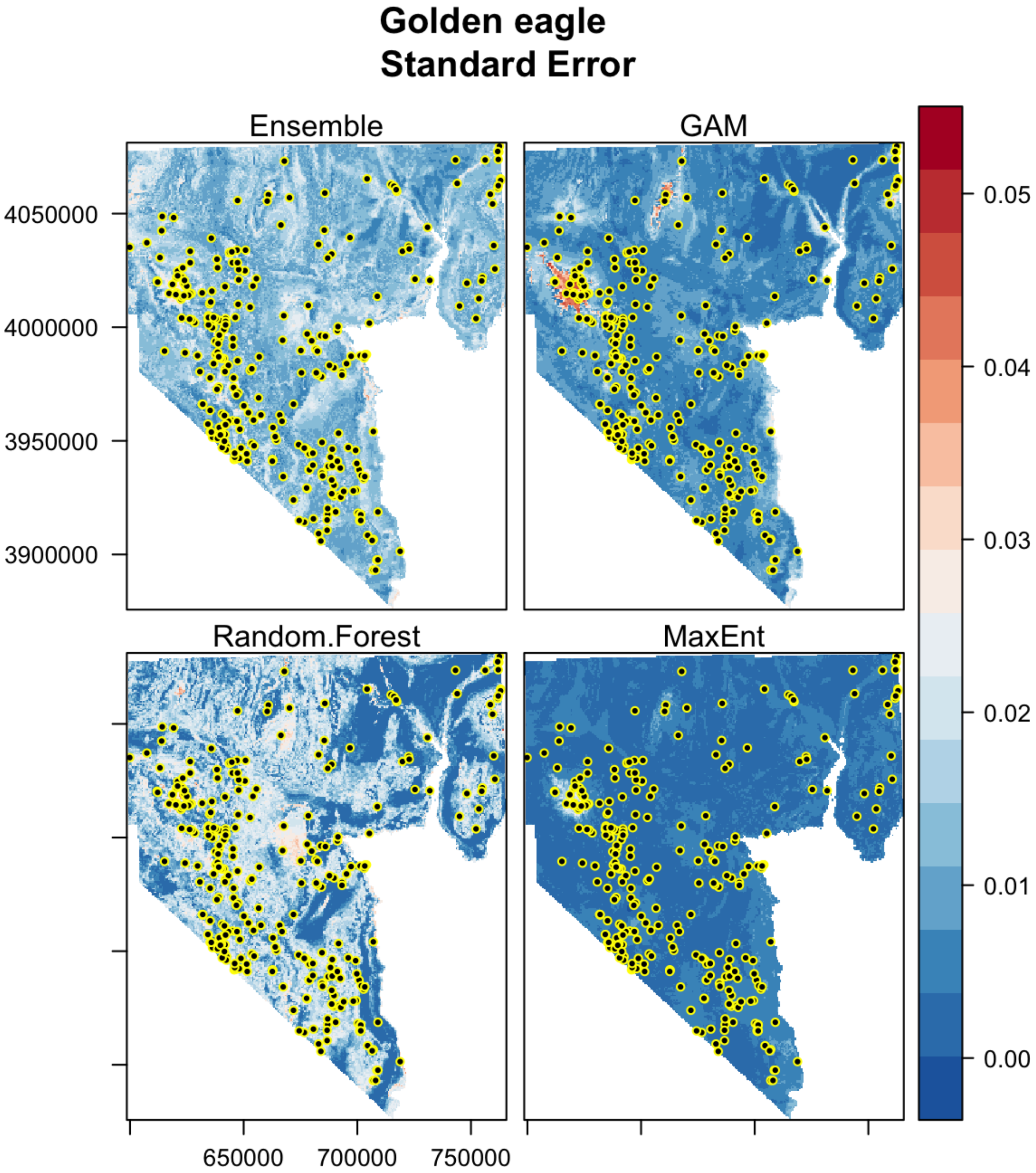
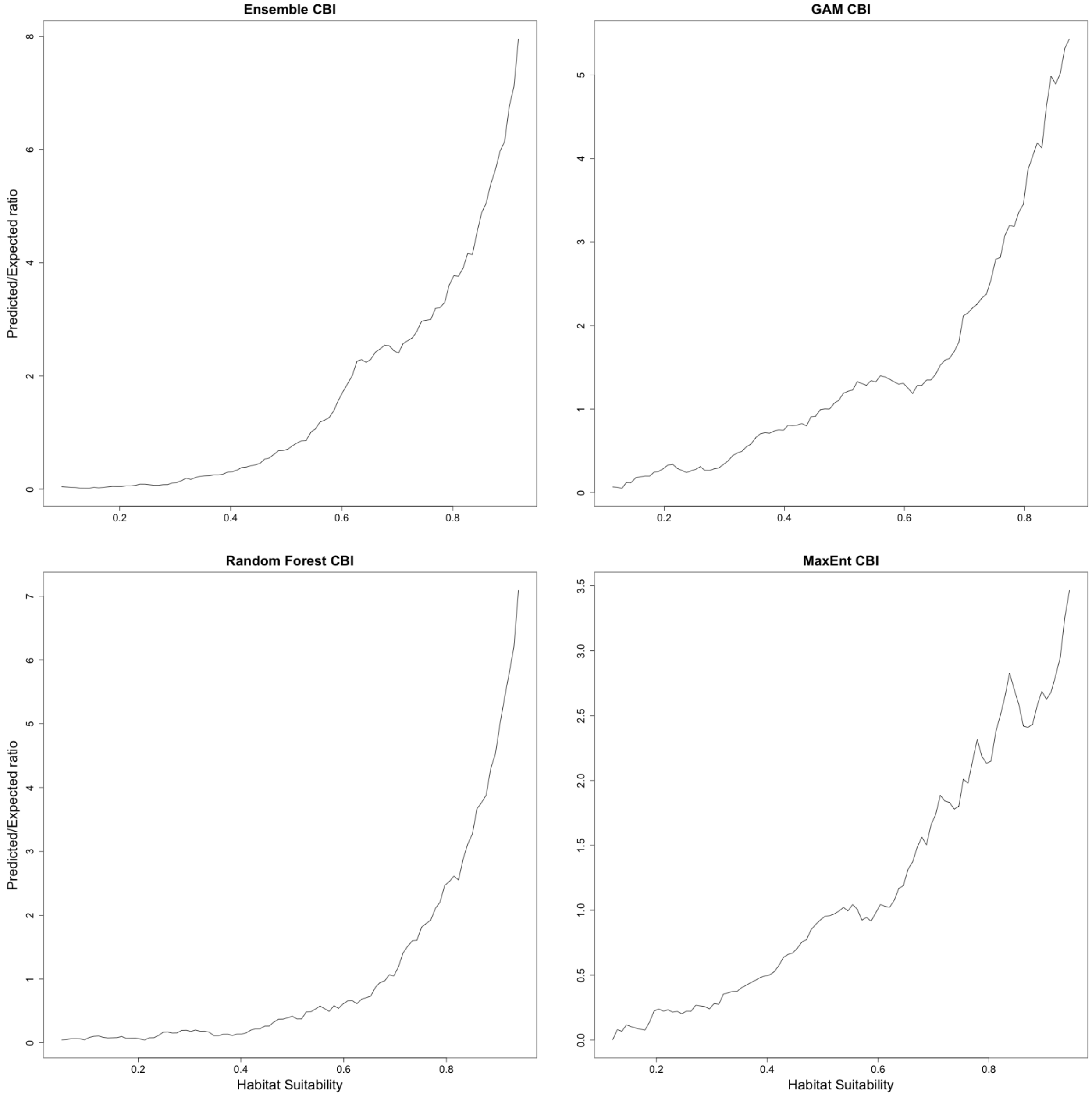


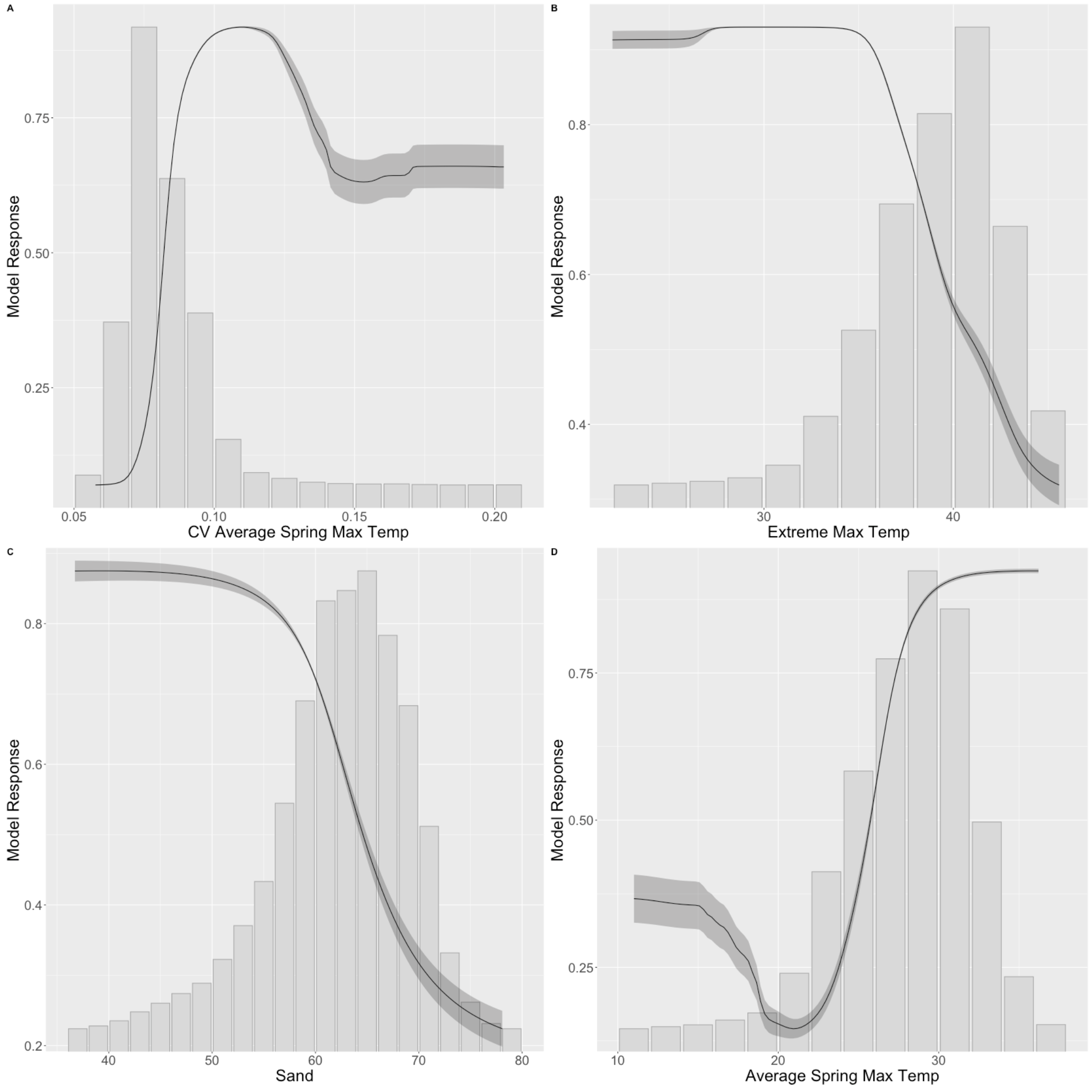
Figure A.16-3. Graphs of Continuous Boyce Indices [CBI] for golden eagle models for the ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).



A.16.4.1 General Additive Model

The top 4 contributing environmental layers were Average Maximum Temperature and its Coefficient of Variation, Extreme Maximum Temperature, and sand component of the soil collectively accounting for 65% of total model contribution (Table A.16-2). Model scores were higher in areas with cooler Extreme Max Temperatures (typically in the summer months, where the higher temperatures are well above 40 ºC) but with warmer Spring Maximum Temperatures (peaking above 30 ºC, Figure A.16-4). Model predictions peaked at temperature CV's slightly higher than the mean environmental values and remained relatively higher thereafter. Habitat was also predicted to be higher in areas with a much lower sand content than found in the County generally, with a strong negative response as sand content increased (Figure A.16-4). This algorithm had very low standard error values, indicating similar predictions among the 50 model cross-validation runs (Figure A.16-3). As stated above, there was only 1 patch of moderate error (0.05) located near Mount Charleston.

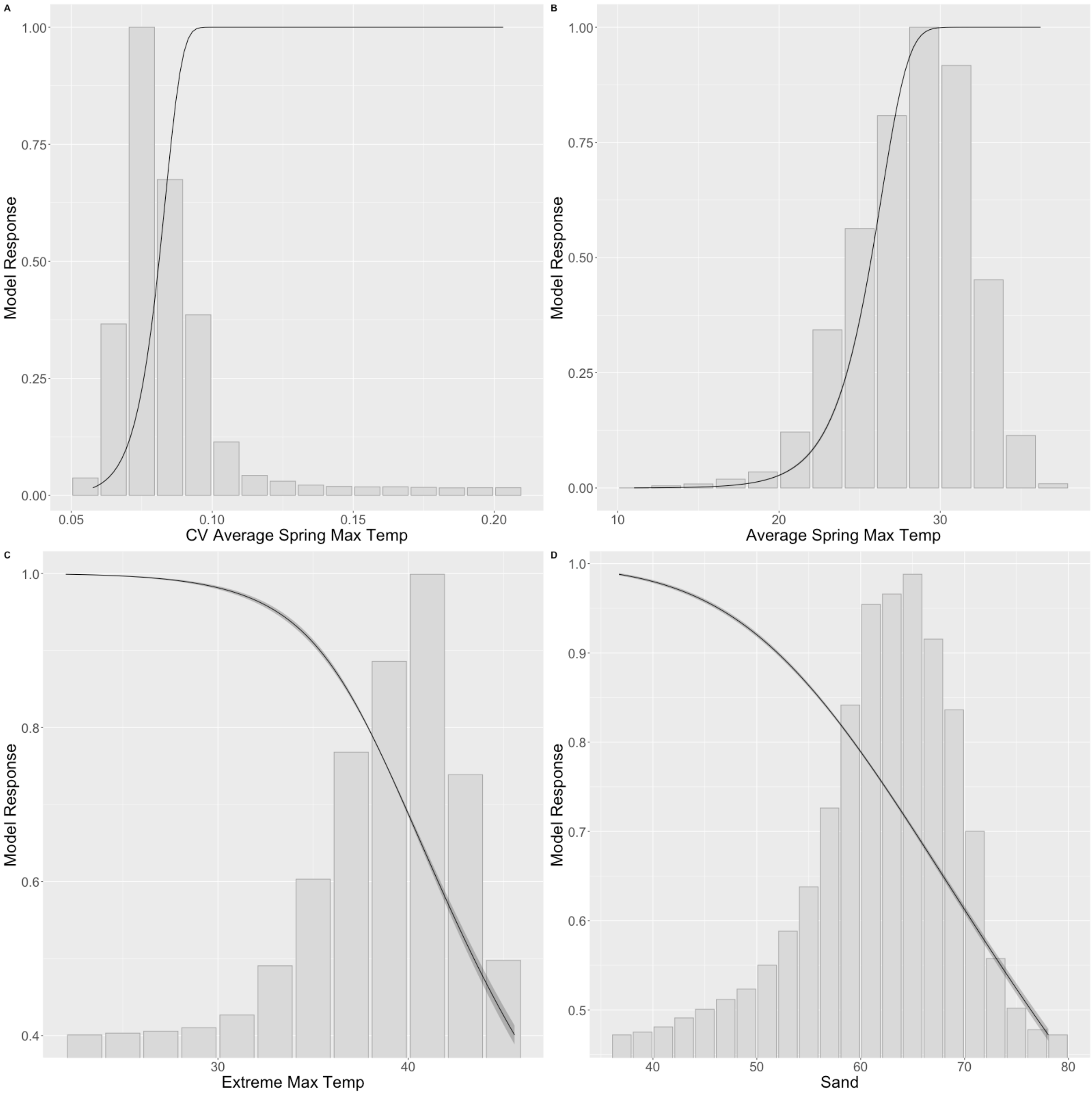
Figure A.16-4. GAM partial response curves for the top four variables in the golden eagle model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.16.4.2 MaxEnt Model

The Maxent models relied heavily on the same four top variables as those in the GAM models contributing 91% of total model contribution (Table A.16-2). This model also had very similar response curves among algorithms to the GAM model indicating relatively robust model selection (Figure A.16-4, Figure A.16-5). The predicted response for the CV of Average Spring Temperature showed the only difference, where there was no decrease in predicted suitability at high values, but rather a threshold response (Figure A.16-5).

Figure A.16-5. Partial response curves for the top environmental variables included in the Maxent ensemble model for golden eagle. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.16.4.3 Random Forest Model

The Random Forest model was largely driven by Slope, CV of Average Maximum Spring Temperature, Extreme Minimum Temperature, and Soil Clay Content (Table A.16-2). The collective model influence was 57%, where additional influence was proved by several other input variables (Table A.16-2). Slope indicated higher habitat suitability at both high and low values, which could indicate habitat predictions for the animals use of different habitat resources those for either nesting sites or foraging sites, as both types of data are present in this model (Figure A.16-6). The temperature variables indicated higher predicted habitat toward areas with warmer Spring Maximum Temperatures, and higher variability in Average Spring Maximum Temperatures. Habitat predictions relative to Soil Clay Content generally mapped the average available values in the County, remaining moderate at elevated values (Figure A.16-6).

Figure A.16-6. Partial response surfaces for the environmental variables included in the Random Forest ensemble model for golden eagle. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

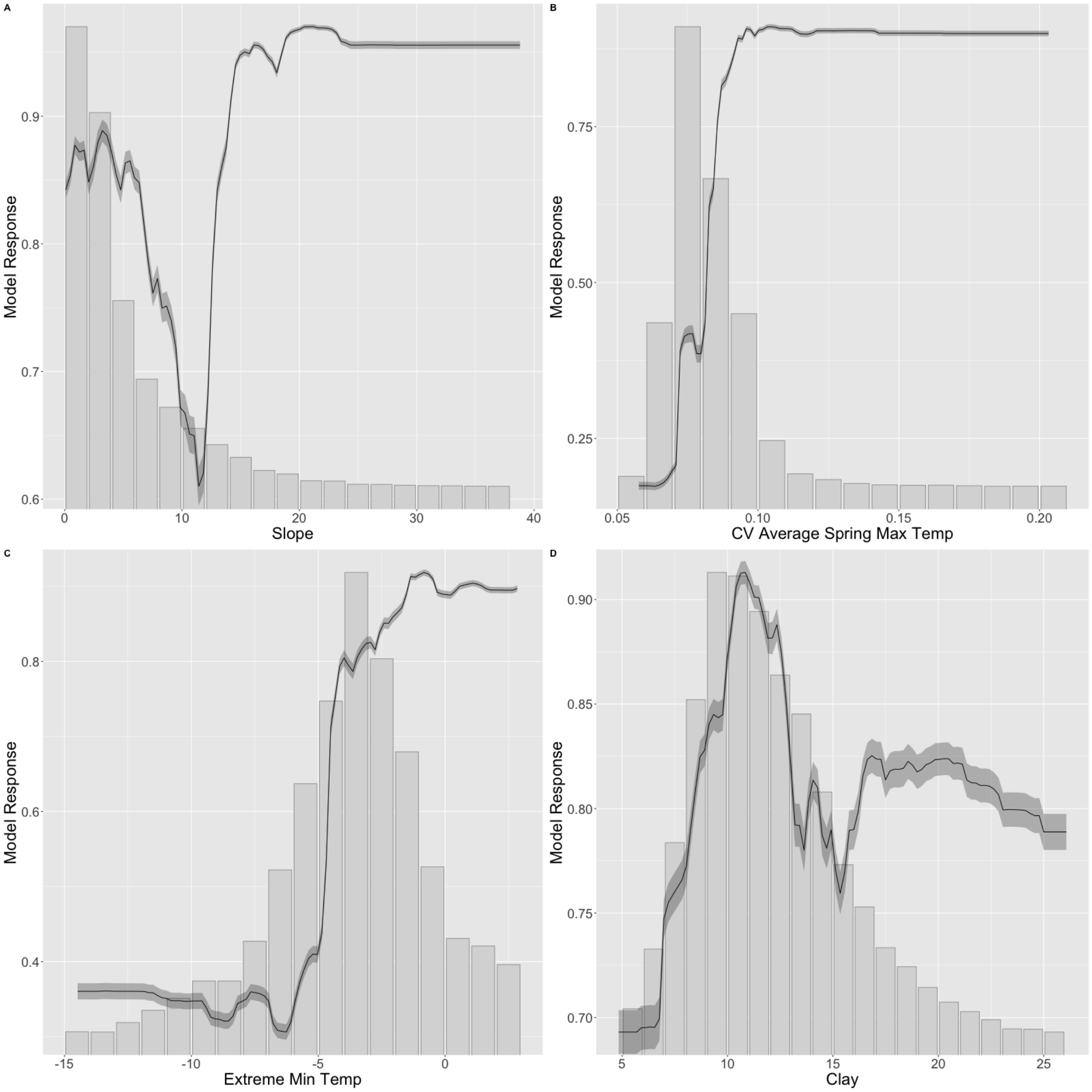


Figure A.16-7. SDM map for golden eagle Ensemble model for Clark County, NV.

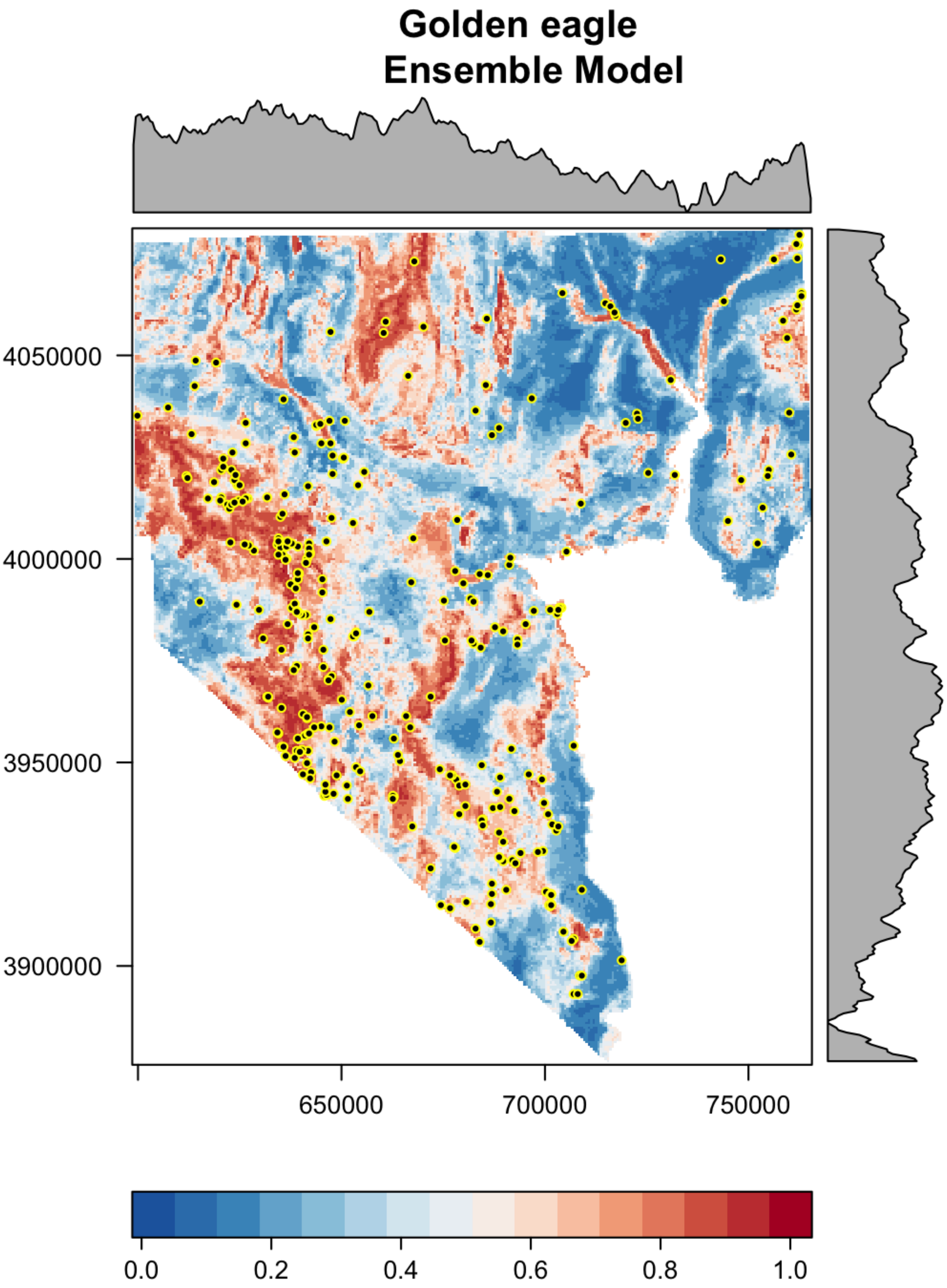
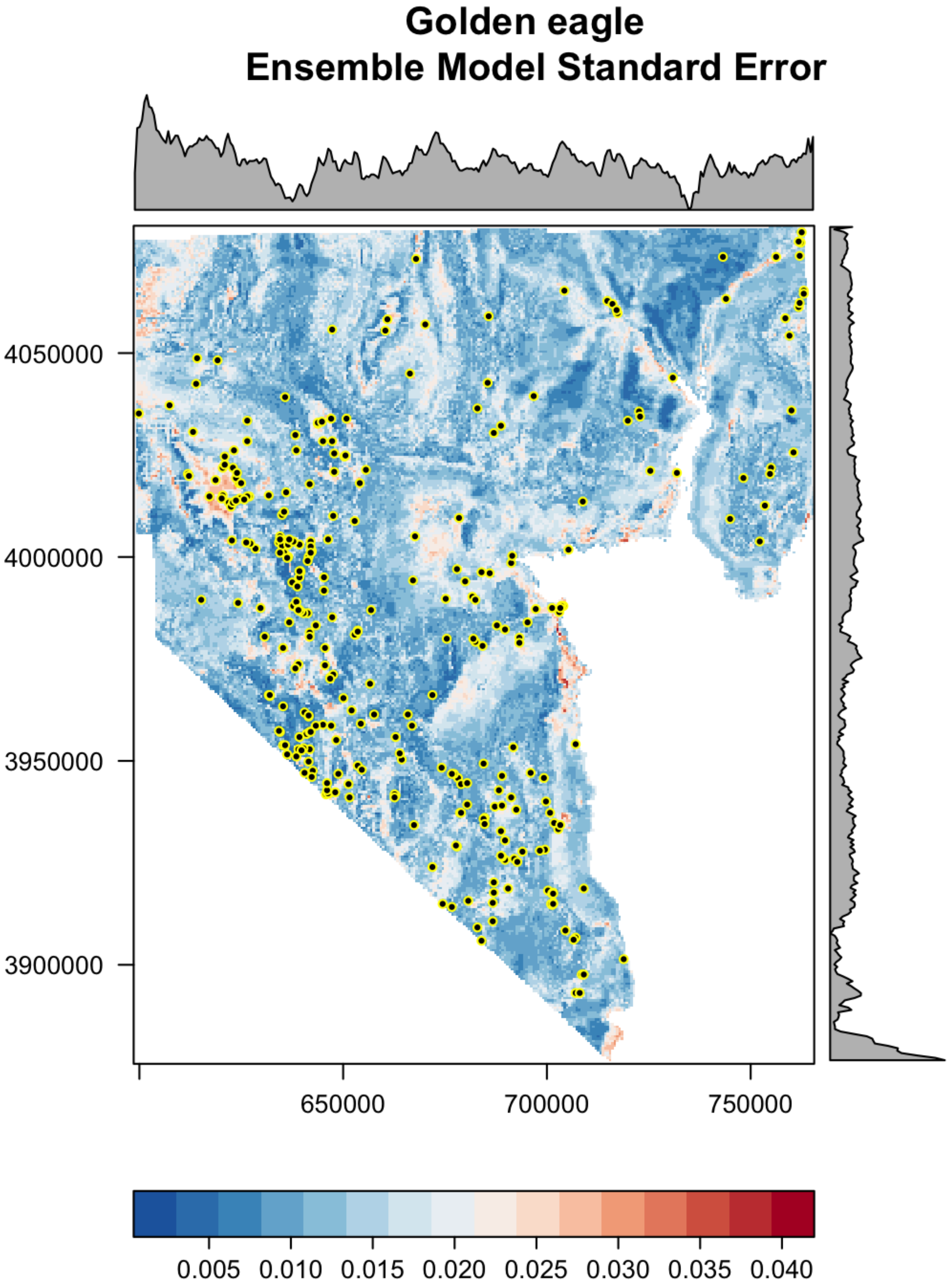


Figure A.16-8. Standard Error map for the golden eagle Ensemble model for Clark County, NV.



A.16.4.4 Model Discussion

This model depended on all available observations of this species, including nesting locations, as well as general sightings of individuals (e.g. foraging or flying). Golden eagles are spread relatively broadly across Clark County, NV (Figure A.16-7) . It should be noted that the species has a pan-hemispheric distribution, across North America and Eurasia, and that individuals can have extremely large home ranges. Home rang size exceeding 1,000 km^2 is not uncommon (Braham et al. 2015). However, predicted habitat for the County was relatively restricted to higher elevation areas, and areas connecting the mountainous areas along the North South oriented ranges in the western half of the County. The northeastern extent of the County, near Mormon Mesa was predicted to have lower habitat values, potentially due to the lower and flatter terrain associated with these areas, that may also experience higher maximum temperatures. Similar areas of lower habitat scores were predicted along the US 95 corridor, the immediate area surrounding Pahrump, CalNevAri, Laughlin, Eldorado Valley, and the area surrounding lake Mojave (Figure A.16-7).

The locality data for this species consisted of 1,304 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 660 records.

A.16.4.5 Standard Error

The standard error map for the ensemble model indicated relatively low error (0.02) throughout much of the study area (Figure A.16-8), with small pockets of moderate error (0.03) located in the Mt. Charleston area, at the Colorado River near Willow Creek, and other areas along the Lake Mead Shoreline. Overall errors were very low, indicating good agreement among the models used in the ensemble.

A.16.5 Distribution and Habitat Use within Clark County

Golden eagles nest in limited numbers throughout Clark County, Nevada. Every major mountain range and several smaller ones are occupied by resident golden eagles (unpublished NDOW raptor nest database). For example, there are multiple nests known from the Spring Mountains, Newberry Mountains, and McCullough Mountains. Modeled nesting habitat by the Great Basin Bird Observatory (Ammon 2015) was located largely within ecosystems classified as Mojave Desert Scrub and Blackbrush although it was restricted to mountains and cliffs within these ecosystems. Table A.16-3 shows the ecosystem types within predicted habitat suitability from the ensemble habitat model which included non-nesting locations.

Breeding pairs of golden eagles occupy and defend large home ranges with little overlap between the territories of pairs (Marzluff et al. 1997, Kochert 2002, DeLong 2004). Breeding season territories range in size from 20 to 54 km^2 (Kochert 2002). By contrast, in the Mojave Desert of southern California, golden eagle home ranges averaged 307.8 km^2 (SE± 66.4) (Braham et al. 2015). New technology that provides a high degree of spatial returns could partially account for the increased numbers on the newer analysis. In high density population with abundant nest substrate and high prey availability, occupied nests could be situated as closely as <1 km between neighboring pairs in some areas (Kochert et al. 2002). In Clark County, known adjacent nests are considerably further apart than reported in the literature (unpublished USGS golden eagle nesting database, NDOW raptor nest database).

Foraging has been documented in most the habitat types occurring in Clark County. Mojave desert scrub habitats in the expansive valley bottoms and outwash plains of Clark County comprise a great deal of the foraging areas, as do mountain slopes, and peaks (Longshore et al. *In Prep.*). Much of what we know about eagle habitat use comes from prey base studies. However, recent advances in tracking technology have provided opportunities to collect data on golden eagle movements relative to habitat use and foraging bouts. Golden eagles also forage near rural communities.

Furthermore, eagles also fly over urban areas, and have been observed flying directly over the city of Las Vegas (Longshore et al. *Unpublished Data*). While golden eagles are capable of taking large prey such as bighorn sheep (*Ovis canadensis*) lambs or mule deer (*Odocoileus hemionus*) fawns, studies of prey delivered at nests in Clark County indicate black-tailed jackrabbits (*Lepus californicus*), rock squirrels (*Otospermophilus variagatus*), and cottontail rabbits (*Sylvilagus auduboni*) comprise a great deal of prey items delivered to young eagles (Dawson 1923, Bent 1961, Johnson et al. 2015). Other items include many medium-sized mammals, birds, reptiles and even fish. Golden eagles also will eat carrion that is scavenged from road kill, escapees from sportsmen, or as refuse from agricultural activities (Olendorff 1976, Brown 1992, Kochert et al. 2002, Longshore et al. *In Prep.*).

Golden eagle nesting areas are frequently in remote mountainous areas, although a few are surprisingly close to human recreation sites (unpublished NDOW raptor nesting database). The known golden eagle nests in Clark County are all on cliff substrate. There are no known tree nests. In southwest Idaho, nesting density was found to depend on availability of good nesting substrate and territorial intolerance, but nesting substrate was more important than the latter factor (Beecham and Kochert 1975). Nests are large and made of sticks, often six feet across on the nesting platform with a central area lined with fine grasses, yucca leaves, pine boughs, and other materials. The accumulation of materials may be several feet thick, with extreme examples measuring upwards to 20 feet tall (Ellis et al. 2009). Most eagle nests have a commanding view of the surrounding area (Dawson 1923).

Resident golden eagle pairs generally remain in long-term pair bonds, but mates are sometimes lost due to a variety of reasons (e.g. mortality, intraspecies agonistic encounters), and in that case a mate may be replaced. Mates can be replaced rapidly, ranging from 1-8 days to replacement in Wyoming, if there are sufficient non- breeding adults in the local population (Philips et al. 1991). Courtship begins in December or January. Territories are often identified by the undulating flight of pairs, which is a behavior associated with courtship or territory defense in golden eagles (Harmata 1982). The behavior consists of a rise upward, tucking of the wings while continuing on a forward trajectory that dips, only to open the wings again and rise up and repeat that behavior (Dawson 1923). Fresh sprigs of vegetation such as pine boughs or *Ephedra* spp. In the Mojave Desert (Joe Barnes – NDOW, Pers. Comm.) may be brought to the nest as well, which is an indication of an occupied territory.

Activity near the nest is generally very secretive; however, undulating flights often occur in front of the nest cliff face. Usually one or two eggs are laid, but there has been documentation of three eggs and rarely four (Beecham and Kochert 1975). Eggs may be laid in February or March and require 41-45 days to hatch (see Kochert et al. 2002 and Watson 2010 for associated citations). For the first three weeks, nestlings are not able to thermoregulate on their own, thus are particularly vulnerable to disturbance. For about 4 weeks, the eaglets are downy white. Another four weeks their plumage emerges as dark brown feathers, and for the next three weeks they continue to develop. Fledgling plumage is a little darker than adults with white windows in the wings and at the base of the tail persists for one year. Full adult plumage is acquired at about four years of age. Fledgling eagles in Clark County are known to have travelled as far as the Pinacate Region of northern Sonora, Mexico on their first summer (Joe Barnes – NDOW, *personal communication*). Eagles that are too young to breed or unpaired adult birds are also known as floaters and may range continentally as they mature and seek their own territories (DeLong 2004).

Table A.16-3. Ecosystems within Clark County, and the area (Hectares) of Low, Medium, and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	113	10
Blackbrush	21339	188322	204437
Bristlecone Pine	0	3091	4442
Desert Riparian	207	4619	5335
Mesquite Acacia	5510	9535	5135
Mixed Conifer	0	491	26839
Mojave Desert Scrub	586508	555688	212613
Pinyon Juniper	2210	19448	94030
Sagebrush	23	2234	2435
Salt Desert Scrub	15322	43134	23881

A.16.6 Ecosystem Level Threats

Widely known and direct ecosystem level threats include electrocution from landing on small poorly configured power poles, collision with transmission wires, gunshots, vehicular collisions while pursuing prey or scavenging road kill, and toxicants such as lead shot from carcasses and misuse or non-targeted mortality by insecticides and rodenticides (DeLong 2004). With recent emphasis on renewable energy the proliferation of wind turbines to generate energy are the newest threat with considerable impacts to golden eagles in some areas of the western United States.

Those direct threat factors can often permeate the entire landscape. Indirect ecosystem level threats include lack of prey availability and habitat degradation due to land use changes from renewable energy development (particularly solar arrays), transportation and utility corridors, and urban development.

Power poles are an attractant to raptors, especially at locations with few natural perches, because they provide an aid to habitat surveillance for prey (APLIC 2006). Areas of higher prey density, may increase the attraction to these features. The broad wingspan of golden eagles increase their risk of electrocution by allowing them to span the distances between energized conductors and (APLIC 2006). The rates of golden eagle electrocutions may have declined during the past 30 years due to utility company efforts to reduce risk (APLIC 2006); however, electrocution risk is still great on many older or non-retrofitted utility lines in rural areas of Nevada (Joe Barnes and Cris Tomlinson – NDOW, Pers. Comm.).

While electrocution has long been known as a source of increased mortality on golden eagles, one study of 126 eagle carcasses along power lines indicated that 84% of the carcasses were killed by gunshot rather than electrocution (Olson 2001).

How wildfires affect prey populations for golden eagles is currently unknown, but the loss of cover over large areas of desert habitat could reduce jackrabbit abundance. Under similar circumstances of habitat conversion from shrubland to annual grassland in the Great Basin, eagles switched prey bases and average annual clutch sizes decreased (Steenhoff and Kochert 1988).

A.16.7 Threats to Species

All of the direct and indirect threats listed above are influential with this species.

Two of three eagles that were studied by USGS in Clark County in 2015 were killed prematurely. While one of them likely died in an encounter with a rival eagle, it also had measurable levels of rodenticide in its system. A second eagle, which also contained measurable levels of rodenticide, died from a collision with a car on Interstate 15 south of Mountain Pass, California. More data will be required to understand the role of poisoning in golden eagle populations.

Renewable energy development presents threats to golden eagles as well. First, wind energy is well documented for golden eagle mortalities due to wind turbine blade strikes. While wind energy is currently not a factor in Clark County, there are plans for increased use of this energy source in the future. Secondly, renewable energy (e.g. wind and solar) industries require extensive open spaces in open flat country that were once prime foraging areas for resident golden eagles. Thus, if enough habitat is converted to solar and wind farming there could be an influence on golden eagles, potentially through expanded territory sizes needed to support reproduction. Whether this would reduce fecundity, or the number if territories in the region is unknown. One important consideration of this scenario is that travelling greater areas may place the eagles in contact with more risk factors for mortality (Wiens et al. 2017).

Urban encroachment on Colorado’s Front Range (i.e., at the eastern foot of the Rocky Mountains), was attributed to the abandonment of historically-used golden eagle nests (Phillips 1986). Human disturbance or activity may cause nest abandonment, render a nest less productive, or prevent a suitable nest site from being used (GBBO 2010). Subsidized predators may also reduce the prey base in proximity to the ever- increasing boundaries of municipalities in Clark County (Esque et al. 2010).

A.16.8 Existing Conservation Areas/Management Actions

The golden eagle is federally protected by the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Lacey Act. The Nevada Wildlife Action Plan considers the golden eagle a Species of Conservation Priority, and recommends the following actions: protection of nesting and roosting sites, research to develop non-lethal wind turbine designs, and the continuation of helicopter surveys to monitor the population (Wildlife Action Plan Team 2012).

The Nevada Comprehensive Bird Conservation Plan considers the golden eagle a Conservation Priority Species, and recommends adequately managing habitat, including cliff nesting sites; managing habitats to encourage healthy prey populations; using Eagle Guards on transmission lines to minimize electrocution deaths; and the burial of mining drip lines to minimize risk of poisoning (GBBO 2010). Partners in Flight's population objective for the golden eagle is to increase the statewide population from 6,200 individuals to 6,800 individuals (Rosenberg 2004).

Both the Nevada Wildlife Action Plan and Bird Conservation Plan emphasize a need for improved monitoring to inform adequate and quantified population trends. Recent state-wide efforts by NDOW have been focused on compiling an inventory of existing cliff-nesting raptor nests, with emphasis on golden eagles, and were not designed to assess territory status or population size (Joe Barnes and Cris Tomlinson – NDOW, *personal communication*).

A.17 WESTERN BURROWING OWL (*ATHENE CUNICULARIA HYPUGAEA*)

The burrowing owl (*Athene cunicularia hypugaea)* was classified by the US Fish and Wildlife Service (USFWS) as a Category 2 candidate for consideration to be listed as threatened or endangered from 1994 to 1996 before the classification was discontinued in 1996 without listing. The species is currently listed as a Bird of Conservation Concern by the USFWS within the Mojave Desert Bird Conservation Region (BCR: USFWS 2008), is protected under the Migratory Bird Treaty Act (MBTA) of 1918 as amended (16 USC 703-712), and is listed on the Convention on International Trade in Endangered Species, Appendix II species list (McDonald et al. 2004).

A.17.1 Species Status

US Fish and Wildlife Service Endangered Species Act: No Status

Migratory Bird Treaty Act: Protected

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No Status

State of Nevada: Protected

NV Natural Heritage Program: Global Rank G4T4, State Rank S3B

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Redlist (v 3.1): Least Concern

CITES: Appendix ii

A.17.2 Range

The western burrowing owl is one of two subspecies of burrowing owl that currently reside in the US The western subspecies (*A. c. hypugaea*) of burrowing owl ranges across most of the western North America from south-central Manitoba, south to Brownsville, Texas, west to the California coast, and north to southern British Columbia (Neel 1999).

A.17.3 Habitat Model

We modeled burrowing owl habitat using 382 point localities distributed largely in the center of the County in a North to South band. The patterns of predicted suitability produced by the three modeling algorithms represent gradient of broad to reduced habitat area being predicted. The GAM model predicted suitable habitat most broadly, followed by the RF model, and finally with the MaxEnt model predicting the most restrictive habitat (Figure A.17-1). As a result, the Ensemble model was most similar to the RF model. Habitat is predicted throughout southern and northeastern Clark County, especially within the valleys and bajadas. (Figure A.17-1).

The random Forest Model had the highest performance among all four models, followed by the Ensemble model (Table A.17-1). The MaxEnt and Ensemble models had similar measures overall, while the GAM model had the lowest performance across all 4 metrics, with TSS and Correlation scores 10 points below the others (Table A.17-1).

The Continuous Boyce Index [CBI] indicated strong performance among all models with an indication of an underperforming model in the GAM (Figure A.17-3). Standard Errors were lowest for the GAM model (which had the lowest performance), the RF model had low to moderately low error patches, while the MaxEnt model had patches of higher Standard Error in the Moapa valley area. The Ensemble model indicated moderately low error (0.04 – 0.06) in the northeastern portion of the County (Figure A.17-2). Approximated bins for the ensemble model based on the CBI were 0-0.5 unsuitable, 0.5-0.55 marginal, 0.55 to 0.6 suitable, and > 0.62 optimal habitat; with a suggested cutoff threshold near 0.58 (Figure A.17-3) and the threshold value calculated from the AUC analysis for the ensemble model was 0.55 (Table A.17-1).

Table A.17-1. Model performance values for western burrowing owl models.

Performance	GAM	RF	MaxEnt	Ensemble
AUC	0.90	0.98	0.94	0.96
BI	0.85	0.89	0.89	0.89
TSS	0.70	0.90	0.78	0.82
Correlation	0.71	0.87	0.79	0.81
Cut-off	0.56	0.59	0.43	0.55

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.17-2. Percent contributions for input variables for western burrowing owl in an ensemble model combining GAM, MaxEnt, and RF algorithms.

Term	GAM	RF	Max	Average
Annual Heat/Moisture Index	4.1	11.9	2.8	13.2
Winter Precipitation	11.4	9.8	6.0	14.8
Summer Precipitation	0	0	0	0
Summer Maximum Temperature	0	11.5	5.0	12.3
Winter Minimum Temperature	46.7	11.5	24.5	34.3
Temperature Range	0	8.7	6.5	10.2
NDVI Amplitude	0.7	4.9	0.5	4.9
NDVI Maximum	0	0	0	0
Surface Texture (ATI)	0	12.3	9.4	14.4
Slope	9.2	12.5	1.5	15.1
Topographic Position (TPI)	27.9	16.9	43.7	39.4

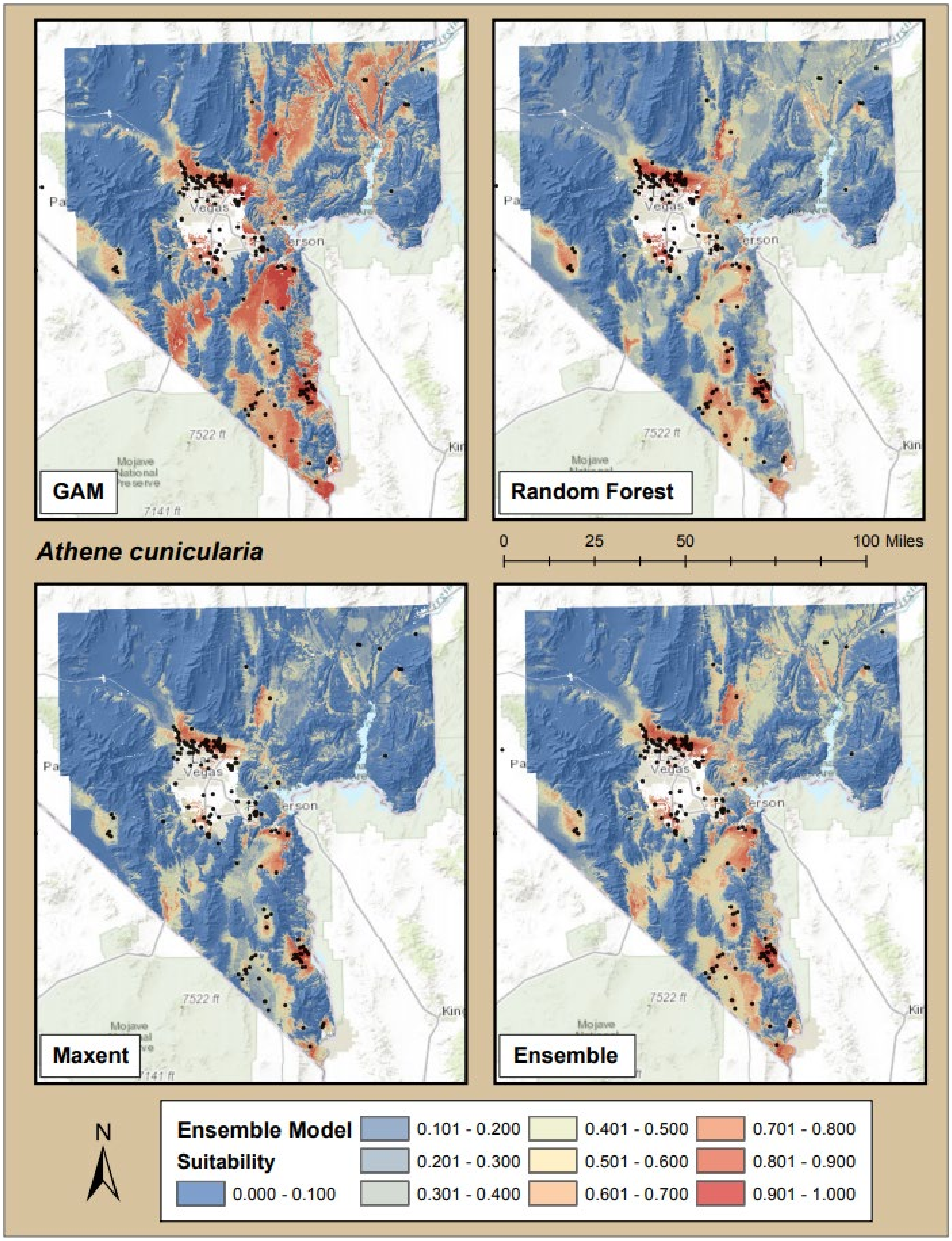


Figure A.17-1 SDM maps for western burrowing owl for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

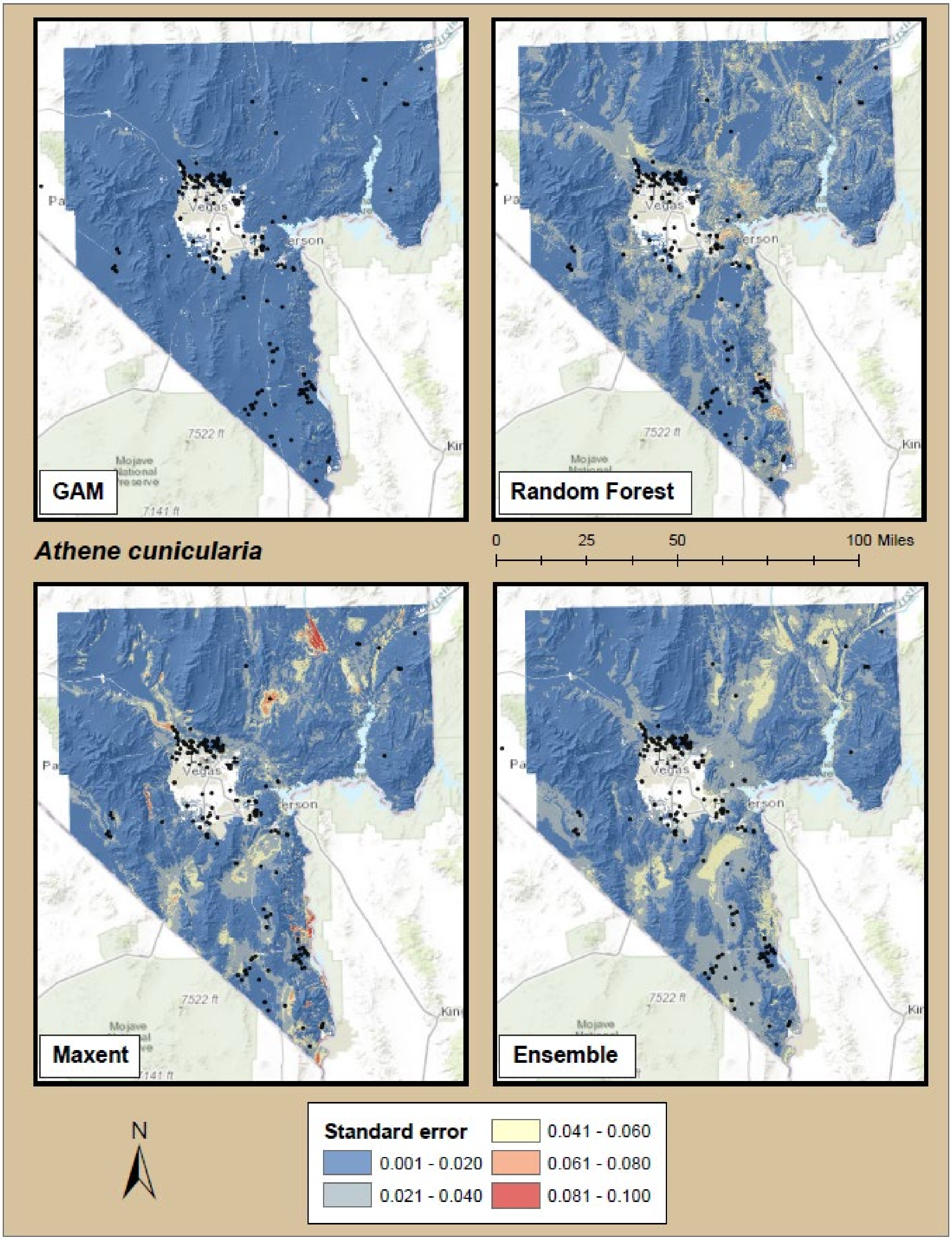


Figure A.17-2. Standard error maps for western burrowing owl models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

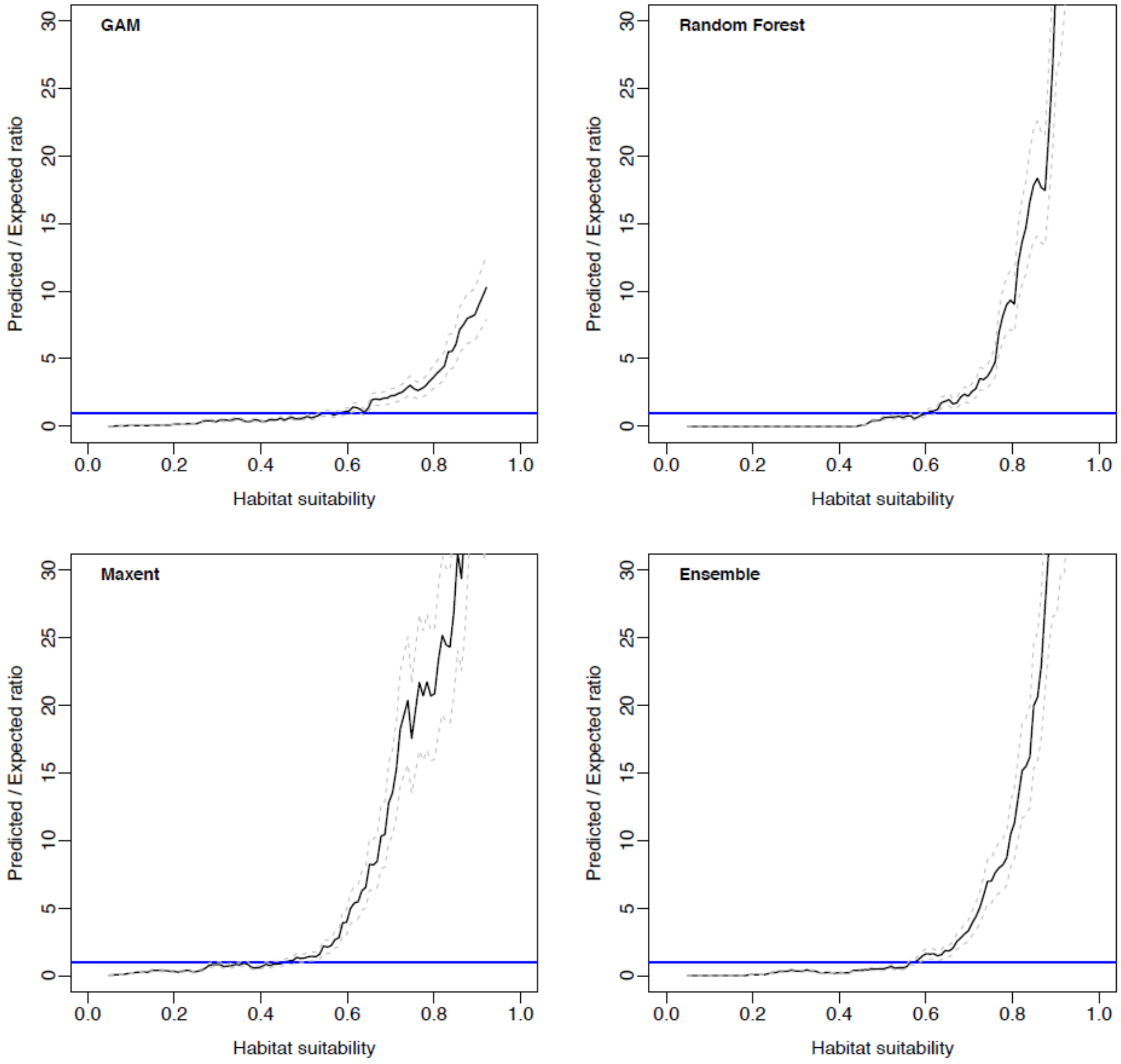


Figure A.17-3. Graphs of Continuous Boyce Indices [CBI] for western burrowing owl models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

A.17.3.1 General Additive Model

Four variables in the GAM ensemble contributed 9% or more to the models, collectively accounting for 95% of total model contribution (Table A.17-2). Winter Minimum Temperature had the largest contribution (47%), and predicted a threshold type response, with positive suitability predicted above average minimum temperatures of 0 ºC (Table A.17-2, Figure A.17-4). Topographic Position (28%) had a peaked response, where habitat was predicted to be positive above 9, peaking at ~ 11.5, and declining afterward with the prevalence of this feature within the County (Figure A.17-4). Winter Precipitation contributed 11% to the model, and had a positive response above ~ 150 mm, and also as lower levels below 70 mm, which is perhaps an artifact of the curve fitting. (Figure A.17-4). The GAM model had a 9% influence due to slope, which had a negative relationship with predicted habitat suitability (Figure A.17-4).

Like many other species, the GAM model predicted the largest extent of habitat for this species. There were large areas of highly suitable habitat predicted for southern through northeastern Clark County (Figure A.17-1). General areas of the highest prediction included valleys and bajadas near Jean, Ivanpah, Piute, Eldorado, Laughlin, Avi, North Las Vegas Valley, Coyote Springs, Hidden Valley, Apex, Mormon Mesa, and Moapa Valley (Figure A.17-1). Standard error for the models within this algorithm were generally low throughout the County, indicating that models within this ensemble predicted similar habitat (Figure A.17-2), but this did not equate with the highest performance (Table A.17-1).

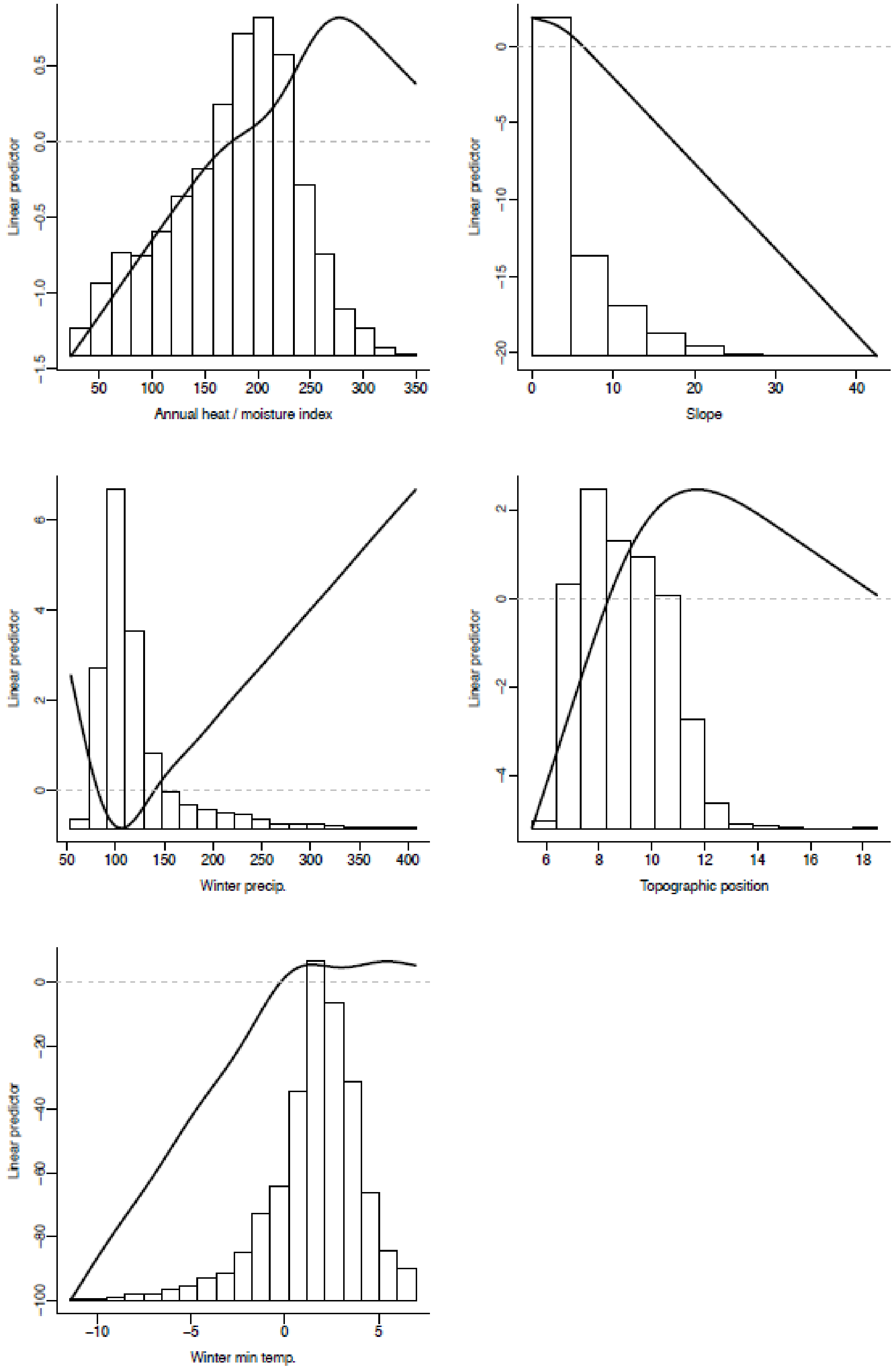


Figure A.17-4. GAM partial response curves for the western burrowing owl model overlaid over distribution of environmental variable inputs in the study area.

A.17.3.2 MaxEnt Model

The MaxEnt model had three variables contributing 10% or more each, accounting for 78% of model contribution. Topographic Position (44%) was the strongest contributor, with a strongly positive non-linear response with predicted suitability (Figure A.17-5). Winter Minimum Temperature accounted for 25% of model performance, with a generally positive response to increasing average minimum winter temperature with a strong positive influence above 0ºC. Surface Texture (9.4%) also had a positive response with increasing values, corresponding with reduced substrate size, indicative of surfaces that are very smooth, such as soils comprised primarily of sand, loam, and silt, or sandier areas (Figure A.17-5). Three additional variables contributed 5-7% (i.e. Temperature Range, Winter Precipitation, Summer Maximum Temperature - Table A.17-2). Habitat prediction for this model indicated suitable habitat in Piute and Eldorado valleys with areas of mixed quality, patches of high suitability habitat near Laughlin, and the Nelson area, north Las Vegas Valley, and Apex (Figure A.17-2). Despite the concentration of localities in nearby North Las Vegas the northeastern extent of the county has a paucity of known localities and little habitat was predicted there by this algorithm (Figure A.17-1). It is not clear if this is a true representation of habitat, or an artifact of a truncated sampling effort – but more surveys in this area would be beneficial to determine the underlying causes of this modeled pattern. Standard Error was low (0.02 – 0.04) to moderate (0.04 – 0.06) in Eldorado and Jean, and in the US 95 habitat corridor (Figure A.17-2). Patches of high Standard Error (0.08 – 1.0) were seen in Apex, and Moapa, with some sections along the Colorado River as well (Figure A.17-2).

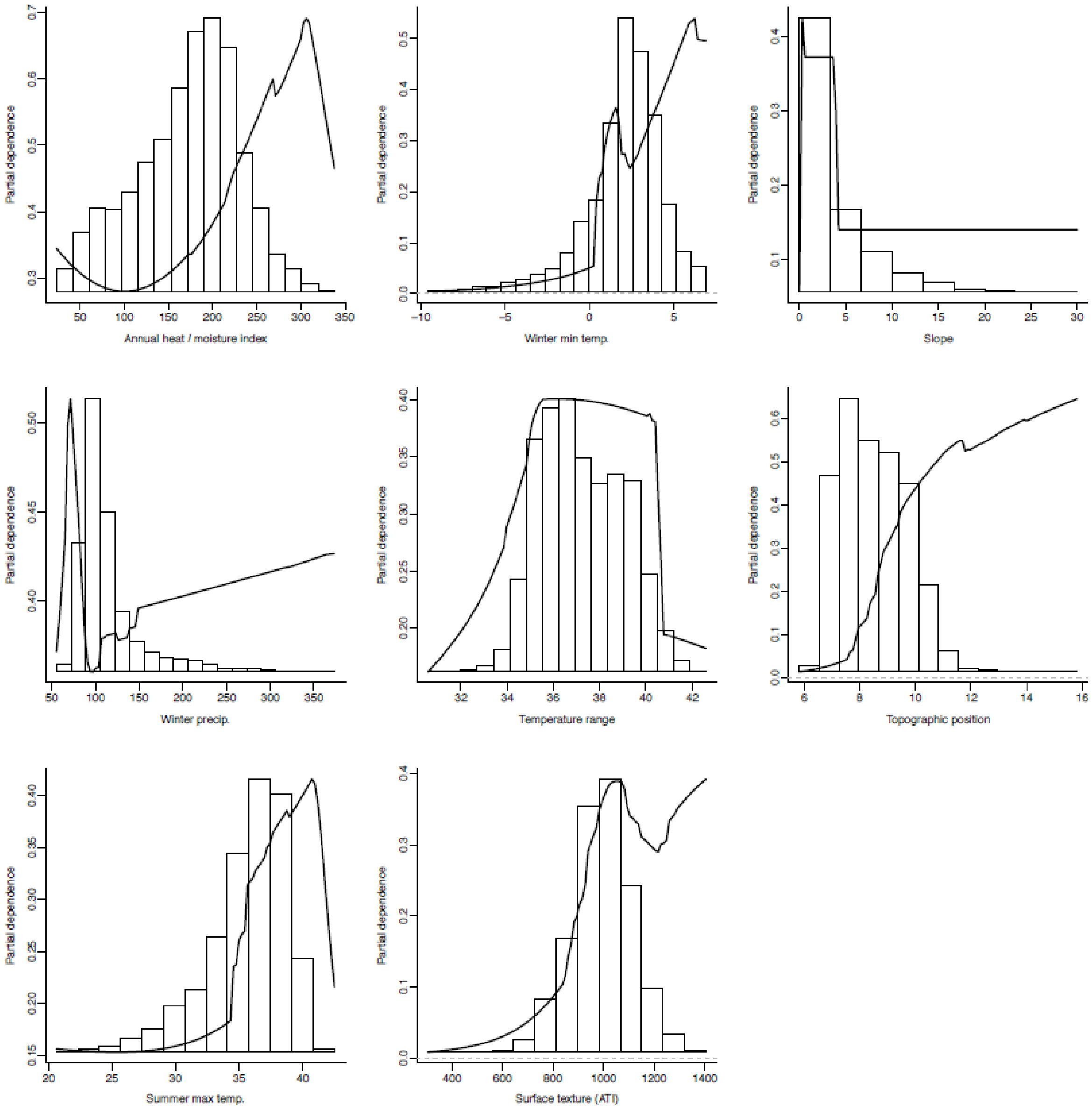


Figure A.17-5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for the western Burrowing Owl.

A.17.3.3 Random Forest Model

The RF models had seven environmental variables contributing ~ 10% or more collectively accounting for 86% of the total model influence, with two additional variables also contributing (Table A.17-2). The most significant contributing variables were: Topographic Position (TPI), Slope, Surface Texture (ATI), Annual Heat/Moisture Index, Winter Minimum Temperature, Summer Maximum Temperature, and Winter Precipitation.

Topographic Position (17%) was the highest contributing variable, with a threshold type response predicting habitat to be suitable above levels of 8 and peaking at 11 (Figure A.17-6). Slope was the second highest contributor (13%), with a strongly negative relationship, and habitat unsuitable in areas with greater than 5º slope (Figure A.17-6). Surface Texture (12%) had an irregular response in this model, with habitat predicted to be higher in areas with both low and high levels of this metric. Annual Heat/Moisture Index (12%) also had a threshold response, with suitability increasing strongly at levels above 200, indicating an association with hotter dryer areas (Figure A.17-6). Winter Minimum Temperature (12%) and Summer Maximum Temperatures (12%) had similar responses, with habitat predicted for areas with higher overall temperatures. Habitat was also predicted to be higher in areas with lower Winter Precipitation (Figure A.17-6), which had a contribution of 10%, and likely indicating the preference of Burrowing Owls for open areas with low density and structure of perennial vegetation.

Standard error maps for this model indicated mostly low (0.02 to 0.04) error rates generally on bajadas throughout the southern and northeastern portions of the County (Figure A.17-2). There are a few relatively small patches of moderate (0.04 – 0.06) SE intermixed throughout the eastern portion of the county (Figure A.17-2). Habitat suitability was predicted to be highest on the northern edge of Las Vegas Valley, the large valley between Searchlight and Cottonwood Cover, Piute Valley, Laughlin, Avi, Sloan Canyon, Trout Canyon, and Apex. In the Eldorado Valley there is a noticeable area of higher habitat suitability predicted toward the eastern side of the valley and above the lowest portions of the drainage in the Boulder City Conservation Easement area (Figure A.17-1).

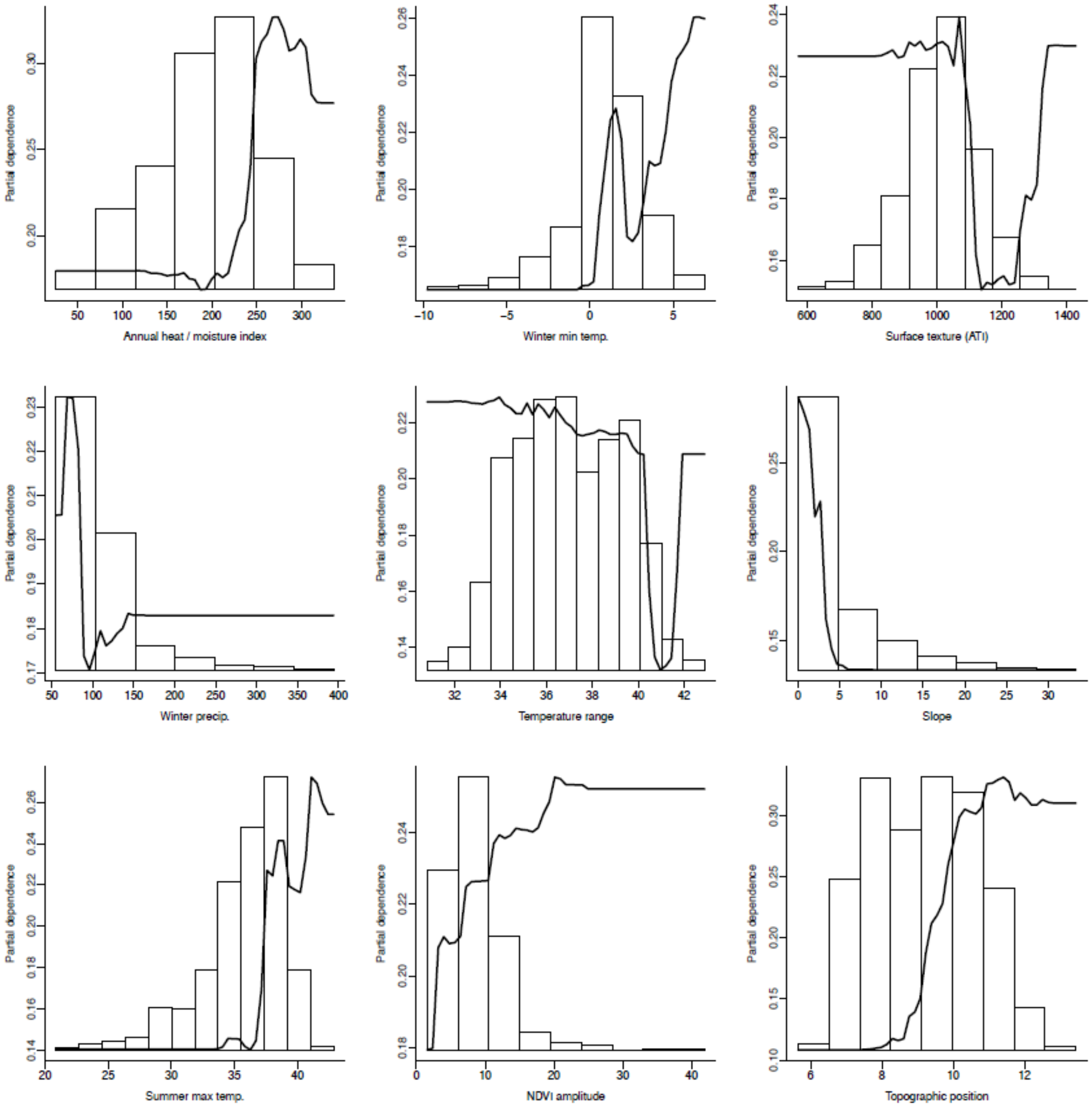


Figure A.17-6. Partial response surfaces for the environmental variables included in the RF ensemble model for western Burrowing Owl. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat

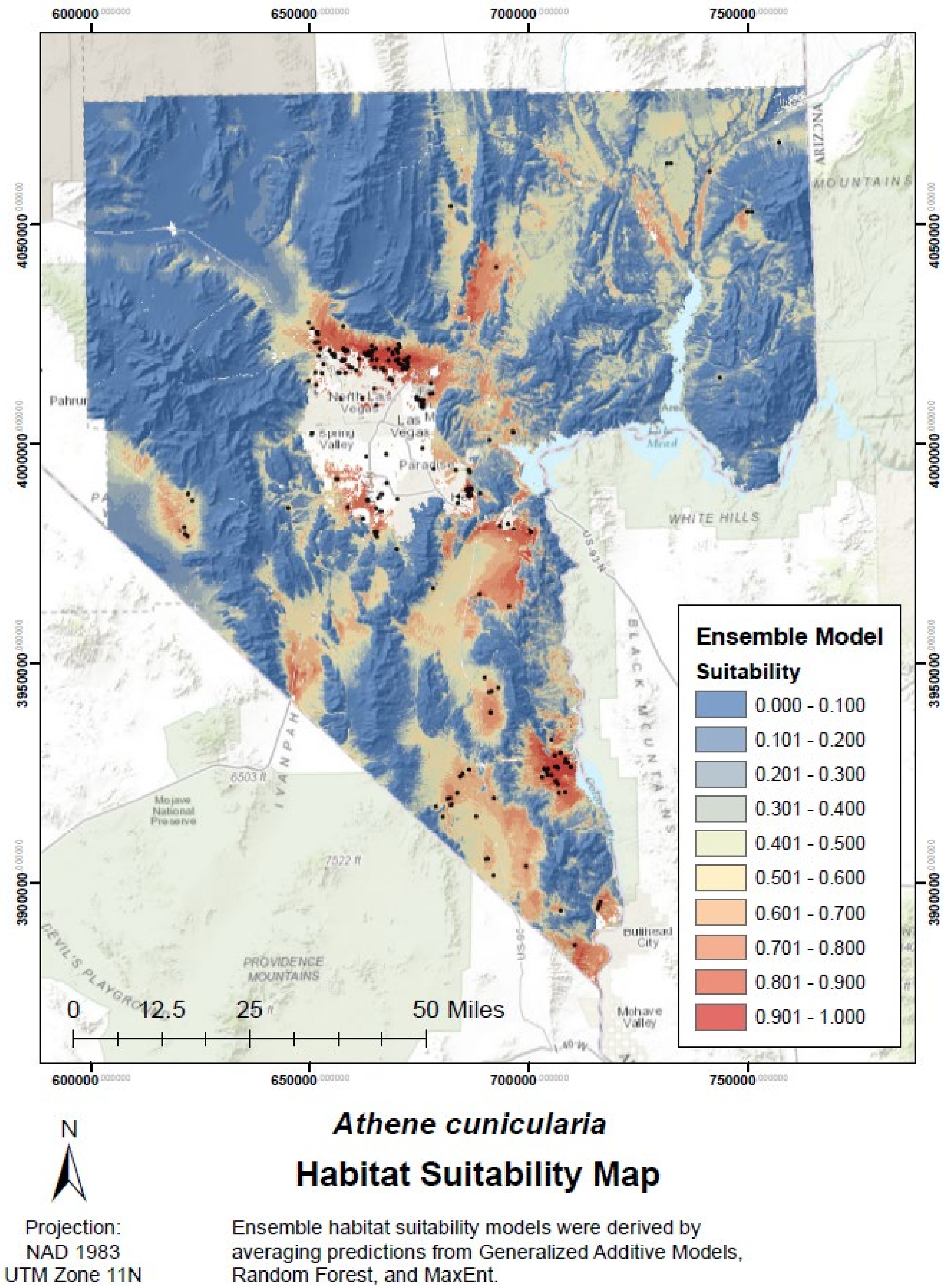
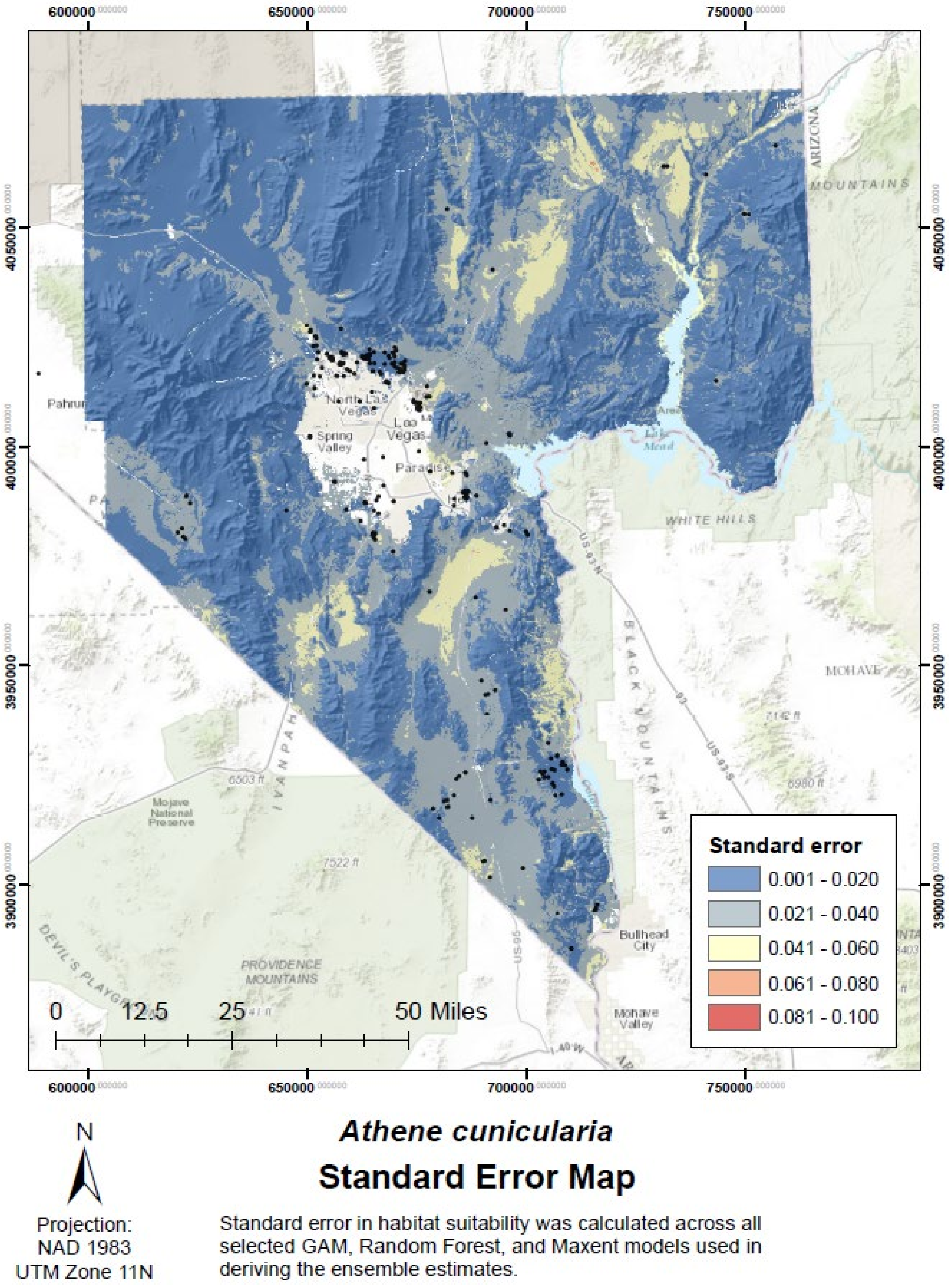


Figure A.17-7. SDM map for the western burrowing owl Ensemble model.



Athene cunicularia

Standard Error Map

Projection:
NAD 1983
UTM Zone 11N

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

Figure A.17-8. Standard Error map for the western burrowing owl Ensemble model.

A.17.3.4 Distribution of Localities

Localities (N=382) for Athene cunicularia were used for modeling, and are distributed along the eastern edge of the county below Las Vegas, all around the Las Vegas Valley, with a few smaller pockets of points in Apex, Mormon Mesa, and

northern Gold Butte, and Trout Canyon (Figure A.17-7). The marked absence of observation points and predicted habitat in the northwest portion of the county on the Nellis Bombing Range and the Nevada National Security Site should be considered further to determine if this pattern represents the species accurately or is an artifact represented by a lack of survey points in this area.

A.17.3.5 Standard Error

Moderate Standard Error (0.04 – 0.06) is predicted along the I-15 corridor northeast of Las Vegas, in Moapa, Mormon Mesa, and in Eldorado and Ivanpah valleys, as well as some of the area between Cottonwood Cove and Nelson (Figure A.17-8).

A.17.4 Distribution and Habitat Use within Clark County

The burrowing owl is a breeding resident in southern Nevada, generally preferring open, arid, and treeless landscapes. Some individuals may reside year-round; however, most will migrate south to the extreme southern US and Mexico during the winter months (Haug et al. 1993). This species is not known to construct their own burrows, and tends to be most common in habitats where suitable burrows already exist (Floyd et al. 2007). In the north end of their range they are largely dependent on prairie dog (Cynomys spp.) colonies for burrow sites, while in the southern portion of their range, owls may use a variety of mammal burrows (ground squirrel [Spermophilus spp.], skunk [Spilogale spp., Conepatus spp., Mephitis spp.], fox [Urocyon spp., Vulpes spp.], or coyote [Canus latrans]) and will use Mojave Desert Tortoise (Gopherus agassizii) burrows throughout the Mojave and Sonoran deserts (Klute et al. 2003, McDonald et al. 2004). In southern Nevada, Burrowing Owls most used Mojave Desert Tortoise burrows. For this reason, the distribution of Burrowing Owls in Clark County largely overlaps that of the Mojave Desert Tortoise. Burrowing Owls have also been known to breed in isolated desert patches within urban landscapes and in these situations will often respond positively to habitat enhancement, such as the installation of artificial nest sites (Klute et al. 2003).

Burrowing Owls are fairly tolerant of human disturbance and will often breed around the fringes of agricultural lands and use crop and pasture lands for foraging throughout the breeding season (Nevada Partners in Flight 1999). In 2008, the Urban burrowing owl Monitoring Project, sponsored by the USFWS and the Red Rock Audubon Society, reported a relatively high number of breeding Burrowing Owls in urban areas in the north end of the Las Vegas Valley with some even nesting in man- made structures, including a hole under a sidewalk and under an old box spring mattress (Manville 2009).

The Western burrowing owl is a widely ranging species that is found in open habitats containing several vegetation types including intermountain cold desert scrub, sagebrush, grasslands and meadows, Mojave Scrub (shrub), and some developed landscapes throughout Clark County (Haug et al. 1993, Johnsguard 2002, Wildlife Action Plan Team 2012). Earlier efforts at species distribution modeling efforts for the Mojave Desert in southern Nevada confirmed these general preferences, and reported positive associations with winter and summer precipitation, and negative associations with slope and perennial cover (Crowe and Longshore 2010).

The highest modeled habitat area was in the Mojave desert scrub ecosystem, which also contained the most moderate habitat (Table A.17-3). Moderate habitat was also high in blackbrush, although much more habitat area in blackbrush was scored as low.

Recent transects in Clark County detected low densities of owls in Mojave Desert Scrub habitats, and no observations of owls in blackbrush or pinyon-juniper habitats (Crowe and Longshore 2010b), while our model/ecosystem overlay indicates a gradient of habitat possible in blackbrush, and confirms that Pinyon Juniper Habitats are unlikely to coincide with burrowing owl habitat. Higher numbers of owls, were noted in Gold Butte, Piute Valley, eastern slopes of Eldorado Valley, and bajadas on the western side of Lake Mojave in Lake Mead National Recreation Area (Crowe and Longshore 2010b).

Modeled habitat in the County is predicted to be highest in north of Las Vegas, within Eastern Eldorado Valley, Ivanpah Valley, most of Piute Valley, and especially the bajadas above Laughlin (Figure A.17-7). Slightly lower habitat suitability is predicted along the I-15 corridor, through the Moapa Valley, Mormon Mesa and Virgin and Muddy river valleys, in the valley east of Searchlight and all the way to the Colorado River, and also habitat patches predicted in Gold Butte (Figure A.17-7). This model greatly extends the predicted habitat identified in the model constructed by Crowe and Longshore (2010b), which predicted similar habitat extent in the Piute and Eldorado Valley, but did not include the areas of high suitability identified here in northern and southwestern Las Vegas (Figure A.17-7).

Table A.17-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	393636	21254	482
Bristlecone Pine	7565	0	0
Desert Riparian	1182	4453	5015
Mesquite Acacia	6507	8234	4924
Mixed Conifer	27339	0	0
Mojave Desert Scrub	675979	425286	178538
Pinyon Juniper	115854	0	0
Sagebrush	4707	0	0
Salt Desert Scrub	67415	7788	3551

A.17.5 Ecosystem Level Threats

Burrowing Owls are declining throughout much of North America with declining populations and range contractions throughout southern Canada, the Great Plains, and many western states. Declines are associated with habitat loss and fragmentation due to agricultural and urban development (Sheffield 1997, Milsap and Bear 2000, Ayers 2003). The most recent cause for loss of habitat is large-scale renewable energy development for solar and wind energy generation. Many reported population declines of this species have been correlated with the declines of mammal species, particularly prairie dogs, on which the burrowing owl relies for burrow sites (Haug et al. 1993, Desmond et al. 2000), although, prairie dogs do not occur in Clark County. However, Burrowing Owls in the Mojave Desert also nest in Mojave Desert Tortoise burrows. Mojave Desert Tortoises populations are also in decline which may have a negative effect on Burrowing Owls (Tracy et al. 2006). Burrowing Owls are heavily impacted by ingestion of rodenticides intended to control mammal species. Threats to this species' habitat also include off-road vehicular activity, and overharvest of reptiles (Wildlife Action Plan Team 2012).

A.17.6 Population Trends

The western burrowing owl was on the Audubon Society's Watch List (formerly referred to as the Blue List) of declining bird populations since 1972 (McDonald et al. 2004), but was recently removed from this list (Audubon Society 2007). The Blue List is intended to provide an early warning for those North American species that are undergoing population or range reductions, and is meant to identify patterns of impending or ongoing serious losses in regional bird populations. Breeding Bird Survey (BBS) data from the last 30 years indicate that the burrowing owl is in decline nation-wide. They are also declining in much of western North America and precipitously in Canada (Holroyd et al. 2001). The survey data also indicate that Burrowing Owls may be increasing in numbers throughout the Mojave and Sonoran deserts (Sauer et al. 2008), but survey densities are fairly low, and more data would be useful to clarify these patterns. In Nevada and other arid parts of the west trends are harder to interpret with conclusions ranging from "declining" to "increasing", depending on sources consulted (GBBO 2010). The primary reason for the contradictory results is that survey data on Burrowing Owls are inadequate to determine trends in Nevada including Clark County (GBBO 2010).

The USFWS Urban burrowing owl Monitoring Project has established a three-year monitoring program to determine the success of Burrowing Owls nesting within the Las Vegas Valley and the general population trend of urban-nesting Burrowing Owls. The results of this study are not yet available, but preliminary results indicate that Burrowing Owls will successfully breed within some urbanized areas of Las Vegas (Manville 2009). However, the success of urban-nesting pairs relative to non-urban nesting pairs is unknown at this time.

Modified survey techniques were developed for the Mojave Desert and conducted transect surveys, including sites in Clark County (Crowe and Longshore 2010a and 2010b). While their surveys were not of sufficient time to document trends, they did quantify relative abundances of owls in areas within the county, and found on average 0.12 owl territories per km2, nest success of approximately 60 percent, and approximately 3 fledged young per nesting attempt over the span of the two year study (Crowe and Longshore 2010b).

NDOW is in the initial stages of developing a western Burrowing Owls monitoring protocol that may be used as a statewide monitoring program. But very early stages and starting at sites in northern portion of Nevada (Cris Tomlinson – Pers. Comm.).

A.17.7 Threats to Species

The USFWS cites habitat loss and fragmentation, primarily due to agriculture and urban growth, as one of the most significant causes of population declines in this species. The most recent cause for loss of habitat is large-scale renewable energy development for solar and wind energy generation. This activity will result in direct loss of habitat by surface disturbance and compaction.

Some artificial perches will no doubt result from these activities, but the net gains or losses to owls have not been calculated. Furthermore, there could be direct losses of owls to wind turbines or other injuries from energy generation. Indirect losses result from the loss of foraging habitat. Other threats include the elimination of suitable burrow sites through rodent control programs, predation from domestic and feral cats (Felis catus), and dogs (Canis familiaris), vehicle collisions, and pesticides or other contaminants (Klute et al. 2003)

Because Burrowing Owls demonstrate a strong preference for burrow sites and foraging areas that are open and relatively sparse with vegetation, there is indication that this species may respond positively to habitats that have recently burned or are subject to cattle grazing (Klute et al. 2003), however, this idea has not been studied, and the many negative aspects of burning or overgrazing desert systems likely outweigh any short-term benefits (e.g. due to loss of reptile diversity). Burrowing Owls are declining in many areas due to habitat degradation (Milsap and Bear 2000) and a reduction in other fossorial species that provide burrows for this owl (Desmond et al. 2000). Direct mortality as a result of rodenticides, and shooting also impact burrowing owl populations.

A.17.8 Existing Conservation Areas/Management Actions

The western burrowing owl is protected under the Migratory Bird Treaty Act, and a detailed conservation plan has been developed by the USFWS (Klute et al. 2003). The primary management actions outlined in this plan include: maintaining large, contiguous areas of suitable habitat; enhancing habitat features (i.e. provide artificial burrows, elevated perch sites, or maintain short vegetation); conserving mammalian species that provide Burrowing Owls with potential nest sites; reintroduction reintroduction or encouraging re-occupation of under-occupied and suitable habitats; and increasing public education and awareness of the species. In addition, recommended conservation actions specific to this subspecies and its habitat are included in the Nevada Wildlife Action Plan. This plan’s recommended approach is to conserve burrowing mammal colonies, adequately manage short-grass habitats, provide protection from shooting, and protect nesting areas and burrows from disturbance during the incubation and nesting stages. Further, the recommended conservation strategies to conserve occupied habitat include: maintaining this species habitat at its current distribution in stable or increasing condition trend; and sustaining stable or increasing populations of wildlife in key habitats (Wildlife Action Plan Team 2012).

This species is also covered under the Nevada Partners in Flight Bird Conservation Plan. Specific objectives for this species outlined in this plan include mitigating the effects of off-road race events, protecting and maintaining populations of other species of animal that provide burrow sites, preserving open space within urban and suburban development, and constructing artificial burrow sites in suitable alternative habitat (Neel 1999, GBBO 2010).

In addition, the western burrowing owl is covered under the Spring Mountains Conservation Agreement. This agreement was developed between state and federal agencies to provide long-term protection for the rare and sensitive flora and fauna of the Spring Mountains National Recreation Area (USFS et al. 1998).

The conceptual management plan for the Overton Wildlife Management Area (OWMA) calls for determining the extent of burrowing owl occurrences at the OWMA, and for determining if there is a need for artificial burrows. If such a need is found, the installation of artificial burrows is recommended (NDOW 2014).

The Nevada Comprehensive Bird Conservation Plan considers the burrowing owl a Special Status Species and recommends the following actions: establish and implement effective monitoring programs to determine population status and trends; maintain short vegetation and healthy prey populations near known colony locations; establish a no-disturbance buffer zone of 60 m (200 ft) around active nest burrows; provide artificial burrows to help restore populations; and discourage the use of pesticides within 600 m of nest burrows (GBBO 2010).

A.18 YELLOW-BILLED CUCKOO (*COCCYZUS AMERICANUS*)

The yellow-billed cuckoo (*Coccyzus americanus*) is a neo-tropical migrant that is widespread throughout North America, but is less common in the western United States due to losses in breeding habitat. The species is characterized as a mid-sized (30 cm in length) primarily insectivorous bird, with a long, tapered tail with white spotted margins continuing to prominent white spots on the ventral surface of the tail. Yellow-billed cuckoo are dorsally brown with a white/cream-colored breast, rufous-colored inner wings, and a characteristic long arched bill – where the lower bill is yellow and the upper is black. They have a yellow to gray eye-ring, and both sexes look alike. The entire family has zygodactyl feet (having two toes pointing forward, and two pointing backward), and many of the species are widely known as brood parasites, laying their eggs in the nests of other birds, although in yellow-billed cuckoo both parents usually brood and feed the young in their own nests (Payne and Sorensen 2005). New-world cuckoos have the shortest incubation time and nesting periods of any birds (Payne and Sorensen 2005). There are size differences between subspecies of yellow-billed cuckoo in the eastern and western US (where western birds are considered larger), and taxonomic status is frequently contested (Ridgway 1887, Laymon 1998, Banks 1988,1990, Pruett et al. 2001, Fleischer 2001), but they are most recently considered a single species (Fleischer 2001, Payne and Sorensen 2005, Farrell 2013, Federal Register 2014).

A.18.1 Species Status

A petition to list the yellow-billed cuckoo as endangered within the states of California, Washington, Idaho, Oregon, and Nevada was filed in 1986. The final ruling on this petition determined that the action was not warranted because the petitioned area did not encompass a distinct subspecies or a distinct population segment (DPS) (Johnson et al. 2007). Subsequently, a petition to list the western yellow-billed cuckoo, a DPS of the yellow-billed cuckoo, (*C. a. occidentalis*; populations west of the continental divide) was filed on February 9, 1998. On July 25, 2001 the USFWS determined that the western yellow-billed cuckoo did meet the criteria for designation as a DPS and published a final rule that the petition to list the western DPS of the yellow-billed cuckoo was warranted but was precluded by other higher-priority listing actions. Ongoing listing petitions and actions were continued from 2000 to 2013, and on November 3, 2014 the western population of the yellow-billed cuckoo was listed as a threatened species under the Endangered Species Act (ESA) (Federal Register 79 FR 59991 60038). The US Fish and Wildlife Service determined that listing of yellow-billed cuckoo as a DPS was warranted in 12 western states, Canada, and Mexico. In the US, the DPS covers parts of Arizona, California, Colorado, Idaho, Nevada, New Mexico, Texas, Utah, Wyoming, Montana, Oregon and Washington. The species is also protected under the Migratory Bird Treaty Act of 1918, as amended (16 USC 703-712). While the western DPS is listed by the USFWS, the IUCN lists this species as one of least concern as it is wide-spread with large population sizes (BirdLife International 2016).

US Fish and Wildlife Service Endangered Species Act: Threatened

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): Threatened

State of Nevada (NAC 503): Sensitive

NV Natural Heritage Program: Global Rank G5 State Rank S1B

NV Wildlife Action Plan: SOCP

IUCN Red List (v 3.1): Least Concern

CITES: No status

A.18.2 Range

The breeding range of the yellow-billed cuckoo occurs throughout much of North America, south to Mexico, and throughout the Greater Antilles (Hughes 1999). However, this species becomes increasingly rare towards the western portions of the US where suitable breeding habitat – once abundant – is now uncommon. The western subspecies formerly encompassed much of the western US, but is now confined to small pockets of breeding birds in California, southern Nevada, Arizona, and New Mexico, where they inhabit riparian woodlands and scrub habitat along major rivers in the region (Payne and Sorensen 2005). The yellow-billed cuckoo is a migratory species that winters primarily in South America east of the Andes, and western and eastern birds appear to winter in similar habitats (Hughes 1999, Payne and Sorensen 2005). Western populations have been reduced drastically from historic numbers due to the widespread loss of riparian habitat through clearing for agriculture, flood control, and urbanization.

A.18.3 Population Trends

Major declines in western populations over the last century have been reported by several sources (Alcorn 1988; Hughes 1999; McKernan and Braden 2001; Wiggins 2005; Johnson et al. 2007, Federal Register 2014). The Breeding Bird Survey has not been able to detect this species adequately enough to determine trends within the Mojave and Sonoran Desert region (Sauer et al. 2008). NatureServe estimates global long-term declines of the western yellow-billed cuckoo to be greater than 90 percent over the last century (NatureServe 2009).

A.18.4 Habitat Model

The number of localities available for modeling this species after removing records that were duplicates or essentially located within the same pixel was reduced to 48 records. This low number caused failure to calculate models using the GAM algorithm, and thus only Random Forest and MaxEnt models are presented here. The habitat models predicted yielded similar predictions, although the MaxEnt models tended to estimate lower suitability scores in general, with few areas of higher suitability (e.g. scores of > 0.7) relative to the Random Forest models, but with moderately high scores (0.6) predicted in similar areas (Figure A.18-1). Habitat for each of the modeling approaches was relatively focused and highlighted the Muddy and Virgin Rivers, Avi, the Las Vegas Valley as the most prevalent habitat areas predicted. Given the preference of this species for denser vegetation this result was expected. Model performance was good for both algorithms, with models exchanging place as the “best” model depending on the performance metric (Table A.18-1). Standard error maps indicate a high level of agreement among the Random Forest models, with elevated error sparsely distributed at the periphery of the Las Vegas valley, and along the shoreline of Lake Mead (Figure A.18-2). In contrast, the MaxEnt models had far more disagreement with many larger areas of higher standard error (SE ~ 0.05) located throughout the county, including the entire Mormon mesa extending through Mesquite, and the northern shores of the Overton arm of Lake Mead, the shoreline along the Colorado river and lake Mojave, the Spring range, etc. (Figure A.18-2). This was associated with some of the lower level habitat scores evident in the MaxEnt predictive map (Figure A.18-1).

The GAM and Random Forest models had very similar performance metrics to one another (Table A.18-1), although the RF models had a higher Boyce Index than the GAM models. The MaxEnt Model was the poorest performing model across all three performance metrics. Since the Ensemble is a weighted average of the three algorithms it is more heavily influenced by the higher performing GAM and Random Forest models, and thus reflects their predictions of habitat more strongly (Figure A.18-1). Relative variable importance was ranked differently among the algorithms, where the Random Forest models was largely driven by Soil Silt content, and the initiation of the spring greenup (NDVI SOS), while the GAM model had higher influence of temperatures (Max, Min and Extreme). The MaxEnt had higher influence by Clay Content and NDVI amplitude, followed by Maximum temperatures and the Start of Season date (Table A.18-2).

The Continuous Boyce Indices showed some irregularities, especially in the MaxEnt models, where there was a peak at the lower end of habitat suitability where there was increased prevalence (Figure A.18-3). This indicated a potentially under predicting model. The Random Forest model had good performance with respect to CBI, but peaked early, with discrimination falling off at the higher suitability values, these shortcomings were translated to the Ensemble Model, which had a peak in the middle habitat scores where prevalence would suggest higher habitat values (Figure A.18-3). The models shared two of the environmental variables among the top four influential variables (Extreme Maximum temperatures and Average Maximum temperatures), although the highest variable contributing to each model differed (Table 2).

Table A.18-1. Model performance values for yellow-billed cuckoo models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given in the last column.

Model	AUC	BI	TSS	PRBE
Ensemble	0.92	0.65	0.8	0.41
Random Forest	0.9	0.82	0.9	
MaxEnt	0.87	0.97	0.8	

Table A.18-2. Percent contributions for input variables for yellow-billed cuckoo for ensemble models using GAM, Maxent and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	RF	MaxEnt
Extreme Max Temp	14.1	21.7
NDVI Max	2.1	29.8
PPT Silt	26	4.6
PPT Sand	17.4	2.3
Start of Season (day)	6.6	12.6
Ave Max Temp	9.9	8
PCT Coarse frags	3.6	5
Winter Precip	6.4	0.6
CV Min Temp	2.8	3.4
NDVI Amplitude	0.9	3.9

Figure A.18-1. SDM maps for yellow-billed cuckoo model - Ensemble (upper left), and for averaged models of each of three modeling algorithms used (Random Forest – upper right, MaxEnt - lower left). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

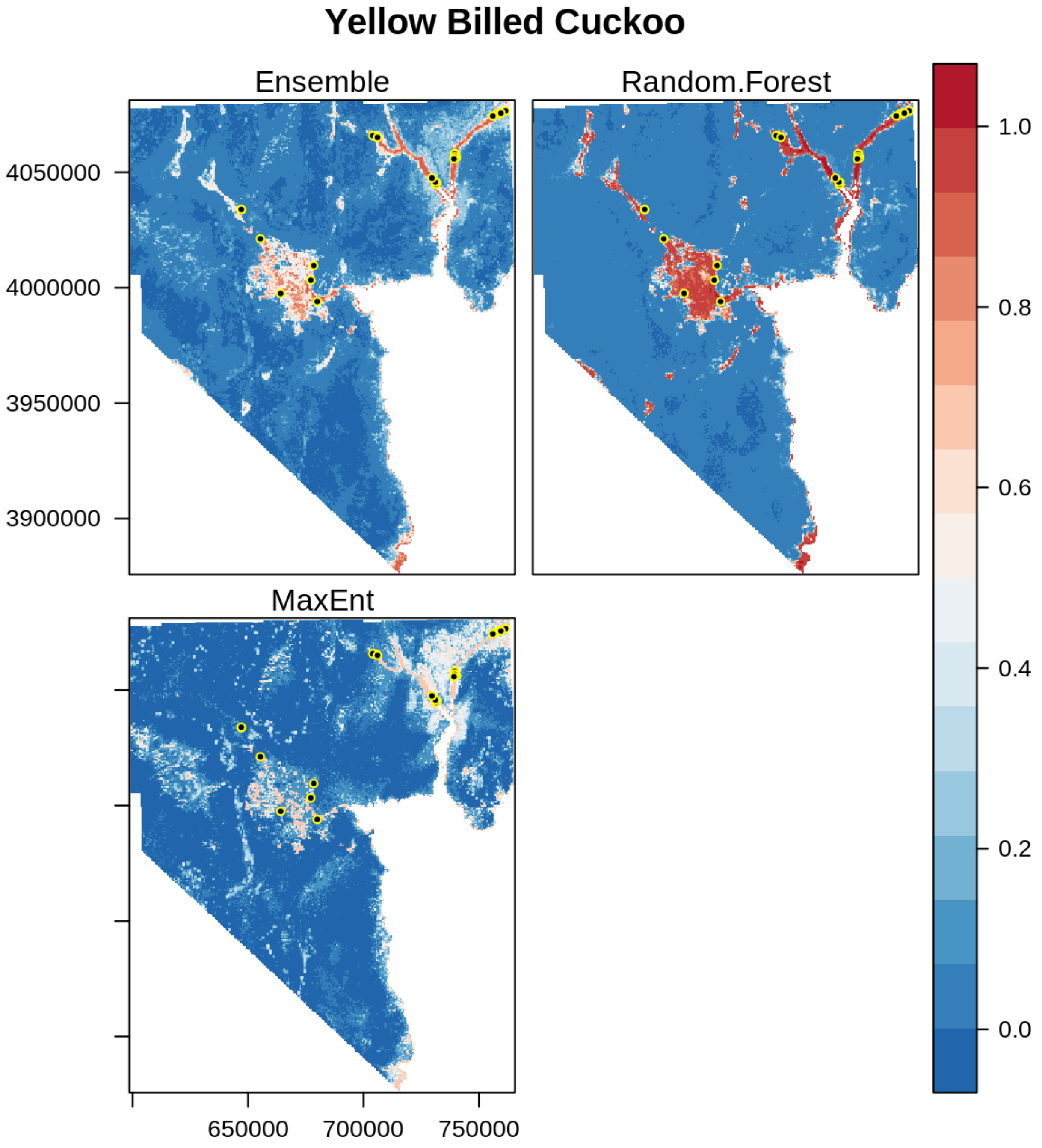


Figure A.18-2. Standard error maps for yellow-billed cuckoo models for each of the modeling algorithms used (Random Forrest – upper right, MaxEnt – lower left), and an Ensemble model averaging the three (upper left).

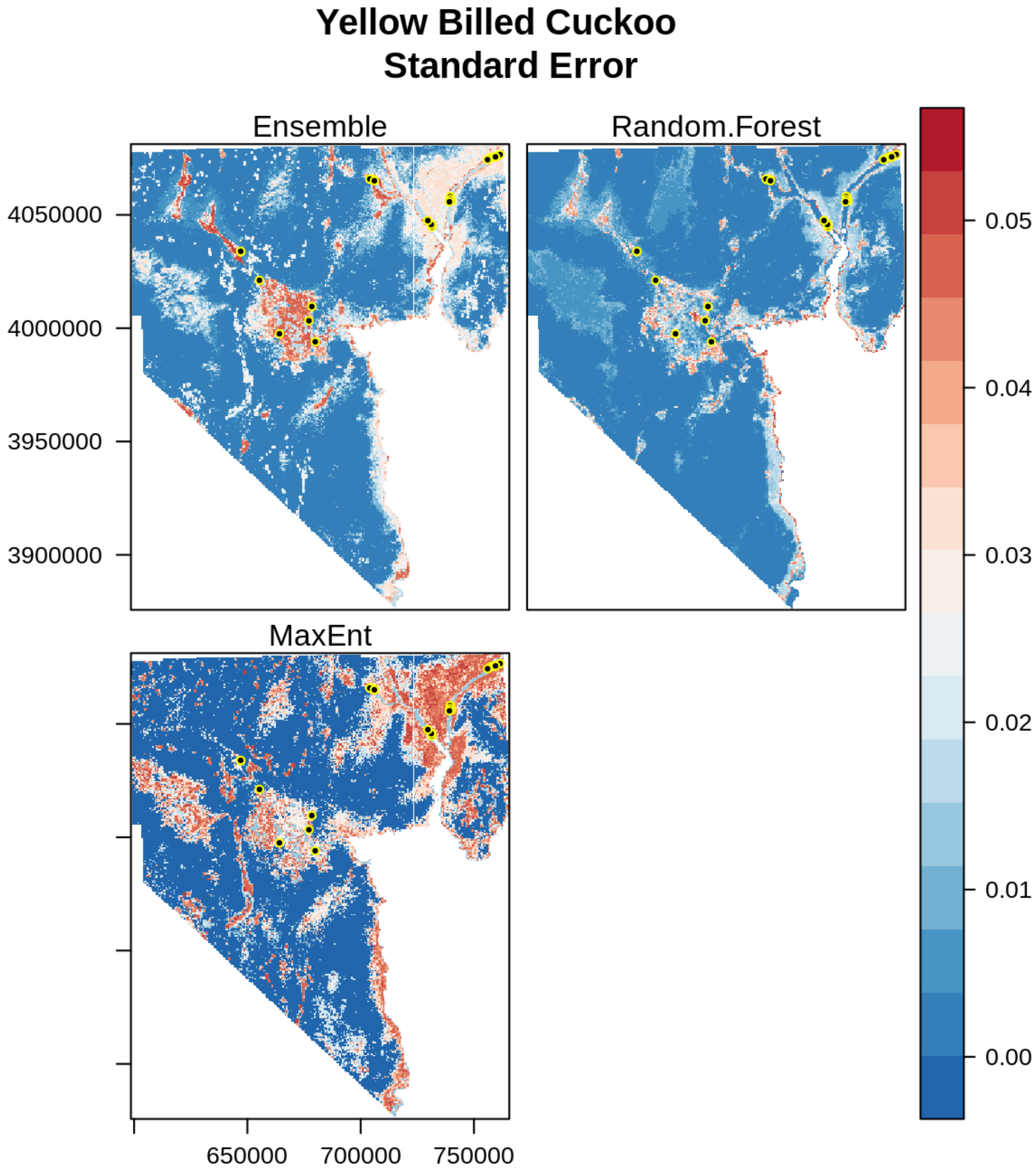
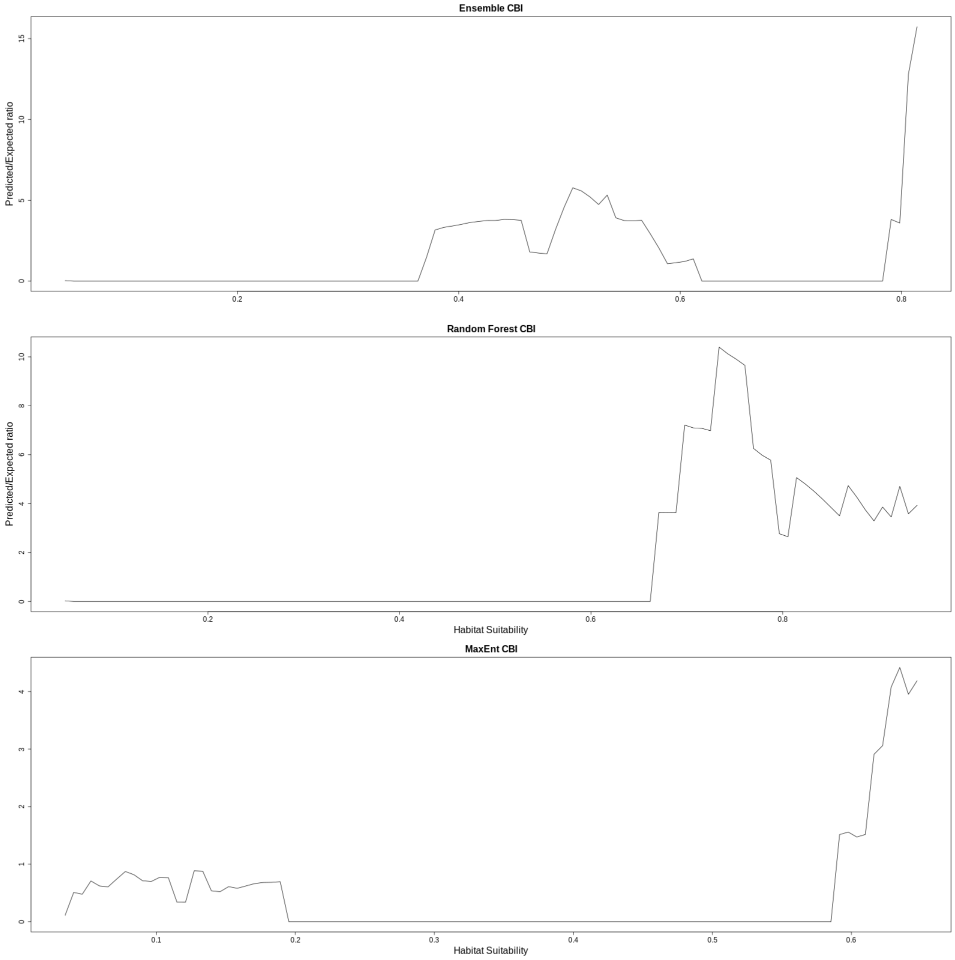


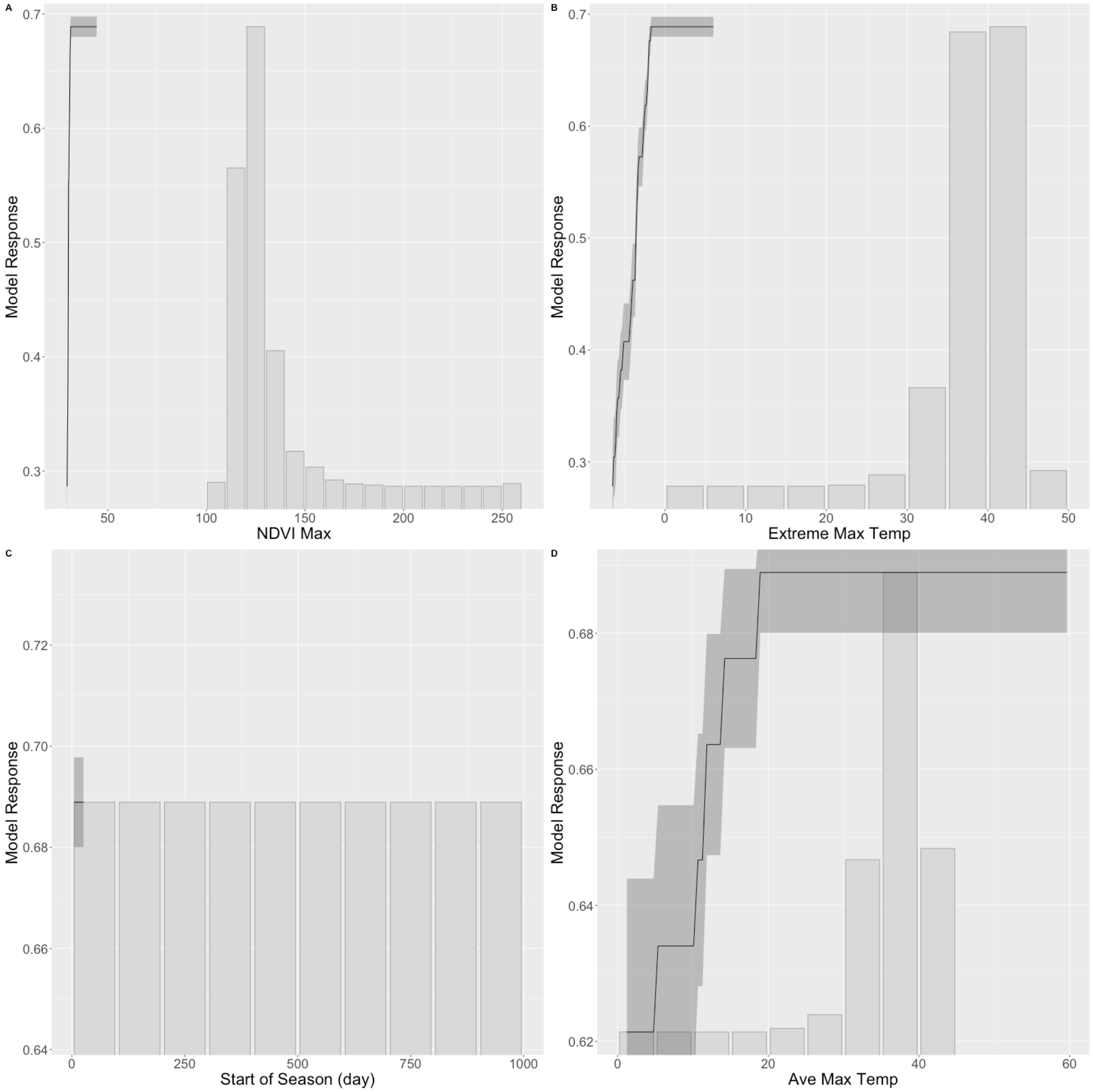
Figure A.18-3. Graphs of Continuous Boyce Indices [CBI] for yellow-billed cuckoo models for the Ensemble model prediction (upper) and for each of the modeling algorithms used (Random Forest – middle, and MaxEnt - lower).



A.18.4.1 MaxEnt Model

The MaxEnt models were most influenced by the NDVI Maximum value, and the Extreme Maximum temperatures (comprising 42% of influence; Table A.18-2). These variables exhibited peaked threshold responses at lower values relative to their presence in the study area (Figure A.18-4). The Start of Season as indicated by NDVI contributed 12.6 %, but had no discernable trend given the response curves. This is due to the nature of the MaxEnt models and the relatively few data points from which to draw curve projections. Average Maximum temperature rounded out the top four contributors, with a thresholded response beginning at lower values, and continuing to remain high. While the performance metrics all indicated high performance for this model, the relatively moderate and widespread habitat predictions (Figure A.18-1), and widespread error (Figure A.18-2) did not reflect strong performance. The CBI curves also showed some discrepancy in the relative strength of the MaxEnt models (Figure A.18-3).

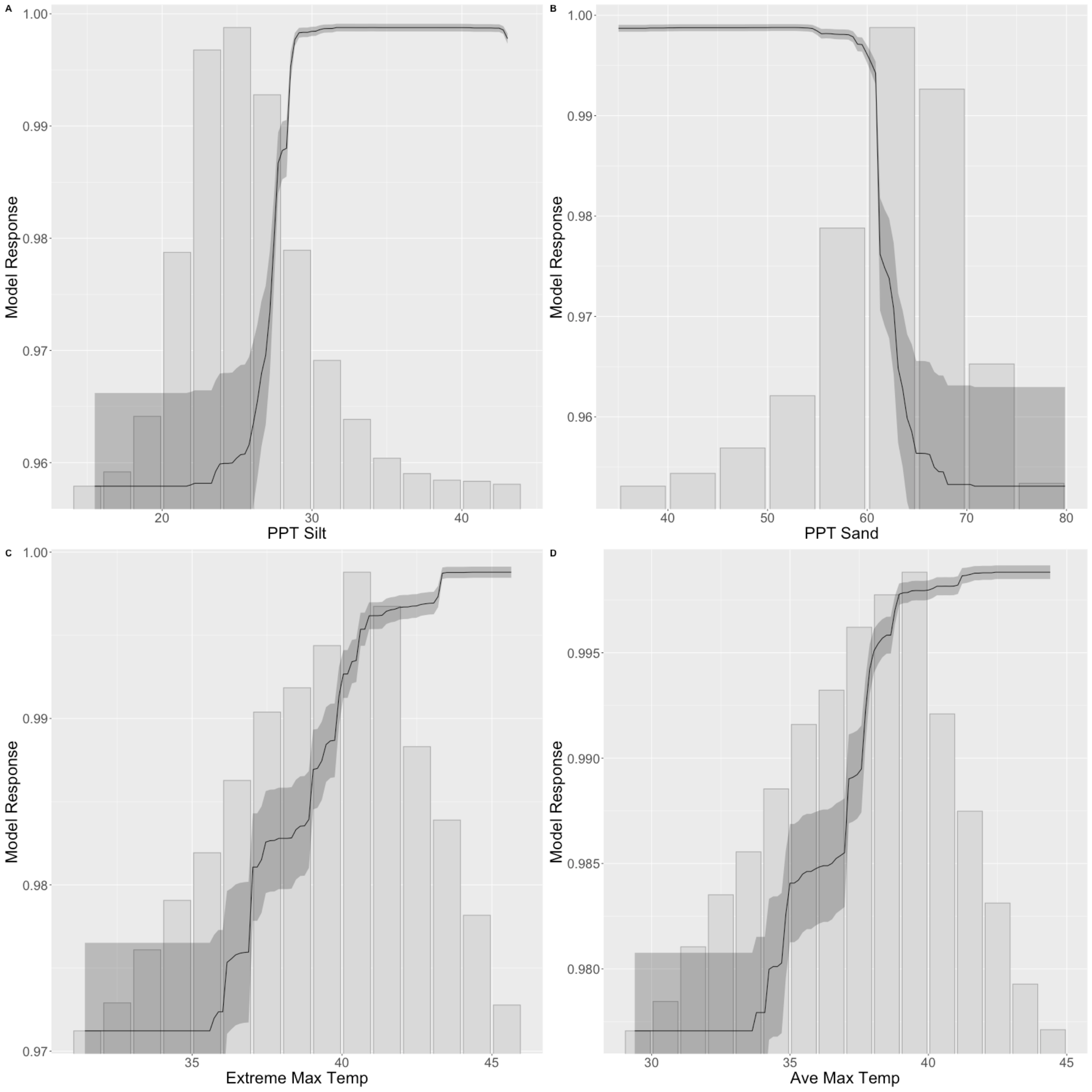
Figure A.18-4. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for yellow-billed cuckoo Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.18.4.2 Random Forest Model

The Random Forest model for this species had two soil-based metrics (the two highest contributors), and two maximum temperature-based metrics providing the largest contributions to the models (collectively 67% of total model contribution; Table A.18-2). Performance curves for these variables indicated higher predicted habitat values in areas with higher Silt Content – suggesting lower areas within drainages, but with higher habitat in areas with a lower Sand Content (Figure A.18-6). Habitat increased with both Maximum temperature values, and remained highest at in the hottest areas of the county. The performance metrics were excellent for this model (Table A.18-1) although the Continuous Boyce plots indicated good model performance although there was a reduction in locality prevalence shown at the highest predicted suitability values (Figure A.18-3). The model predicted a relatively discriminating habitat scores, with either very high or very low habitat scores produced, and very little marginal habitat indicated (Figure A.18-1). This was in contrast to the MaxEnt model that predicted only marginal values at best. Standard error maps showed that the model predictions were very consistent among model runs (Figure A.18-2)

Figure A.18-5. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for yellow-billed cuckoo. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.18.4.3 Model Discussion

The yellow-billed cuckoo largely occupy the riverine and larger drainage systems located along the Muddy and Virgin rivers. There are also several localities in and around the Las Vegas valley and to the northwest near the USFWS refuge. The Ensemble model predicted the highest habitat values in the immediate Virgin and Muddy river drainages, near Laughlin and the flatter areas near Avi, and along the Las Vegas wash and throughout the Las Vegas Valley (Figure A.18-6). Model performance for the Ensemble model was high for all metrics (Table A.18-1), which is surprising given the limited number of localities available for modeling. The locality data for this species consisted of 96 records within the buffered modeling area, which had a high degree of overlap and or duplication. Spatial thinning of the data (which removes repeated observations within nearby pixels) reduced the number of localities used for training and testing to 48 records.

A.18.4.3 Standard Error

There are several areas of relatively higher error rates (SE > 0.04) located for the in the Las Vegas valley in the lower habitat areas of the US 95 highway corridor to the northwest. There were also several areas of error in and around the dry lakes in Eldorado, Ivanpah, and Mesquite valleys to the south and southwest of Las Vegas. Other areas of elevated error were along the western edge of the Colorado river and Lake mead shoreline (Figure A.18-7). The Mormon mesa area had widespread areas of moderate standard error (SE 0.02 - 0.03; Figure A.18-7).

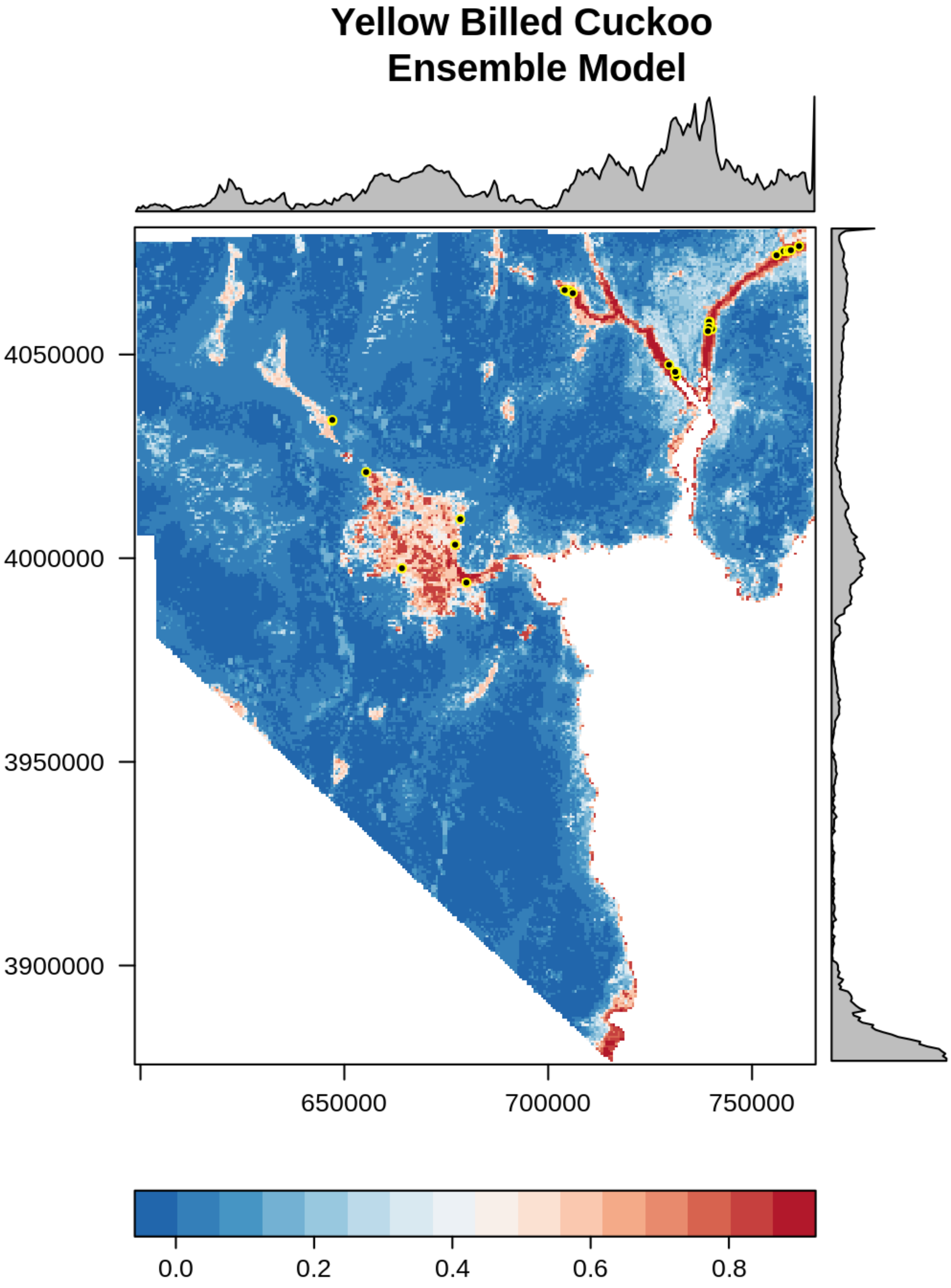


Figure A.18-6. SDM map for yellow-billed cuckoo Ensemble model for Clark County, NV.

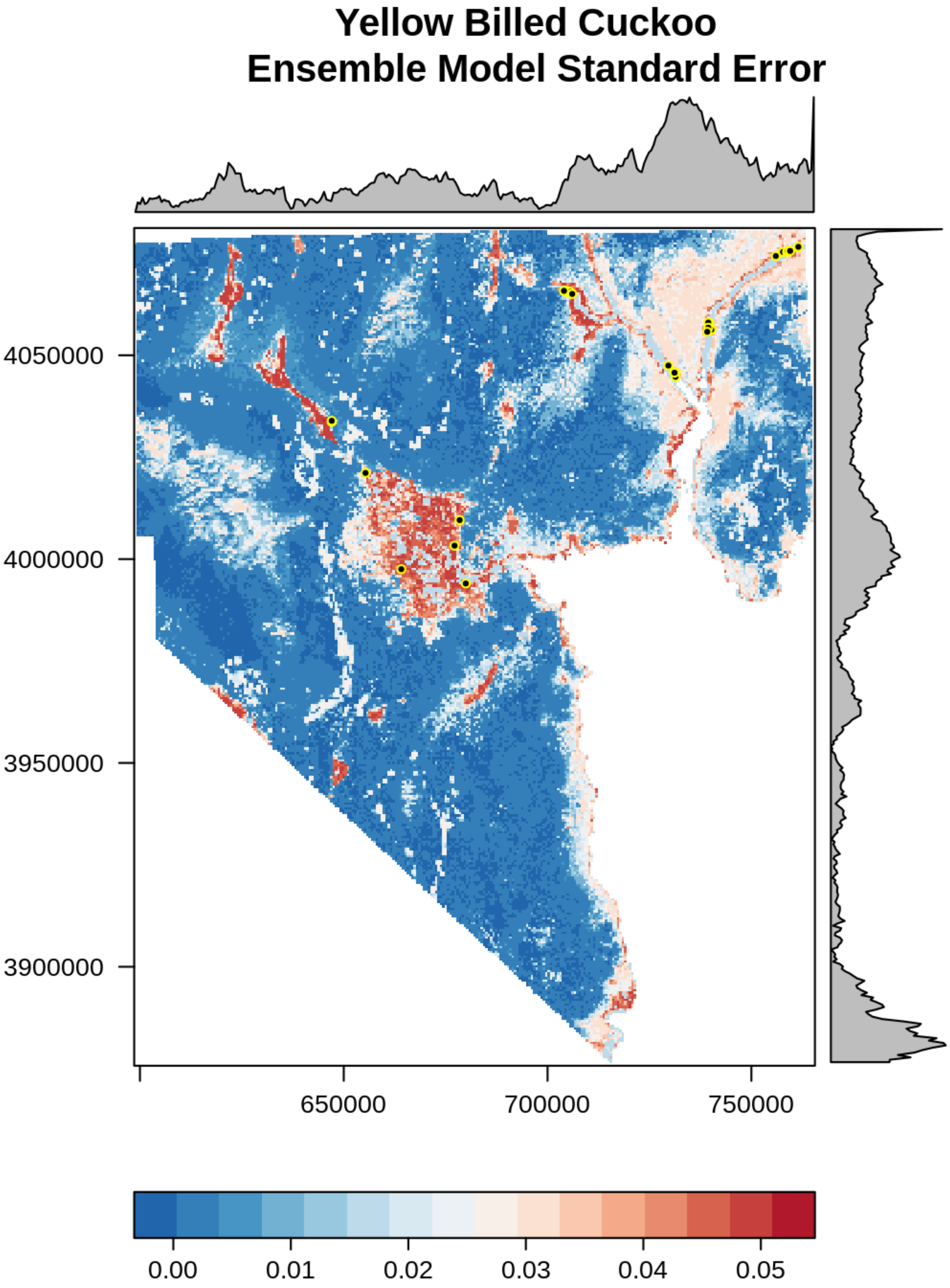


Figure A.18-7. Standard Error map for the yellow-billed cuckoo Ensemble model for Clark County, NV.

A.18.5 Distribution and Habitat Use within Clark County

The yellow-billed cuckoo requires riparian habitats with a dense understory. In the southwestern US yellow-billed cuckoos prefers to nest in low-elevation riparian habitat consisting of open woodlands with an understory of dense vegetation. Yellow-billed cuckoos depend on large tracts of riparian forest and show a strong preference for nesting in areas with at least 10 hectares of contiguous forest (Wiggins 2005). There is very little of this habitat type that remains within Clark County today due to conversion of the land for agriculture and urban development. It was once thought that breeding populations of yellow-billed cuckoo were possibly extinct in southern Nevada (Alcorn 1988). This species is a very rare summer resident in southern Nevada with very few breeding sites confirmed, and to date, there are only two known confirmed breeding locations in Clark County (McKernan and Braden 2001, Floyd et al. 2007). They are reported from two of the seven Important Bird Areas of Clark County: Moapa Valley and Virgin River (McIvor 2005). Modeled habitat for this species within the county (Boykin et al. 2008) identified potential habitat within the Desert Riparian and Mesquite Acacia, and Mojave Desert Scrub bordering the former two ecosystems. A series of surveys conducted from 2000 to 2006 detected yellow-billed cuckoos in Corn Creek and Moapa Valley during most survey years, but breeding was not confirmed at either of these sites (Klinger and Furtek 2007). The US Geological Survey (USGS) has also detected cuckoos in the Overton Wildlife Management Area, but was unable to confirm breeding, and cuckoos were not detected around Lake Mohave, despite the existence of suitable habitat (Johnson et al. 2007). yellow-billed cuckoo have also been detected in the Las Vegas Wash with breeding still unconfirmed. The Nevada Breeding Bird Atlas has, however, reported breeding cuckoos on a private ranch on the upper Muddy River (Floyd et al. 2007). This property has since been purchased by the Southern Nevada Water Authority (SNWA). Breeding was also confirmed along the Virgin River in 2001 during surveys conducted by San Bernardino County Museum (SBCM) (McKernan and Braden 2001). SBCM also detected cuckoos in the Mormon Mesa area of the Virgin River in 2006 and 2007 (Braden et al. 2007, 2008, 2009). Ecosystems with predicted high habitat suitability contained within the riparian areas in this model included Mojave Desert Scrub, Desert Riparian, and Mesquite Acacia (Table A.18-3).

Table A.18-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415246	22	0
Bristlecone Pine	7562	2	0
Desert Riparian	41	257	9880
Mesquite Acacia	14947	1312	3970
Mixed Conifer	27175	150	0
Mojave Desert Scrub	1204464	90350	63032
Pinyon Juniper	115404	442	0
Sagebrush	4706	0	0
Salt Desert Scrub	65022	16056	1474

A.18.6 Ecosystem Level Threats

Ecosystem threats include habitat fragmentation and loss (Nevada Partners in Flight 1999). Principal causes of riparian habitat losses are conversion to agricultural and other uses, dams and river flow management, stream channelization and stabilization, and livestock grazing (Wiggins 2005).

Habitat degradation is also a significant ecosystem threat affecting this species. Significant habitat degradation in the southwest has been caused by the invasion of tamarisk (*Tamarix* spp.) in riparian habitats. Tamarisk changes riparian forests by destroying community structure, replacing three or four vegetation layers with one monotypic layer. However, yellow-billed cuckoos have been observed occupying stands of mixed tamarisk and native vegetation (Sogge et al. 2008). Extensive cattle grazing in the southwest has also contributed to degradation of existing riparian habitats. The overuse of riparian habitats by livestock has been a major factor in the degradation and modification of these areas. The effects include changes in plant community structure and species composition and in relative abundance of species and plant density.

A.18.7 Threats to Species

The primary threats currently facing the yellow-billed cuckoo include the destruction and modification of habitat, and pesticide application. Available breeding habitat for cuckoos have also been substantially reduced in area and quality by groundwater pumping and the replacement of native riparian habitats by invasive nonnative plants, particularly tamarisk. While tamarisk is indeed potentially influencing breeding habitat, care must be made if eradication/restoration plans are implemented to ensure breeding birds have sufficient nesting habitat (Sogge et al. 2008). Pesticides are a potential threat to this species. When DDT was widely used there were reports of significant accumulation of toxins in body tissues and eggs, and even direct mortality of adults following DDT applications to foliage. While DDT is no longer used in the US it is still used in Central and South America. It has also been noted that population declines occur in areas where heavy pesticide use is common in agricultural areas bordering cuckoo habitat (Wiggins 2005). Prey scarcity (linked at least in part to pesticide use) may also play a role in declines even where suitable habitat remains.

A.18.8 Existing Conservation Areas/Management Actions

The western DPS of the yellow-billed cuckoo is protected under the US Endangered Species Act (Federal Register 2014), critical habitat designation is ongoing, and a recovery plan has not been published to date.

The yellow-billed cuckoo is also protected under the Migratory Bird Treaty Act. This species is also included in the Nevada Partners in Flight Bird Conservation Plan (Nevada Partners in Flight 1999). The goal for this species under the plan is to establish two breeding pairs of yellow-billed cuckoos by 2010. To achieve this goal, the plan proposes to maintain and increase riparian habitat consisting of cottonwood and willow forests in southern Nevada. Conservation of this species is also addressed in the Lower Colorado River Multi-species Conservation Plan.

The Virgin River Habitat Conservation and Recovery Program, Clark County, NV proposed preservation of habitat for this and other species within the 100-year flood plain of the Virgin River, extending from Mesquite to the confluence of the Virgin River into Lake Mead near Fish Island on the Overton Arm, however the plan was never completed (USFWS 2007).

Much of the cattle grazing rights were purchased by Clark County after the Mojave Desert Tortoise was listed as threatened. This act has served to reduce the understory grazing of many historic breeding areas, in turn making them more suitable for yellow-billed cuckoo nesting. The Nevada Department of Wildlife (NDOW) is also working with private landowners and federal agencies in order to manage grazing in areas that contain populations of yellow-billed cuckoos (NDOW 2003).

SNWA purchased a 1,218-acre property formerly known as the Warm Springs Ranch in 2007, which supports one of the two recent breeding sites for yellow-billed cuckoo in Clark County. The primary purpose of this acquisition was to protect the endangered Moapa dace (Moapa coriacea) and its habitat, and to restore and manage the area as an ecological reserve. SNWA has purchased this property exclusively for environmental management purposes and does not intend to develop the groundwater resources of the site (Curtis 2006). The Virgin River Conservation Partnership, composed of federal, state, and local agencies including SNWA, has been established to coordinate conservation and water development issues in the lower Virgin River Valley.

A.19 GILDED FLICKER (*COLAPTES CHRYSOIDES*)

Gilded flicker (*Colaptes chrysoides*) habitats can be found in desert riparian habitats with well-developed tree-lined corridors (e.g. along the lower Colorado River and its tributaries), Mojave Desert scrub, and suburban areas with appropriate vegetation, including housing developments, golf courses, and parks. Key to the nesting habitat of these large woodpeckers are columnar cacti (e.g. saguaro – *Carnegiea gigantea*), Joshua tree (*Yucca brevifolia*), or other tall trees (e.g. Fremont cottonwood – *Populus fremontii*) where they may excavate large nesting cavities. Gilded flickers in Nevada are clearly associated with Joshua trees and other tall yuccas which provide a substrate for nest cavities (GBBO 2010). The cavities may be used by a variety of other cavity nesting birds including western screech owl (*Megascops kennicottii*), pygmy owl (*Glaucidium californicum*) ash-throated flycatchers (*Myiarchus cinerascens*), and European starlings (*Sternus vulgaris*; Hardy and Morrison 2001). Gilded flickers also require open habitat such as bare ground, which can include lawns or golf course fairways, where they can forage on the ground for invertebrates (Turner 2006) such as ants and beetles. While beneficial to some bird species, the presence of a gilded flicker nest in a giant saguaro cactus increased the mortality rate for the cactus (McAuliffe and Hendricks 1988). The same may be true for Joshua trees.

A.19.1 Species Status

Gilded flicker was formerly considered a subspecies of northern flicker (*Colaptes auratus cafer*), but was later elevated to its own generic status (Eisenman et al. 1973). This species is not declining sufficiently range-wide to be considered a Species of Concern (Birdlife International 2012). Thus, no federal or state of Nevada listing petitions were found specifically for this species. However, the taxon *Colaptes auratus chrysoides,* was petitioned for listing in California by the California Department of Fish and Game in 1987, citing loss of saguaro and other habitat needs, and hybridization with *Colaptes auratus cafer* in Joshua tree woodlands near Cima Dome, San Bernardino, County, California.

US Fish and Wildlife Service Endangered Species Act: No Status

Migratory Bird Treaty Act: Protected

US Bureau of Land Management (Nevada): No Status

US Forest Service (Region 4): No Status

State of Nevada: Protected

NV Natural Heritage Program: Global Rank G5, State Rank S1

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Least Concern

CITES: No Status

A.19.2 Range

The gilded flicker has a large range and is found primarily in the Arizona Upland of the Sonoran Desert (Hardy and Morrison 2001). Its range potentially includes all of the Sonoran Desert in Arizona, US, and Sonora, Mexico – where sufficient nesting substrate are available. Gilded flickers are also found in the Colorado Desert of southern California, and through eastern and southern Baja del Norte, and Baja del Sur, Mexico.

A.19.3 Population Trends

The gilded flicker is thought to be declining throughout its range (Wildlife Action Plan Team 2012). The known population of gilded flickers in Nevada is currently very small and has remained that way for several years. Records from the Breeding Bird Atlas (Floyd et al. 2007 – as conveyed by C. Tomlinson-NDOW, pers. comm.) note 20 pairs in the foothills of the Eldorado Range. Furthermore, an adult male and adult female were observed together, just south of the Highland Range, near Walking Box Ranch and it was stated that this is a breeding population (GBBO 2015); however, no breeding data are currently known to be available. The potential for gilded flickers to use other Joshua tree habitats or suburban areas in Clark County may exist and analysis of data emerging from bird surveys should be scrutinized to determine if the population is growing in extent.

A.19.4 Habitat Model

While the three model algorithms generally predicted similar habitat arrangements throughout the county, the Maxent models generally predicted more habitat than either the GAM or Random Forest models (Figure A.19-1). Large areas of habitat in the southern extent of the county were predicted by all models. In addition, each of the models predicted bands of habitat along the southern uplands surrounding the Spring range near Trout canyon, the Red Rock area, extending northward. The southern margins of the Sheep range were also predicted to have a band of habitat, as did the Las Vegas Valley generally. The northeastern extent of the county had little to no habitat predicted, with the exception of the GAM model (Figure A.19-1).

The Ensemble model had the highest performance relative to other models in all three performance metrics. The Random Forest model had similarly high AUC and TSS scores, but a lower Boyce Index. The GAM model was the second highest scoring model with respect to AUC and BI scores, but had a lower TSS than the others (Table A.19-1). The four variables with the greatest contribution among models were Average Spring Maximum temperature – which was among the top four in all three algorithms. NDVI Maximum, and The CV of Winter Precipitation ranked in the top four in the GAM and Random Forest models, and 5th in the MaxEnt model. The CV of Average Spring Maximum temperatures was among the most influential variables in the GAM and MaxEnt models, and Slope was highly ranked in the Random Forest and MaxEnt models (Table A.19-2).

Standard error maps indicated maximum SEs of approximately 0.07, and that these were widespread in the GAM models, with more moderate error among models in the MaxEnt outputs in localized areas around the Spring and Sheep Ranges. The Random Forest had the lowest overall standard error, and the Ensemble Model, had moderate error (~0.04) near the Las Vegas Valley (Figure A.19-3). The Continuous Boyce Indices showed good model performance in all algorithms, where all but the MaxEnt models had sharply increasing performance curves (Figure A.19-3).

Table A.19-1. Model performance values for gilded flicker models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.95	0.94	0.84	0.52
GAM	0.91	0.89	0.72	
Random Forest	0.94	0.66	0.84	
MaxEnt	0.91	0.81	0.64	

Table A.19-2. Percent contributions for input variables for gilded flicker for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Dist to cliffs	4	0.7	2.2
NDVI Amplitude	9.3	1.9	2.8
NDVI Length of Season	6.7	1.9	1.2
NDVI Max	15.8	20.6	2.3
Winter Precip	6.1	5.2	4.3
CV Winter Precip	10.3	40.6	10.2
Average Spring Max Temp	16.7	13.8	36.8
CV Average Spring Max Temp	11.4	2.2	11.5
Slope	9.6	7.7	16.1
NDVI Start of Season	7.3	2.4	10.5
Flow Accum	2.6	3.2	2.1

Figure A.19-1. SDM maps for gilded flicker model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

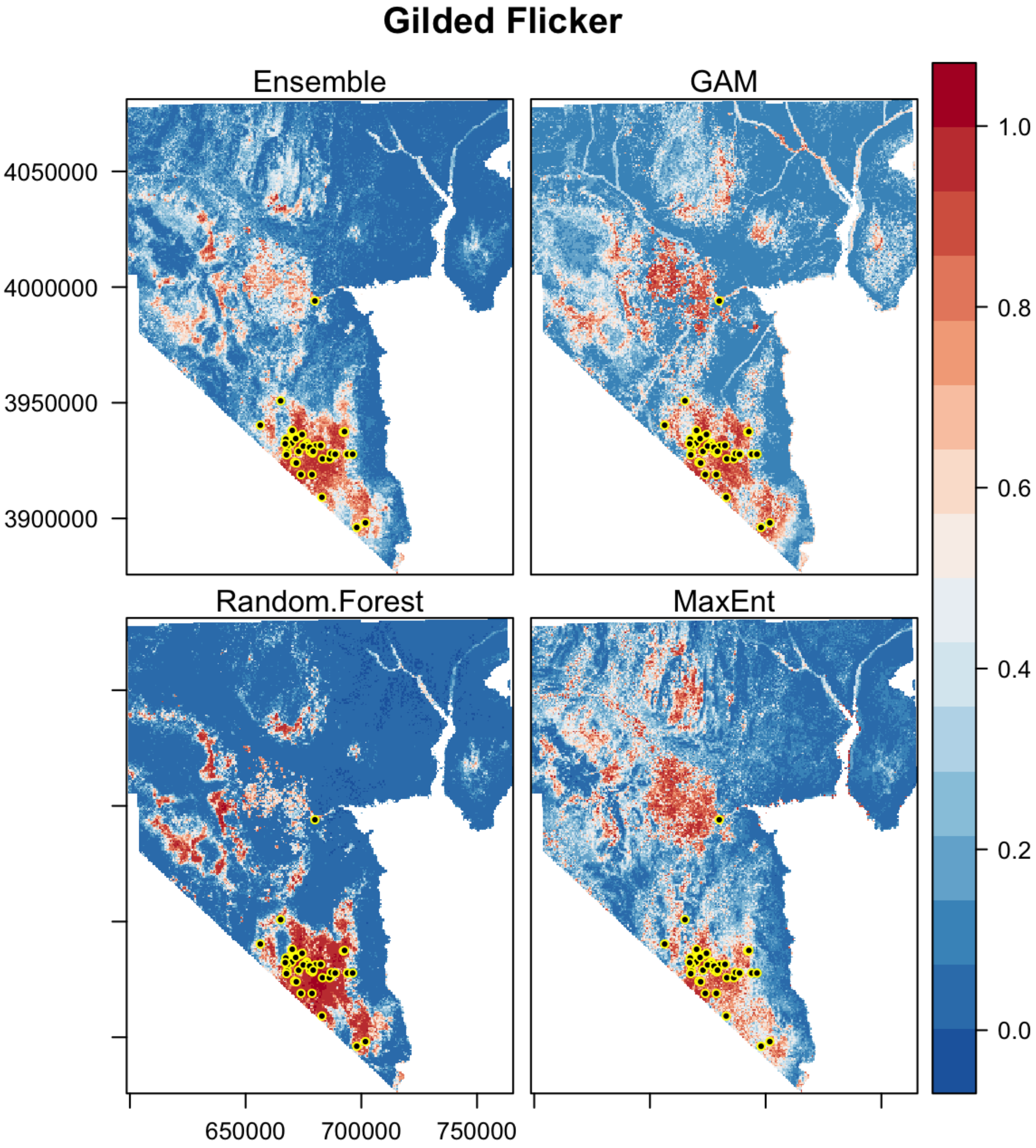


Figure A.19-2. Standard error maps for gilded flicker models for each of three modeling algorithms used (Ensemble - upper left, GAM - upper right, RF - lower left, and MaxEnt - lower right).

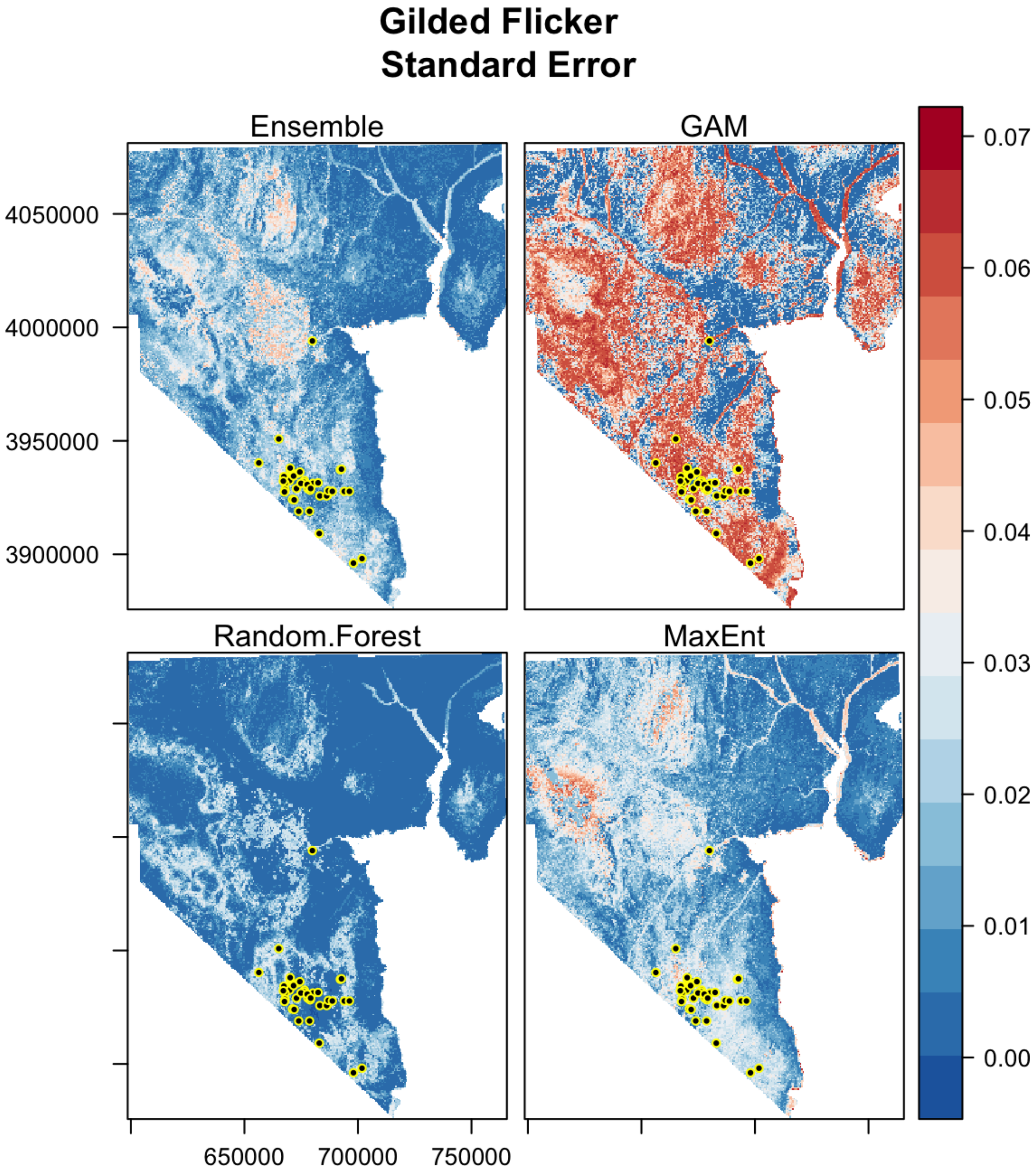
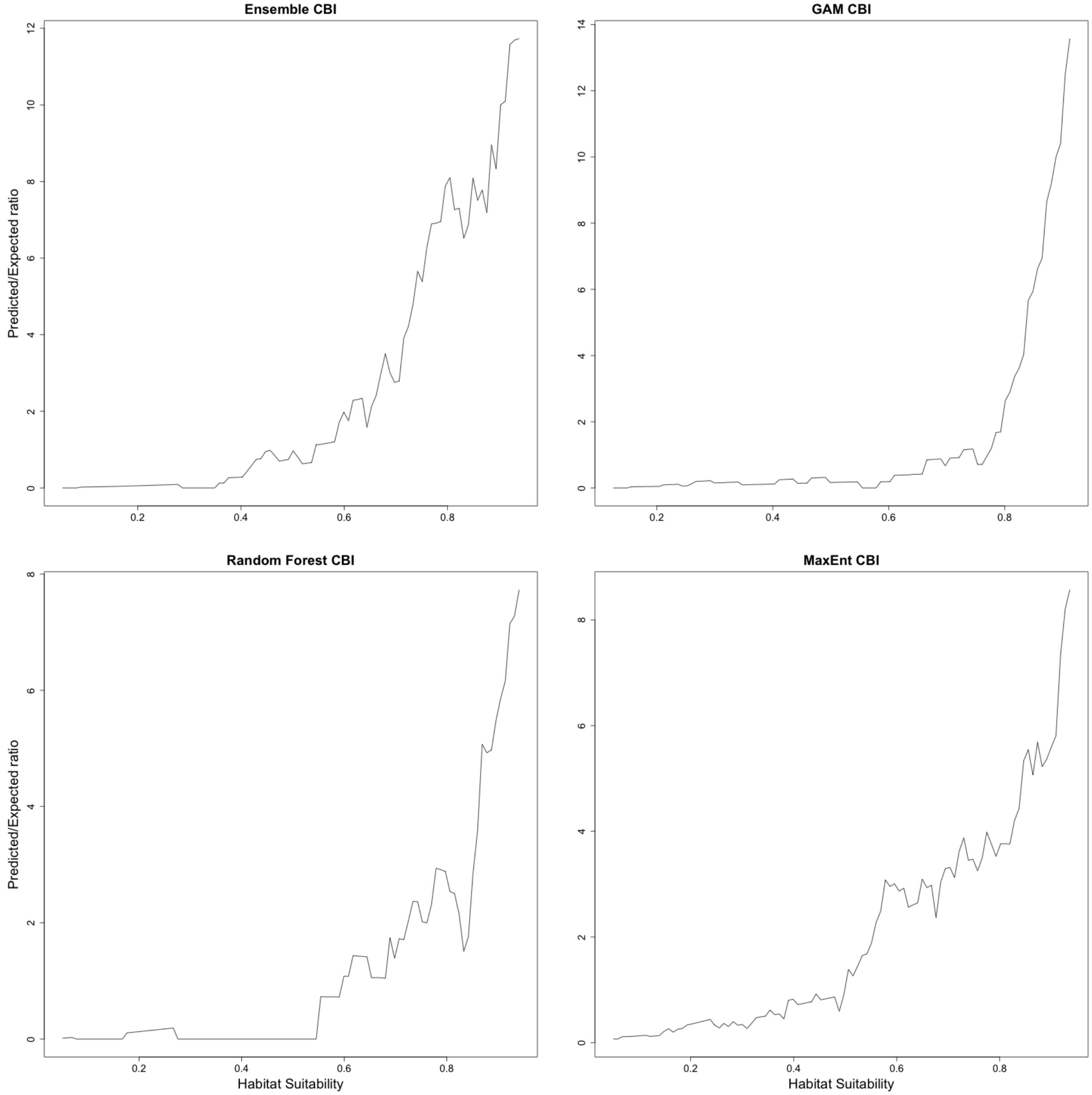


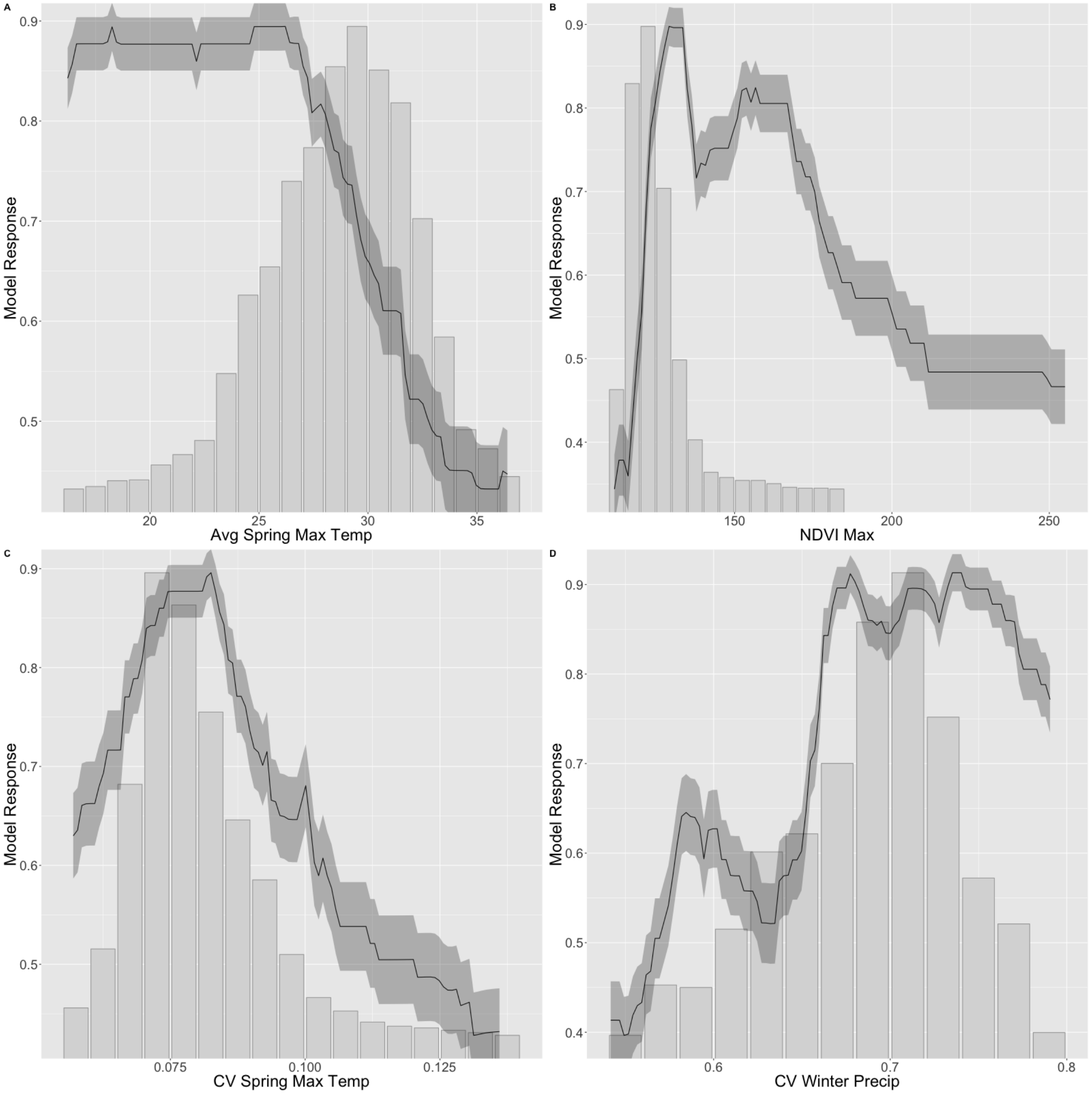
Figure A.19-3. Graphs of Continuous Boyce Indices [CBI] for gilded flicker models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).



A.19.4.1 General Additive Model

The top four contributing environmental layers were Average Spring Maximum temperature and its coefficient of variation, NDVI Maximum, the CV of Average Winter Precipitation and the NDVI Maximum value for the year (Table A.19-2). Model scores were higher in areas with lower Spring temperatures, and higher variability in Winter Precipitation. Model scores tended to be higher in areas above the average value for the study area, and the CV of Spring Maximum temperature mirrored its prevalence in the study area (Figure A.19-4).

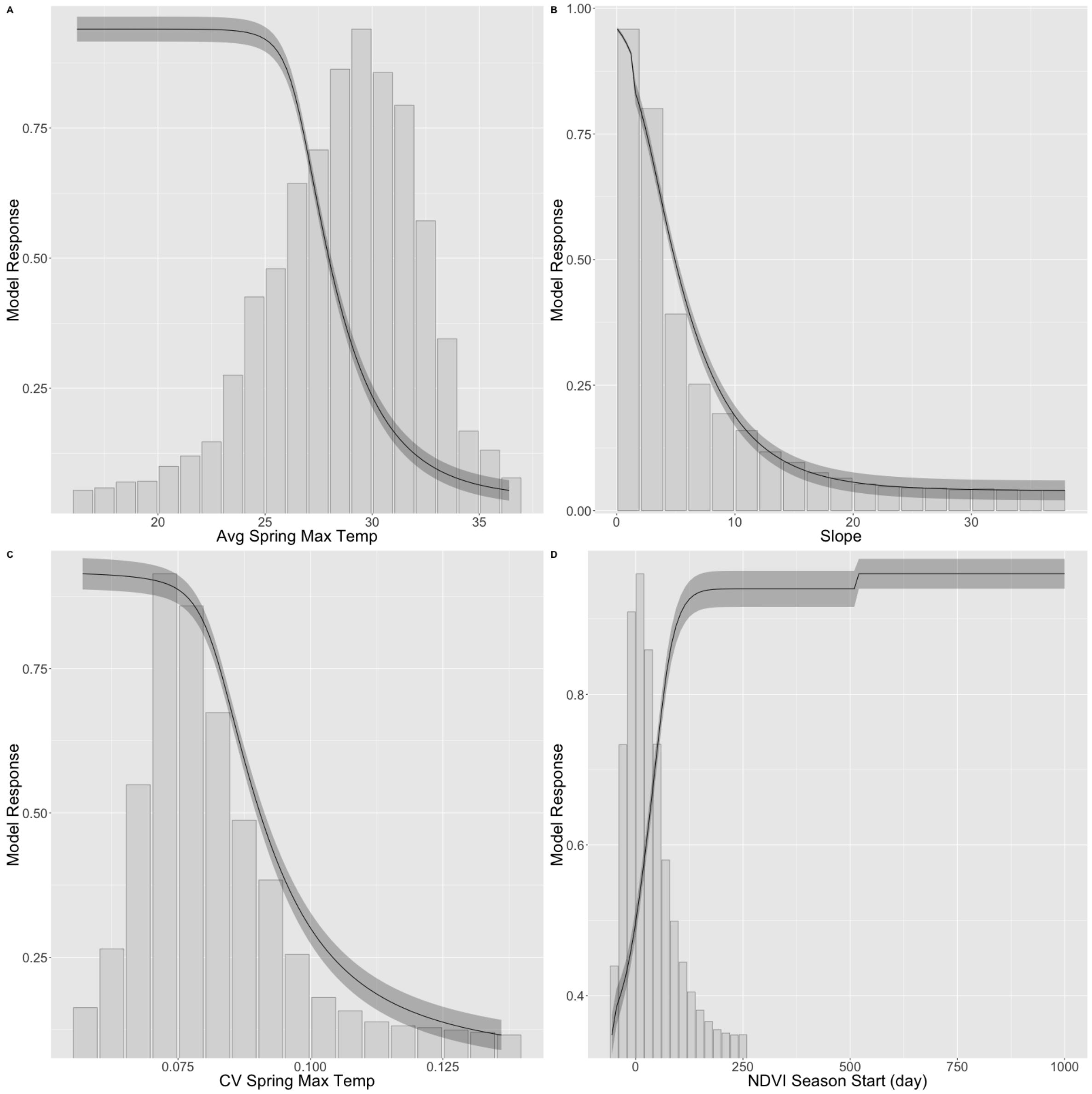
Figure A.19-4. GAM partial response curves for the top four variables in the gilded flicker model overlaid over distribution of environmental variable inputs in the study area.



A.19.4.2 MaxEnt Model

The MaxEnt models was largely driven by three of the four top variables as those in the GAM models, and two of the higher Random Forest models (Table A.19-2). Average Spring Maximum temperature and its Coefficient of Variation were among the top four, with higher habitat scores predicted for cooler areas with lower variability (Figure A.19-5). Habitat was also predicted in areas of later NDVI Start of Season dates, corresponding with later green up. Finally, there was a negative association with Slope that mirrored its prevalence in the habitat, which may not be an indication of selection (Figure A.19-5). The MaxEnt predicted slightly more area than the GAM models, which is unusual for this algorithm. The increased areas were in the Las Vegas valley extending toward the northwest, and in the Sheep range (Figure A.19-1).

Figure A.19-5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for gilded flicker.



A.19.4.3 Random Forest Model

The top four contributing variables for the Random Forest model were the CV of Winter Precipitation, the NDVI Maximum value, the Average Maximum temperature, and Slope of the terrain (Table A.19-2). These had the same pattern of influence as in the other algorithms, where cooler areas with higher variation in precipitation had higher predicted habitat values. The association with NDVI Maximum and habitat was a threshold response that peaked at the most common habitat value and remained high above that value (Figure A.19-5). Slope had a negative association with habitat and largely mirrored its availability, as was seen in the MaxEnt model (Figure A.19-6, Figure A.19-5). The Random Forest model had more conservative predictions than the other models, predicting similar areas as habitat, with fewer areas of habitat predicted below approximately 0.8 (Figure A.19-1). Standard Error values were relatively low throughout the county (Figure A.19-2).

Figure A.19-6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for gilded flicker. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

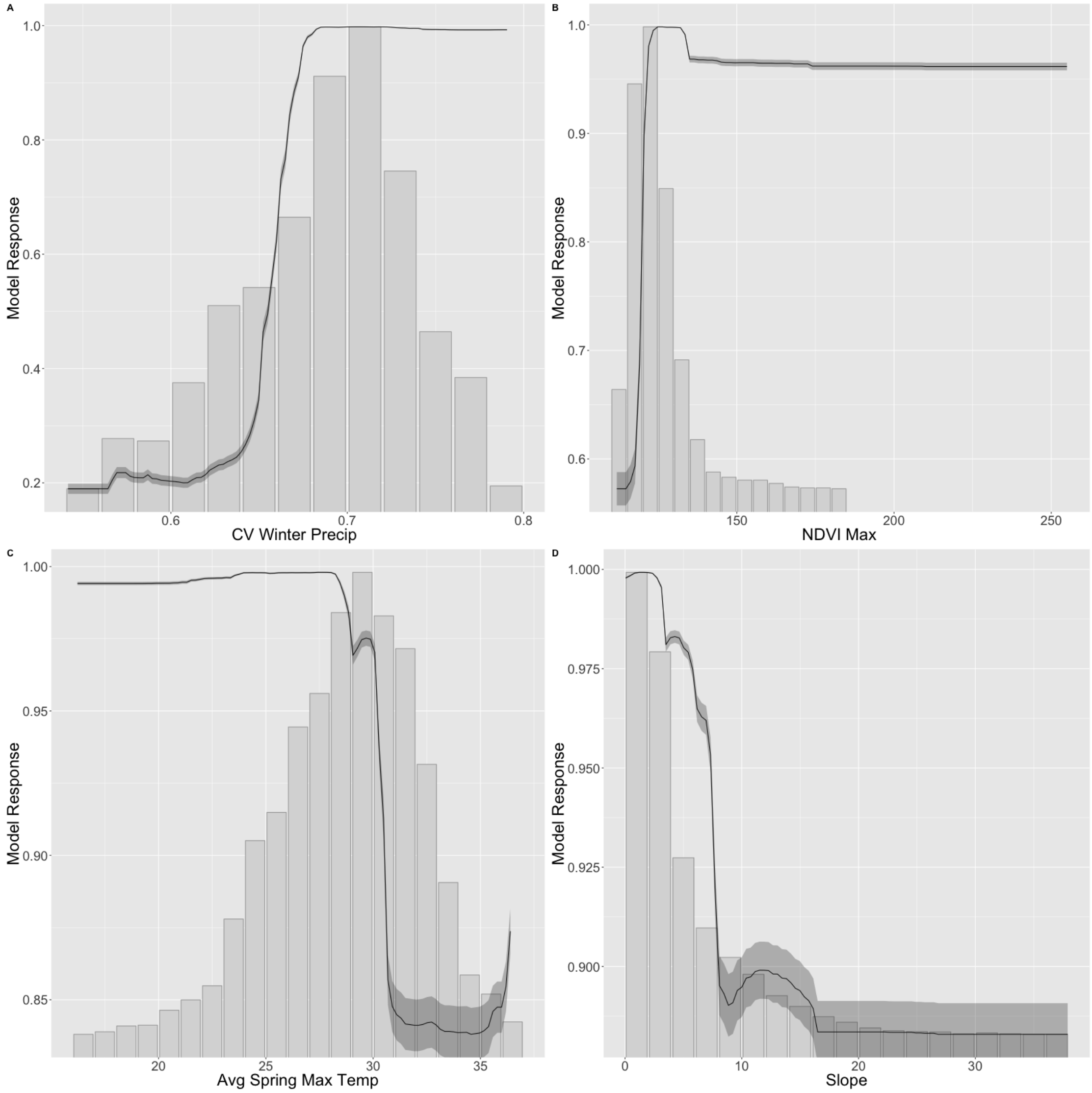


Figure A.19-7. SDM map for gilded flicker Ensemble model for Clark County, NV.

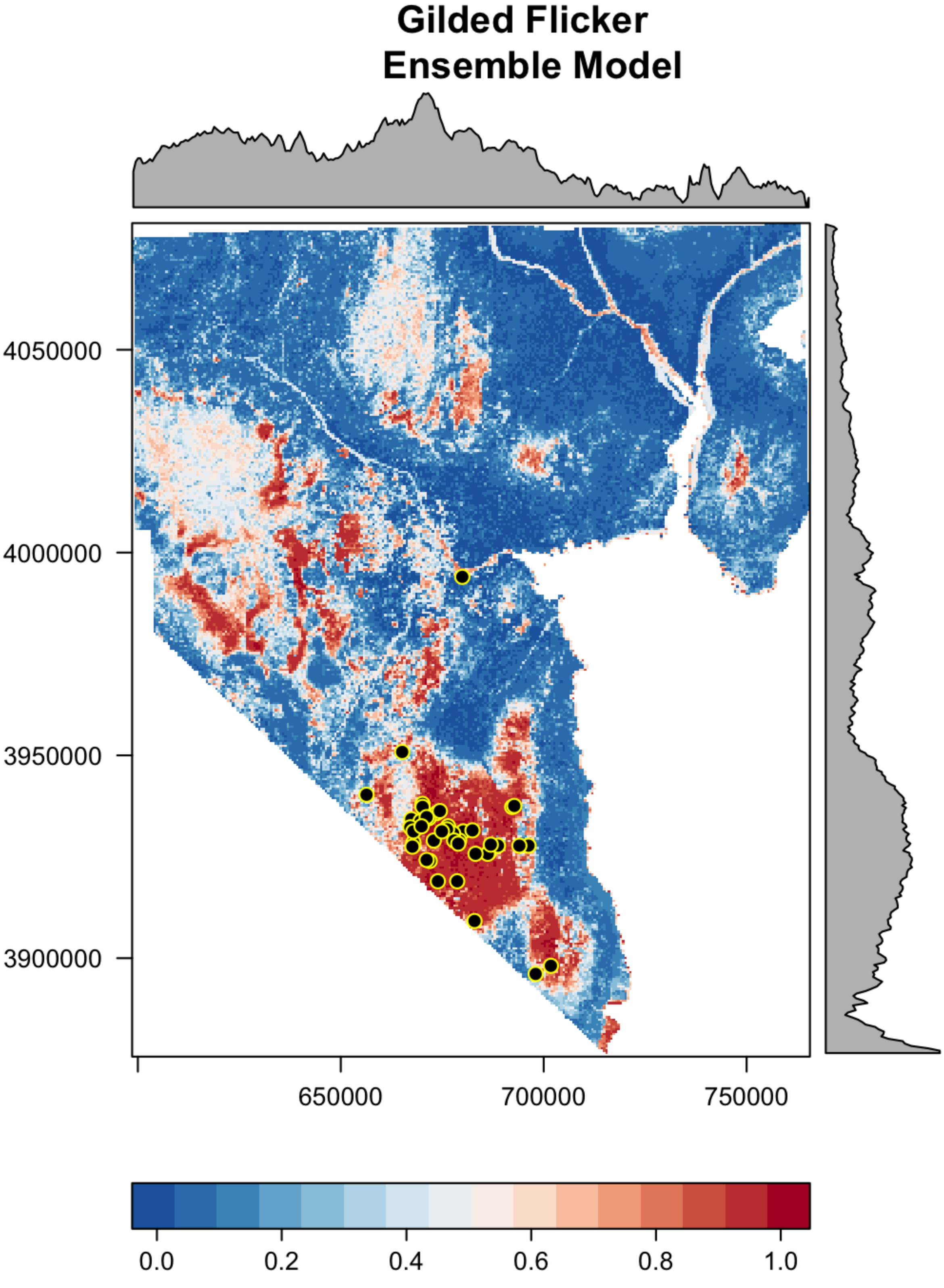
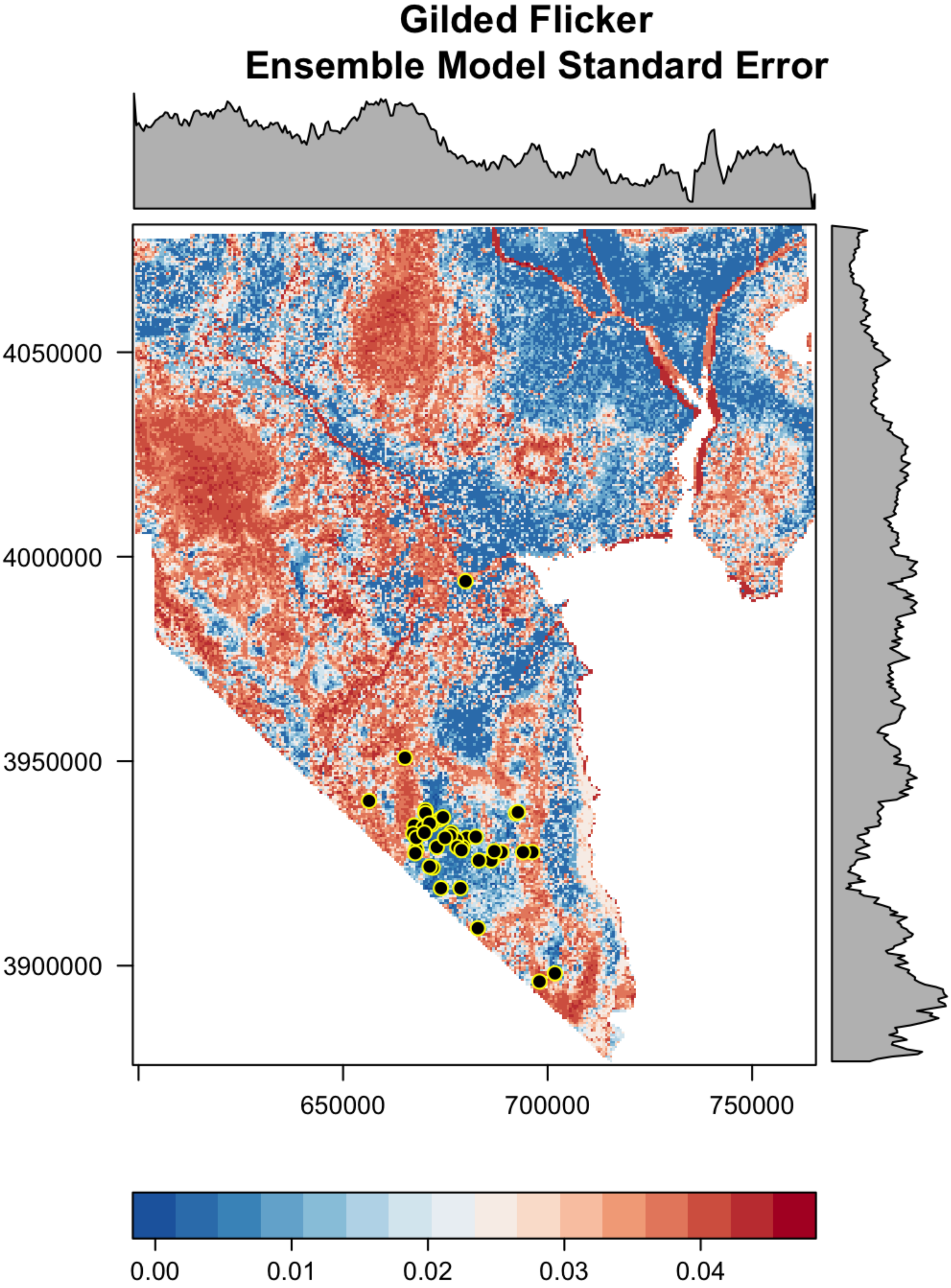


Figure A.19-8. Standard Error map for the gilded flicker Ensemble model for Clark County, NV.



A.19.4.4 Model Discussion

Gilded flickers largely occupy the southern-most portions of Clark County, NV. While there are additional habitat areas predicted around the Spring range, and the southern extent of the Sheep range, there are no localities in the data collected that far north. Indeed, the farthest north point was located in the Las Vegas wash area (Figure A.19-7).

As the models collectively indicated that the species is associated with cooler temperatures and variable precipitation, these predicted habitat areas to the north seem feasible, but as this area is toward the northern extent of the species range their presence there may be rare. There is also a large habitat area predicted to the east the Colorado river in Arizona near Laughlin.

The locality data for this species consisted of 223 records. Spatial thinning of the data reduced the number of localities used for training and testing to 127 records.

A.19.4.5 Standard Error

Standard error for the Ensemble model was relatively low. The Las Vegas area was an area with higher SE values, but these were relatively moderate (SE ~ 0.03 - 0.04, Figure A.19-8).

A.19.5 Distribution and Habitat Use within Clark County

In Clark County, Nevada, gilded flickers are known only from area surrounding the southern Highland and Eldorado mountain ranges, just north and northwest of Searchlight, Nevada (GBBO 2015). There have been 10 sightings there in the past two decades including a male and female observed at the same place on the same day. This area is visually dominated by the Joshua tree, where it is presumed the gilded flicker could nest. There are many other valleys in Clark County where Joshua trees occur and gilded flickers may exist, but have not been detected to date. Besides Joshua tree woodlands, suburban areas supporting large shade trees also provide potential habitat for gilded flickers. Ecosystems within Clark county that contain modeled higher habitat suitability for this species are Mojave Desert Scrub, and Blackbrush ecosystems, while moderate habitat broadens predicted ecosystem presence (Table 3). Hybrids of the gilded flicker and the northern flicker also exist, and were collected for museum specimens nearby in the riparian corridor of the Virgin River, Washington County, Utah (Behle 1976).

Table A.19-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	237889	98361	75838
Bristlecone Pine	7539	25	0
Desert Riparian	5151	3671	1306
Mesquite Acacia	9341	6066	4797
Mixed Conifer	25874	1259	0
Mojave Desert Scrub	1101789	154936	100748
Pinyon Juniper	82693	24739	862
Sagebrush	2808	1777	106
Salt Desert Scrub	67387	14107	984

A.19.6 Ecosystem Level Threats

Within Clark County the gilded flicker is known to occupy Blackbrush and Mojave Desert Scrub ecosystems (Table A.19-3). They may also occupy Mesquite Acacia, and Desert Riparian, with a lesser presence in other ecosystems (Table A.19-3).

Ecosystem level threats likely to impact this species due to habitat conversion are effects of climate change on Joshua trees; solar and wind development, where habitat is removed for utility scale facilities; and the potential for localized changes in local climate due to heat island effects caused by increasing temperatures in proximity to solar facilities. Invasive grasses and wildfire result in loss of nesting habitat because trees in riparian areas and Joshua trees do not respond well to fire. The gilded flicker may be more adaptable than many native species due to their ability to occupy suburban areas, parks, and golf courses.

A.19.7 Threats to Species

Threats to gilded flicker include any disturbance that reduces nesting substrate of large plants that provide nesting substrate such as cottonwood, and Joshua tree. Disturbances that can reduce nesting habitat include invasive species that lead to wildfire, urban development, military training, and large scale energy development. Wind turbines are also known to cause losses in a variety of bird species.

A.19.8 Existing Conservation Areas/Management Actions

The gilded flicker is protected at the federal level by the Migratory Bird Treaty Act, and is considered a Species of Conservation Priority by the Nevada Wildlife Action Plan due to its restricted range within Nevada, and its declining population trends range-wide (Wildlife Action

Plan Team 2012). Conservation actions recommended by the plan include: monitoring status and trends; determining their level of dependence on Joshua tree and paloverde-mixed cactus habitat, which is predicted to expand into Nevada with climate change; and determining the gilded flicker's capability to adapt away from paloverde-cactus habitats typically used in Arizona.

The Nevada Comprehensive Bird Conservation Plan designates the gilded flicker as a Conservation Priority species. Population declines, significant threats, dependence on restricted or threatened habitats, or small population size can all contribute to this designation and exist for the gilded flicker (GBBO 2010). This plan's recommendations include: protecting current known habitat from development and heavy recreational use; aggressively fighting fire that threatens known habitat; searching for additional breeding locations, including in Wee Thump Joshua Tree Wilderness Area; conducting research to determine habitat needs, patch size, and seasonal movements; and continuing and enhancing monitoring to estimate population size and determine needs (GBBO 2010).

The gilded flicker is a covered species under the Lower Colorado River Multi-Species Conservation Plan (LCR MSCP 2004). Conservation measures to avoid, minimize, and mitigate impacts include: creating, maintaining, and adaptively managing 4,050 acres of cottonwood-willow habitat; installing artificial snags to provide nest sites; avoiding and minimizing the impact of covered activities (operation, maintenance, and replacement of hydroelectric generation and transmission facilities, dredging, bank stabilization and other river management activities) on habitat; avoiding and minimizing disturbance during the breeding season; conducting surveys and research to better identify habitat requirements; and conducting research to determine and address effects of nest site competition with European starlings on reproduction (LCR MSCP 2004).

A.20 SOUTHWESTERN WILLOW FLYCATCHER (*EMPIDONAX TRAILLII EXTIMUS*)

The southwestern willow flycatcher (*Empidonax traillii extimus*) is one of four recognized subspecies of *E. trailii*. The *E.t. extimus* subspecies is a small (< 6 in total length) migratory generalist insectivore inhabiting riparian habitat in the southwestern United States (Durst et al. 2008). It is gray/green dorsally with a white throat, and olive-colored breast with the belly becoming yellow. The bill is dark on top, with a lighter-colored lower mandible. It breeds in May to June, primarily in riparian woodlands comprised of cottonwood (*Populus* spp.) and willow (*Salix* spp.), but also breeds in areas inundated with introduced salt cedar (*Tamarix* spp.) (Durst et al. 2008b). As with many species, there continues to be contention over the genetic justification for the distinction of the southwestern willow flycatcher as a distinct "subspecies" (Paxton et al. 2008, Zink 2015, Theimer et al. 2016).

A.20.1 Species Status

In 1995, the southwestern Willow Flycatcher was listed as endangered under the Endangered Species Act of 1973, three years after conservation organizations originally petitioned US Fish and Wildlife Service (USFWS) for the listing (USFWS 1995). In 2015, USFWS received a petition from the Pacific Legal Foundation requesting that the southwestern willow flycatcher be delisted (USFWS 2016). In 2016, USFWS found that delisting may be warranted, based on information related to taxonomic status, but that a status review thoroughly evaluating all potential threats would need to be undertaken (USFWS 2016). The southwestern willow flycatcher is also protected under the Migratory Bird Treaty Act (USFWS 2003).

US Fish and Wildlife Service Endangered Species Act: Endangered

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): Endangered

State of Nevada (NAC 503): Endangered

NV Natural Heritage Program: Global Rank G5T2 State Rank S1B

NV Wildlife Action Plan: SOCP

IUCN Red List (v 3.1): No status

CITES: No status

A.20.2 Range

The breeding range of the southwestern willow flycatcher includes southern California, Arizona, New Mexico, extreme southern portions of Nevada and Utah, far western Texas, perhaps southwestern Colorado, and extreme northwestern Mexico. This species winters from Mexico south to northwestern Colombia (USFWS 1995).

A.20.3 Population Trends

Populations of the southwestern willow flycatcher have declined an estimated 75 to 90 percent over the last century (NatureServe 2009). Recent efforts to recover the subspecies are believed to be lessening the rate of decline, however, range-wide population trends are obscured by variations in annual survey effort and locations, making it difficult to determine if the population is increasing, decreasing, or stable (Sogge et al. 2003). The southwestern willow flycatcher Breeding Site and Territory Summary documents all known southwestern willow flycatcher breeding sites, and assembles data on population size, location, habitat, and other information for all breeding sites from 1993 through 2007 (Durst et al. 2008). These summaries show an increase in the number of known breeding locations over the survey period; however, this result is skewed by a recent increase in intensive survey efforts. Arizona, New Mexico, and California account for the greatest number of known southwestern willow flycatcher breeding sites and territories. Nevada, Colorado, and Utah, combined, account for approximately 12 percent of territories, primarily because these states have few areas with breeding appropriate habitat occurring far enough south to fall within the willow flycatcher's range. In 2007, there were 13 known breeding sites and 76 known territories recorded in Nevada (Durst et al. 2008). The Nevada Department of Wildlife estimates there are 90 southwestern willow flycatchers in the state, and assumes the trend is stable (Wildlife Action Plan Team 2012).

A.20.4 Habitat Model

The habitat models predicted under the three different algorithms were different from one another, in that the MaxEnt model predicted far more restricted habitat that was limited to the areas near the footprint of the observations. The Random Forest and GAM models predicted a greater area of habitat, and the predicted areas were similar to one another, but with varying levels of suitability for some areas. For example, the RF model predicted habitat more strongly in and around the Las Vegas metropolitan area. All models had the highest habitat predictions in areas that might be traditionally considered habitat for the flycatcher – in the riparian areas typically associated with breeding. These were located as expected along the Muddy and Virgin Rivers, and in the extreme southern extend of the Colorado River, near Avi and Needles CA (Figure A.20-1).

The GAM and Random Forest models had very similar performance metrics to one another (Table A.20-1), although the RF models had a higher Boyce Index than the GAM models. The MaxEnt Model was the poorest performing model, although it did have a slightly higher Boyce Index than did the GAM models. Since the Ensemble is a weighted average of the three algorithms it is more heavily influenced by the higher performing GAM and Random Forest models, and thus reflects their predictions of habitat more strongly (Figure A.20-1). Relative variable importance was ranked differently among the algorithms, where the Random Forest models was largely driven by Soil Silt content, and the initiation of the spring greenup (NDVI Start of Season), while the GAM model had higher influence of temperatures (Max and Extreme). The MaxEnt had higher influence by NDVI Maximum, followed by Coarse fragments, Maximum Temp and the Start of Season date (Table A.20-2).

The Random Forest models had the lowest standard error values among the modeling algorithms (Figure A.20-2), where the areas of moderate error (~ 0.02 – 0.03) were surrounding the habitat predicted in the Spring and Sheep ranges. The GAM model had more areas of higher error (SE 0.04 – 0.06) and these were more broadly distributed throughout the county. The MaxEnt model had higher levels of error in the areas that were also predicted to be habitat for the Flycatcher (Figure A.20-2 and Figure A.20-1). The Continuous Boyce Indices showed some irregularities, especially in the MaxEnt models, and to a lesser degree in the Random Forest models, where there were peaks at the lower predicted habitat values – indicating habitat predictions in areas with lower prevalence of presence values (Figure A.20-3). The GAM model had a more uniform cure, indicative of a good model fit, and the Ensemble model benefited from this influence, resulting in good model fit relative to habitat discrimination. (Figure A.20-3).

Table A.20-1. Model performance values for southwestern willow flycatcher models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given in the last column.

Model	AUC	BI	TSS	PRBE
Ensemble	0.92	0.94	0.77	0.30
GAM	0.92	0.72	0.77	
Random Forest	0.91	0.91	0.79	
MaxEnt	0.87	0.84	0.65	

Table A.20-2. Percent contributions for input variables for southwestern willow flycatcher for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	25.9	3.4	4.9
Average Spring Max Temp	9.3	2.8	3.6
Coarse frags	4.3	6.6	18.2
Extreme Max Temp	13.6	4.8	14
NDVI Amplitude	7.7	1.5	9.6
NDVI Max	20.4	7.7	22.6
Sand	2.1	6.7	3.1
Silt	11.2	36.6	5.7
Slope	2.2	2.5	4.6
Start of Season (day)	3.3	27.5	13.7

Figure A.20-1. SDM maps for southwestern willow flycatcher model - Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

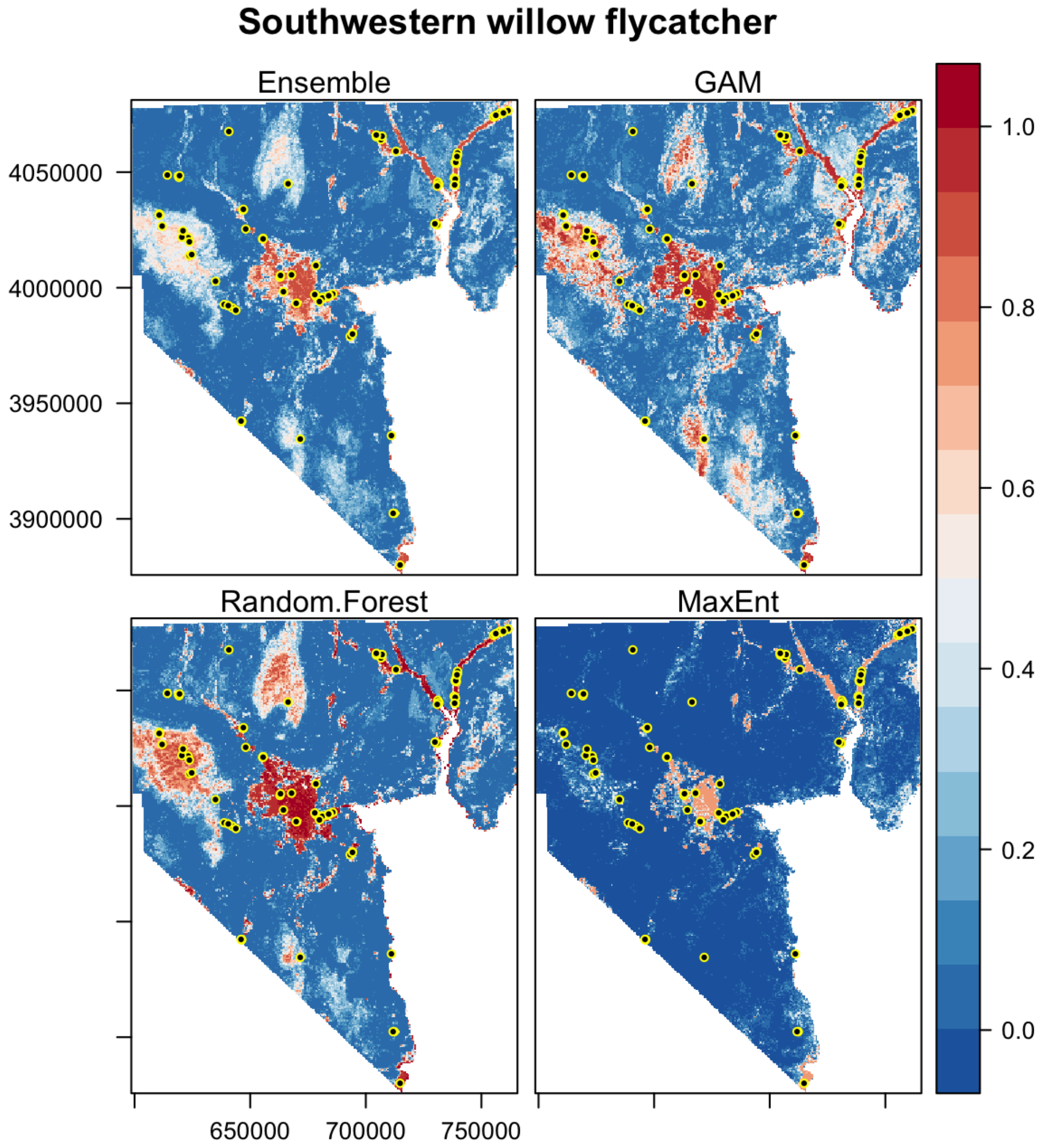


Figure A.20-2. Standard error maps for southwestern willow flycatcher models for each of three modeling algorithms used (Ensemble - upper left, GAM - upper right, RF - lower left, and MaxEnt - lower right).

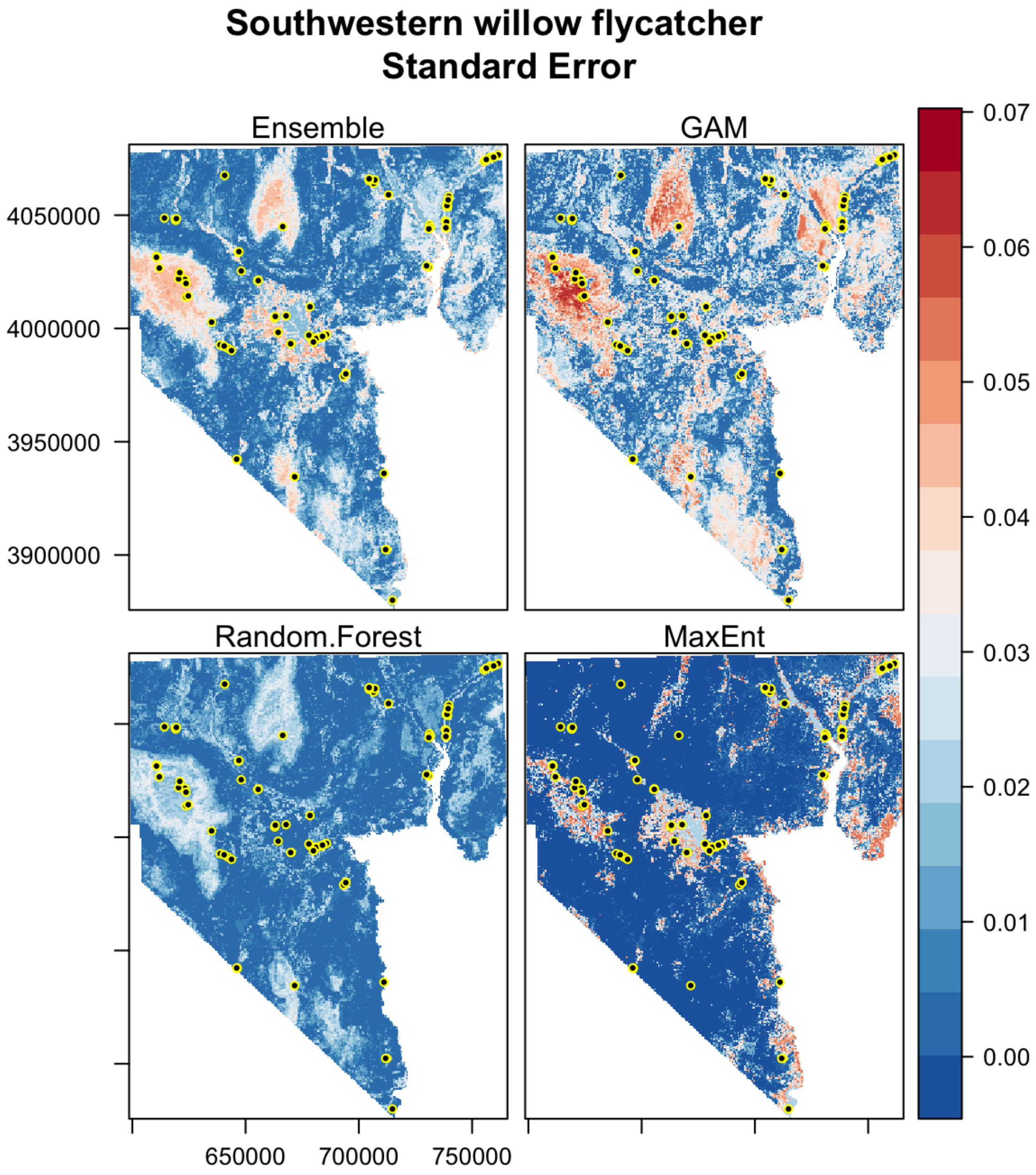
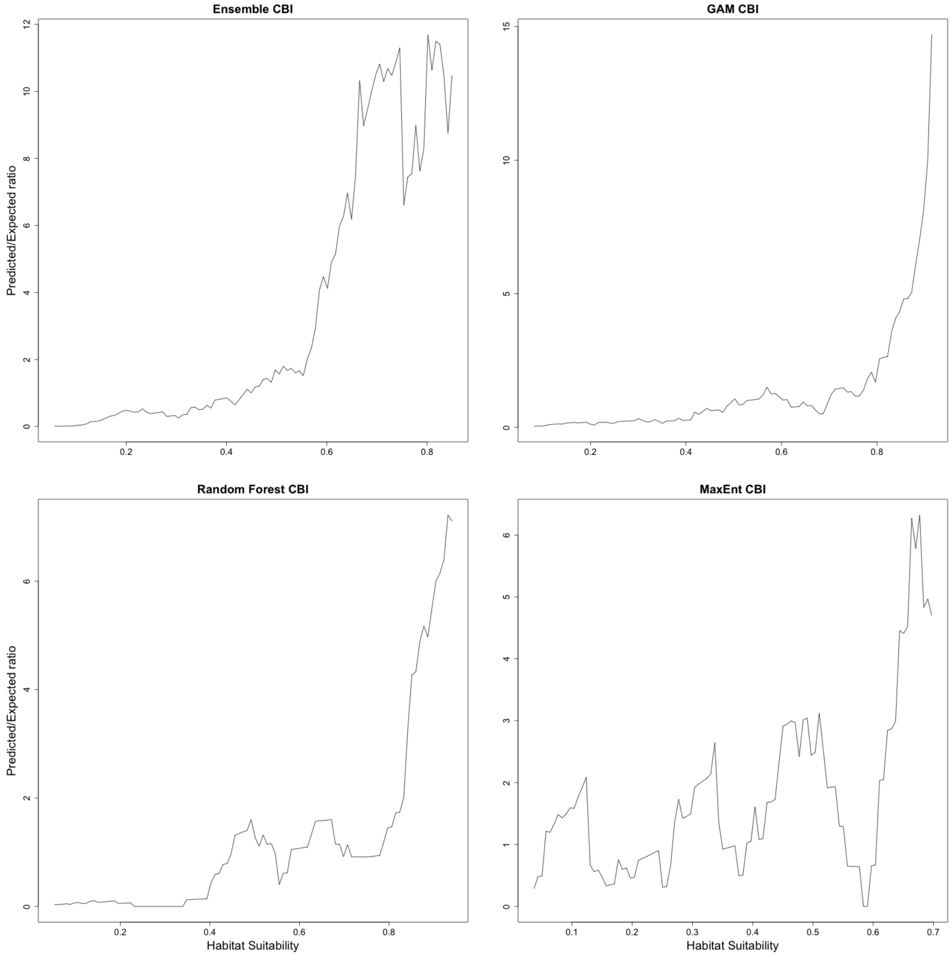


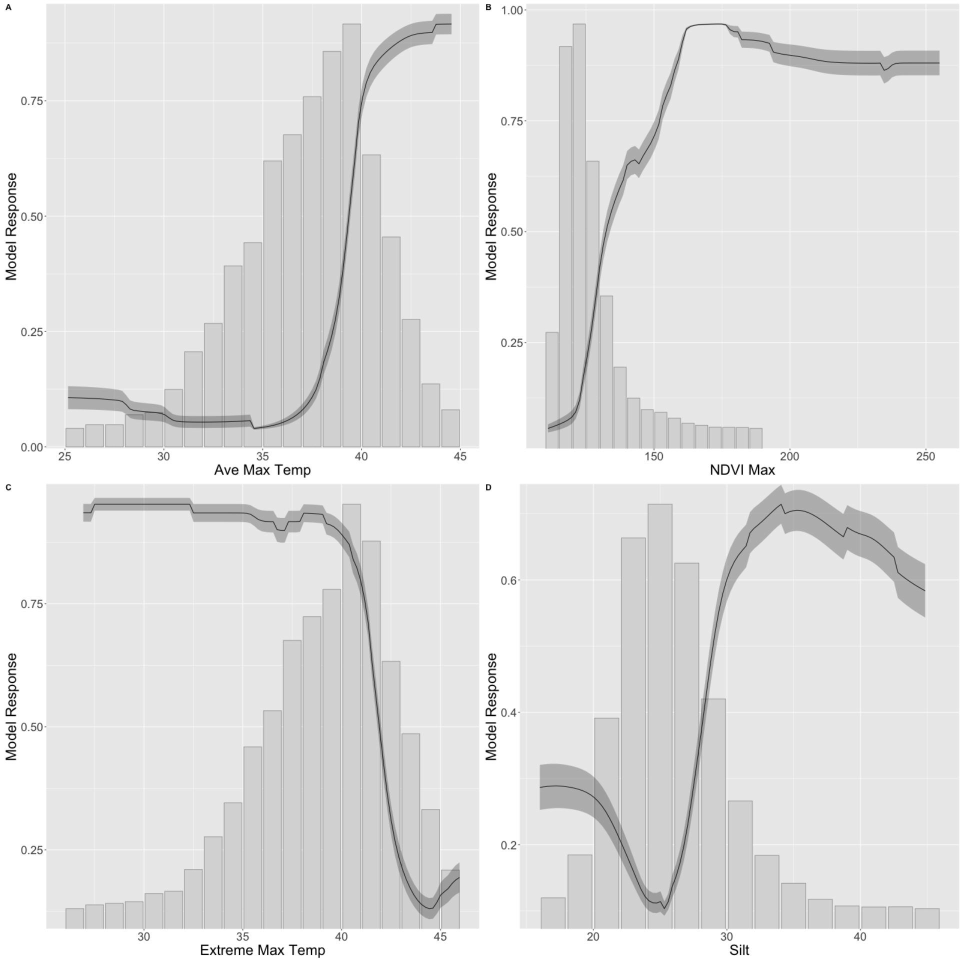
Figure A.20-3. Graphs of Continuous Boyce Indices [CBI] for southwestern willow flycatcher models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).



A.20.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, and NDVI Maximum, followed by the Extreme Maximum temperature, and Silt content of the soil (Table A.20-2). Model scores were higher in areas with higher Average Maximum temperatures, but lower Extreme Maximum temperature (Figure A.20-4). Habitat was also higher in areas with increasing NDVI maximum. Habitat was positively associated with soil Silt Content, with values above 0.5 having the higher model scores (Figure A.20-4). Standard errors were often elevated indicating disagreement among the multiple runs of this model. The areas with elevated error (although this peaked at a standard error of about 0.06) were associate with more mountainous areas such as the Spring range, and the Sheep range.

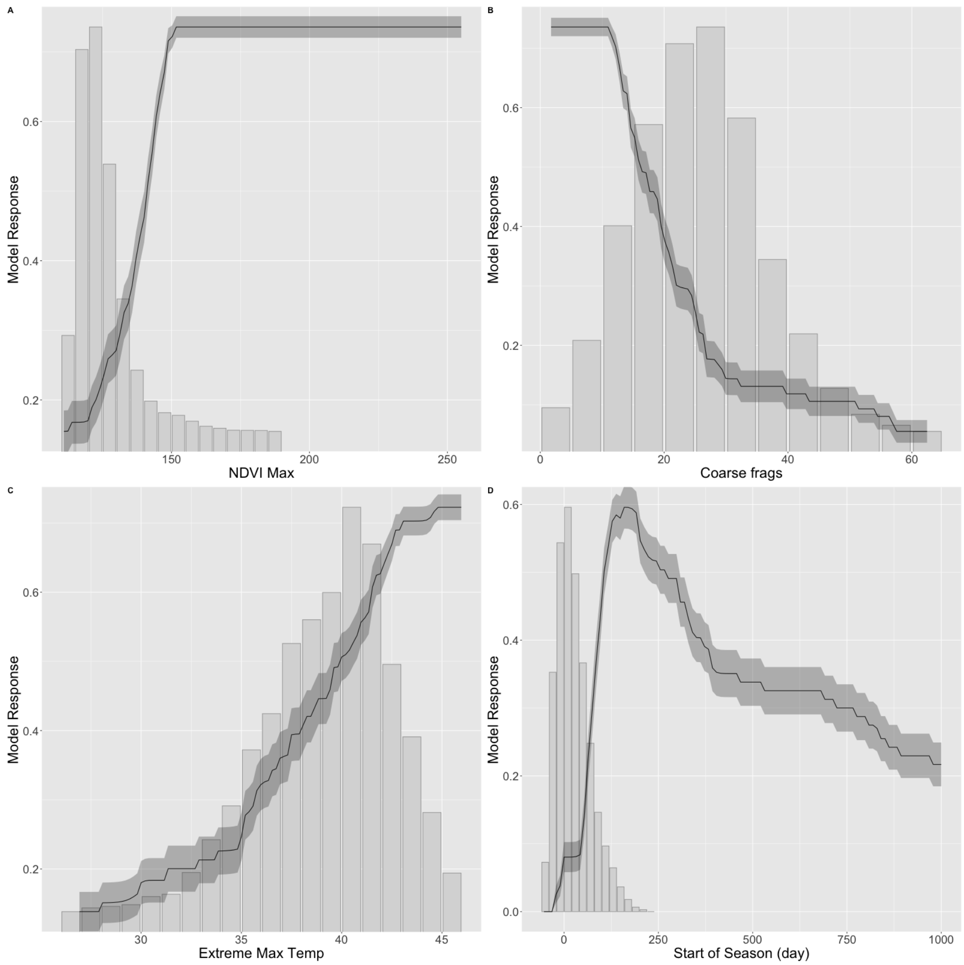
Figure A.20-4. GAM partial response curves for the top four variables in the southwestern willow flycatcher model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.20.4.2 MaxEnt Model

The MaxEnt models had a more even contribution among the input layers used. The most influential contributions were from NDVI Maximum and Coarse Fragments, followed by Extreme Maximum temperature, and the Start of the Spring Season (as indicated by NDVI). (Table A.20-2). Like the GAM model, habitat values increased with greater NDVI Maximum and plateaued at a high level (Figure A.20-5). Higher habitat values were predicted when Coarse fragments were lower (< 30%) and declined with higher values (Figure A.20-5). lowest Maximum temperature values, peaking at 30 C and remaining higher thereafter (Figure A.20-5). Habitat values increases steadily with higher Extreme Maximum temperature. This response is dissimilar to the response of the GAM model for the same variable (Figure A.20-4, Figure A.20-5). High habitat values were predicted when start of the season occurred at about 240 days, and declined with higher or lower values (Figure A.20-5).

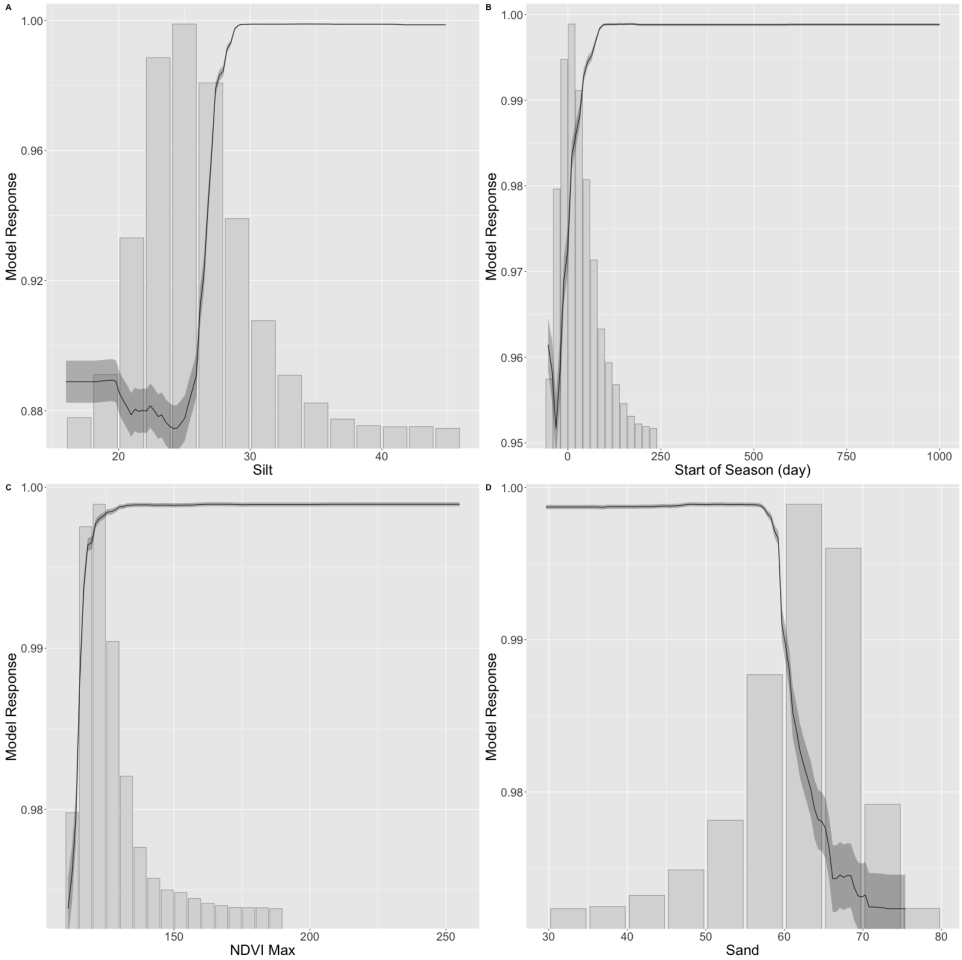
Figure A.20-5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for southwestern willow flycatcher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.20.4.3 Random Forest Model

The Random Forest model for this species has heavily influenced by the Silt Content of the soil, and Start of Season (collectively 64.1%, Table A.20-2). Performance curves for these variables indicated higher predicted habitat values in areas with higher Silt Content – suggesting lower areas within drainages, but with higher habitat in areas with a lower Sand Content (Figure A.20-6). Habitat was also higher in areas with later spring photosynthetic start dates (Start of Season), and that had higher Maximum NDVI values (typically associated with lower, greener areas such as riparian areas; Figure A.20-6). Habitat was also higher in areas with a lower concentration of Sand Content (<55%; Figure A.20-6). The performance metrics were excellent for this model (Table A.20-1) although the Continuous Boyce plots indicated good model performance with some anomalies (Figure A.20-3) likely caused by moderate habitat prediction values peaking in areas with lower locality density, such as the Spring Range (Figure A.20-1).

Figure A.20-6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for southwestern willow flycatcher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.20.4.4 Model Discussion

Southwestern willow flycatcher largely occupy the riverine and larger drainage systems located along the Muddy and Virgin rivers. There were also many localities along the Las Vegas wash system. These locations are associated with the typical preference toward riparian and wetter areas expected for this species. There were several observations were also located within the municipal limits of the city and outlying areas, which likely contributed to the larger areas of predicted habitat there. Surprisingly there were also many locations associated with the spring and montane systems located northwest of Las Vegas, and these contributed to the habitat predicted within the Spring range, and along the US 95 corridor (Figure A.20-7).

The locality data for this species consisted of 321 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 213 records.

A.20.4.5 Standard Error

There are several areas of relatively higher error rates (SE ~ 0.02 - 0.04) located for the most part in and around the Spring and Sheep ranges. There is also an area higher error near the Weethump area west of Searchlight (Figure A.20-8).

Figure A.20-7. SDM map for southwestern willow flycatcher Ensemble model for Clark County, NV.

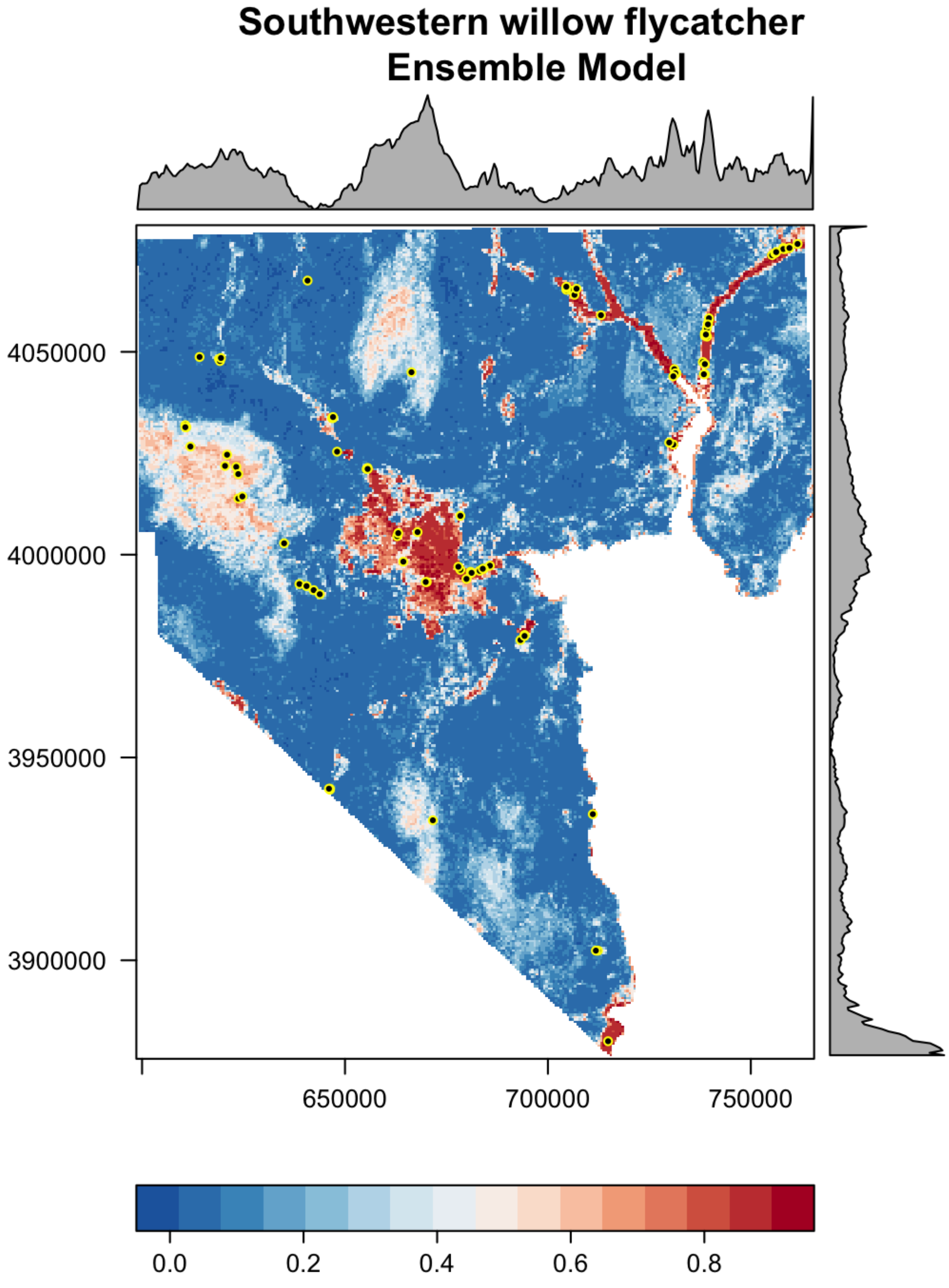
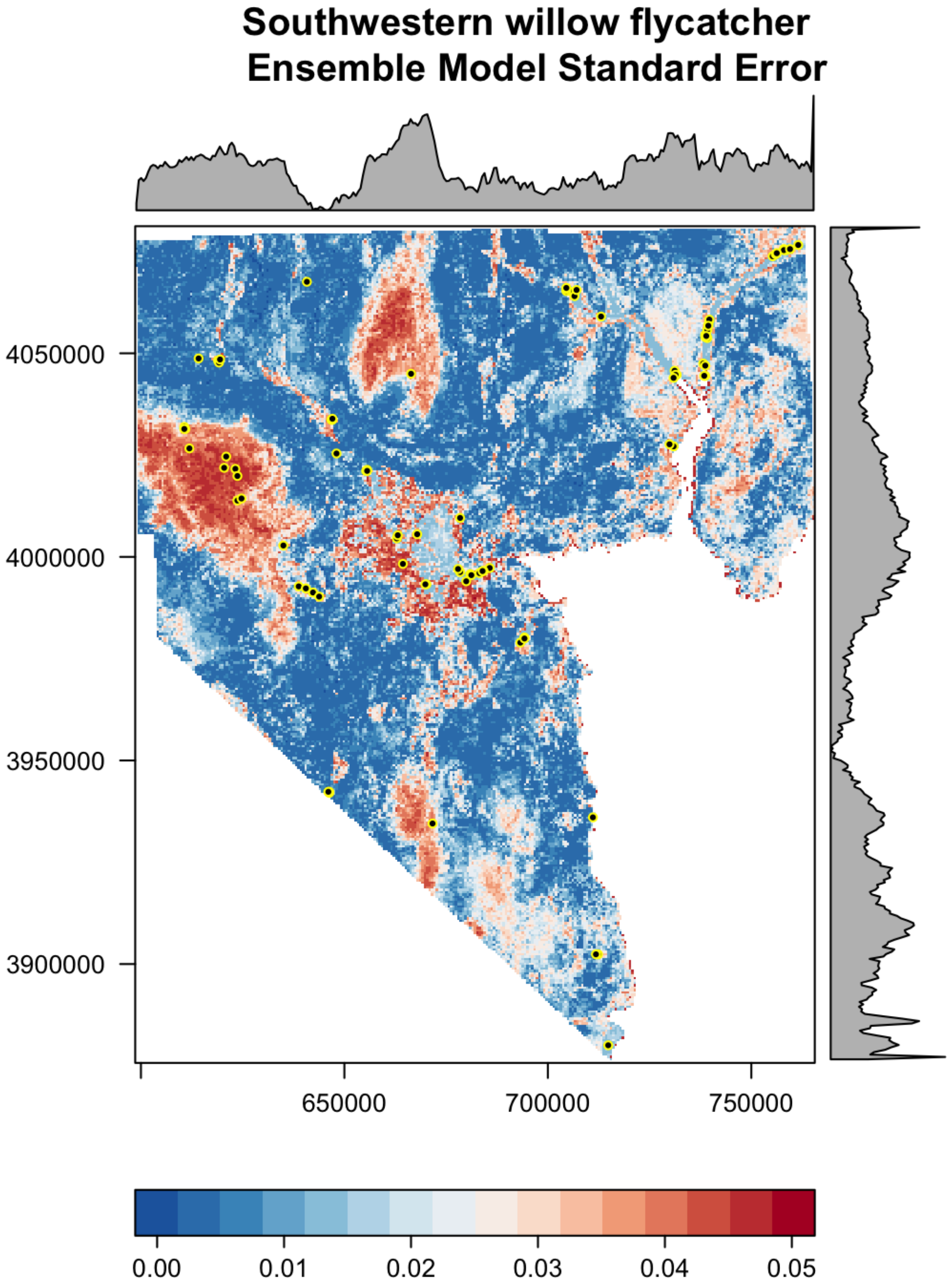


Figure A.20-8. Standard Error map for the southwestern willow flycatcher Ensemble model for Clark County, NV.



A.20.5 Distribution and Habitat Use within Clark County

In Clark County, the southwestern willow flycatcher can be found in isolated pockets of the Colorado River drainage, the Las Vegas Wash, the Virgin River above Lake Mead, and the Muddy River (Nevada Partners in Flight 1999). They are reported from four of the seven Important Bird Areas of Clark County; Lake Mead, Moapa Valley, Spring Mountains, and Virgin River (McIvor 2005). However, breeding has only been confirmed in riparian habitat along the Virgin River and along the upper and lower Muddy River (Krueger 2007). Preferred breeding habitat includes dense vegetation near watercourses or wetlands, and in southern Nevada, preferred vegetation includes willow (*Salix* spp.), cottonwood (*Populus* spp.), salt cedar or tamarisk (*Tamarix* spp.), and Russian olive (*Eleagnus angustifolia*) (Krueger 2007). Modeled habitat for this species indicates high suitability habitat for this species in Mojave Desert Scrub, Desert Riparian, Mixed Conifer, and Salt Desert Scrub ecosystems (Table A.20-3), although breeding habitat is likely far more restricted.

Table A.20-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	124	0
Blackbrush	371582	43320	89
Bristlecone Pine	0	7069	472
Desert Riparian	106	211	9860
Mesquite Acacia	14036	1938	4241
Mixed Conifer	272	19637	7310
Mojave Desert Scrub	1174838	94346	88665
Pinyon Juniper	42338	67423	5722
Sagebrush	1937	2738	14
Salt Desert Scrub	70638	7886	4021

A.20.6 Ecosystem Level Threats

Threats to southwestern willow flycatcher habitat include removing, thinning, or destroying riparian vegetation (USFWS 2002). Riparian ecosystems have declined throughout the southwest from reductions in water flow, interruptions in natural hydrological events and cycles, physical modifications to streams, modification of native plant communities by invasion of exotic species and grazing of livestock, and direct removal of riparian vegetation, including habitat modifications resulting from water diversions and groundwater pumping, which can alter the structure of riparian vegetation and flood plains (USFWS 2002, Brodhead et al. 2007). While salt cedar appears to have lower preference by breeding birds (Brodhead et al. 2007), there appears to be no effect on nutritional condition of birds breeding in habitat invaded by salt cedar (Owen et al. 2005).

Fire is also a threat to riparian ecosystems. Many native riparian plants are not fire-adapted and recover poorly following fire events (USFWS 2002). Fires in riparian habitats are typically catastrophic, causing immediate and drastic changes in riparian plant density and species composition.

Development of land for agriculture can also pose a significant threat to riparian ecosystems. Agricultural development not only impacts this ecosystem through direct clearing of riparian vegetation, but additional impacts may result when floodplains are re-engineered (e.g., draining, protecting with levees) to divert water for irrigation, and through groundwater pumping. The use of herbicides and pesticides on these lands may also affect the ecosystem (USFWS 2002, Brodhead et al. 2007).

A.20.7 Threats to Species

This subspecies has declined because of overstocking or other mismanagement of livestock, habitat loss, and recreational development. In addition to the above threats, the southwestern willow flycatcher is also subject to cowbird parasitism (USFWS 1995, Brodhead et al. 2007). Brood parasitism has been cited as a significant threat to this species, with 20-30% of nests being parasitized (Brodhead et al. 2007). Brood parasitism by brown-headed cowbirds (*Molothrus ater*) negatively affects the flycatcher by reducing reproductive performance. Parasitism typically results in reductions in number of flycatcher young fledged per female per year (USFWS 2002). Cowbirds are increasingly abundant in floodplains and areas of increased grazing, and modified habitats with increased edge-of-habitat patches are also associated with increased nest parasitism (Brodhead et al. 2007), Additionally, since southwestern willow flycatcher population numbers are small in any given area (largely due to the infrequency of large patches of suitable habitat), they are highly susceptible to stochastic environmental factors. A single severe weather event can reduce a small population below a threshold level from which it cannot recover (USFWS 2002). Sex biases have also been reported in small declining populations, where they are in some cases male biased, and in others female biased, and these severe biases may have conservation and management implications as different management techniques may be required for recovery (Durst et al. 2008).

A.20.8 Existing Conservation Areas/Management Actions

USFWS' Southwestern Willow Flycatcher Recovery Team Technical Subgroup prepared a final recovery plan for the Southwestern Willow Flycatcher. The southwestern willow flycatcher recovery plan's main objectives are to increase and improve occupied, suitable, and potential breeding habitat; increase metapopulation stability; improve demographic parameters; minimize threats to wintering and migration habitat; survey and monitor; conduct research; provide public education and outreach; assure implementation of laws, policies, and agreements that benefit the flycatcher; and rank recovery progress (USFWS 2002).

In 2013, as required by the Endangered Species Act of 1973, USFWS designated approximately 1,975 stream kilometers (1,227 stream miles) in Arizona, California, New Mexico, Nevada, and Utah as critical habitat for the southwestern willow flycatcher. This included the lateral extent of each stream segment (the riparian areas and streams that occur within the 100-year floodplain), for a total area of approximately 84,569 hectares (208,973 acres) of critical habitat. Critical habitat within Clark County, Nevada is limited to a 48.4 km (30.0 mi) segment of the Virgin River running from the Arizona border to Colorado River Mile 280 at the upper end of Lake Mead. The 3.1 km (1.9 mi) segment of the Muddy River within the Overton State Wildlife Area in Clark County was also identified as essential to flycatcher conservation, but was excluded from the critical habitat designation because the State of Nevada is already managing riparian habitat within the wildlife area for the flycatcher. This 2013 critical habitat designation was a revision of earlier critical habitat rules from 2005 and 1999 (USFWS 2013).

The Nevada Wildlife Action Plan identifies the southwestern willow flycatcher as a species of conservation priority, and recommends: protecting nesting habitat from disturbances, degradation, and conversion; restoring lost or degraded riparian habitat to a willow-dominated condition; phasing restoration projects to avoid the removal of large amounts of tamarisk before suitable replacement habitat is created; and continuing intensive monitoring efforts to track population trends (Wildlife Action Plan Team 2012). The plan notes that USFWS, BLM, NPS, Forest Service, Nevada Department of Wildlife (NDOW 2008), and other entities have already conducted extensive surveys for the flycatcher (Wildlife Action Plan Team 2012).

The Nevada Comprehensive Bird Conservation Plan, prepared by the Great Basin Bird Observatory (GBBO 2010) also recommends the approach described by NWAP summarized above (2012). In addition, GBBO's plan recommends developing strategies to address the potential loss of current tamarisk breeding habitat to biocontrol agents, and developing comprehensive fire management strategies to protect important breeding habitat (GBBO 2010). The NV Comprehensive Bird Conservation Plan is a revision of the Nevada Partners in Flight Bird Conservation Plan (1999). The original plan stated an objective of establishing between 40 and 50 successful breeding pairs in suitable habitat in Nevada by 2010, but the revised plan does not have specific population objectives.

One of the goals of the conceptual management plan for the Overton Wildlife Management Area (OWMA) is to protect and enhance habitats and populations of endangered species, including the southwestern willow flycatcher (NDOW 2014). Specific objectives within the plan related to this subspecies include: monitoring changes in population; protecting, enhancing, and/or restoring habitat, emphasizing diverse, healthy, and naturally-functioning habitats; and coordinating and collaborating with NDOW's conservation partners. Actions listed in the plan related to the southwestern willow flycatcher include: planting new cottonwoods and willows on the lower reaches of the Muddy River and in habitat where biological vegetation control has taken place; conducting surveys and inventorying existing and potential habitat and assessing for habitat suitability; maintaining wet soils and/or inundated area from May 1 through August 1 within breeding sites; and increasing the removal of tamarisk and replacing with plantings of cottonwood and willows (NDOW 2014).

This subspecies is also covered under the Lower Colorado River Multi-Species Conservation Program. The goal of this program is to conserve habitat of threatened and endangered species and reduce any additional species being listed; accommodate present water diversions and power production; and provide the basis for incidental take authorizations (Lower Colorado River Multi-Species Conservation Program 2004).

In addition, the southwestern willow flycatcher is covered under the Spring Mountain Conservation Agreement USFS 1998). This agreement has been developed between various agencies to provide long-term protection for the rare and sensitive flora and fauna of the Spring Mountains National Recreation Area.

A.21 LOGGERHEAD SHRIKE (*LANIUS LUDOVICIANUS*)

The loggerhead shrike (*Lanius ludovicianus*) is a medium-sized bird with a striking black mask across the eyes, on its wings, and tail, contrasting with the white breast and other highlights on the wings and tail, against a grey base color. This small hunter is the only raptorial songbird with a notch in its beak for trimming prey. Its beak is shaped similarly to that of the American kestrel (*Falco sparverius*). Also known as the butcherbird, loggerhead shrikes have a habit of impaling their small prey on sharp features such as yucca leaves, mesquite spines, creosotebush twigs, and barbed wire across the American southwest. The prey: scorpions, beetles, centipedes, Jerusalem crickets, house finches, adult and young horned larks, meadow mice and kangaroo rats, side-blotched lizards, horned lizards, coachwhip snakes, carrion, and others (Dawson 1923, Bent 1965, Kridelbaugh 1983, Yosef 1996, T. Esque – pers. Observation). Once impaled and stabilized, prey is stripped of flesh to feed their young. Vertebrate prey are killed by biting the neck and disarticulating cervical vertebrae (Pruitt 2000). The shrike must use these tools to assist in handling prey because they do not grasp the prey in their feet as do other raptorial birds (Dawson 1923). Like other raptorial birds and some Corvidae, the shrike regurgitates indigestible portions of their prey including exoskeletons and bones (Dawson 1923). Loggerhead shrikes inhabit open to semi-open habitats where they perch on prominent plants, power wires and poles, and fence posts to watch for prey (Dawson 1923, Rotenberry and Wiens 1980, Dechant et al. 2002). Their nests are found at medium heights, often in thorny plants such as Joshua tree (*Yucca brevifolia*), mesquite (*Prosopis* spp.), or catclaw (*Acacia* spp.), but also in sagebrush (*Artemisia* spp.) or greasewood (*Sarcobatus* sp.) in some locations across the west (Dawson 1923, T. Esque – pers. Obs.). Eggs number from 5 to 7 and are pale bluish gray, or dull grayish-white for ground colors with nearly uniform yellow-brown to gray brown blotches (Dawson 1923). Loggerhead shrikes may have two clutches in a season.

A.21.1 Species Status

Loggerhead shrikes are the only member of the shrike family that occurs in North America. The loggerhead shrike is not protected by the Endangered Species Act of 1973, and no petitions have been filed for its listing. The USFWS designated the loggerhead shrike as a Migratory Nongame Bird of Management Concern in the United States in 1987 due to range-wide declines in populations, and the species is listed as sensitive or threatened at the state level in 14 states. In Canada, the eastern population of the loggerhead shrike is listed as endangered and the western population is listed as threatened (Pruitt 2000). While populations are declining, they are not at a sufficient rate to warrant concern (BirdLife International 2016).

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): No status

US Forest Service (Region 4): No status

State of Nevada (NAC 503): Sensitive

NV Natural Heritage Program: Global Rank G4 State Rank S4

NV Wildlife Action Plan: SOCP

IUCN Red List (v 3.1): Least Concern

CITES: No status

A.21.2 Range

Loggerhead shrikes have a broad distribution across central and southern Canada, most of the United States and Mexico (Dawson 1923, Pruitt 2000, Dechant et al. 2002, Sibley 2003). They prefer open habitat with sufficient perching/prey handling resources for hunting (Brooks and Temple 1990). In the desert southwest they are known to in-habitat a variety of habitat types, including shadscale in east and central Nevada (Medin 1990), Sagebrush habitats in the Great Basin (McAdoo et al. 2004), Mojave Desert Creosote/Bursage in the West Mojave (Brooks 1999) and southwestern Clark County (Ironwood 2012), and Mixed Mojave Desert Scrub in Southern Nevada (Blake 1984).

A.21.3 Population Trends

Population declines for this species have been reported throughout the eastern US (Brooks and Temple 1990, Pruitt 2000). For example, the Breeding Bird Surveys have documented widespread declines of 3.7% per year from 1966-1998 (Pruitt 2000, Sauer et al. 2013). While exact causes of decline are unknown, habitat loss and degradation are suspected to be major contributing factors, but are not sufficient to explain the levels of documented decline (Pruitt 2000). Although some western populations have been reported as stable during the same time period (Peterjohn and Sauer 1995) there is still concern that the sources of declines are unknown, and a series of measures have been proposed to improve habitat conditions (Cade and Woods 1997) including restoring nesting habitat, habit diversity, and hunting perches in habitat (Yosef 1994, 1996).

A.21.4 Habitat Model

Predicted habitat for loggerhead shrike is widespread throughout the county, with habitat extending from the southern tip of the county, along the border with California with patches of fairly connected habitat extending through the Pahrump and Amargosa area. Additional fairly large areas of predicted habitat are on the western edges of the Las Vegas Valley, and along the Muddy and Virgin rivers in the northeastern portion of the county. Smaller less-connected habitat areas occur sporadically throughout the county in most lowland areas (Figure A.21-1).

Overall performance metrics were a bit lower than the other models done to date, with the highest AUC scores being 0.78 for the Ensemble and Random Forest models. Boyce indices for all models were relatively high ranging from 0.92 to 0.97, but the TSS scores were also low (Table A.21-1). The Ensemble model had the best overall performance, while the MaxEnt model performed relatively poorly. Visually the MaxEnt model predicted more restricted habitat in areas where the other models predicted more broadly (Figure A.21-1). The three model algorithms were influenced differentially by environmental data, where several variables were among the top four in two algorithms (Flow Accumulation, NDVI Start of Season, NDVI Maximum, and the Coefficient of Variation for Winter Precipitation (Table A.21-2).

The Standard error maps for all algorithms very low, with the GAM having the lowest SE across the county, and the others with only low to moderate error rates for the most part (Figure A.21-4). The Continuous Boyce curves indicated good model performance, however the MaxEnt had a much more gradual curve, likely due to its reduced accuracy (Figure A.21-3).

Table A.21-1 Model performance values for loggerhead shrike models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.78	0.97	0.42	0.47
GAM	0.7	0.94	0.31	
Random Forest	0.78	0.94	0.43	
MaxEnt	0.69	0.92	0.26	

Table A.21-2. Percent contributions for input variables for loggerhead shrike for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Dist to cliffs	0.1	1.5	0.8
NDVI Amplitude	8.4	3.1	3.2
NDVI Length of Season	0.8	1.7	1.7
NDVI Max	15.6	7	13.7
Winter Precip	10.5	10.5	7.1
CV Winter Precip	9.4	12.1	11.8
Average Spring Max Temp	23.5	2.8	9.7
CV Average Spring Max Temp	13.6	2.6	5.4
Slope	10.7	9.3	7.4
NDVI Start of Season	6.9	17.8	15.3
Flow Accum	0.3	31.7	23.8

Figure A.21-1. SDM maps for loggerhead shrike model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

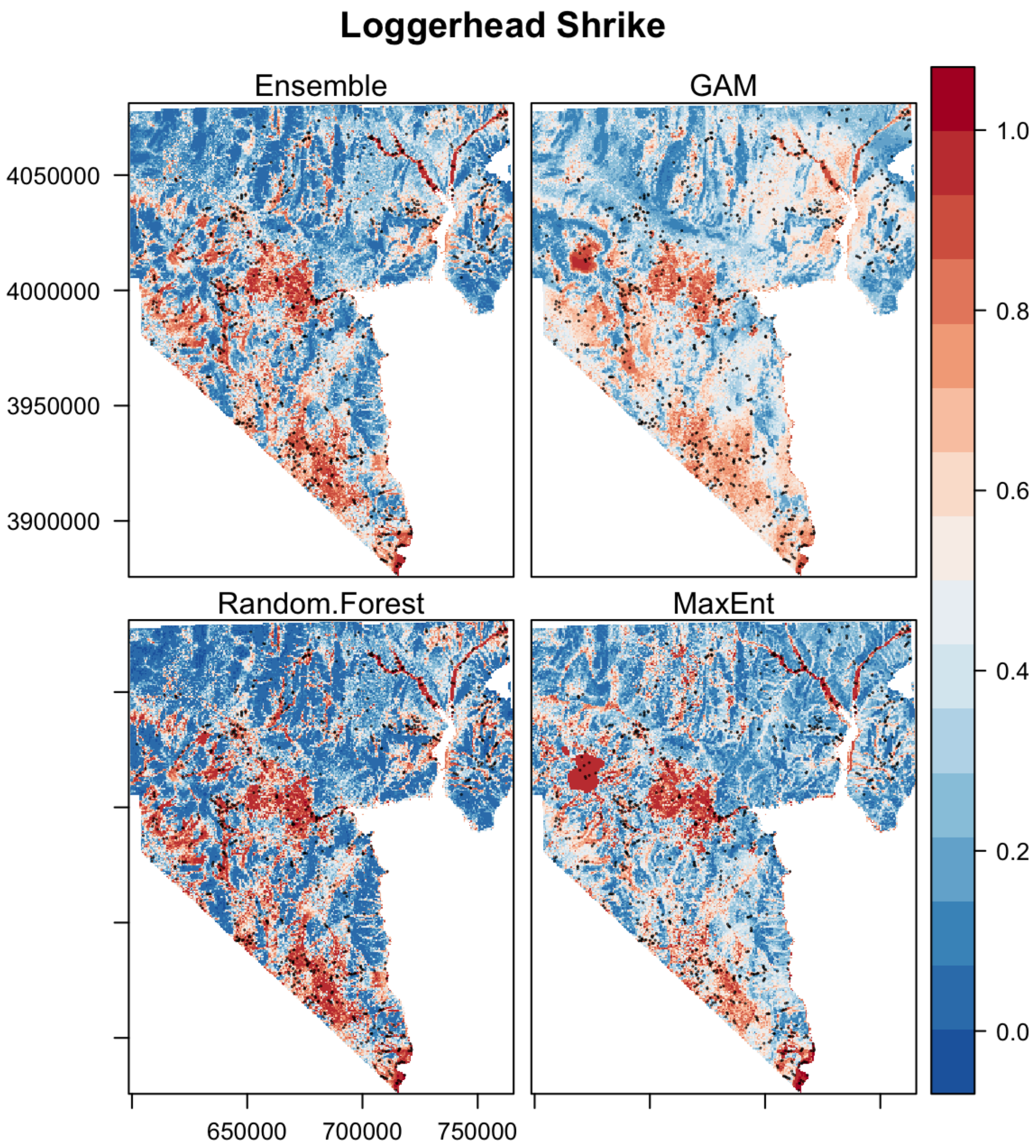


Figure A.21-2. Standard error maps for loggerhead shrike models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

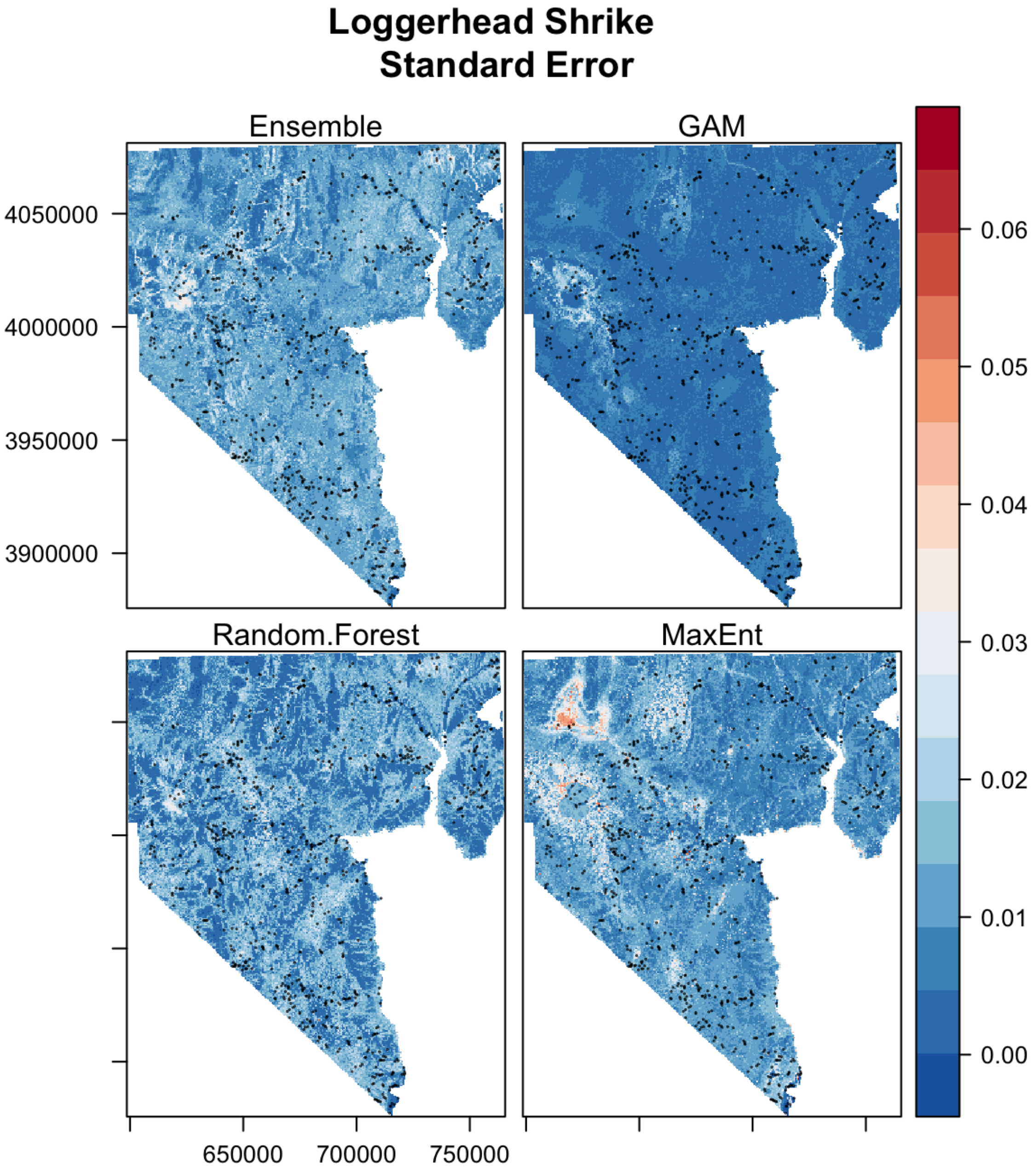
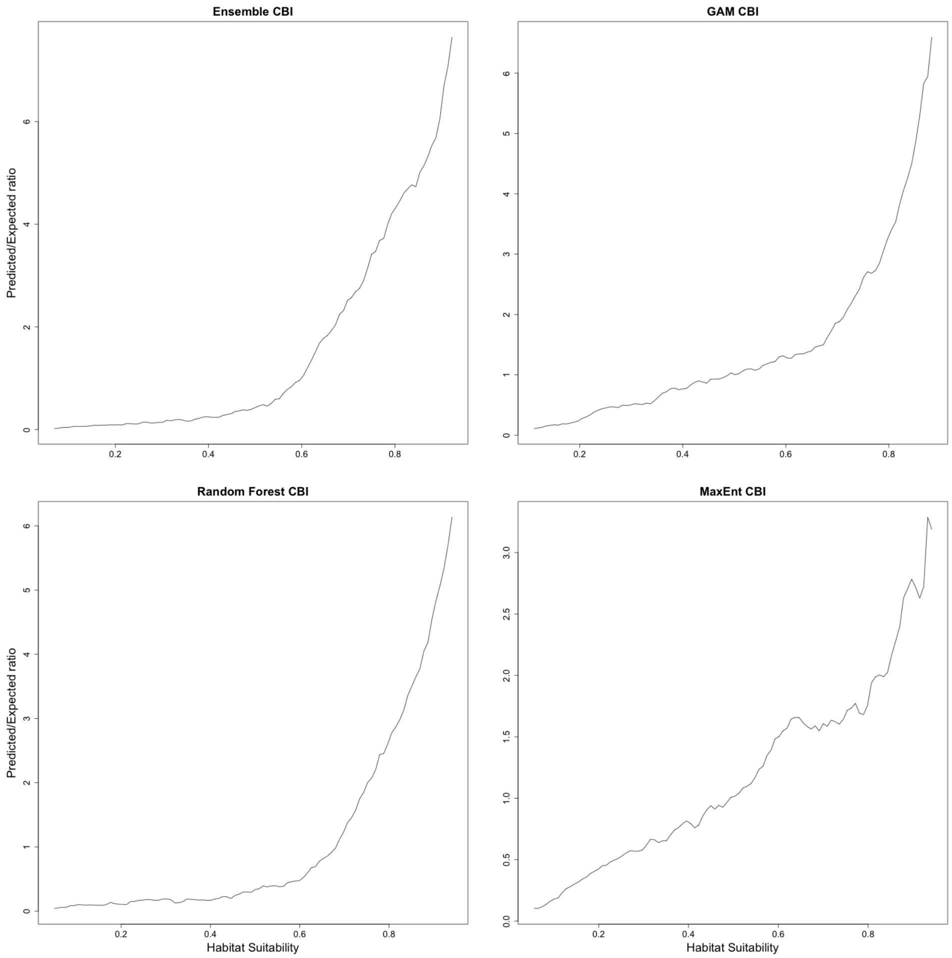


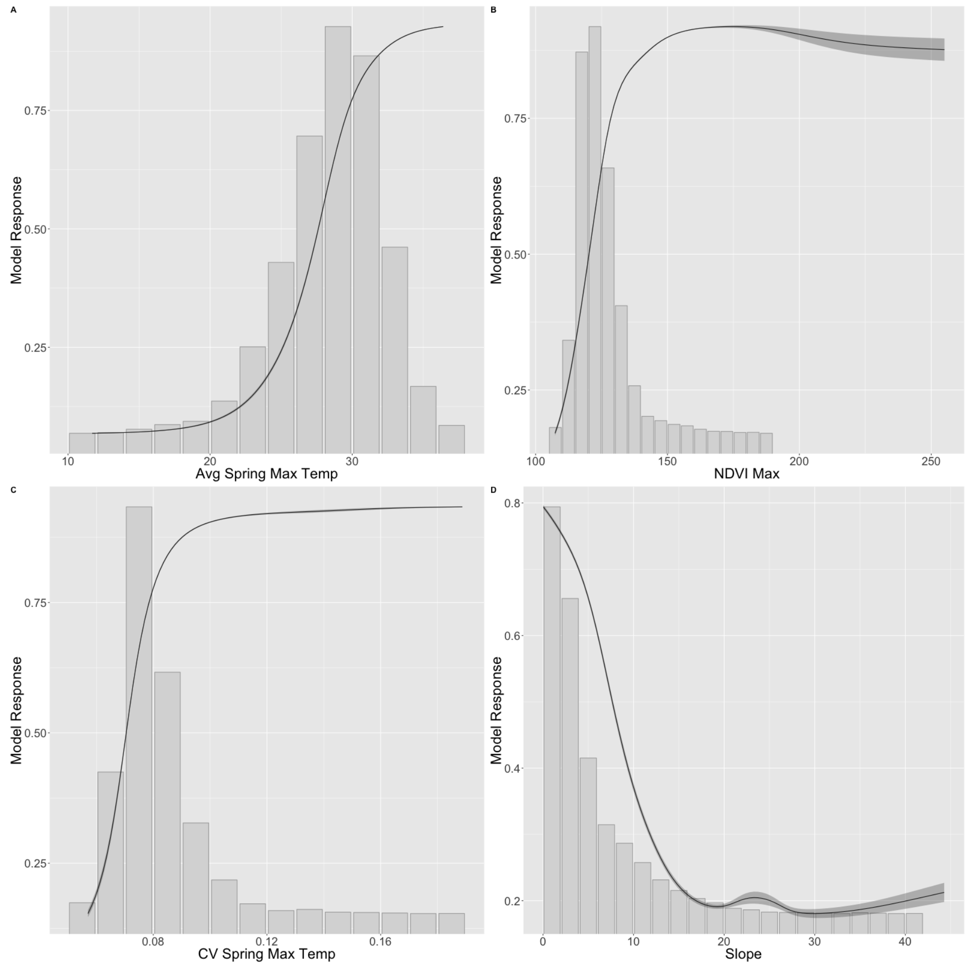
Figure A.21-3. Graphs of Continuous Boyce Indices [CBI] for loggerhead shrike models for the Ensemble model prediction (upper left), and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).



A.21.4.1 General Additive Model

The top four contributing environmental layers for the GAM model were Average Spring Maximum temperature and its CV, the Maximum NDVI value, and Slope. Average Winter Precipitation also contributed nearly as highly (Table A.21-2). Habitat for the shrike was predicted to be highest in areas with higher and more variable Maximum Spring temperatures, and high NDVI max values (Figure A.21-4). Conversely, habitat was predicted to be lower with increasing Slope, in a pattern that was similar to the availability, but with more of a shoulder in areas with lower Slope values (Figure A.21-4).

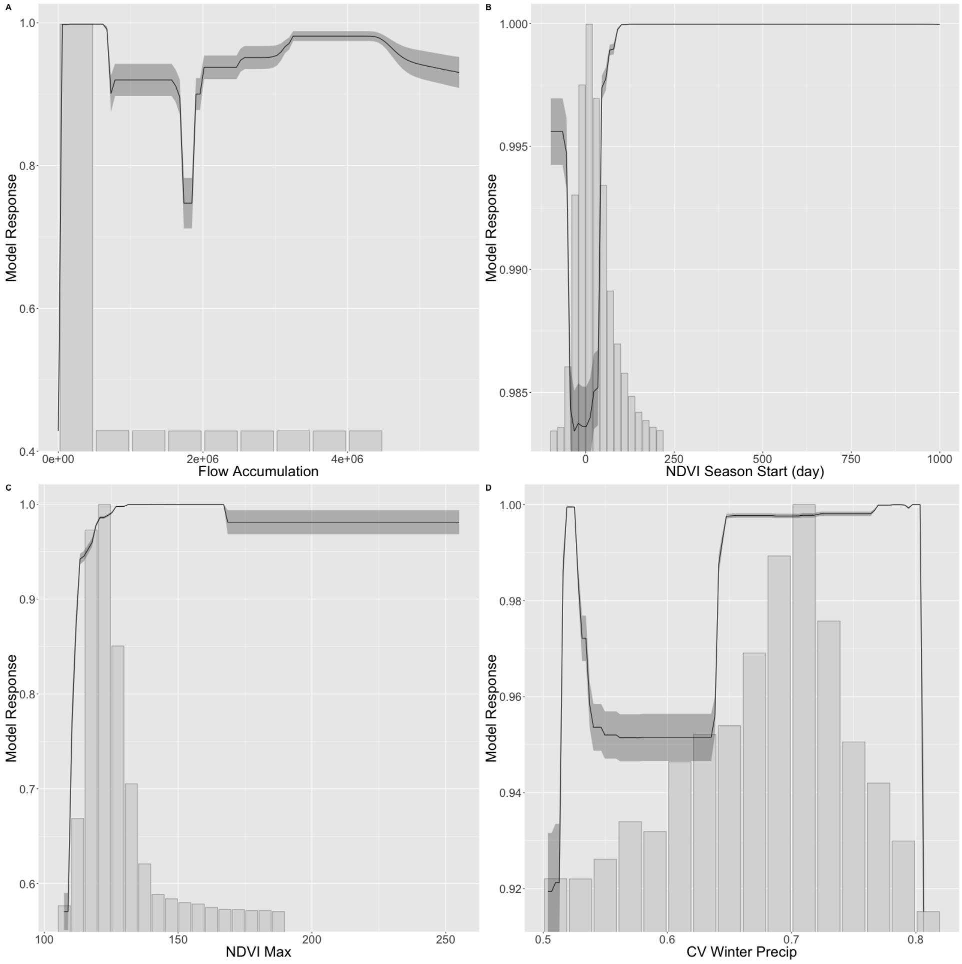
Figure A.21-4. GAM partial response curves for the top four variables in the loggerhead shrike model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.21.4.2 MaxEnt Model

The top four influencing variables in the MaxEnt models were Flow Accumulation, NDVI indication of the Start of Season, the Maximum NDVI value, and the CV of Winter Precipitation (Table A.21-2). The response curves for maxent indicated threshold type responses for most of these, with higher habitat predicted at the highest values for each of the environmental variables (Figure A.21-5). The irregular curve shapes in areas wih fewer points, and thud higher error rates reflect the model over fitting on the training data, and likely result in the relatively poorer performance metrics which were calculated using the withheld testing data set (Table A.21-1).

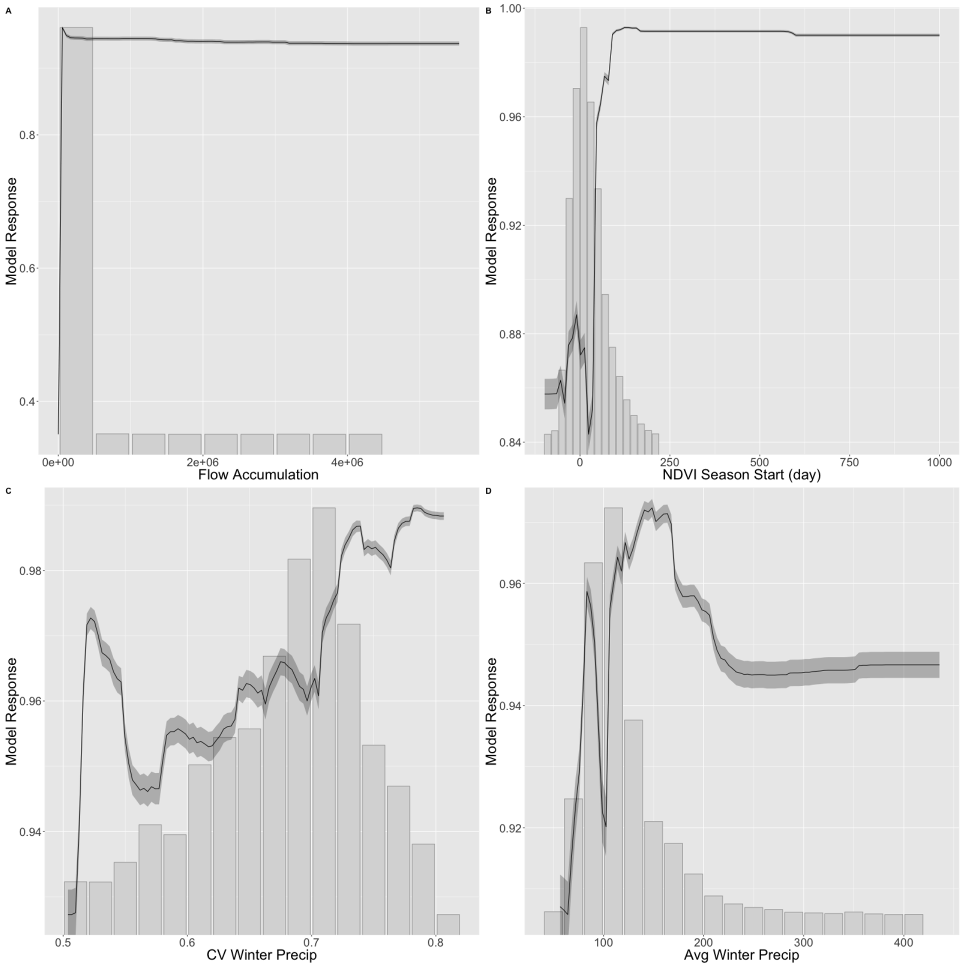
Figure A.21-5. Response surfaces for the top four environmental variables included in the MaxEnt Ensemble model for loggerhead shrike. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.21.4.3 Random Forest Model

The Random Forest model performance curves for Flow Accumulation was similar to that in the MaxEnt model, where higher values were predicted for all areas above the lowest (Figure A.21-6). The NDVI Start of Season day also had a threshold type response, where predicted habitat peaked just above the area average, and remained high (Figure A.21-6). The CV of Winter Precipitation had a gradually increasing influence on model scores, and the Average Winter Precipitation had a peaked response above the area average (at approximately 180 mm) and remained fairly high thereafter (Figure A.21-6). Standard Error rates for this, as well as the other models were relatively low throughout the county (Figure A.21-3).

Figure A.21-6. Partial response surfaces for the top four environmental variables included in the Random Forest Ensemble model for loggerhead shrike. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.21.4.4 Model Discussion

Loggerhead shrike habitat is predicted to be prevalent throughout much of the lowland habitats in the southern 2/3 of Clark County (Figure A.21-7). Range maps for this species indicate widespread occurrence through much of the western United States. The Ensemble model had relatively high performance values (Table A.21-1), and discriminatory ability (Figure A.21-3). The model for this species used 3348 localities within the buffered modeling area, which were geographically thinned to 1570 localities that were split into the training and testing sets.

A.21.4.5 Standard Error

The Ensemble model had low error rates (SE 0.01 – 0.02) among models across most of the study area (Figure A.21-8). Areas of moderate error were in small portions near Amargosa Valley.

Figure A.21-7. SDM map for loggerhead shrike Ensemble model for Clark County, NV.

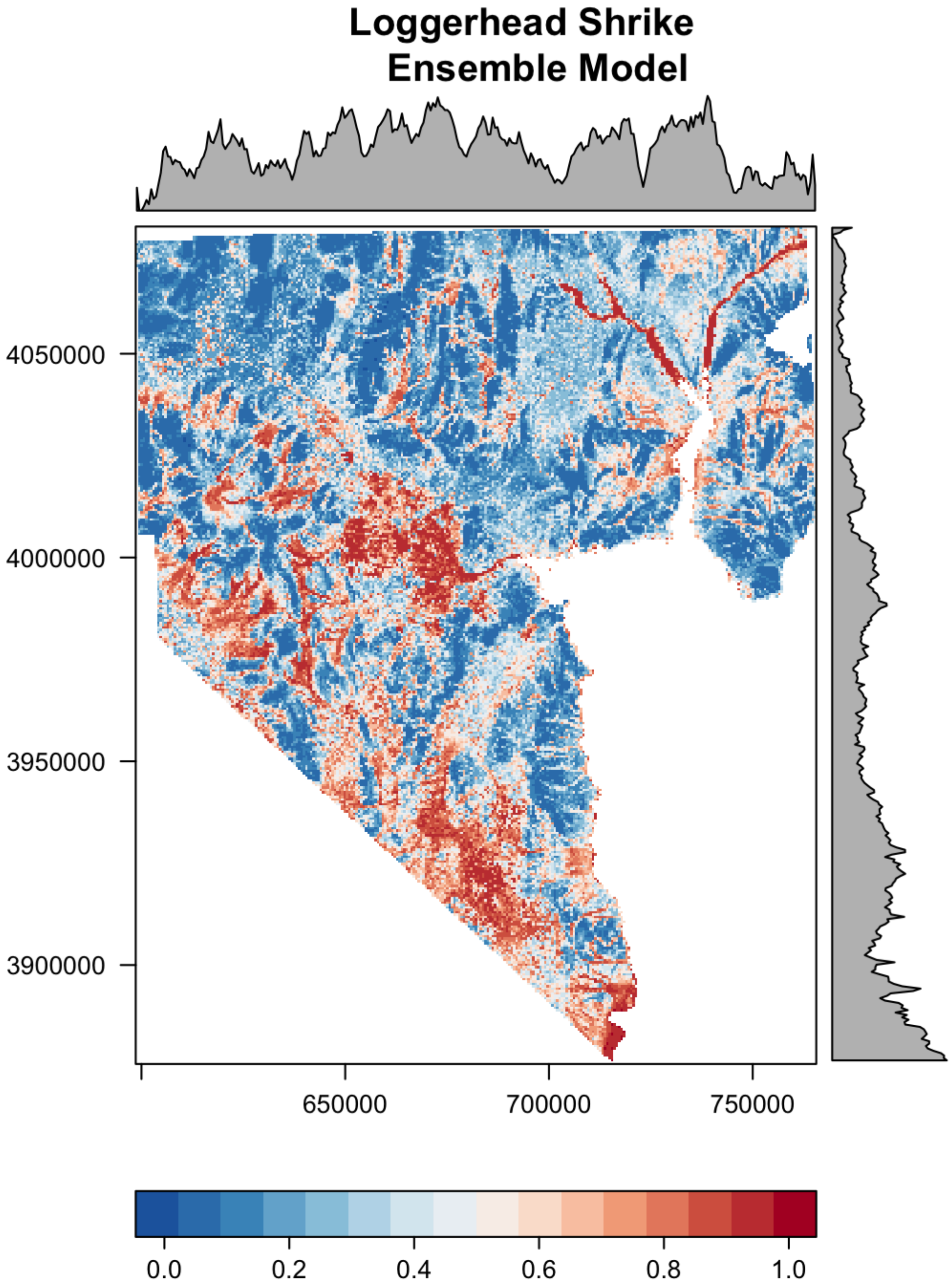
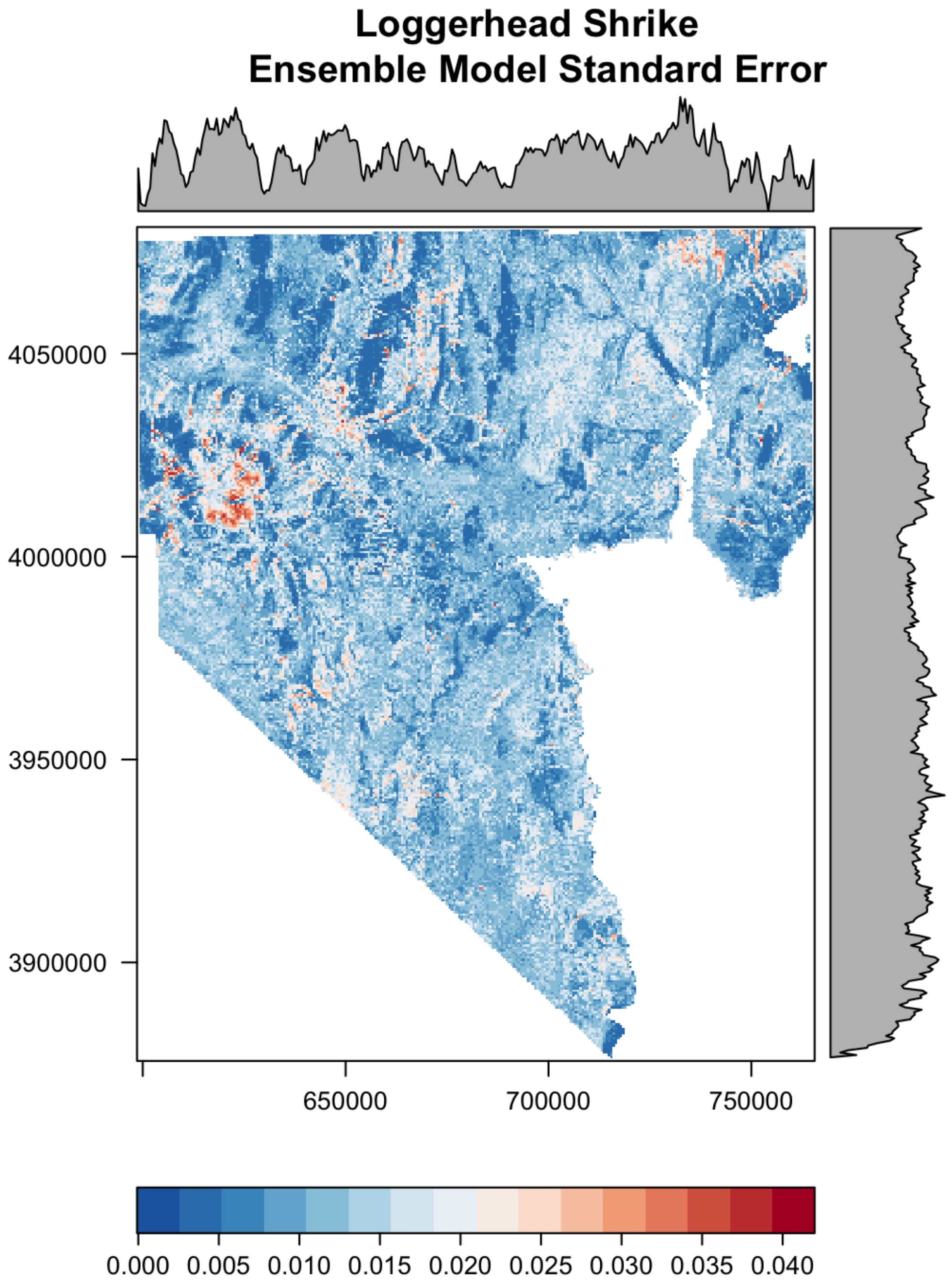


Figure A.21-8. Standard Error map for the Loggerhead shrike Ensemble model for Clark County, NV.



A.21.5 Distribution and Habitat Use within Clark County

In Clark County, Nevada the loggerhead shrike is very widespread and fairly common. Loggerhead shrikes are seasonal visitors to lower mountain slopes of semi-open woodlands, and year-round residents of desert shrub communities on lower bajadas and valley bottoms (Blake 1984). Suitable environments to support shrikes include open desert to woodlands, pastures, fencerows or shelterbelts of agricultural fields, orchards, riparian areas, ranches, suburban areas, roadsides, cemeteries, and golf courses (Prescott and Collister 1993, Dechant et al. 2002). Loggerhead shrikes are found throughout desert shrub communities dominated by creosotebush (*Larrea tridentata*), burro brush (*Ambrosia dumosa*), sagebrush (*Artemisia* spp.) or saltbush (*Atriplex* spp.) interspersed by Joshua trees, catclaw, or mesquite. Shrikes inhabit areas of low slope and high horizontal and vertical structural diversity (Poole 1992 *in* Dechant et al. 2002). Ecosystems in Clark County that contain high densities of these birds include all ecosystems in the County (Table A.21-3). In Idaho, impaling stations, where they cache food items on sharp objects, were 7 to 65 m from nests and were protected within shrubs (Woods 1995). Impaling stations in southern Nevada are frequently on exposed yucca leaves. Territory sizes of loggerhead shrikes throughout North America range from 2.7 to 25 ha (Dechant et al. 2002).

Table A.21-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	0	124
Blackbrush	214588	90787	106760
Bristlecone Pine	2299	1943	3313
Desert Riparian	83	490	9584
Mesquite Acacia	2315	5246	12641
Mixed Conifer	18316	6512	2282
Mojave Desert Scrub	541799	509321	304219
Pinyon Juniper	77197	23563	7546
Sagebrush	2424	1436	831
Salt Desert Scrub	46959	24881	10597

A.21.6 Ecosystem Level Threats

Loggerhead shrikes occupy all ecosystems within the County, with highest areas in Mojave Desert Scrub, Blackbrush, Mesquite/Acacia, Salt Desert Scrub, and Desert Riparian (Table A.21-3), as well as rural and suburban parkland areas and near human habitations. Losses of open habitat and importantly perching and nesting sites may be a threat to Shrike populations (Yosef 1994).

A.21.7 Threats to Species

The most important manageable threats to loggerhead shrikes are activities or processes that reduce nesting and perching substrates or reduce primary production on which most prey species depend (GBBO 2015). Activities in this category are Off-Highway Vehicle use – especially when it occurs on closed roads and trails. Urbanization or development of energy development and supporting infrastructure also can reduce available habitat. Wildfire has negative impacts to loggerhead shrikes. In sagebrush steppe, wildfire reduced shrike densities and nest survivorship by 50%, and resulted in a switch in the tree species where nests occurred (Himple and Holmes

2006). However, in that study, shrikes persistently re-nested and fledged similar numbers of young before and after the fires (Himple and Holmes 2006). Urbanization has also been associated with reduction or loss of shrike population at some locations (Jones and Bock 2002), while in the east Mojave Desert of southern California loggerhead shrikes were most abundant in urban areas (Knight et al. 1999). However, qualitative comparisons cannot be made between the studies. Habitat conversions from unimproved pasture to croplands have been correlated with loggerhead shrike declines greater than 50% (Dechant et al. 2002), in comparison with more moderate habitat declines that had less dramatic losses of shrike populations. Grazing by livestock and feral horses in sagebrush areas is considered to be negative to shrike populations as well Wood 1995a). Some populations of shrikes have shown decreased reproductive success near roads (Yosef 1995). While brown-headed cowbird (*Molothrus ater*) nest parasitism has been recorded, it is relatively rare among loggerhead shrike nests (Dechant et al. 2002). Furthermore, shrikes may be able to discern parasitic eggs, and remove them from their nests (Rothstein 1982). Organochlorides have been associated with eggshell thinning in loggerhead shrikes in some areas (Pruitt 2000). These chemicals have been banned for use in the United States, however, wintering shrikes may bio-accumulate some organochlorides in Mexico.

A.21.8 Existing Conservation Areas/Management Actions

Protection of desert shrub communities may be increased by land management actions that reduce surface disturbances and increase vegetation cover. Fencing protected areas to reduce livestock grazing and OHV activities can result in greater cover of perennial plant species thus increasing food and cover for many species (Brooks 1999). Fewer disturbances and increases in food availability can increase densities and nesting in many species including the loggerhead shrike (Brooks 1999). Loggerhead shrike habitat may be protected through incentive programs such as county reserves, easements, land trusts, leases, purchases or through the protection of natural areas that are set aside for other species such as the Mojave Desert Tortoise (Hands et al. 1989, Dechant et al. 2002).

The Nevada Wildlife Action Plan considers the loggerhead shrike a Species of Conservation Priority, and recommends the following: maintain suitable nesting and wintering habitat in areas of regular shrike activity; maintain thorny shrubs, barbed-wire fences, and other objects suitable for impaling prey; and restrict pesticide use to avoid decreasing the prey base (Wildlife Action Plan Team 2012).

Partners in Flight Landbird Conservation Plan’s 2016 Revision for Canada and Continental United States considers the loggerhead shrike to be a “common bird in steep decline”, with the population in the intermountain west region – which includes all of Nevada – declining by 48% over the long-term (1970-2014), and by 1.3% in the short-term (2004-2014). The plan recommends generic actions for conserving bird populations, including: reduce and prevent collisions with buildings and other structures; reduce the loss of habitats in nonbreeding areas; and implement conservation practices in agricultural and rangeland landscapes (Rosenberg et al. 2016).

A.22 YUMA RIDGWAY'S RAIL (*RALLUS OBSOLETUS YUMANENSIS*)

Yuma Ridgway's rail (*Rallus obsoletus yumanensis*), formerly known as the Yuma Clapper rail (*R. longirostris yumanensis,* Chesser et al. 2014, Dickey 1923, Maley and Brumfield 2013, Pranty et al. 2014), is listed as an endangered species at both the federal and state level. It is a relatively small species of *Rallus*, 20-23 cm in height and weighing an average of ~250 g (males slightly larger than females), with brown dorsal (back) feathers edged grayish and bright rufous breast (Maley and Brumfield 2013, Rush et al. 2012). It is a secretive bird and is seldom seen, with its dense marsh habitat providing camouflage and cover. A typical marsh bird, it has long legs and a short tail and eats primarily crayfish, clams, isopods, freshwater shrimp, fish beetles, and various insects (Ohmart and Tomlinson 1977). These rails are monogamous and both sexes assist in incubation and brood-rearing in the spring, usually laying 7 to 11 eggs in a cup nest of grasses or sedges. Young are precocial and can fly in about 9 to 10 weeks.

A.22.1 Species Status

The Yuma clapper rail was listed as an endangered species under Section 1(c) of the Endangered Species Preservation Act of 1966 (80 Statute 926; 16 USC 668aa(c)) on March 11, 1967 (DOI FWS 1967). This species was subsequently included on the list of endangered species under the ESA when the act was enacted in 1973. A down-listing package was prepared for the Federal Register in 1983; however, flooding of important clapper rail habitat on the lower Colorado River in that year resulted in the proposal not being published (USFWS). Instability of population numbers after 1983 precluded reconsideration of the proposal (USFWS 2006). The species is also protected under the Migratory Bird Treaty Act of 1918, as amended (16 USC 703-712), and listed as endangered in Arizona, California, and Nevada. IUCN Lists the Ridgway's rail at the species level as Near Threatened, since the moderately small population is thought to be declining due to habitat losses from agriculture and other development.

US Fish and Wildlife Service Endangered Species Act: Endangered

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): Endangered

State of Nevada (NAC 503): Endangered

NV Natural Heritage Program: Global Rank G1 State Rank S1

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Near Threatened

CITES: No status

A.22.2 Range

There are three subspecies of Ridgway's rail in the US (Maley and Brumfield 2013): California Ridgway's rail (*R. o. obsoletus)* in the San Francisco Bay area (Wood et al. 2017), light-footed Ridgway's rail (*R. o. levipes*) in costal southern California, and Yuma Ridgway's rail (*R.o. yumanensis*), found along the lower Colorado River and its tributaries and around the Salton Sea in California (Tomlinson and Todd 1973, Hinojosa-Huerta et al. 2001, Pranty et al. 2014, USFWS 2006). Additional subspecies of Ridgway's rail are found only in Mexico (Pranty et al. 2014). The Yuma Ridgway's rail is the only subspecies present in Clark County, NV.

A.22.3 Population Trends

Variable survey methods and locations have made it difficult to accurately estimate population trends for the Yuma Ridgway's rail (USFWS 2006). Expert sources estimate that populations are likely declining due to widespread loss of breeding habitat (NatureServe 2009). Few population estimates exist, although early estimates for the US population were in the 400 - 1000 range in the 1960's to mid-1970s, and 500 – 1000 birds from 1990 - 2005 (AGZFD 2006). Ehrlich et al. (1992) estimated 1,700-2,000 individuals. Hinojosa-Huerta et al. (2001) surveyed for the Yuma Ridgway's rail in 1999 and 2000 in the Ciénega de Santa Clara, the largest marsh wetland (5800 ha) in the Colorado River delta in Mexico, finding an estimated average of 6040 individuals (S.E. = 313) over four surveys (2001). Garnett et al. (2004) performed surveys within Clark County from 1999 through 2003, finding between 2 and 32 individuals in any given year (average of 13.6), with the majority of occurrences along the Virgin River. No population estimates were generated from the counts (Garnett et al. 2004).

A.22.4 Habitat Model

The models for this species were conducted with very few localities (47), and thus the GAM algorithm could not be used. The remaining Random Forest and MaxEnt models had very good performance overall – with the exception of the BI score for the RF model (Table A.22-1). The habitat models predicted under these two algorithms accentuated the same core areas, along the Virgin and Muddy rivers within the county, and along the Las Vegas wash (Figure A.22-1). The MaxEnt Model had additional low-level habitat (scores of ~ 0.04) predicted in the Spring and Sheep ranges, as well as indications of potential habitat in other minor drainages (Figure A.22-1, Table A.22-1). Overall the models highlighted this species' dependence on wetland areas. Standard error rates were higher for the maxent model with areas of elevated error (SE ~ 0.06 in and around the Las Vegas metropolitan area, and in the marginal habitat predicted in the Spring and Sheep ranges (Figure A.22-2). The Random Forest models had relatively low standard error rates, which indicated high model agreement among the iterations of the model. The Continuous Boyce Index curves give an irregular appearance that is attributed to the smaller sample sizes available for this species (Figure A.22-3). Still, the CBI for the Random Forest model showed the expected pattern of higher model scores discriminating habitat at areas with higher proportion of presences, while the MaxEnt models were penalized for some of the habitat overprediction given in Figure A.22-1.

The top four influential variables were different between the two modeling approaches, sharing only the soil Sand component. The top four influential variables for the Random Forest models were rounded out by Clay Content and Extreme Minimum and Average Maximum temperatures, while the Random Forest models highlighted Flow Accumulation, and NDVI metrics for Start of the Spring Season, and NDVI Amplitude values (Table A.22-2).

Table A.22-1. Model performance values for the Yuma Ridgway's rail models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given in the last column.

Model	AUC	BI	TSS	PRBE
Ensemble	0.98	0.96	0.86	0.64
GAM	-	-	-	
Random Forest	0.98	0.5	0.88	
MaxEnt	0.92	0.99	0.86	

Table A.22-2. Percent contributions for the top 10 input variables for the Yuma Ridgway's rail for Ensemble models using MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	RF	MaxEnt
PPT Sand	25.7	8.3
Flow Accum	4.9	23.1
Start of Season (day)	2.6	19.6
NDVI Amplitude	4.2	11.7
PPT Clay	13.3	2.3
Ave Min Temp	5.1	7.9
NDVI Max	4.6	6.9
Extreme Min Temp	5.6	0.8
PPT Silt	5.4	4.7
Ave Max Temp	6.6	2.6

Figure A.22-1. SDM maps for the Yuma Ridgway's rail model Ensemble (upper left), and for averaged models of each of the modeling algorithms used (Random Forest - upper right, MaxEnt – lower left). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

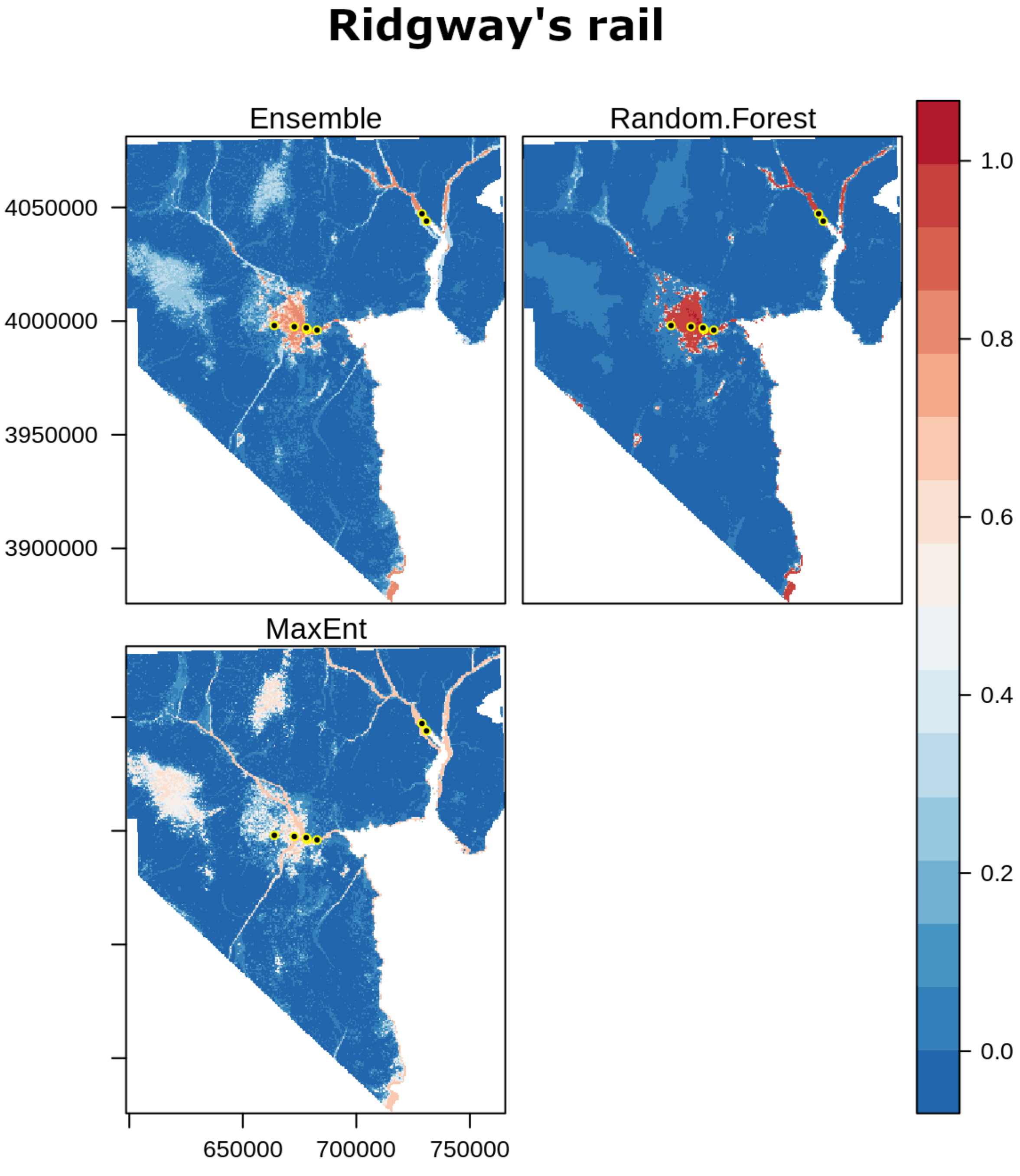


Figure A.22-2. Standard error maps for the Yuma Ridgway's rail models for each of the modeling algorithms used (Ensemble - upper left, Random Forest - upper right, MaxEnt - lower left).

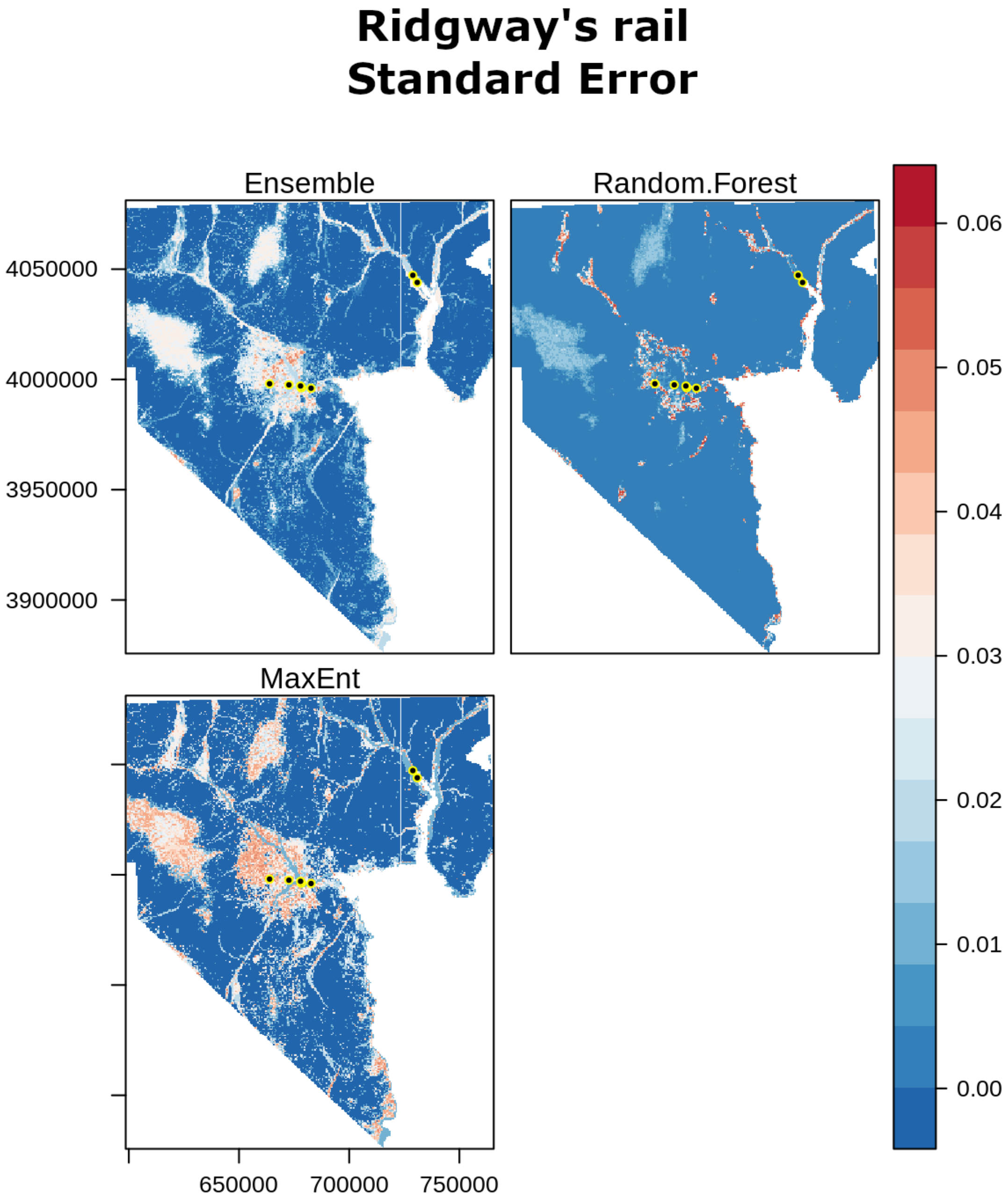
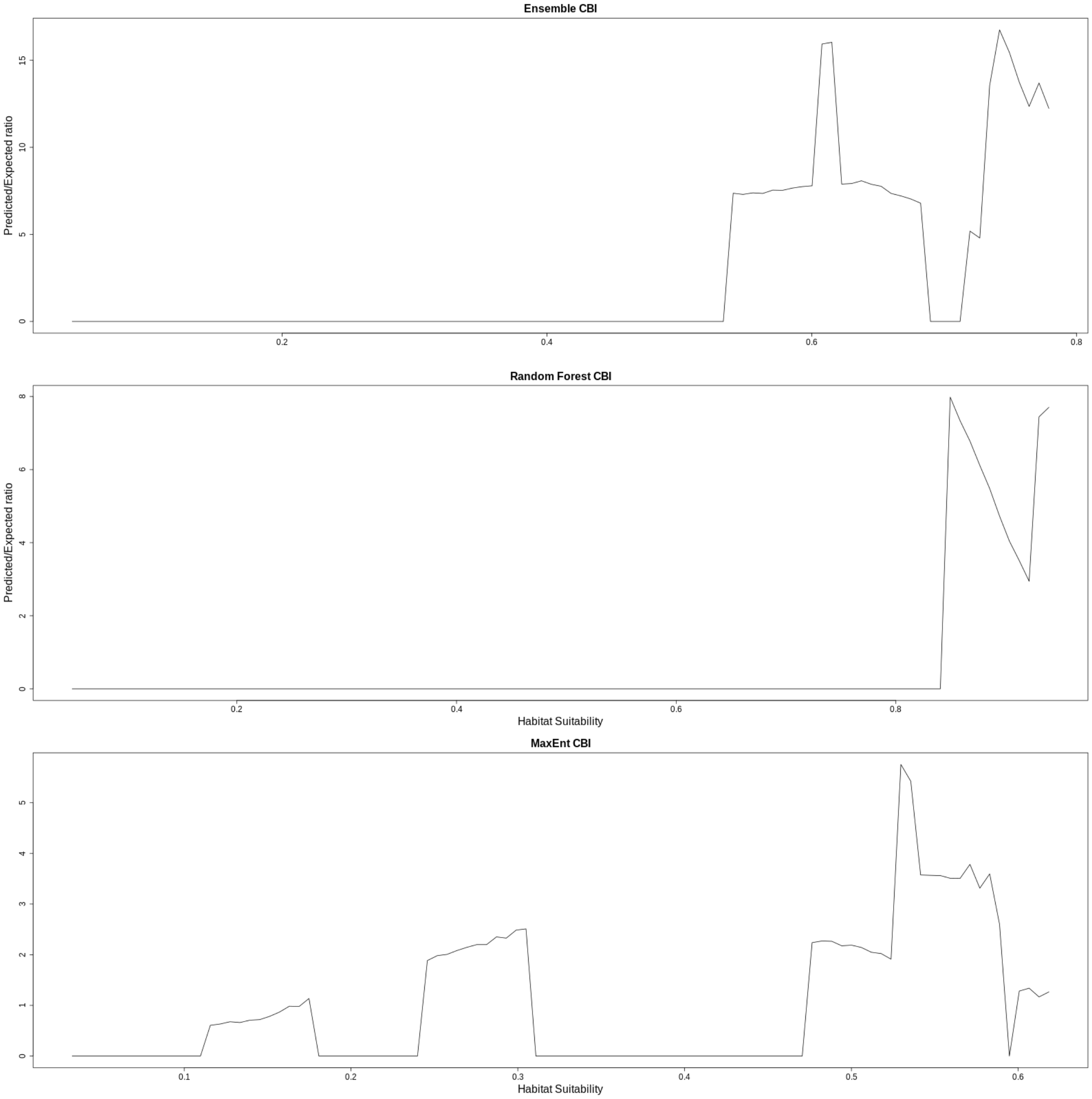


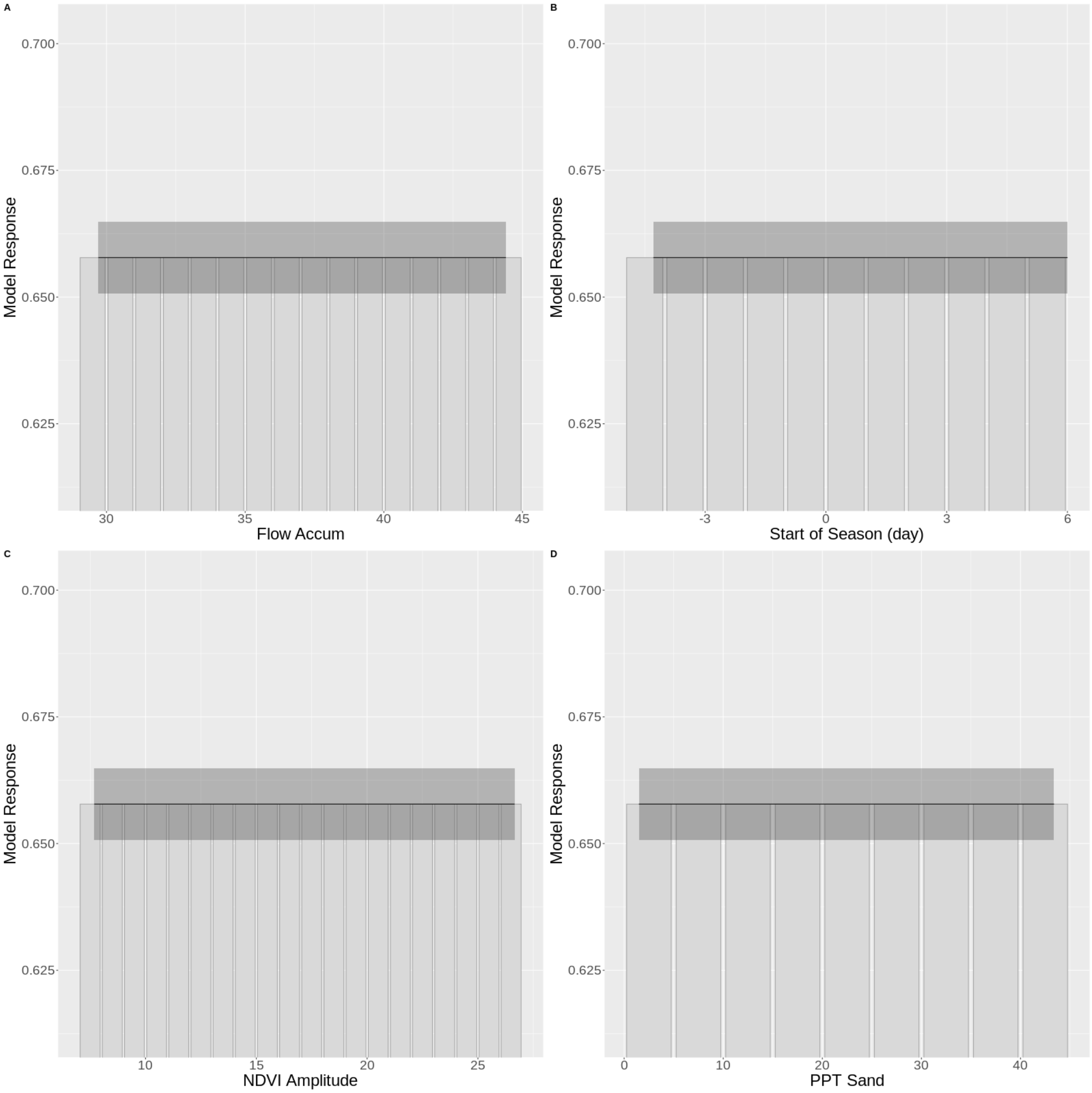
Figure A.22-3. Graphs of Continuous Boyce Indices [CBI] for the Yuma Ridgway's rail models for the Ensemble model prediction (top and for each of the modeling algorithms used (Random Forest – center, and MaxEnt - bottom).



A.22.4.1 MaxEnt Model

The MaxEnt models were most influenced by the terrain index describing the potential for Flow Accumulation, the Start of the Spring Season (as indicated by NDVI) and the Amplitude of NDVI signal at its peak value. Collectively these contributed to 63% of the model influence. Due to the lower sample sizes – contribution curves for this algorithm did not indicate discernable trends, as the ranges of the input values for the county are under-sampled given the constricted nature of the localities (Figure A.22-4). The MaxEnt habitat map had widespread prediction of habitat patches in unexpected areas, including the more mountainous areas that are not associated with this species. Interestingly the riparian areas more commonly considered habitat were not predicted with high values, but rather values of ~ 0.6. With relatively few points available for evaluation performance metrics can be elevated for overpredicting models as too few of the absences are available to catch these areas.

Figure A.22-4. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for the Yuma Ridgway's rail. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

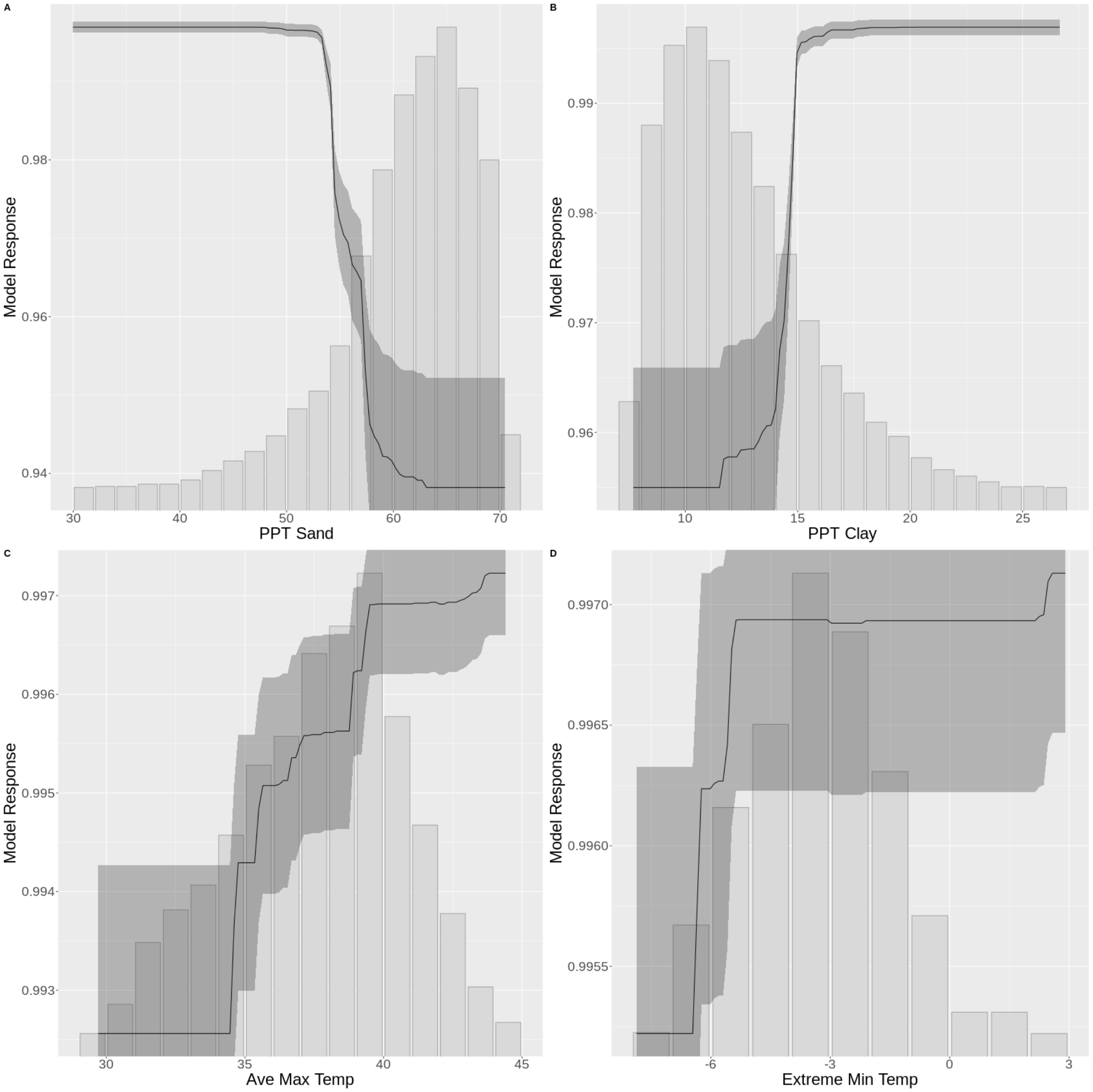


A.22.4.2 Random Forest Model

The Random Forest model was mode influenced by soil Sand Content, followed by soil Clay Content, and then the Average Maximum temperature and Extreme Minimum temperature. The response curves for this algorithm indicated increased habitat predictions in areas with lower Sand Content (much lower than the county average) and increased Clay Content (higher than the county average; Figure A.22-5). Habitat predictions had a positive relationship with areas that experienced higher Average Maximum temperatures, and had a peaked response at higher

Extreme Minimum temperatures as well. Habitat predictions were very restricted spatially, where habitat was restricted to riparian areas, with the exception of the Las Vegas valley, where the vegetation associated developed areas likely contributed to these predictions. There were a significant number of observations located in the Las Vegas wash that likely contributed to these predictions (Figure A.22-1).

Figure A.22-5. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for the Yuma Ridgway's rail. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.22.4.3 Model Discussion

In Clark County, Yuma Ridgway's rail are known only in the riparian areas of the Muddy and Virgin rivers, and the Las Vegas wash. The Ensemble model highlights predictions in these areas, as well as a broader prediction in the Las Vegas valley that is likely inaccurate, and would be eliminated if impervious surfaces were masked from the models. Along the Colorado river there are few areas predicted as habitat southward with the exception of the more open areas near Avi and Needles CA (Figure A.22-6).

The locality data for this species consisted of 82 records within the buffered modeling area. Spatial thinning of the data and the removal of duplicated records (or multiple within a given pixel size) reduced the number of localities used for training and testing to 47 records. The rarity of this species within the county makes modeling difficult, and as with all rare species, models would benefit from increased observations.

A.22.4.4 Standard Error

Areas of elevated standard error rates (SE ~0.05) were largely located within the Las Vegas area and near Primm (Figure A.22-7), and there were several larger expanses of moderate error rates in the periphery of the valley, as well as throughout the Spring and Sheep Ranges. Moderate error was also indicted throughout the lowland areas in Moapa, and along the US 95 corridor, as the MaxEnt models yielded some predictions of habitat in those areas.

Figure A.22-6. SDM map for Yuma Ridgway's rail Ensemble model for Clark County, NV.

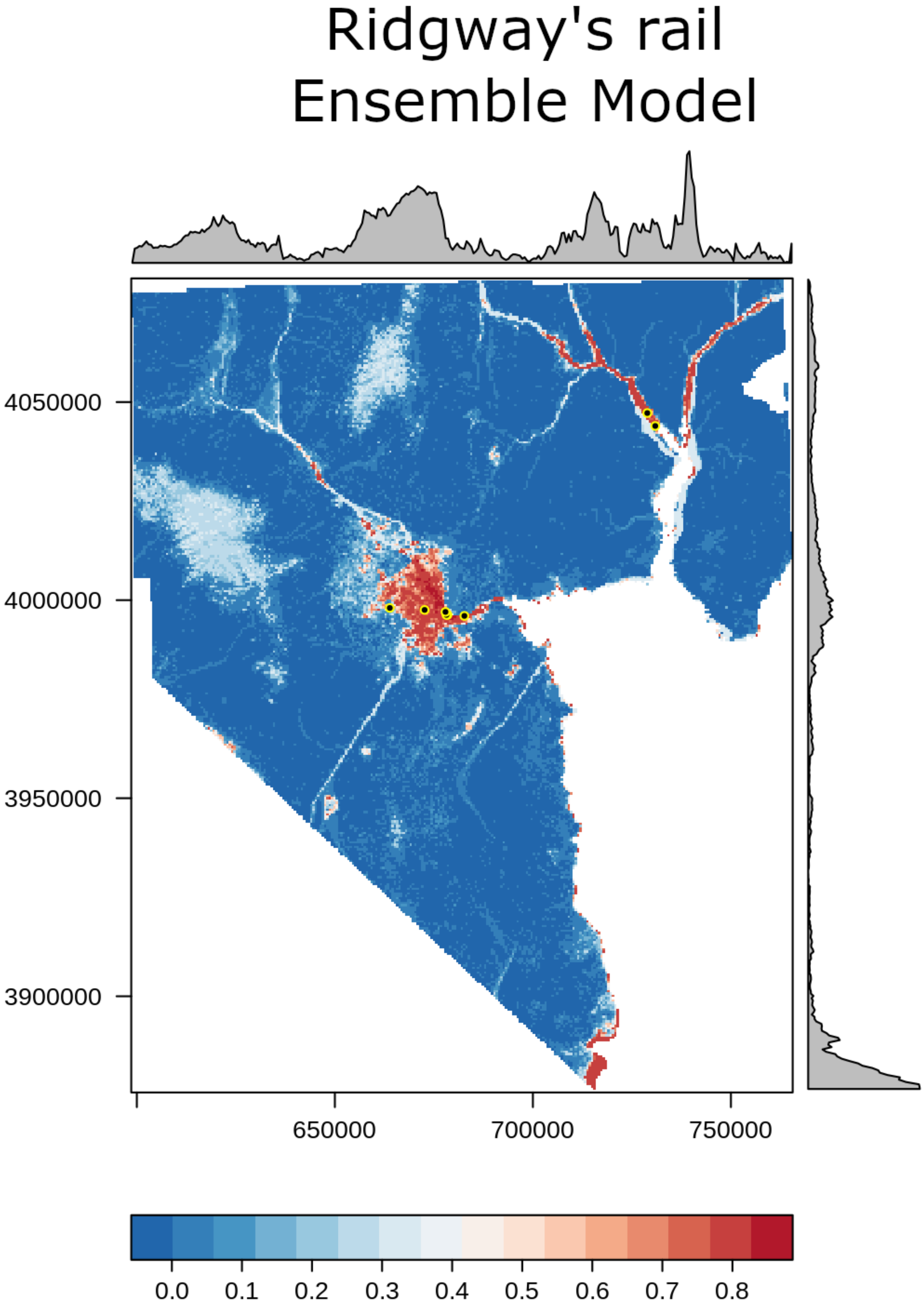
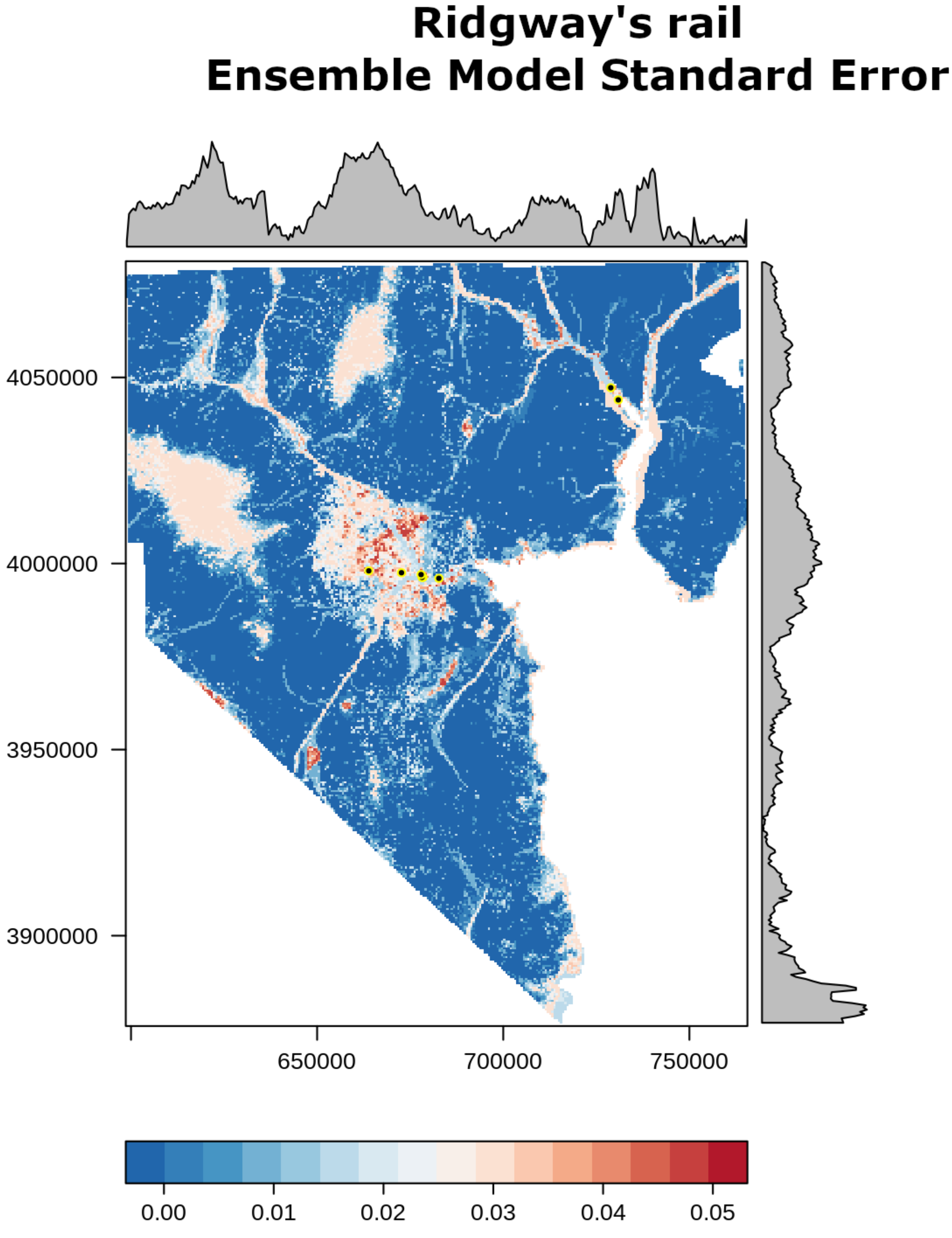


Figure A.22-7. Standard Error map for the Yuma Ridgway's rail Ensemble model for Clark County, NV.



A.22.5 Distribution and Habitat Use within Clark County

The Yuma Ridgway's rail is found in marshes along rivers, backwaters, and in drains or sumps supported by irrigation water (USFWS 2006). This species generally requires a wet substrate, such as mudflats, and drainage bottoms that are densely vegetated. Vegetation density is the critical element for suitable nesting habitat (Rush et al. 2012). This subspecies breeds in heavily vegetated fresh-water marshes with vegetation cover of moderately dense stands of cattail (*Typha* spp.) and bulrushes (Scirpus spp.) along the Colorado River and its tributaries (Tomlinson and Todd 1973).

The Yuma Ridgway's rail is the only subspecies present in Clark County, NV, where it occurs in freshwater marsh habitat along the Virgin, Muddy, and lower Colorado Rivers, and has been sighted in the Las Vegas Wash (Garnett 2004, Van Dooremolen 2015). It is the only subspecies known to occupy freshwater marshes during the breeding season, and is known to visit brackish and saltwater marshes south of the US in the non-breeding season (Tomlinson and Todd 1973). It is found in elevations ranging from below sea level to around 1,300 feet (AZGFD 2006).

Nesting of multiple pairs in 2001 was confirmed at Big Marsh along the western portion of the Virgin River - one of the seven Important Bird Areas of Clark County (Floyd et al. 2007). Despite yearly surveys, Yuma Ridgway's rail detections in the Las Vegas Wash vary from year-to-year (Van Dooremolen 2015). A single Yuma Ridgway's rail was detected in the Wash, within Clark County Wetlands Park, in 1998, 2005, 2006, and 2015 (SWCA 2006, SWCA 2007, Van Dooremolen 2015). The Lower Virgin River and Muddy River areas are likely more important areas for Ridgway's rail in Clark County, with regular (albeit decreasing) occurrences (Garnett et al. 2004), and an existing habitat conservation and recovery program (USFWS 2006).

A.22.6 Ecosystem Level Threats

This subspecies occurs exclusively in the Mojave Desert Scrub, Desert Riparian and Mesquite Acacia habitats of Clark County, NV (Table A.22-3). Threats to these ecosystems include loss and degradation of freshwater marsh habitat, through irregular water availability due to manipulation of stream banks and water flow, and invasive species (Wildlife Action Plan Team 2012). Ecosystem threats due to conversion of lands to agriculture, and agricultural practices (e.g. maintenance of drainages and chemical/pesticide use should also be considered (Hinojosa-Huerta et al. 2001)

Table A.22-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	192983	9	0
Bristlecone Pine	7090	354	0
Desert Riparian	895	1337	7765
Mesquite Acacia	11092	752	3206
Mixed Conifer	23995	2790	0
Mojave Desert Scrub	674960	39300	36402
Pinyon Juniper	103294	1581	0
Sagebrush	3971	6	0
Salt Desert Scrub	56234	4179	931

A.22.7 Threats to Species

Selenium is a potential threat to the Yuma Ridgway's rail. High levels of selenium can result in acute toxicity, chronic poisoning and tissue damage, and reproductive impairment in birds. The birds accumulate selenium from the invertebrates and fish they eat (USFWS 2006). Another significant threat to this species is the inadequacy of existing regulatory mechanisms for the Ciénega de Santa Clara population in Mexico. The Ciénega, a 6,000-hectare wetland in the Colorado River Delta, contains the largest known population of Yuma Ridgway's rail and is believed to be the source population for this subspecies throughout the remainder of their range. A population decline of 23 percent was observed between 1999 and 2002 at this site. Habitat loss for the Ciénega de Santa Clara remains a significant threat to the Yuma Ridgway's rail because the Ciénega's water supply is entirely dependent on drain flows from the US which could be cut at any time (USFWS 2006).

Within Clark County, most of the rail habitat is reportedly within the Virgin and Muddy river 100-year flood plains (Garnett et al. 2014). This area has some agricultural areas, as well as potential contaminants form the cities of Mesquite, and runoff from cities in Washington County, Utah that are potential sources of water contamination. Threats to species are largely due to losses of habitat due to water management, altering marsh habitats or conversion for other anthropogenic purposes.

A.22.8 Existing Conservation Areas/Management Actions

Conservation measures for the Yuma Ridgway's rail are addressed in the *Yuma Clapper Rail Recovery Plan* of 1983 (USFWS). This plan's goals are to: have a stable population of 700 to 1,000 individuals; preserve habitat; and carry out a program of public education (USFWS 1983). The plan recommends: maintaining consistent water levels in marshes in the Virgin and Muddy River valleys; controlling invasive plants in marshes; controlling nest predators when unusual predation levels are documented; and continuing surveys and research to better determine population trends, threats, and habitat requirements (USFWS 1983). In 2010, USFWS released a draft revision to the recovery plan, but no further actions regarding the revision have been taken. The revision includes additional scientific information about the species and provides the criteria and actions needed to delist the species (USFWS 2010). Critical habitat, as required by the Endangered Species Act of 1973, has not been designated yet (USFWS 2010).

Yuma Ridgway's rail is listed as a covered species under the Lower Colorado River Multi-Species Conservation Plan (LCR MSCP 2004). The LCR MSCP is a 50-year, comprehensive habitat conservation plan that addresses the effects of water use and hydropower generation along the Lower Colorado River on 26 species, including the Ridgway's rail. Conservation measures outlined in this plan include the creation of 512 acres of habitat, and the maintenance of existing habitat (Lower Colorado River MSCP 2004).

This subspecies of rail is considered a Species of Conservation Priority by the Nevada Wildlife Action Plan (2012). The plan considers the main threat to the subspecies to be the loss or degradation of marshes due to water diversions, decline in water quality, and development, and recommends implementing the conservation strategies outlined in the Recovery Plan released by USFWS (Wildlife Action Plan Team 2012).

The Nevada Comprehensive Bird Conservation Plan recommends creating artificial wetlands if habitat parameters are suitable, using prescribed fires in overgrown marshes, and conducting studies to determine whether seasonal movements occur (GBBO 2010).

A.23 BENDIRE'S THRASHER (*TOXOSTOMA BENDIREI*)

Bendire's thrashers are medium-sized and long-tailed desert songbirds in the Mimidae family or "mimic thrashers". Thrashers typically perch on vegetation to sing, and when disturbed drop to ground level to fly or run away from their pursuer. Thrashers can be difficult to survey for because of their wariness (Fisher 1903). The uncertainty of detections can increase false negatives during presence surveys, thus increasing the error in distribution and density surveys. While they are perfectly capable of robust song, the Bendire's thrasher may be less vocal that other desert thrashers (Brown 1901); however, they may be attracted by recordings of their vocalizations and those of other thrashers (Fletcher 2009).

Bendire's Thrasher nests have been found in shrubs (e.g. *Lycium* spp.), cactus (e.g., cholla - *Cylindropuntia* spp.), desert trees (e.g. *Acacia greggii*, *Prosopis* spp.), and tree yuccas (*Yucca brevifolia* and *Y. schidigera* – Gullion et al. 1957), or mistletoe (*Phoradendron* sp.) (Brown 1901, Gilman 1909). Nests are typically placed about 1 meter above the ground, but may be placed as low as 0.15 m, or as high as 6 m above the surface. Bendire's thrasher nests resemble other thrasher nests. The rough outside includes many interwoven twigs (less than 1 centimeter), and the interior is lined with grasses, feathers, horsehair, and other fine threaded materials including materials from human habitations such as twine (Gilman 1909). The Bendire's thrasher nest differs from others in that they use finer outer twigs and they are woven more tightly together for a more compact cupped shape. There are usually three eggs in the nest, sometimes four, and very rarely five. The ground coloration of the eggs ranges from clay to light green with fine specks or blotches of darker colors in highly variable patterns.

A.23.1 Species Status

No federal or state listing petitions have been filed for the Bendire's thrasher, although it is a USFWS "Species of Concern", and also listed so by California Fish and Game (Shuford and Gardali 2008), a Species of Conservation Priority in Nevada (GBBO 2010, Nevada Action Plan Team 2012), and Arizona (AZGFD 2012). This species is thought to be rapidly declining as a result of negative impacts from urban and agricultural expansion (BirdLife International 2012).

Bendire's thrashers are among a small number of North American bird species whose conservation concerns may have 'fallen through the cracks.' They are a species of global conservation concern by a number of authorities on this topic (Wells et al. 2010, BirdLife International 2012). Yet they are not listed at the federal level under the Endangered Species Act (ESA), and only special consideration in three of the six states they occupy.

US Fish and Wildlife Service Endangered Species Act: No Status

Migratory Bird Treaty Act: Protected

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): No Status

State of Nevada: Protected

NV Natural Heritage Program: Global Rank G4G5, State Rank S1

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Vulnerable

CITES: No Status

A.23.2 Range

Bendire's thrashers are resident in southern Utah and Colorado, western New Mexico, the northern half of Arizona, southern Nevada, and the eastern Mojave Desert of California. Scattered vagrants have been observed mostly in southern California, but also across the western US Bendire's thrashers are migratory and spend part of the year in southern Arizona and Sonora, Mexico (Sibley 2000). In Nevada, the Thrasher is known from Lincoln (Austin and Bradley 1965), Nye and Clark counties, with most observations in southern Clark County in upland mixed Mojave Desert scrub habitat (GBBO 2010), and adjacent to this area in California in San Bernardino County (Shuford and Gardali 2008).

Bendire's thrashers appear to occupy somewhat contiguous habitat in parts of Arizona's Sonoran Desert, but in the Mojave Desert, Colorado Desert, Colorado Plateau, and Chihuahuan Desert they occupy many small and scattered populations, which contributes to the concern for the species. Concern for the species stems from the risk of inbreeding or local extinctions for small, isolated populations (England and Laudenslayer, Jr. 1995). However, one source noted that the breeding range of Bendire's thrasher is thought to have increased in Arizona and New Mexico during the period between 1890 and 1990 (Brown and Davis 1996). This is hard to imagine in the face of the declining population trend data that are available (please see Trends section of this document), and their rarity may be due in part to lack of survey effort (Shuford and Gardali 2008). However, yet another source used a habitat suitability model to project Bendire's thrasher ranges into the future, and predicted that their ranges would increase substantially during the next 50 years into southeastern New Mexico (Menke and Bushway 2015).

A.23.3 Population Trends

Based on analyses of the most comprehensive data source that is available for population trends of North American birds, the mimic thrushes (Curve-billed thrasher, LeConte's thrasher, and Bendire's Thrasher) are all significantly declining across their ranges (Sauer 2013). The Bendire's thrasher, in particular, is declining precipitously in New Mexico since at least 1970 (Menke and Bushway 2015), and is thought to be declining rapidly throughout its range (BirdLife International 2012), but see Shuford and Gardali (2008). The species is thought to have a low population size (i.e. probably not historically very numerous) and is more vulnerable to habitat degradation (Wildlife Action Plan Team 2012). Also, GBBO (2010) notes Nevada's population may be less than 50 birds, compared to California's population of less than 400 birds (England and Laudenslayer 1993).

A.23.4 Habitat Model

While the three model algorithms generally predicted similar habitat arrangements throughout the county, the GAM models generally predicted more habitat, organized in less cohesive patches, than either the Random Forest or MaxEnt models (Figure A.23-1). Key areas of similarity among models were in the southern extent of the county centered at Searchlight, and encompassing Paiute Valley, the Weethump area and parts of southern Eldorado Valley, extending westward toward Nipton CA. There is also habitat predicted along the upland bajadas surrounding the Spring and Sheep Ranges. Important differences in predicted habitat for this species are along the northeastern I-15 corridor where the GAM models predict habitat more habitat, and near Mesquite, where the GAM and Random Forest models predict a smaller habitat patch in association with the observations located there, but the MaxEnt model does not (Figure A.23-1).

The Ensemble model had high performance relative to other models, scoring the highest on all of the performance metrics AUC and TSS when considering the testing, and all data combined. The GAM and Random Forest models were nest highest performing algorithms, but all models have relatively high, and similar performance metrics (Table A.23-1). Relative variable importance highlighted the importance of Average Winter Precipitation, the Coefficient of Variation in Winter Precipitation, and Average Spring Maximum temperatures as the highest predicting variables across the three algorithms (Table A.23-2). The MaxEnt Models had higher contribution due to Slope, and with the Average Spring Maximum temperature as the fifth most important variable (Table A.23-2). The Standard Error maps indicated higher standard error among the GAM models than the others ,with maximum SEs of approximately 0.07, although error rates for the other algorithms and the Ensemble model were relatively low throughout the county (Figure A.23-3). The Continuous Boyce Indices showed good model performance in all algorithms, with some notable irregularity scores for the MaxEnt models, but where all models and the Ensemble indicated good model discrimination (Figure A.23-3).

Table A.23-1. Model performance values for Bendire's thrasher models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	AUC	BI	TSS	PRBE
Ensemble	0.89	0.94	0.68	0.73
GAM	0.87	0.85	0.66	
Random Forest	0.87	0.9	0.63	
MaxEnt	0.85	0.86	0.63	

Table A.23-2. Percent contributions for input variables for Bendire's thrasher for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Dist to cliffs	2.8	1.1	0.9
NDVI Amplitude	6.3	1.8	0.5
NDVI Length of Season	2.9	1.2	0.6
NDVI Max	9.4	4.8	1.2
Winter Precip	13.8	12.6	11.4
CV Winter Precip	12.9	37.3	29.2
Average Spring Max Temp	13.5	11	3.9
CV Average Spring Max Temp	24.2	12.3	34
Slope	9.6	9.3	16
NDVI Start of Season	3.1	2.4	1.9
Flow Accum	1.6	6.2	0.3

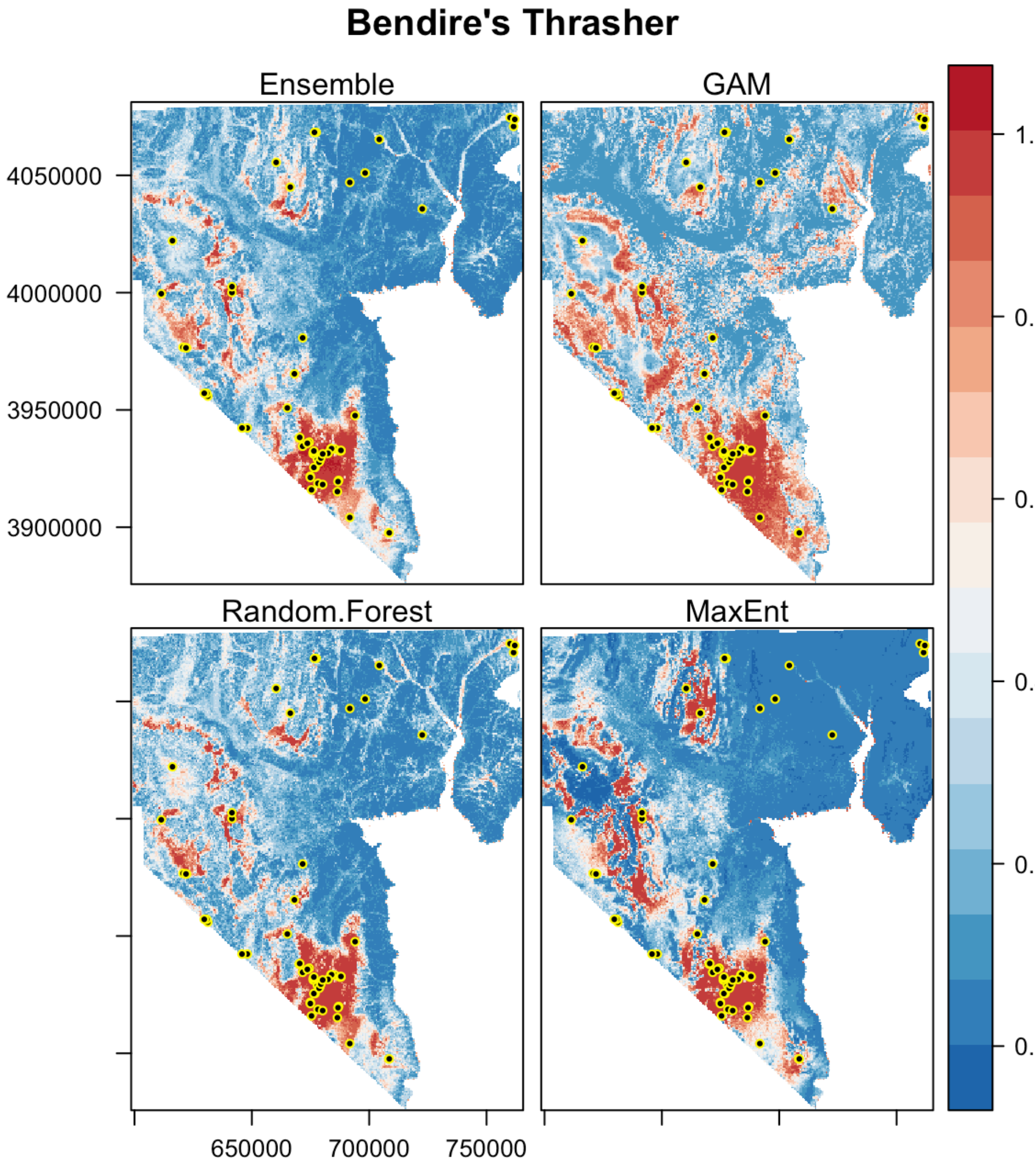


Figure A.23-1. SDM maps for Bendire's thrasher model Ensemble (upper left), and the three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

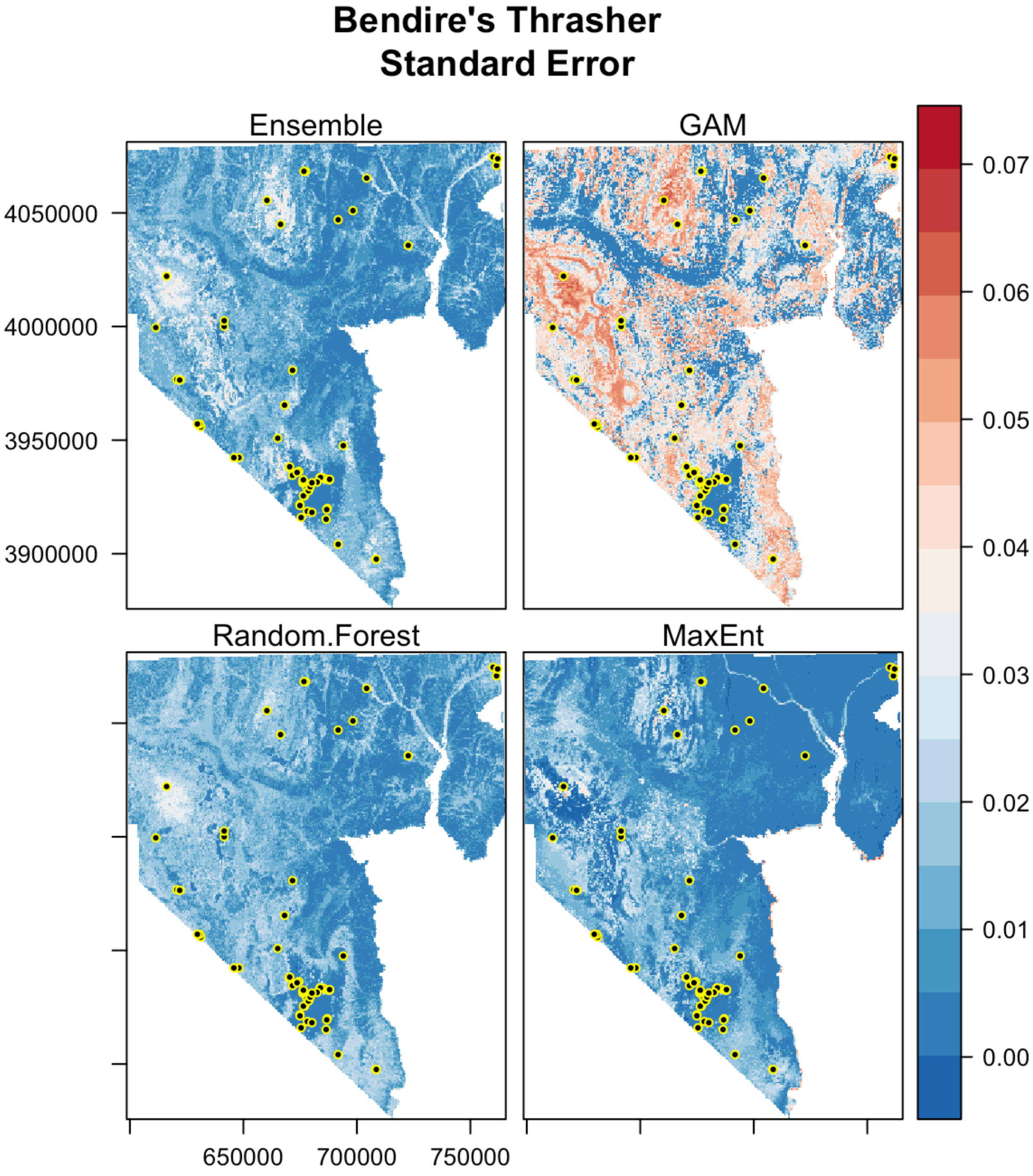


Figure A.23-2. Standard error maps for Bendire's thrasher models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper right).

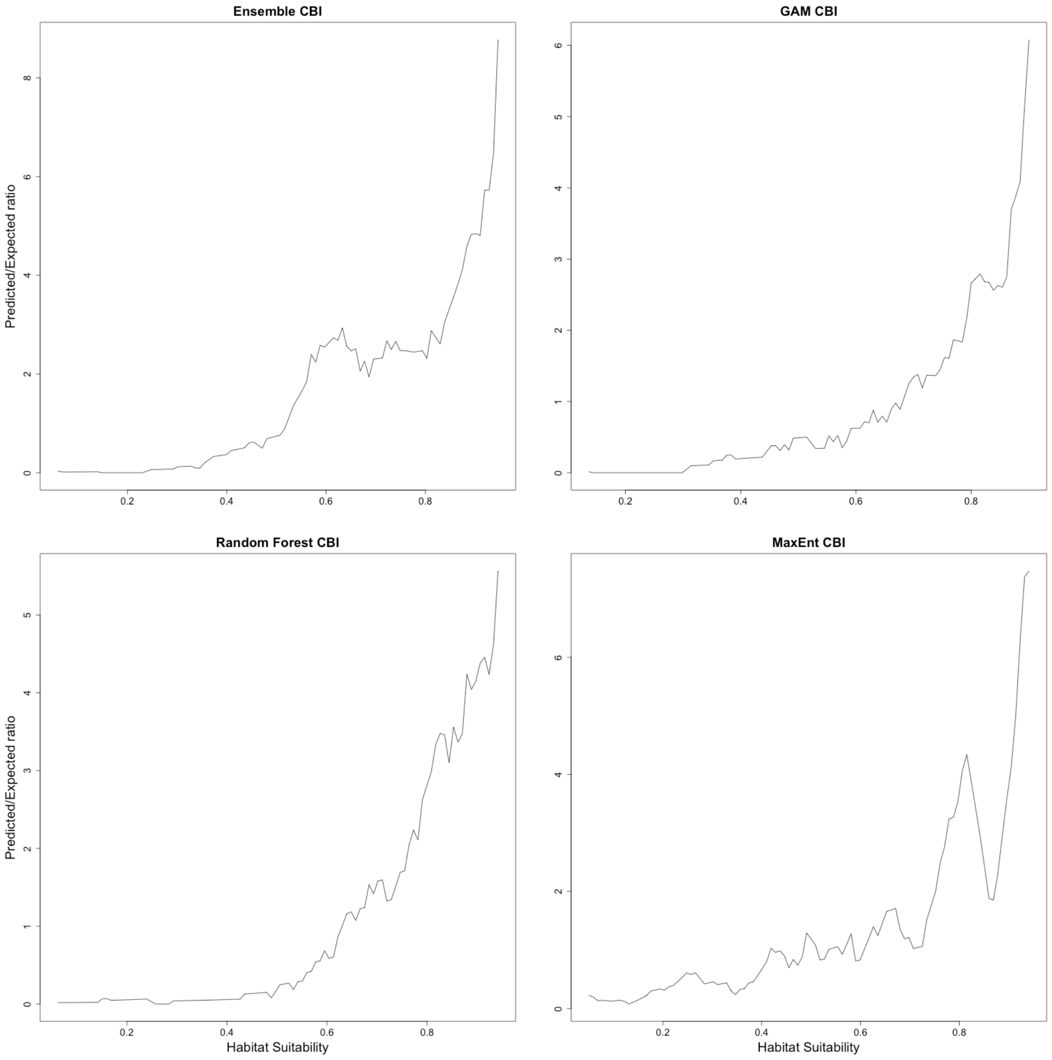


Figure A.23-3. Graphs of Continuous Boyce Indices [CBI] for Bendire’s thrasher models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.23.4.1 General Additive Model

The top four contributing environmental layers were Average Winter Precipitation and its coefficient of variation, and the Average Spring Maximum temperature and its coefficient of variation (Table A.23-2). Model scores were higher in areas with more Winter Precipitation than average, with a peak value slightly above the average for the study area, and falling off in areas with the highest amounts of rainfall (Figure A.23-4). The Coefficient of Variation for Winter Precipitation was more evenly distributed across the area, and habitat scores tended to be higher where this metric was more variable. Average Spring Maximum temperature was negatively associated with habitat at cooler temperatures, and the highest habitat predictions were at higher values of this metric than generally found in the study area, peaking near the mean value (Figure A.23-4). Predicted habitat values peaked just above the mean CV for this metric, and were lower but trending higher in more variable areas (Figure A.23-4). This algorithm had more disagreement among the model runs than did the others, especially in areas around the Spring and Sheep ranges, and the Overton area (Figure A.23-3).

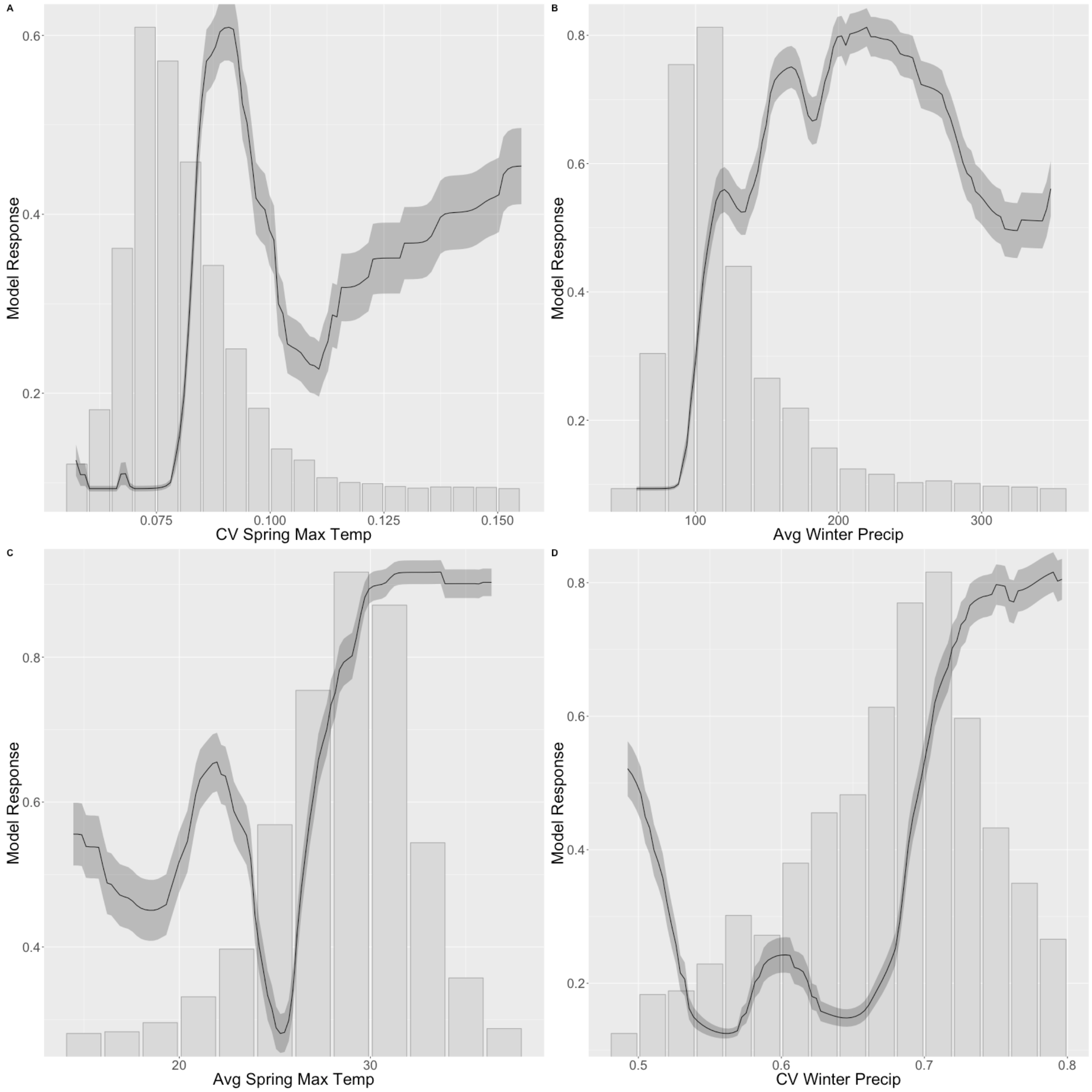


Figure A.23-4. GAM partial response curves for the top four variables in the Bendire's thrasher model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.23.4.2 MaxEnt Model

The MaxEnt models relied heavily on three of the four top variables as those in the GAM models, with the addition of Slope into the top four performing models contributing 16% (Table A.23-2). This model also had similar response curves among algorithms indicating relatively robust model selection (Figure A.23-4, Figure A.23-5). Higher habitat values were predicted in warmer and more variable areas with respect to temperature, and in areas in higher Winter Precipitation. There was a negative association with Slope that paralleled that of the average habitat values.

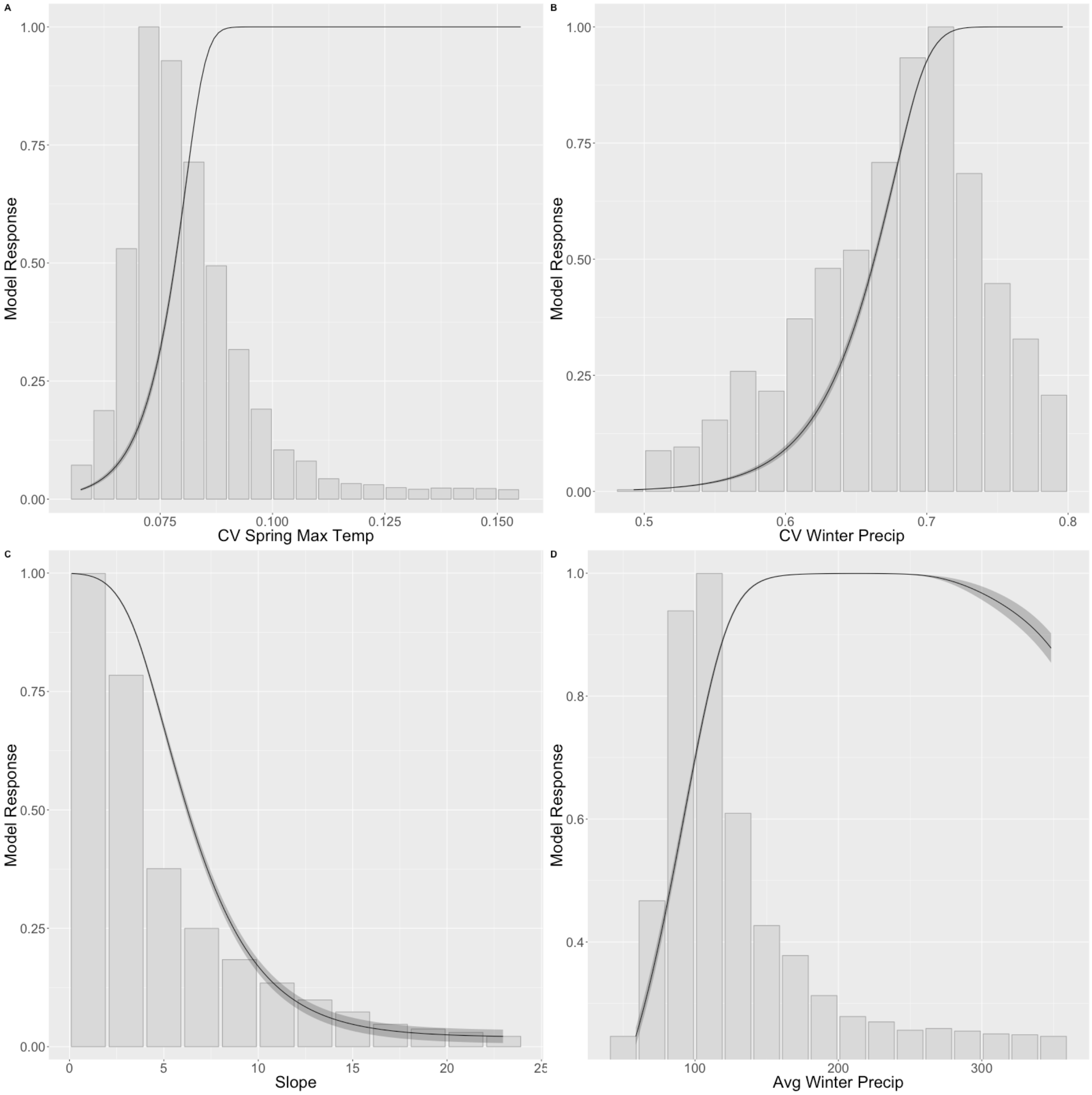


Figure A.23-5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for Bendire's thrasher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.23.4.3 Random Forest Model

The Random Forest model for this species had the same top four input variables as the GAM models (Table A.23-2). Performance curves for these variables indicated higher predicted habitat values in areas with higher and more variable Winter Precipitation, more variation in Spring Maximum temperatures, but with a reduction in predicted habitat at the highest Average Spring Maximum temperatures. The performance metrics (Table A.23-1) as well as the Continuous Boyce plots indicated high model performance (Figure A.23-3).

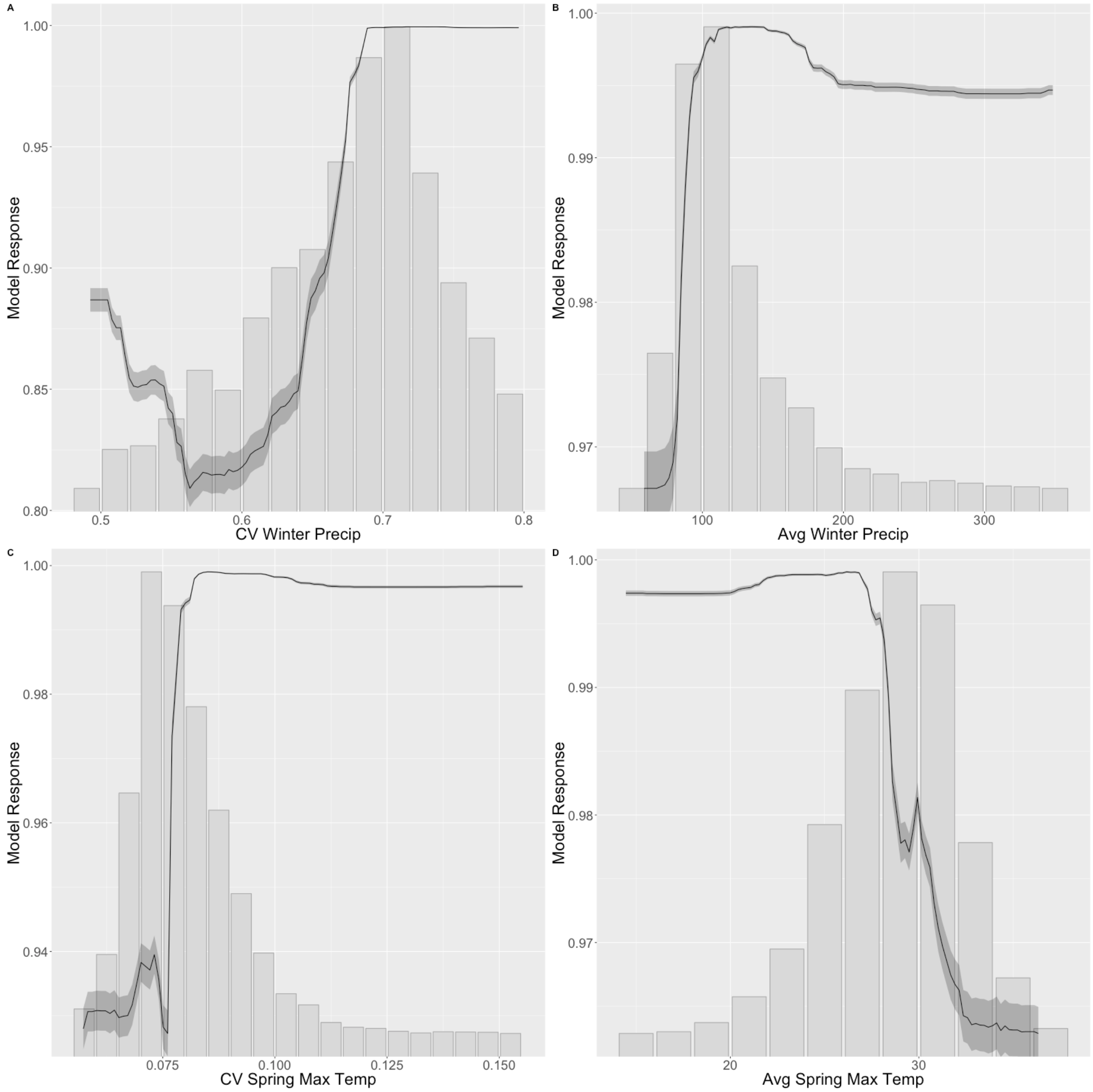


Figure A.23-6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for Bendire's thrasher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.23.4.4 Model Discussion

Bendire's thrasher largely occupy the western half of the southern-most portions of Clark County, NV, with additional localities in lower predicted suitability areas in the lower slopes of the Sheep and Spring ranges. There are additional localities in in the northern and eastern extent of the county that did not correspond with high modeled habitat values (Figure A.23-7), and the Mesquite area has several localities associated with higher modeled habitat for that area.

The models indicated that the species is associated with areas lower Winter Precipitation, and variable temperatures. It should be noted that it is also likely that habitat selection for this species is influenced by other species within the genus (Leconte's and Crissal Thrasher) that also occupy areas of overlapping habitat, and may compete with this species for habitat.

The locality data for this species consisted of 400 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 208 records.

A.23.4.5 Standard Error

There are several areas of relatively higher error rates (SE ~ 0.03 - 0.04) and these are located for the most part in areas with sparse localities recorded in the areas surrounding the Spring and Sheep ranges, and through the Good Springs, Blue Diamond and Trout Canyon areas (Figure A.23-8). There is also an area higher error along the Virgin river.

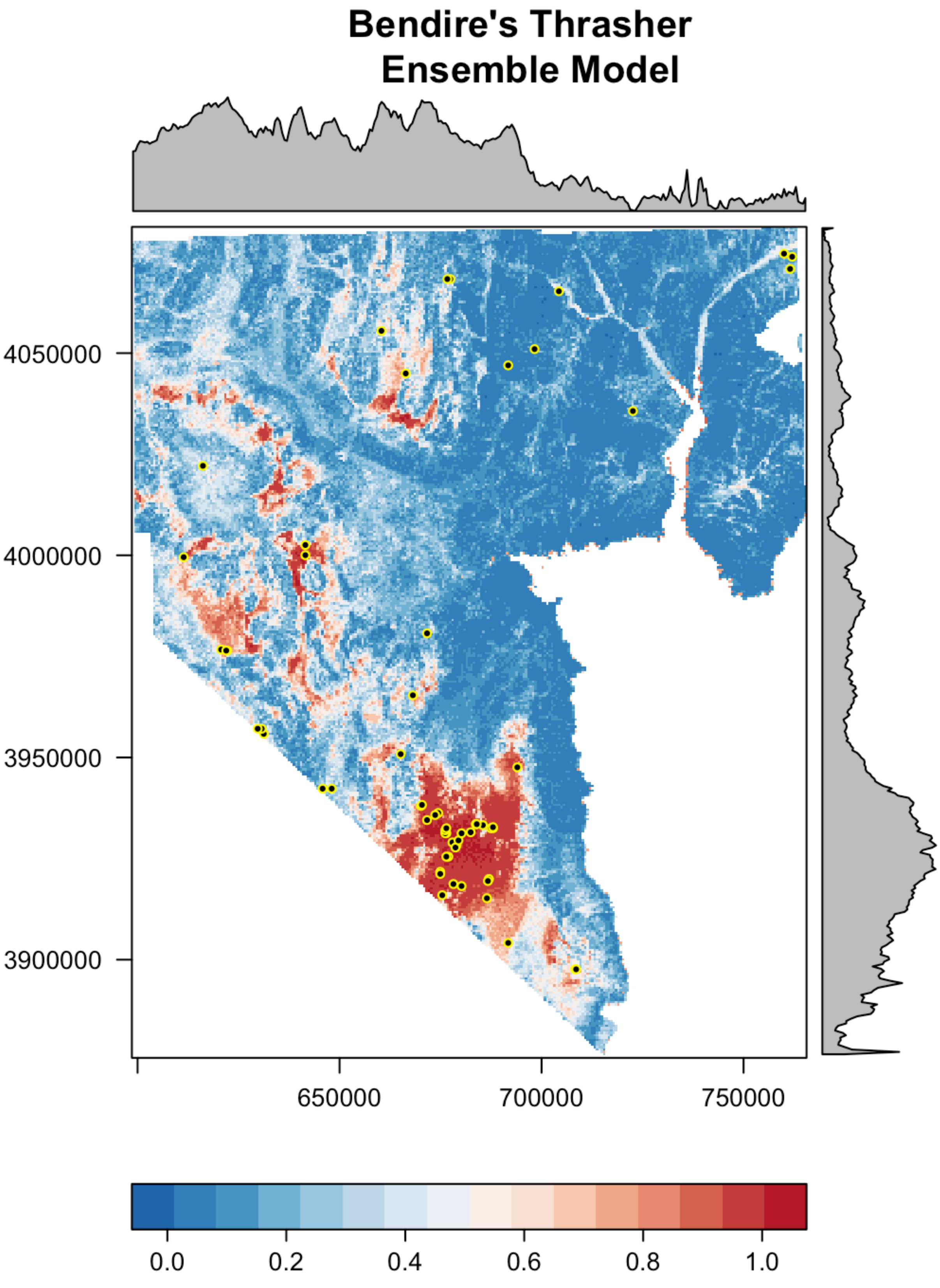


Figure A.23-7. SDM map for Bendire’s thrasher ensemble model.

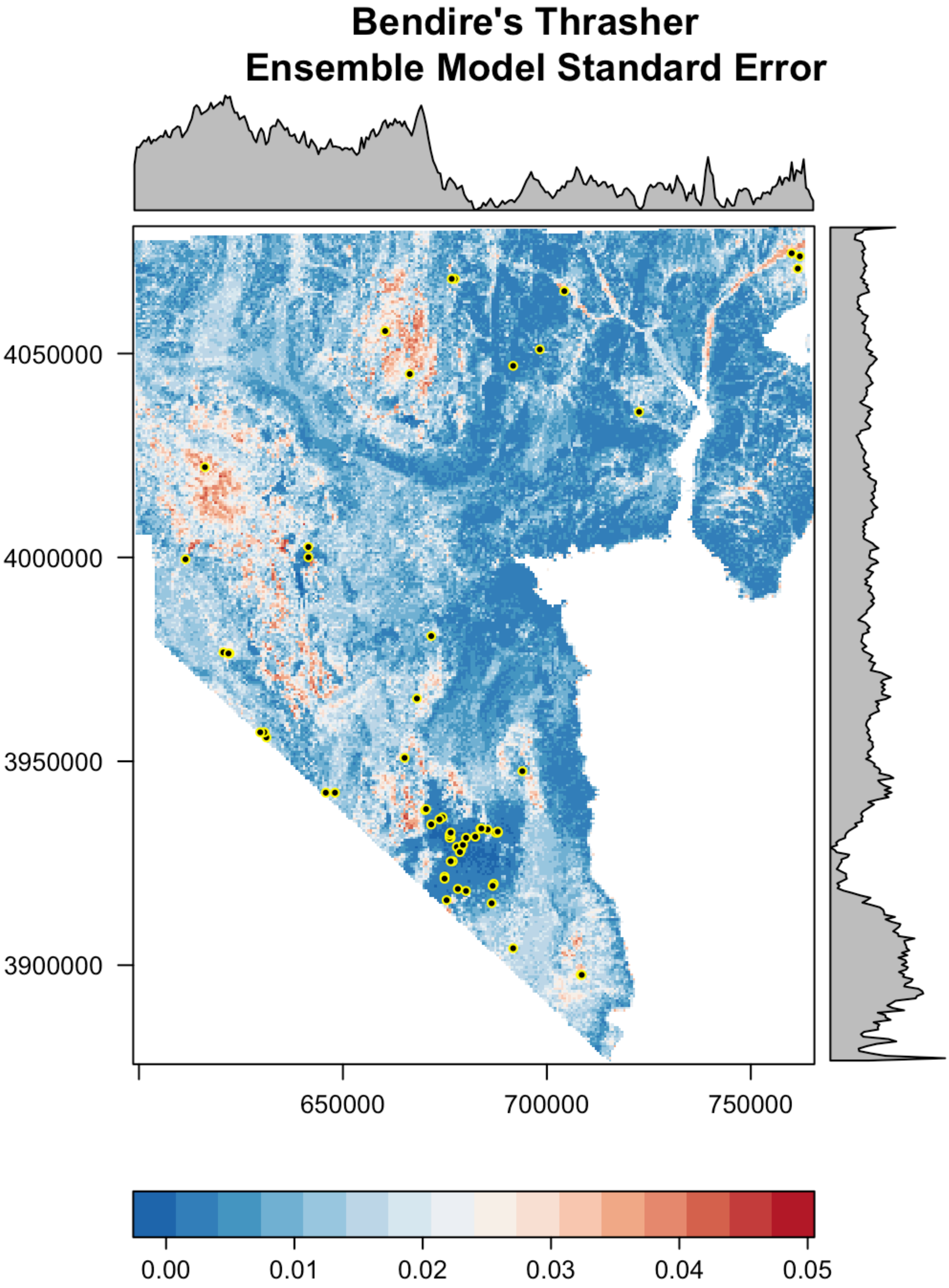


Figure A.23-8. Standard Error map for the Bendire’s thrasher ensemble model for Clark County, NV.

A.23.5 Distribution and Habitat Use within Clark County

GBBO (2013) report that Bendire's thrashers were sparsely distributed and associated with stands of Yucca and Cholla indicative of Upland Mixed Mojave desert scrub habitats, and is likely restricted to those habitats. Modeled habitat for this species included estimated high suitability habitat largely within the Mojave Desert Scrub, and Blackbrush ecosystems, with some habitat within other ecosystems as well (Table A.23-3). Moderate habitat was similarly distributed, and included large amounts of Salt Desert Scrub (Table A.23-3).

Major habitat variables considered to be important to Bendire's thrashers in New Mexico and their respective contributions to the final models (%) were: Average Annual Precipitation (36.5%), Average Annual Maximum temperature (21.8%), Vegetation Type (18.4%), Elevation (10.6%). Minor habitat model components included: Average Annual Minimum temperature (4.2%), Average Spring Minimum temperature (2.8%), Topographic Position (2.8%), Slope (1.6%), Canopy Height (0.7%), and Canopy Height (0.5 %) (Menke and Bushway 2015).

The elevational range of locations where Bendire's thrashers have been documented from 0 to 1800 m in Utah (Birdlife International 2012). However, at least one individual was observed as high as 2560 m (8400') in Clark Canyon in the Spring Mountains, of Clark County, NV. That juvenile bird was collected (killed for a scientific specimen) in a fir-pine forest with shrubby undergrowth. It was presumed that the bird may have wandered from its usual habitat type because it was young and inexperienced (Austin and Bradley 1965).

Table A.23-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	77	46	0
Blackbrush	201661	109590	89682
Bristlecone Pine	1167	6328	39
Desert Riparian	3403	6259	464
Mesquite Acacia	8524	5979	5080
Mixed Conifer	13876	12902	257
Mojave Desert Scrub	1064382	185324	98742
Pinyon Juniper	70663	32111	5435
Sagebrush	2291	1182	1208
Salt Desert Scrub	58408	22001	2011

A.23.6 Ecosystem Level Threats

It can be inferred from publications about the plants that Bendire's thrashers nest in that they inhabit a range of ecosystem types native to Clark County, NV including: Blackbrush (e.g. in association with yuccas, Desert Riparian, Mesquite/Acacia, Mojave Desert Scrub, and Salt Desert Scrub (Brown 1901, Gilman 1909, Gullion et al. 1959). Disturbances to these habitats due to increasing wildland fire, or development are likely to result in the continued decline of this species.

A.23.7 Threats to Species

The first step to understanding the role potential threats play in regard to populations of native species involves understanding population trends. In other states, the status of species has been analyzed using the Breeding Bird Survey data. Trends in Clark County are unknown, however the apparent restriction to mixed Mojave Desert scrub habitats and the conceptual model of threats found in the GBBO report (2013) can serve to provide a starting point for conservation planning regarding this species. Like all other species they are sensitive to destruction and degradation of their habitat, and because the nests are built relatively low in vegetation (e.g. often approximately 1meter above the ground surface – Brown 1901). Predators (esp. coyote and fox) that are subsidized from suburban and urban areas with food (e.g. from garbage, gardens, and abundant small animals), and water (golf courses, and overwatering) are capable of accessing the nests, and this may expand the influence of urban areas as has been documented for other species (Esque et al. 2010).

Wildfire has been increasing in the northeastern Mojave Desert as a result of increased fuels provided by invasive species (D'Antonia and Vitousek 1992, Brooks and Esque 2002). Fire and habitat loss are known to negatively affect bird populations (Bock and Block 2005) by destroying and degrading habitat and removing vegetation required for nesting. Bendire's thrashers (along with many other desert dwelling species) were shown to respond positively to restoration of desert habitats (e.g. cessation of over-grazing, addition of water spreading features– Monson 1941).

A.23.8 Existing Conservation Areas/Management Actions

Bendire's thrasher is protected at the federal and state level by the Migratory Bird Treaty Act, and is considered a Species of Conservation Priority by the Nevada Wildlife Action Plan (Wildlife Action Plan Team 2012). This plan establishes a strategic vision for wildlife conservation in Nevada at the landscape level, and identifies the species of greatest conservation need. Plan objectives for Bendire's Thrasher are to stabilize declining population trends and distribution. Recommended conservation actions for this species are as follows: conduct research investigating distribution, population demography, and ecology; establish targeted point count transects to supplement the Nevada Bird Count's ability to detect and monitor this species; develop predictive models and inventory occupied habitat for the purpose of developing reliable population estimates; habitat use, and restore and maintain associated habitats occupied by the Bendire's thrasher (Wildlife Action Plan Team 2012).

The Nevada Comprehensive Bird Conservation Plan designates Bendire's thrasher a Conservation Priority species. Population declines, significant threats, dependence on restricted or threatened habitats, or small population size can all contribute to this designation (GBBO 2010). This plan's recommendations include: protecting occupied habitat from habitat conversion, energy development, and fire; monitoring and possibly limiting off-highway vehicle use in occupied habitat; controlling invasive weeds to reduce fire risk; inventorying and mapping important habitat; developing an improved method for monitoring this species; and conducting studies to better estimate minimum patch size, home range, landscape mosaic use, vagrancy, and response to edge effects (GBBO 2010).

Partners in Flight's (PIF) North American Landbird Conservation Plan identified Bendire's thrasher as a Species of Continental Importance for the US and Canada, further designating it as a Watch List species with restricted distribution or low population size (Rich et al 2004). At the state level, PIF identified Bendire's thrasher as a priority species, and set an objective of doubling the Nevada population from 1,000 individuals to 2,000 individuals (Rosenberg 2004). In order to meet continental population objectives, statewide population targets were set at 2,046 individuals (Rosenberg 2004).

A.24 LECONTE'S THRASHER (*TOXOSTOMA LECONTEI*)

LeConte's thrasher (*Toxostoma lecontei*) is among four species of desert thrashers found in Clark County, Nevada; including: Bendire's (*T. bendirei*); Crissal (*T. crissale*); and Sage thrashers (*Oreoscoptes montanus*). All of these thrashers are roughly the same size and color – drab shades of brown to grey. They are also similar in size to the more frequently observed Mockingbird (*Mimus polyglottos*) which is abundant in urban areas of southern Nevada. LeConte's thrasher is generally grey and is the palest thrasher except for the dark tail and pale buffy under-tail coverts (Sibley 2003). In good light, this thrasher has dark red-brown eyes (Fisher 1893), and this characteristic distinguishes it from the other thrasher species whose eyes are yellowish. The call of this secretive bird "resembles closely the whistle a man employs on calling a dog, short, and with rising inflection at the end" (Gilman 1904). The song is heard much less frequently than the call and is recognized as distinctive and melodious, and similar to the mockingbird but of higher pitch and richer (Gilman 1904). Although they are shy, a playback tape of the birds' song is said to elicit a call from the birds in any time of year (Sheppard 1970). It was noted that in many places throughout the LeConte's thrasher's range, the young, nearly ready to fledge, were captured by Native Americans and Anglos for the purpose of making them cage-birds to enjoy their song (Fisher 1893). At the Nevada National Security Site in Nye County, NV nesting was observed to occur in the middle of shrubs ~40 cm above the ground, almost exclusively in *Lycium andersonii*, or *L. pallidum*. At other sites, LeConte's thrashers nest in *Opuntia ramosissima*, *O. echinocarpa*, and *Atriplex polycarpa* (Dawson 1923, Jongsomjit et al. 2012). In Rock Valley, NV, LeConte's thrashers attempted two to three nests per breeding season, with one pair laying four clutches in the spring of 1973, following a wet winter (Hill 1980). Mean clutch size was 3.3 to 3.8 eggs/clutch, and was higher in a wetter year (Hill 1980). LeConte's thrashers are shy birds that prefer running away from intruders to flying (Fisher 1893).

A.24.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Not listed, no petitions for listing.

US Bureau of Land Management (Nevada): No status

US Forest Service (Region 4): No status

State of Nevada (NAC 503): Protected

NV Natural Heritage Program: Global Rank G4 State Rank S2

NV Wildlife Action Plan: SOCP

IUCN Red List (v 3.1): Least Concern

CITES: No status

A.24.2 Range

LeConte's thrashers are a hot desert species. In the United States they inhabit the San Joaquin Valley, Colorado and Mojave deserts of California, extreme southern Nevada, western Arizona, and extreme southwestern Utah (Fisher 1893, Dawson 1923, Sibley 2003). In Nevada, LeConte's thrashers occur in Clark, Nye, Esmeralda, and Lincoln counties (Hayward et al. 1963, Sheppard 1996, Fletcher 2009, GBBO 2013). In Mexico they occur in Sonora, Baja Norte, and Baja Sur (Sheppard 1970, Riddle et al. 2000). They are permanent residents throughout their range (Sheppard 1970).

A.24.3 Population Trends

LeConte's thrashers respond to variability in precipitation by increasing nesting and production in wetter years with higher primary and secondary production (Gilman 1904). At Rock Valley, NV – on DOE's Nevada National Security Site (formerly Nuclear Test Site) – LeConte's thrasher had breeding densities of 3/100 ha, which stayed constant among years (Hill 1980). They were regular breeders in that habitat, and were found there year round in desert habitat, but not on the higher mesas (Hayward et al. 1963). At other locations throughout their range they are estimated to be found in densities of zero to five per square mile, and near Maricopa, California there were 10 pairs / square mile (Sheppard 1970).

The Death Valley Expedition (Fisher 1893) reported that LeConte's thrashers were "common at [nearby] Ash Meadows", and they collected specimens in the "Pahrump and Vegas valleys". This species was also said to be "tolerably common" in the Virgin and Muddy river valleys, and a nest was seen on the Mormon Mesa (Fisher 1893). Gilman (1904), however, noted that the birds are never abundant or even fairly common and found few at most locations, though he reported having seen as many as six pairs in one day at one site and six nests in one day at another site.

The Nevada Wildlife Action Plan estimates there are 100 individuals in the Nevada population, and states that the trend is inconclusive (Wildlife Action Plan Team 2012). While quantitative time-trend data are not available for this species in Clark County, large-scale habitat disturbances such as those in the Eldorado, Indian Springs, and Ivanpah valleys may have reduced populations in those key areas.

A.24.4 Habitat Model

Predicted habitat for LeConte's thrasher is fairly widespread throughout the lowlands of the southern portion of the county. Paiute and Eldorado Valley, Ivanpah Valley and the Ivanpah Corridor, and Trout Canyon/Mesquite valley all contain large areas of predicted habitat. Additional habitat is predicted along the US 95 highway corridor, and along the I-15 corridor just north of the Las Vegas Valley. Smaller less-connected habitat areas are near Mormon Mesa, and Mesquite, NV. The three modeling algorithms produced fairly similar predictive maps, differing only in the extent of smaller habitat patches predicted (Figure A.24-1).

The Ensemble model had good performance relative considering all three performance indices, and was high, but not the top model in the BI and TSS metrics. The Ensemble and Random Forest models had slightly higher AUC scores (0.85) relative to the others that were just below (0.8). The MaxEnt model had a notably high Boyce Index, followed by the Ensemble Model, while the others had relatively similar scores (Table A.24-1). Average Spring Maximum temperatures, and the CV of Winter Precipitation were among the highest contributing variable in each of the models, while its Coefficient of variation, and Slope were each in the top four predictors of two models (Table A.24-2).

The Standard error maps indicated higher standard error among the MaxEnt models than the others, with widespread SE's of approximately 0.05. The GAM model had a larger area of elevated SE in the North Central portion of the County near the NNTS. Error rates for the other Random Forest and the Ensemble Model were relatively low throughout the county (Figure A.24-2). The Continuous Boyce curves indicated good model performance across all algorithms (Figure A.24-3).

Table A.24-1. Model performance values for LeConte's thrasher models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets.

Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.85	0.83	0.6	0.46
GAM	0.78	0.77	0.45	
Random Forest	0.85	0.78	0.62	
MaxEnt	0.79	0.95	0.5	

Table A.24-2. Percent contributions for input variables for LeConte's thrasher for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	**GAM**	**RF**	**MaxEnt**
Dist to cliffs	0.1	1	0.1
NDVI Amplitude	9.5	1.4	1.1
NDVI Length of Season	0.2	0.9	1
NDVI Max	7.2	1.4	1.6
Winter Precip	13.1	10.6	3.3
CV Winter Precip	19.1	40.5	23.2
Average Spring Max Temp	17.5	11.4	16.4
CV Average Spring Max Temp	21.1	4.1	23.9
Slope	10.3	11.3	26.1
NDVI Start of Season	1.2	5.6	3.1
Winter Precip	0.6	11.8	0.2

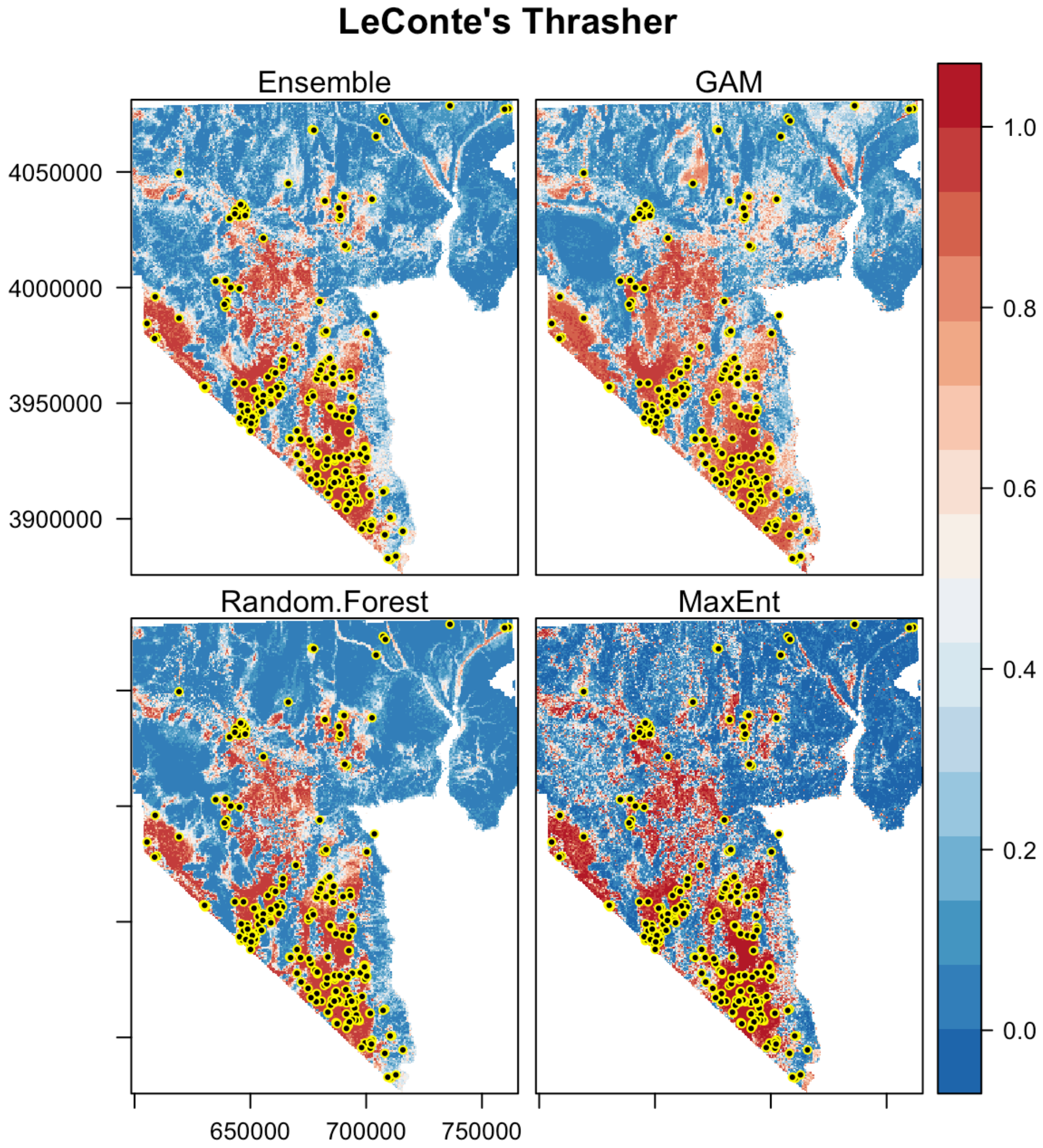


Figure A.24-1. SDM maps for LeConte's thrasher model - Ensemble (upper left), and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

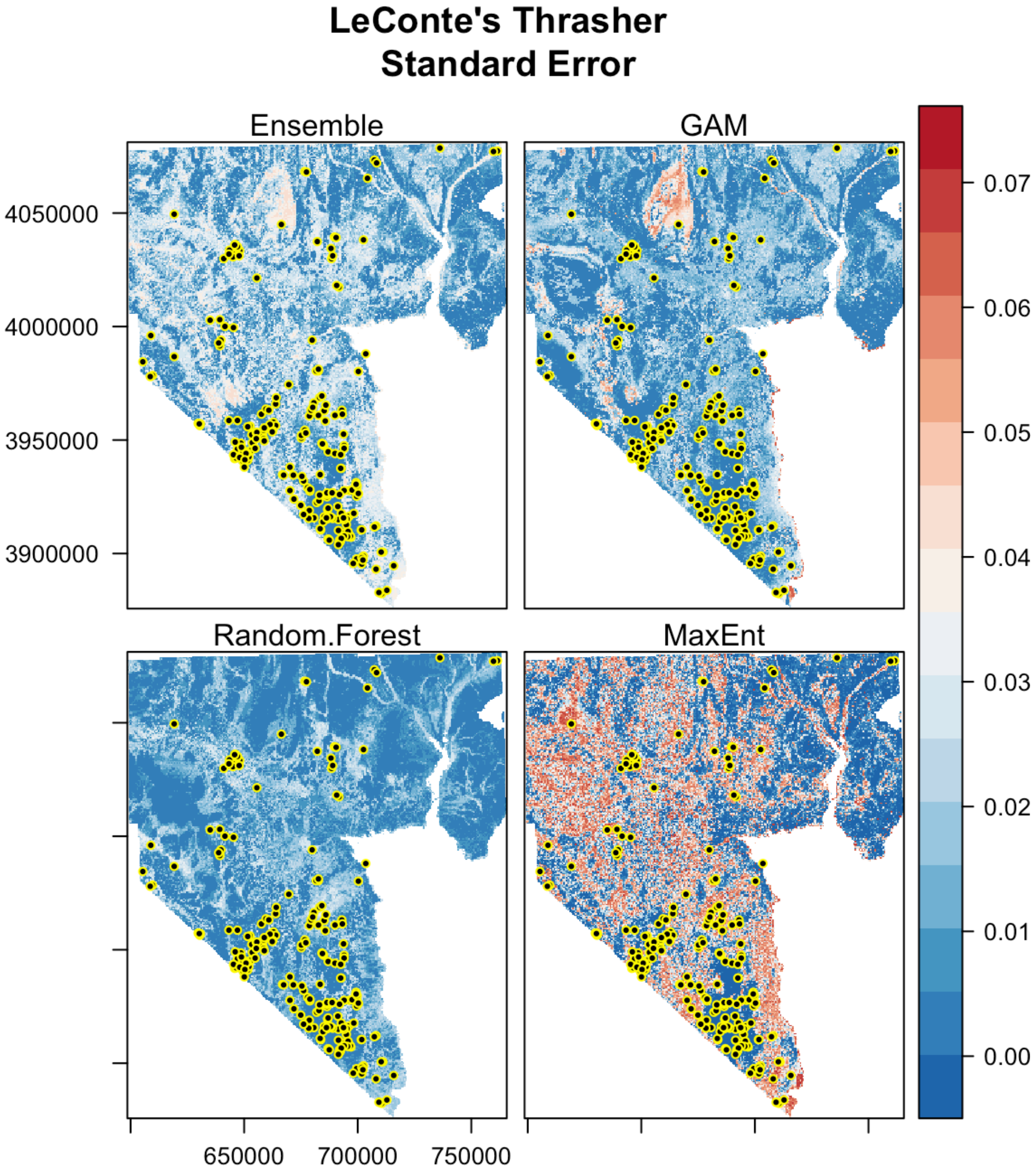


Figure A.24-2. Standard error maps for LeConte’s thrasher models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

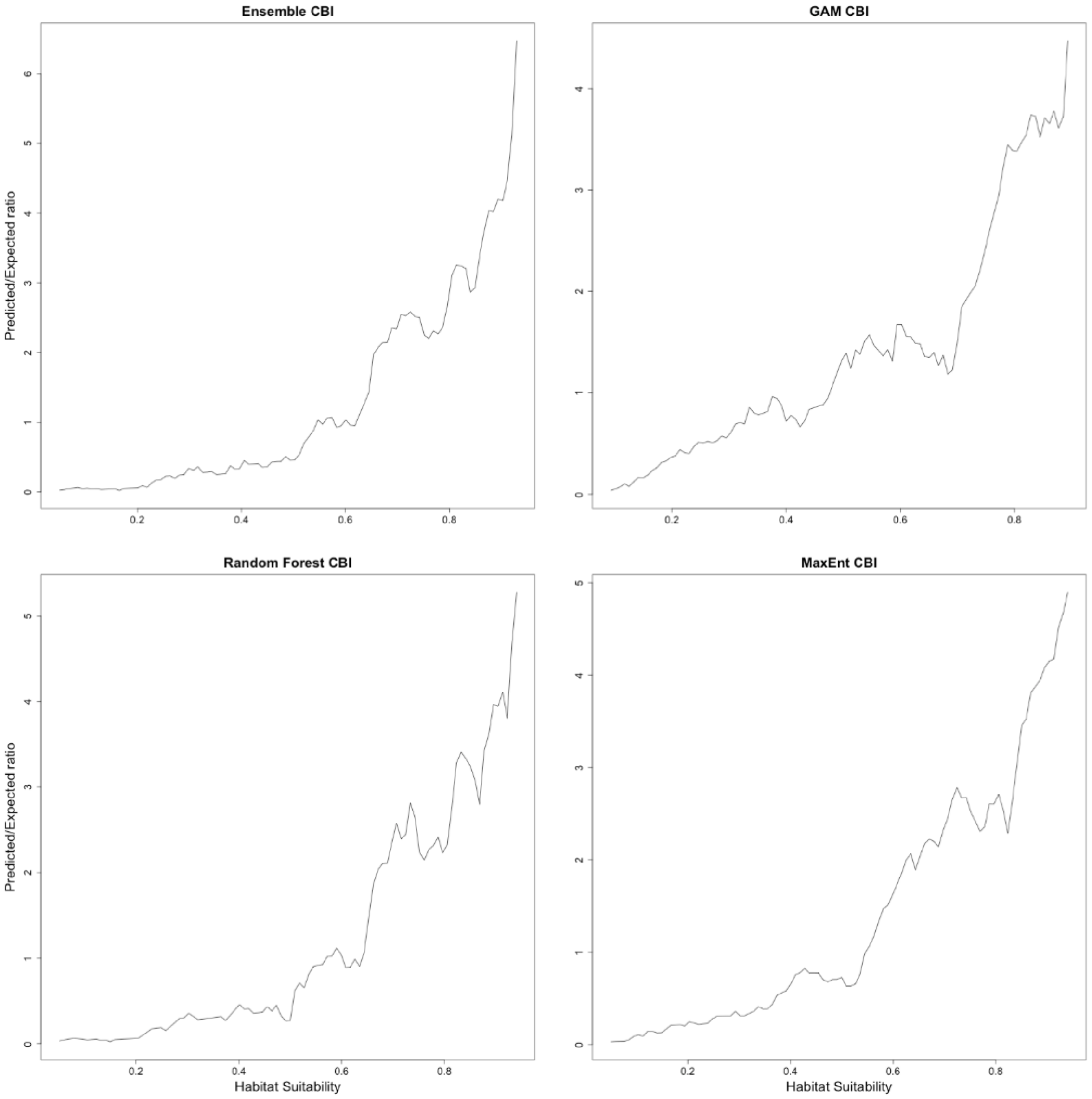


Figure A.24-3. Graphs of Continuous Boyce Indices [CBI] for LeConte's thrasher models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

A.24.4.1 General Additive Model

The top four contributing environmental layers were Average Winter Precipitation and its Coefficient of Variation, and the Average Spring Maximum temperature and its Coefficient of Variation (Table A.24-2). Model scores were higher in areas with more variation in Winter Precipitation than average, but with suitability associated with precipitation values themselves peaking just above the average for the study area (Figure A.24-4). The relationship of predicted habitat with Average Spring Maximum temperature appeared to have a bimodal shape, where a few locations (with higher variability) indicated increased habitat in cooler areas, whit a second peak where Average Spring Maximum temperatures were 30 or above (Figure A.24-4). The Coefficient of Variation for Spring Maximum temperatures peaked in areas where the temperature was just above the average for the study area (Figure A.24-4).

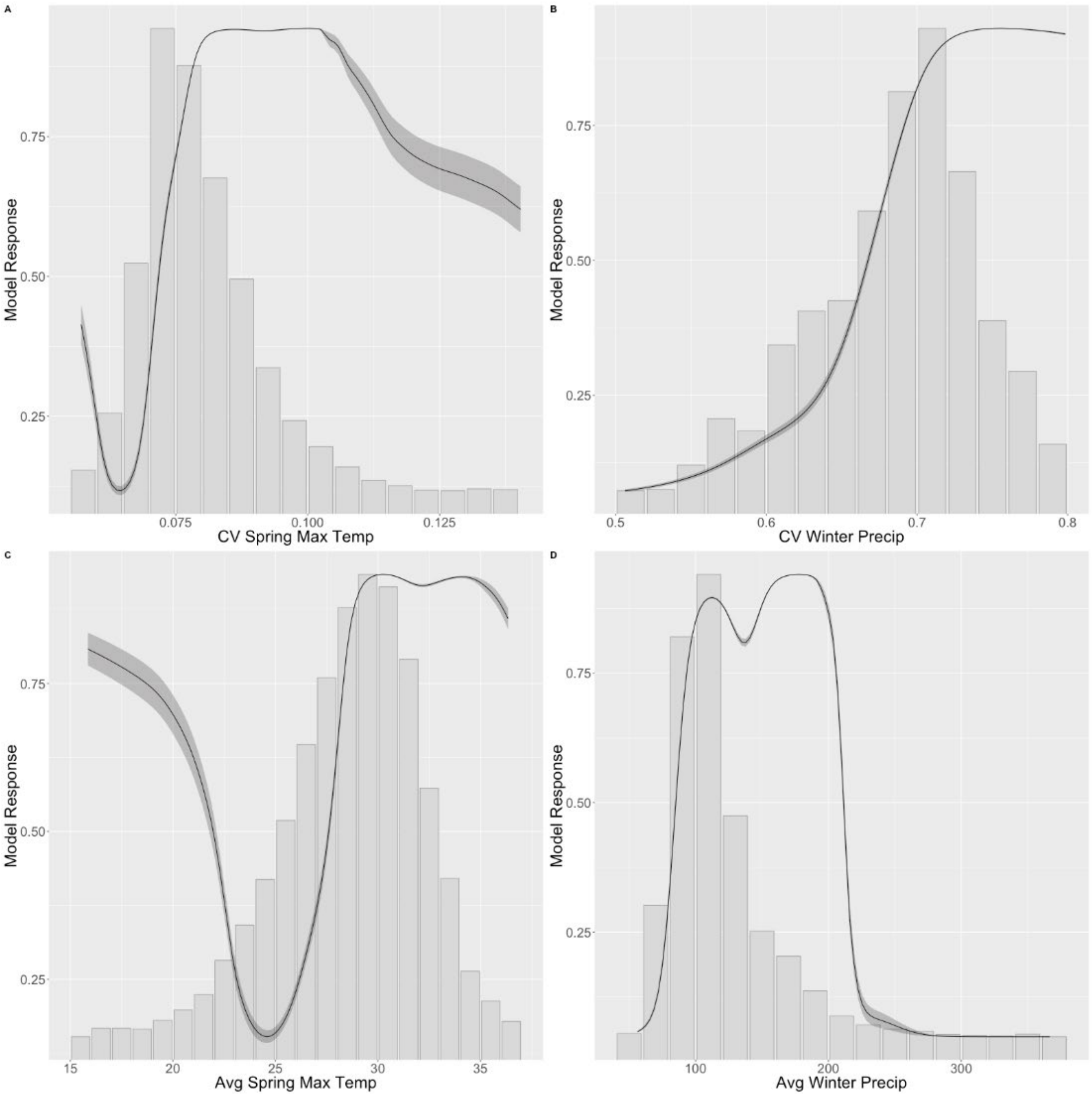


Figure A.24-4. GAM partial response curves for the top four variables in the LeConte’s thrasher model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.24.4.2 MaxEnt Model

The top four influencing variables in the MaxEnt models were the same as three out of the four top variables as those in the GAM models, with the addition of Slope (Table A.24-2). This model also had similar response curves among algorithms indicating relatively robust model selection (Figure A.24-4, Figure A.24-5). The Average Spring Maximum temperature curve had more realistic behavior than in the GAM model, with habitat predictions increasing with higher values, and higher than the average for the study area. The models also predicted higher habitat values where the CVs of Average Spring Maximum temperature, and Winter Precipitation were higher. There was a negative association with Slope that paralleled that of the average habitat values (Figure A.24-5).

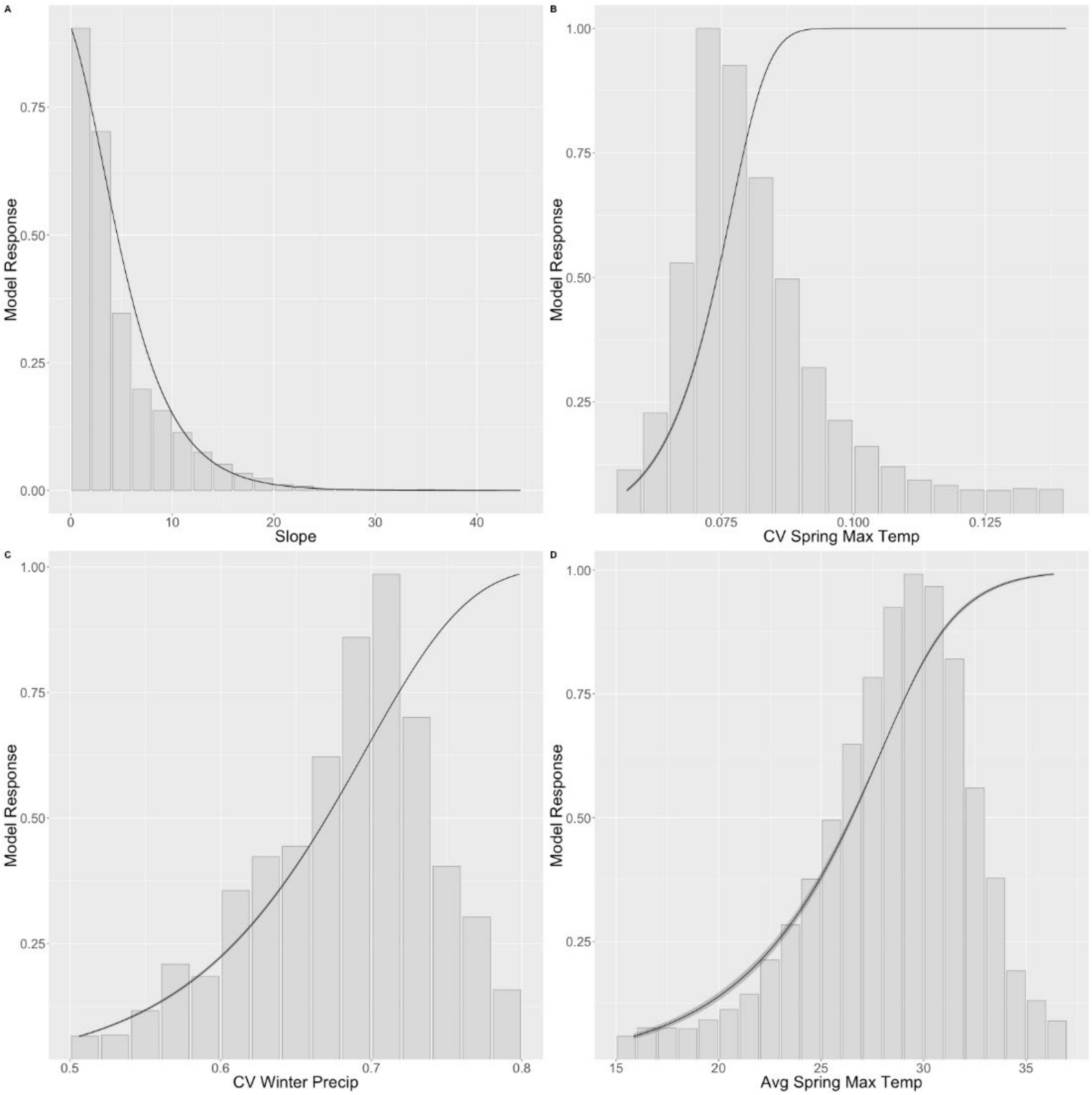


Figure A.24-5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for LeConte's thrasher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.24.4.3 Random Forest Model

The Random Forest model performance curves for Slope and the CV of Winter Precipitation were similar to the other two algorithms (Figure A.24-6, Figures A.24-4 and A.24-5), however, Average Spring Maximum temperature had a different relationship, instead predicting higher habitat scores at lower temperatures while the other variables remained constant (Figure A.24-6). Flow Accumulation had a sharp and early peaked response which likely indicates habitat occurring in lowland areas and not at the peaks of watersheds. The Random Forest model had among the lowest overall standard error rates, indicating relative agreement among the 50 modeling runs of bootstrapped training data (Figure A.24-3).

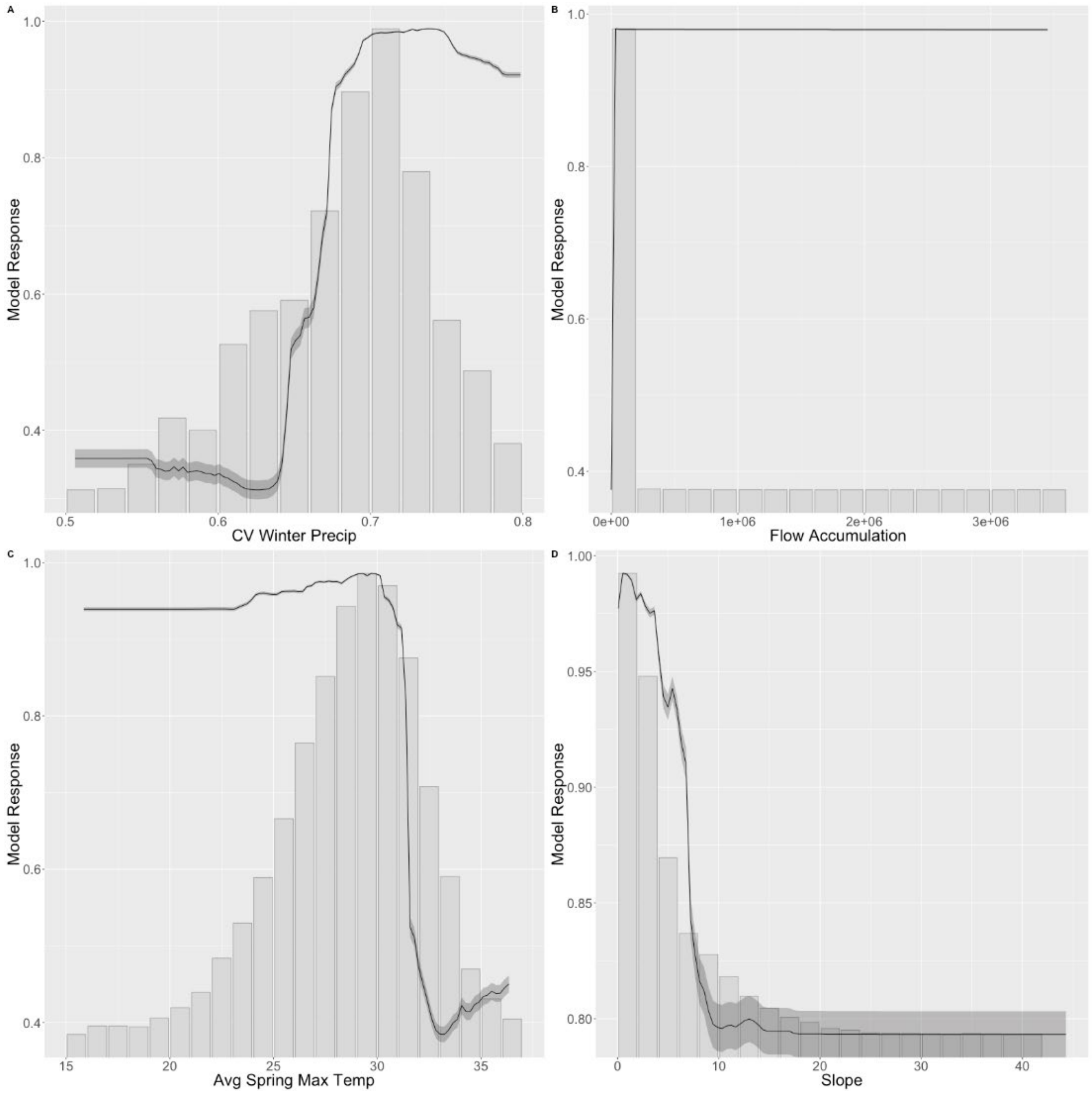


Figure A.24-6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for LeConte's thrasher. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

A.24.4.4 Model Discussion

LeConte's thrasher habitat is predicted to be widespread in the southern and western lowland areas throughout the county. The model discrimination indicated that models were correctly capturing predictions for most of the locality locations (Figure A.24-3), and where localities were less common, there were predictions of only isolated patches of habitat (Figure A.24-7). The model for this species used 605 localities within the buffered modeling area, which were thinned to 388 localities to exclude dense point aggregations. The model largely agrees with range maps for the species, where Nevada includes the northern most distribution for this species, with some observations occurring up toward St George Utah, but where habitat is largely contained in southern California and along the larger Colorado River Drainage (but not specialized in riparian areas. Again, for this species it should be noted that its predicted habitat overlaps with, and is likely influenced by, other species within the genus (Bendire's and Crissal Thrasher).

A.24.4.5 Standard Error

The Standard Error for the Ensemble model is relatively low (0.04 or lower) with relatively widespread error rates throughout the county. Areas with higher error rates are in the vicinity of the Nellis bombing range and the NNTS with some areas of higher error in the mountains between the Ivanpah and Mesquite valley to the north. Areas of predicted higher habitat have generally lower error, indicative of good overall model fit (Figure A.24-8).

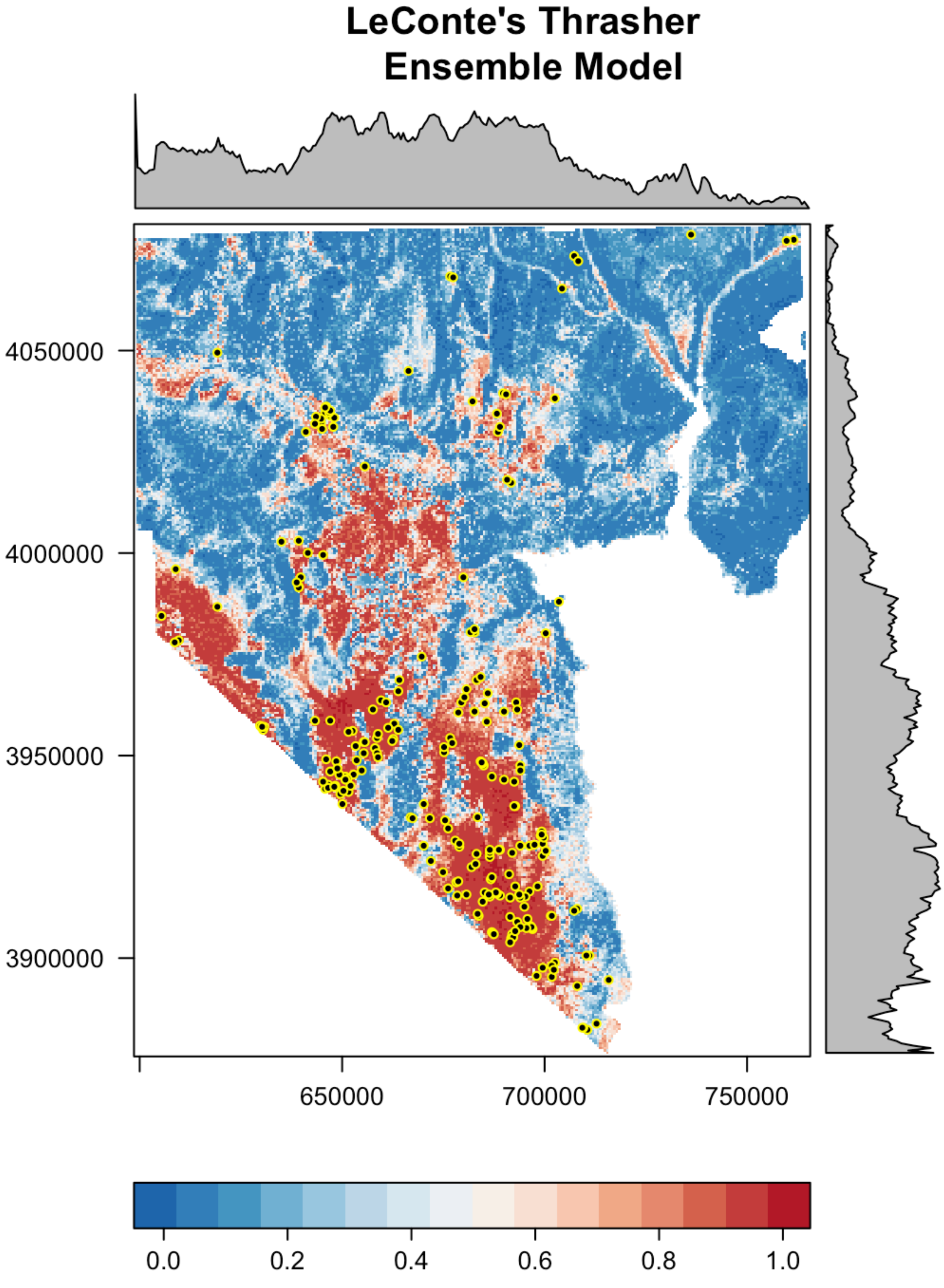


Figure A.24-7. SDM map for LeConte’s thrasher Ensemble model in Clark County, NV.

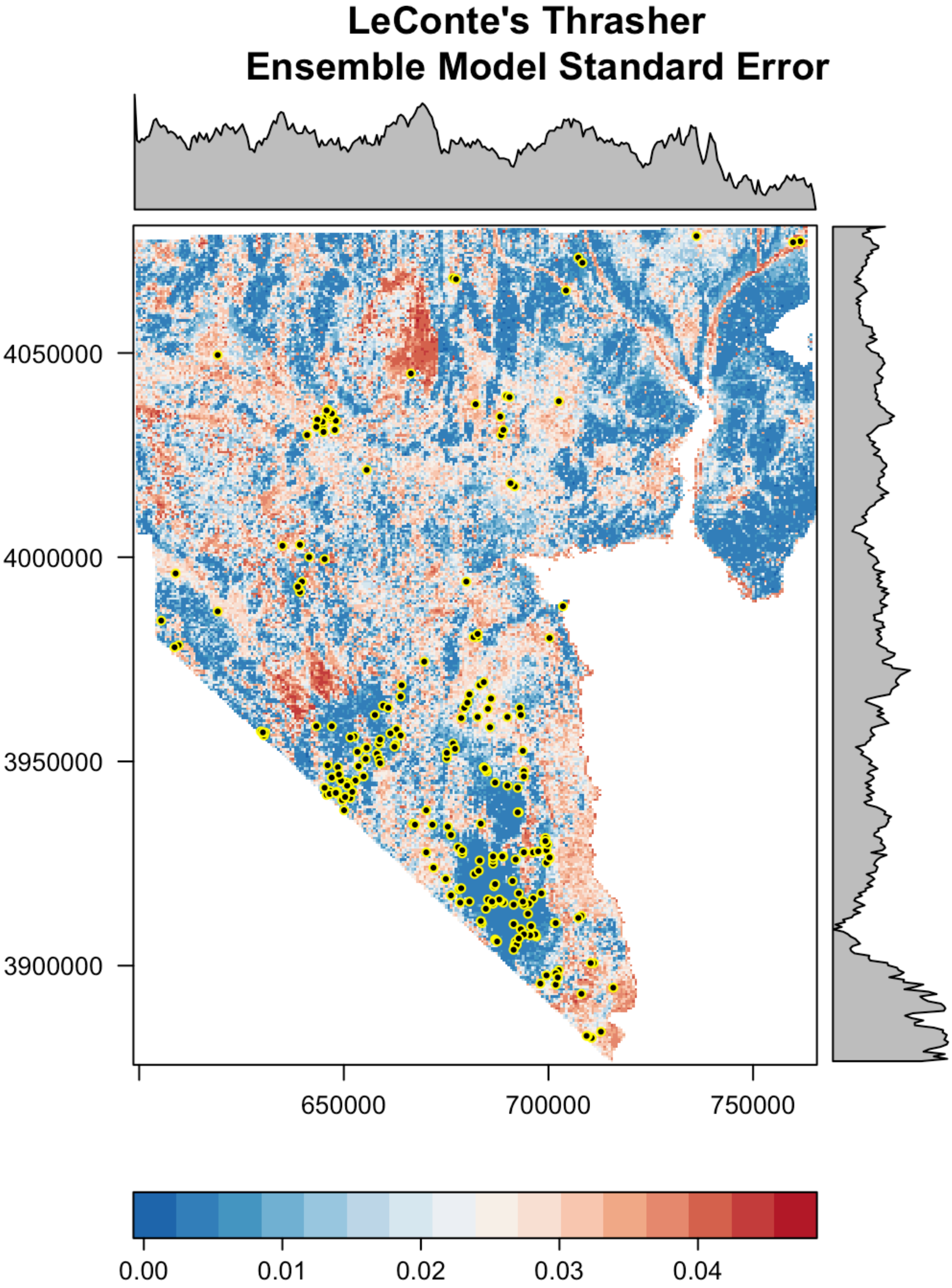


Figure A.24-8. Standard Error map for the LeConte’s thrasher Ensemble model for Clark County, NV.

A.24.5 Distribution and Habitat Use within Clark County

LeConte's thrashers are found in open shrublands with sparse shrubs and seasonally little to no annual vegetation. Surface litter accumulations around the shrubs are important where they acquire invertebrates such as scorpions, beetles, grasshoppers, spiders, Lepidoptera, many larvae, and small lizards (e.g. *Uta stansburiana*, Sheppard 1970). Habitats are relatively flat with slope generally < 4 degrees throughout Clark County, NV (Sheppard 1970, Fletcher 2009). Soils in areas where the bird is found are silty or sandy and often alkaline. Areas inhabited by these shy Thrashers include saltbush (*Atriplex polycarpa*, and *A. canescens*), cholla (*Opuntia echinocarpa, O. ramosissima*), Mojave mixed-shrub communities, and wash vegetation including mesquite (*Prosopis* spp.), smoketree (*Psorathamnus spinescens*), and catclaw acacia (*Acacia greggii*) (Dawson 1923, Fletcher 2009). The association with *Prosopis*/*Acacia* vegetation was the strongest, with moderate association to Saltbush Playa (Jaeger et al. 2010). A weaker association was found with *Yucca brevifolia* and Mojave Mixed Scrub associations, however, mixed shrub encompasses many species that vary spatially and therefore the accuracy of this association in some cases is questionable (Jaeger et al. 2010). LeConte's thrashers show a strong positive response to the presence of wash habitat and this may be due to the increased presence of large thorny tree, shrub and cactus species that provide both protection from predators, and ameliorate harsh desert conditions for young birds in the nest (Johnston and Ratti 2002, Fletcher 2009). Nest sites are usually between 1 to 2 m above the ground surface. Blackbrush and pinyon/juniper communities were found to have a negative relationship for the presence of LeConte's thrashers (Fletcher 2009). Both of those vegetation types are correlated with mountain slopes or hillslopes of > 4%, and steep hillslopes were also negatively associated with this thrasher. Zonal analysis of the habitat model with the Clark County ecosystems developed by Heaton et al. 2011 indicated that most of the highest suitability habitat for this species is located in Mojave Desert Scrub, Mesquite Acacia, and Salt Desert Scrub ecosystems. Moderate habitat also followed this pattern, with an increase in the Blackbrush ecosystem as well (Table A.24-3)

Valleys throughout Clark County were surveyed at 432 random sites for presence of LeConte's thrashers between 2005 and 2007, and positive detections were made at 41 of the random survey locations with 24 additional non-random incidental sites (Fletcher 2009). An occupied nest was observed on Mormon Mesa, but the thrashers were not detected on Mormon Mesa during recent surveys (Fisher 1893, Fletcher 2009). While survey sites were extensive during the 2009 surveys, the Las Vegas Valley was not surveyed, and the Nevada National Security Site (most of which is in Nye County) was not surveyed. The largest contiguous area where LeConte's thrashers were not detected was most of Gold Butte and the Virgin River Valley. This is in contrast to observations during the late 1800's when LeConte's thrashers were observed in the Virgin River Valley (Fisher 1893), although other surveys and a habitat model for this species in Gold Butte reported no sightings, and limited suitable habitat (Nussear et al. 2011),

Fletcher (2009) predicted high quality habitat suitability areas occur in Nevada on the western border with California in the Pahrump and Sandy valleys, Ivanpah Valley, south of Jean Dry Lake, the valley south of Sloan Canyon, the northwestern bajada of Eldorado Valley, the vicinity of Corn Creek, and several highly suitable habitat patches near Indian Springs (Fletcher 2009), and we had predictions in similar areas here (Figure A.24-7). Fletcher also predicted several small patches of highly suitable predicted habitat in the Muddy Mountains of Lake Mead National Recreation Area, along the Muddy River, on Mormon Mesa, and a few patches between Devil's Kitchen and St. Thomas Gap in Gold Butte. However, the highly suitable habitat that was modeled in eastern Clark County did not coincide with any observations of LeConte's thrashers, and only the Riparian areas in the northeast quarter of the county are predicted in our model (Figure A.24-7).

Table A.24-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	281676	75434	55118
Bristlecone Pine	7565	0	0
Desert Riparian	1276	4712	4131
Mesquite Acacia	4765	4509	10931
Mixed Conifer	26862	282	0
Mojave Desert Scrub	706583	252111	398157
Pinyon Juniper	94113	13982	264
Sagebrush	3186	1423	84
Salt Desert Scrub	54890	15364	12223

A.24.6 Ecosystem Level Threats

The LeConte's thrashers are predicted to inhabit Mojave Desert Scrub, Blackbrush, Salt Bush Scrub, Mesquite/Acacia, and Desert Riparian habitats (Fisher 1893, Dawson 1923, Fletcher 2009), with limited habitat in Pinyon Juniper and Sagebrush ecosystems (Table A.24-3). Ecosystem level threats for this species are similar across the species' range in hot desert habitats. This includes any type of surface disturbance that destroys desert vegetation thus modifying or reducing cover, foraging sites, and nesting areas. Such disturbances include industrial or urban development, military training, and off-highway vehicle use – particularly that occurring along desert washes. Wildfire or prescribed fire fueled by invasive non-native annual plants can also be detrimental to LeConte's thrashers (Germano et al. 2001).

A.24.7 Threats to Species

The greatest current threats to LeConte's thrasher habitat are land disposals for construction projects. Planned land disposals by BLM are documented on the largest single habitat patch of the highest predicted quality in Ivanpah Valley. Many of the other large areas of predicted highly suitable habitat are within or adjacent to other disposal areas including parts of Sandy Valley, Jean Dry Lake, and the upper Muddy River drainage. Large portions of the only large predicted habitat in Eldorado Valley are already covered by solar energy development.

LeConte's thrasher habitats are particularly vulnerable to solar energy farms because the Thrashers and the farms both require the flattest landscape available. Therefore, the highest quality LeConte's thrasher habitat and the most sought after solar development areas overlap nearly 100%.

A.24.8 Existing Conservation Areas/Management Actions

Most of the modeled habitat of high habitat suitability does not occur within protected areas. The LeConte's thrasher is not protected by the ESA, and therefore are no lands set aside specifically for them (Fletcher 2009). However, other low desert valley areas that are protected for a variety of other reasons can also be considered beneficial for a great deal of habitat that modeling indicated was of moderate quality.

LeConte's thrasher habitats are afforded some protections on lands administered by the National Park Service, US Bureau of Land Management, US Fish and Wildlife Service, and US National Forest. Specific parcels include Lake Mead National Recreation Area, Gold Butte National Monument, Desert National Wildlife Refuge, Red Rock National Conservation Area, the Weethump Wilderness and others, Toiyabe National Forest, and several Areas of Critical Environmental Concern throughout Clark County. Habitat restoration activities are currently widespread on public lands in Clark County including the reduction of invasive species that promote fire. Habitat restoration in low valley habitats is likely to be beneficial to LeConte's thrashers.

LeConte's thrasher is considered a Species of Conservation Priority by the Nevada Wildlife Action Plan (Wildlife Action Plan Team 2012). Conservation challenges listed by the plan include sensitivity to habitat fragmentation, degradation, or conversion from disturbances such as urban/agricultural/industrial development, heavy OHV use, fire, and energy development; extended late-summer livestock grazing; and invasive plants. The plan recommends: protecting occupied habitat at the recommended patch size; maintaining corridors of suitable habitat between occupied areas; and minimizing habitat fragmentation (Wildlife Action Plan Team 2012).

The Nevada Comprehensive Bird Conservation Plan (GBBO 2010) LeConte's thrasher a priority species. Conservation strategies recommended by the plan include: inventory and map critical habitat; improve monitoring efforts and generate improved population size and trend estimates; control invasive weeds in and near occupied habitat to reduce fire risk; monitor and (if necessary) limit OHV use in occupied habitat (GBBO 2010).

A.25 ARIZONA BELL'S VIREO (*VIREO BELLII ARIZONAE*)

There are four subspecies of Bell's vireo whose range occurs in North America. Population trends have been declining for this species and the least Bell's vireo (*Vireo bellii pusillus*) is recognized as endangered under the Federal Endangered Species Act, as well as the California Endangered Species Act. The Arizona Bell's vireo (*Vireo bellii arizonae*) subspecies occurs in desert riparian areas along the Colorado River drainage and is known to use various types of desert riparian vegetation.

A.25.1 Species Status

US Fish and Wildlife Service Endangered Species Act: Not Listed

US Bureau of Land Management (Nevada): No Status

US Forest Service (Region 4): No Status

State of Nevada (NAC 503): Protected

NV Natural Heritage Program: Global Rank G5T4; State Rank S2B

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): No status for this subspecies, however *Vireo bellii* is listed as Near Threatened

CITES: No status

The least Bell's vireo subspecies was listed as an endangered species under the ESA in 1986, but this subspecies is not known to occur in southern Nevada. The Arizona Bell's vireo subspecies occurs in southern Nevada, but has no federal designation as endangered or threatened, although it is listed as Endangered under the California Endangered Species Act (CDFG 2016). The Arizona Bell's vireo is protected under the Migratory Bird Treaty Act of 1918 as amended (16 USC 703-712).

The IUCN Redlist lists the species as "Near Threatened" due to widespread population declines of approximately 2.7% per year, although subspecies trends are not reported (BirdLife International. 2012). This species is also listed as a Bird of Conservation Concern by the USFWS within the Mojave Desert BCR (USFWS 2008). It is also listed as a covered species under the Lower Colorado River Multi-Species Conservation Program.

A.25.2 Range

The breeding range of the Bell's vireo occurs throughout central and southwestern US and south through northern Mexico. Breeding habitat generally consists of dense, low, shrubby vegetation, in riparian areas, brushy fields, young second-growth forest or woodland, scrub oak, coastal chaparral, and mesquite brushlands, often near water and in desert washes in arid regions (Hutto 1985, Brown 1993). The winter range of the Bell's vireo extends from south Baja California along the west coast of Central America, through Mexico, El Salvador, Guatemala, Nicaragua and Honduras (Brown 1993). This species winters in habitat that contains thornscrub vegetation adjacent to watercourses or in riparian gallery forests along the west coast of northern and central Mexico. Arizona Bell's vireo occur in Arizona, Utah, Nevada and California along the Colorado

River and extends into Sonora Mexico where they winter (Franzreb 1989). They have been observed to use willow (*Salix goodingii*) and honey mesquite (*Prosopis glandulosa*) for nesting, and avoid salt cedar (*Tamarix chinensis*), arrow weed (*Pluchea sericea*) and giant reed (*Phragmites communis*, Serena 1986).

A.25.3 Population Trends

The current population of this species is estimated to be approximately 1,500,000. Bird Life International estimates that this species is declining at an average rate of 2.7 percent per year since 1966 (BirdLife International 2009), although no subspecies trends are identified. The North American Breeding Bird Survey data also indicates a significant survey wide decline that averages 3.2 percent per year (Sauer et al. 2008). Recent Great Basin Bird Observatory (GBBO 2009) data shows Bell's Vireo population declines in most regions, but that trend was not confirmed for Nevada. Some studies have shown recovery trends in this species as a result of the removal of stressors and subsequent vegetation recovery (e.g. grazing removal - Krueper et al. 2003).

A.25.4 Habitat Model

The GAM and Random Forest models provided similar habitat predictions for this species, while the MaxEnt models provided far more spatially conservative predictions (Figure A.25.1). The GAM and RF models also had higher performance metrics than the MaxEnt model, although none of the models performed poorly with respect to AUC, BI, or TSS (Table A.25.1). By design the Ensemble model had similarly high performance metrics. Both the GAM and RF models captured similar habitat predictions in the Muddy and Virgin river drainages, along the Lake Mead shorelines and down the Colorado river, throughout the Las Vegas wash and LV valley, and around the lower elevation bajadas of the Spring range (Figure A.25.1). The Random Forest model had a lowest standard error among the 50 model repetitions, with only low values (SE ~ 0.02) predicted within the county (Figure A.25.2). The GAM model had greater differences among models with pockets of higher disagreement (SE ~ 0.05) located around the Spring and Sheep ranges. The MaxEnt models had the highest and most widespread areas of disagreement, with areas of higher standard error (SE ~ 0.05) nearly everywhere that there were localities (Figure A.25.2).

The Continuous Boyce Index curves all indicated good performance and discrimination among all models (Figure A.25.3). The additive effects of small variations in the other models creates the appearance of a dip in the Ensemble model CBI when habitat suitability is high (Figure A.25.3).

The top four environmental variables driving habitat predictions among models in the RF and GAM models were the same for one of the four variables examined (Table A.25.2), maximum greenup, expressed as the Normalized Difference Vegetation Index maximum (NDVI maximum). The MaxEnt models also had high influence of NDVI maximum, and Average Spring Maximum temperatures (shared with GAM), but included variation in Average Minimum temperature and Extreme Minimum temperature among its more influential inputs (Table A.25.2).

Table A.25-1. Model performance values for Arizona Bell's vireo models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given in the last column.

Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.87	0.85	0.37
GAM	0.94	0.89	0.78	
Random Forest	0.96	0.71	0.87	
MaxEnt	0.89	0.85	0.69	

Table A.25.2. Percent contributions for the top 10 input variables for Arizona Bell's vireo for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Ave Max Temp	8.7	3.9	5.3
Ave Min Temp	7	1.1	13.6
Average Spring Max Temp	24.6	2.9	11.9
CV Average Spring Max Temp	7.7	2.6	5.1
Extreme Max Temp	7.4	5.6	4.2
Extreme Min Temp	7	1.4	16.6
NDVI Amplitude	4.9	2.4	10.7
NDVI Max	21.1	35.5	22.6
Start of Season (day)	7.2	38.6	7.7
Winter Precip	4.5	6	2.3

Figure A.25.1. SDM maps for Arizona Bell's vireo model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

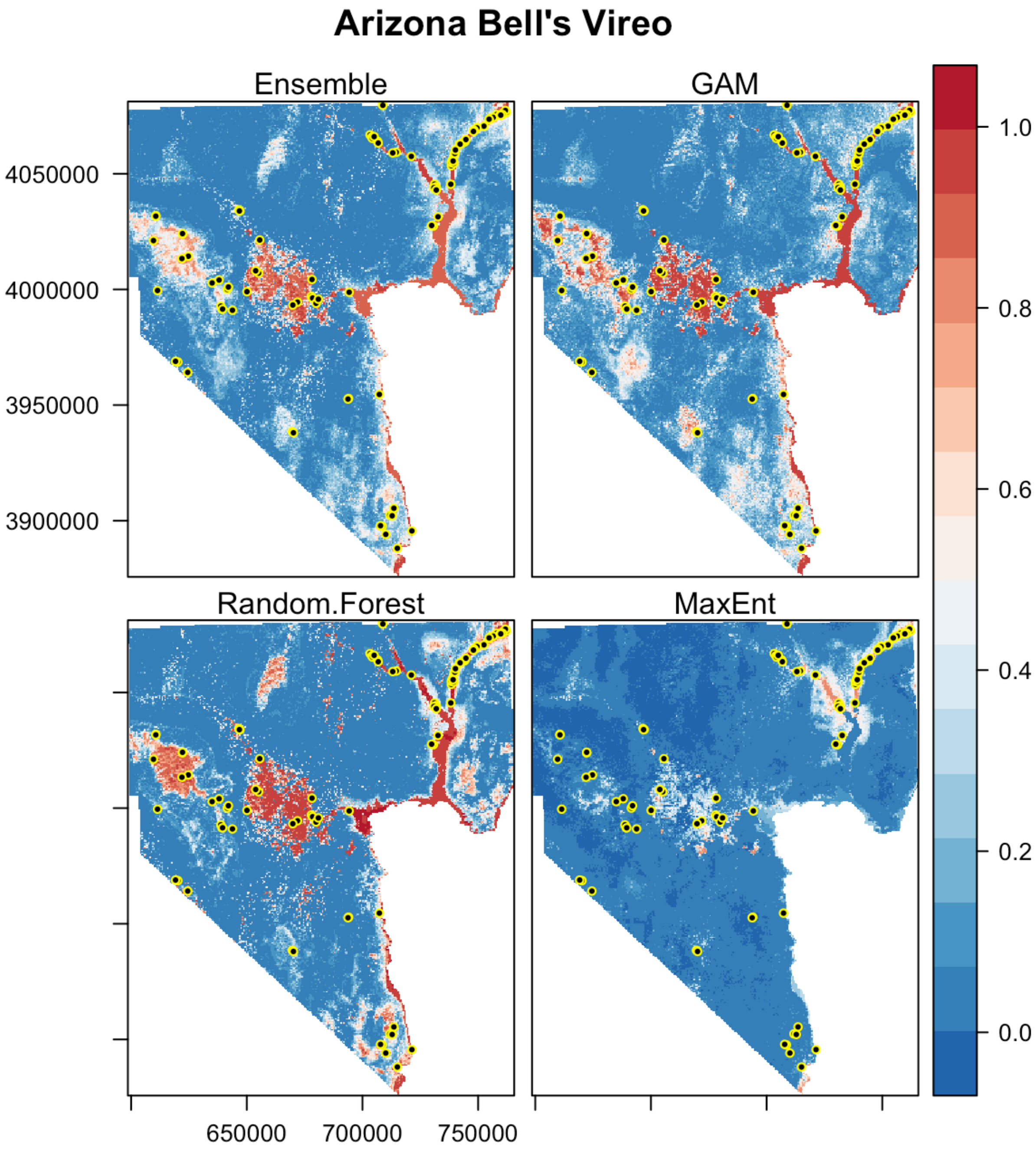


Figure A.25.2. Standard error maps for Arizona Bell's vireo models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).

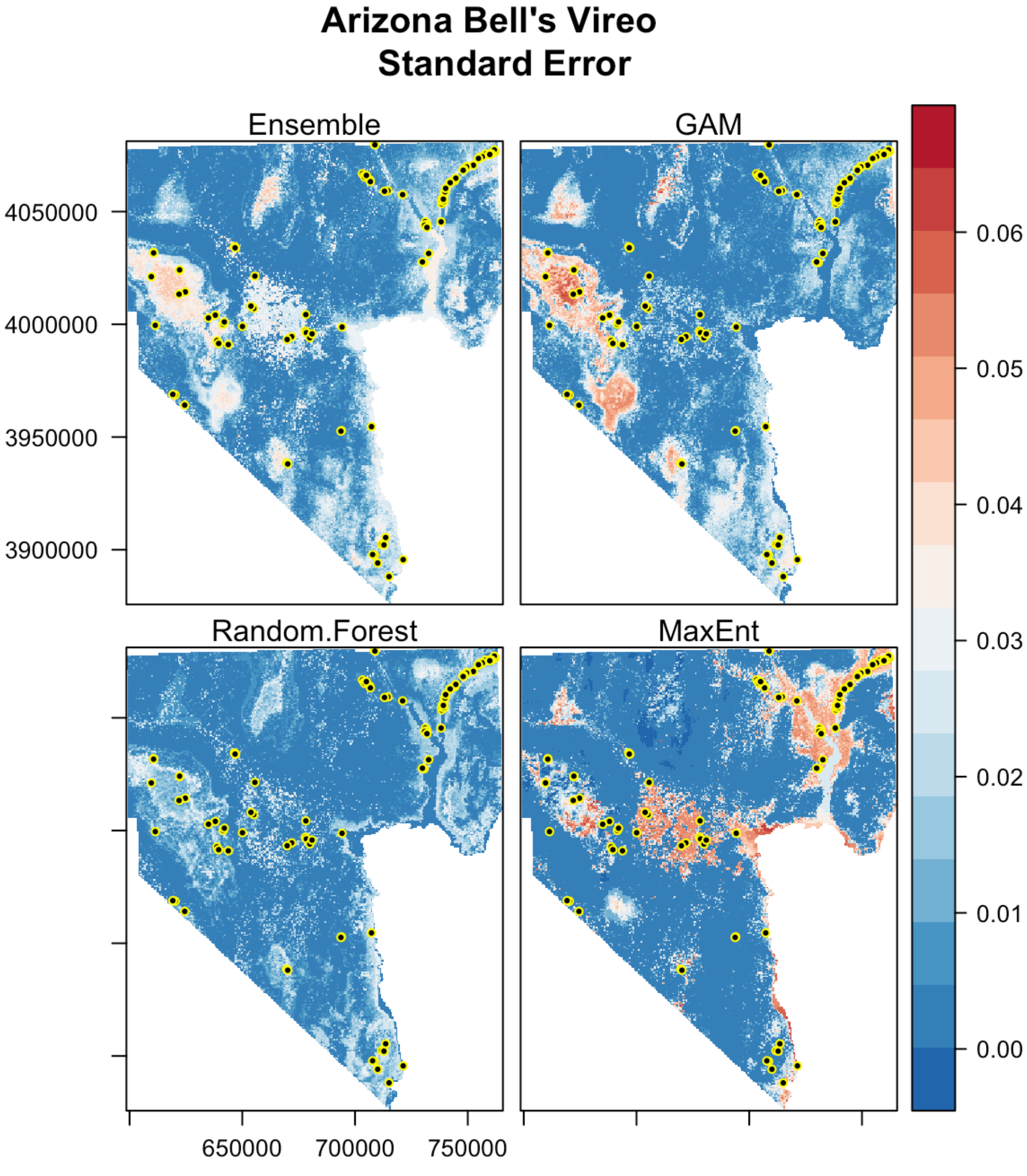
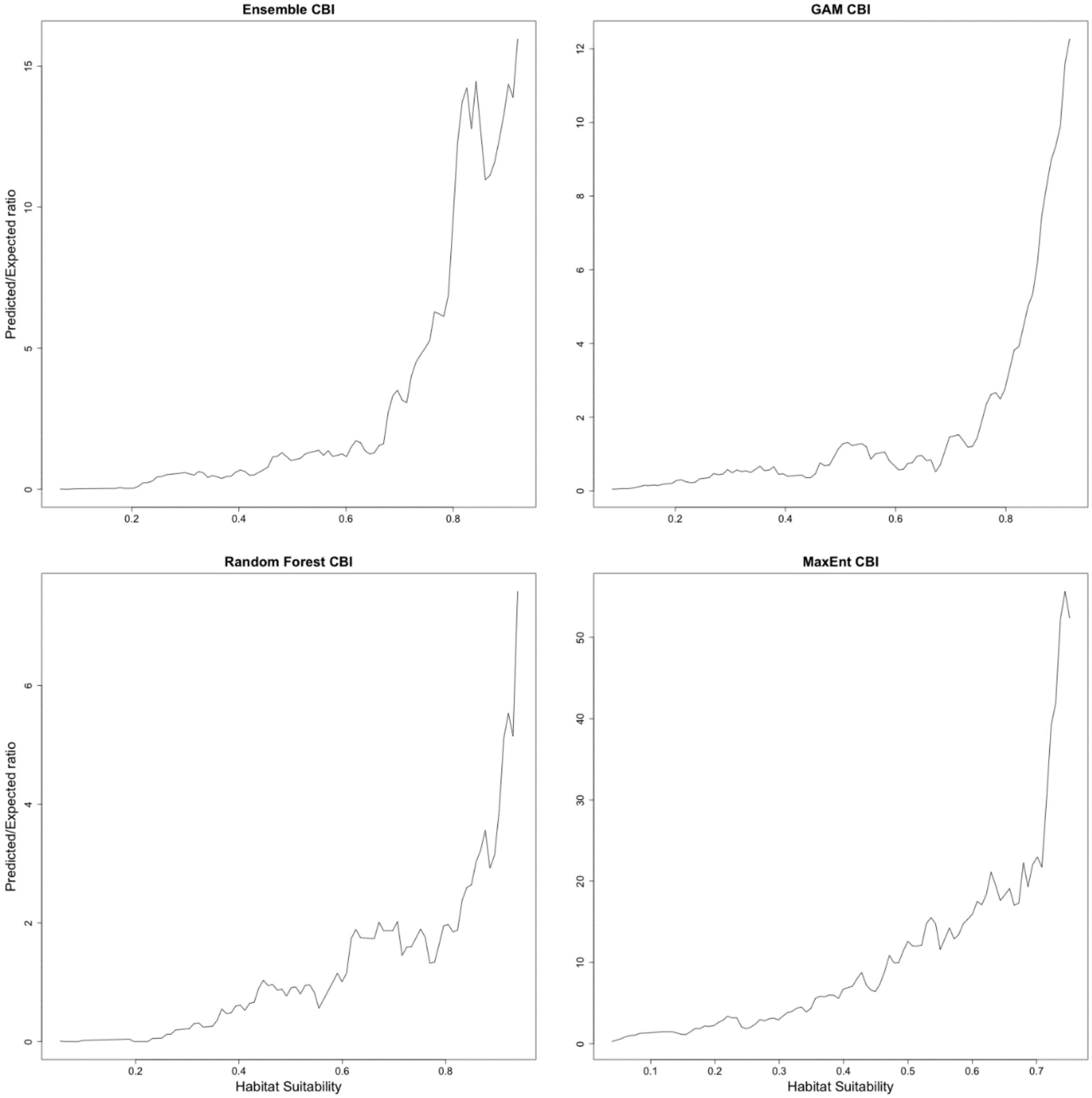


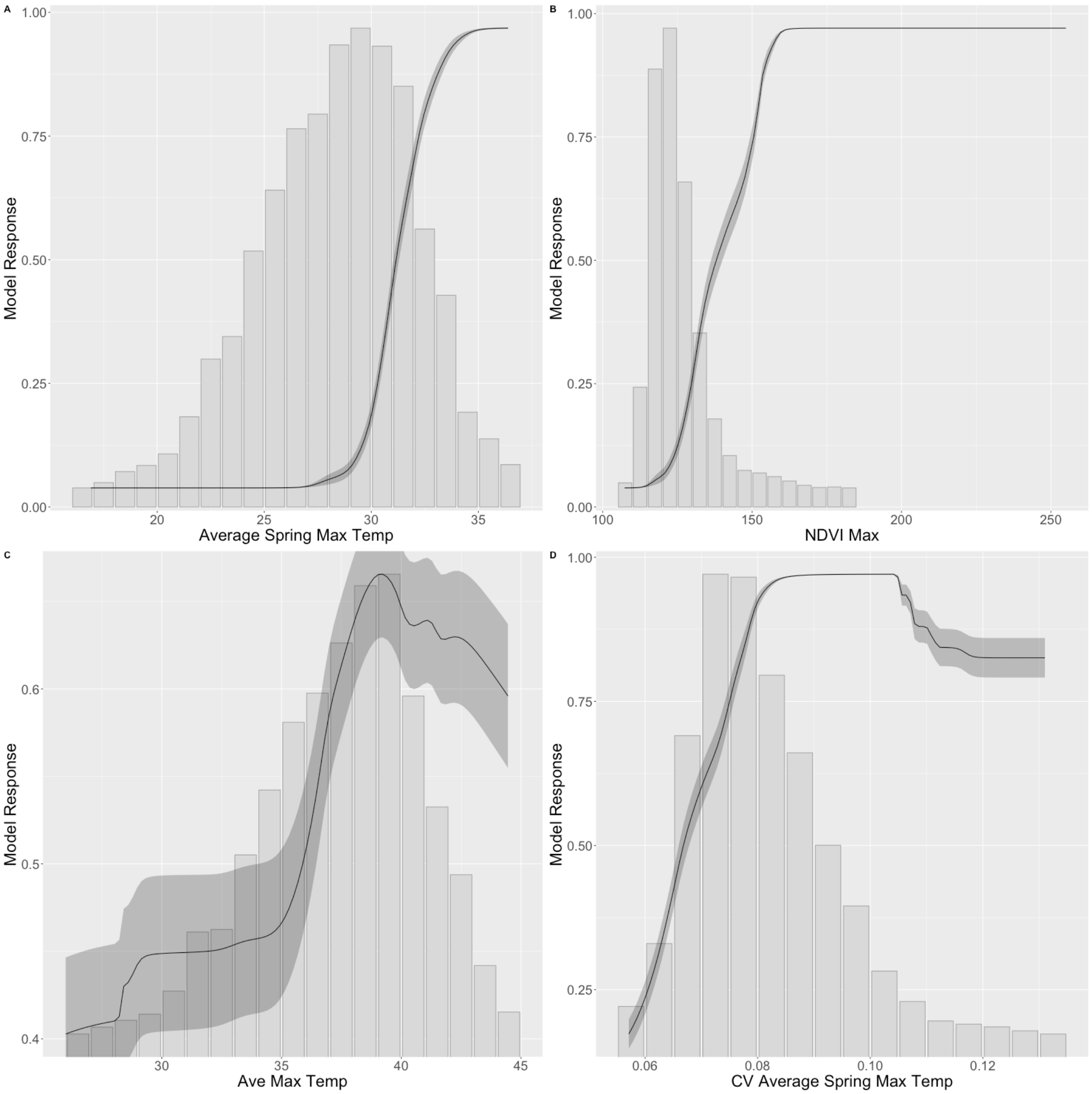
Figure A.25.3. Graphs of Continuous Boyce Indices [CBI] for Arizona Bell's vireo models for the Ensemble model prediction (upper left), and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).



A.25.4.1 General Additive Model

The top four contributing environmental layers were Average Maximum temperature, Average Maximum Spring temperature, CV of Average Maximum Spring temperature, and NDVI Maximum (Table A.25.2). Model scores were higher in areas with higher Average Maximum Spring temperature, peaking and remaining high at the mean values for the county (Figure A.25.4), a response also seen in the MaxEnt model. The same pattern was seen with the CV of Average Spring Maximum temperature and Average Maximum temperature, with an increase to a plateau for higher values. Habitat was also higher in areas with elevated Maximum NDVI values (NDVI max; Figure A.25.4), a response also shown in the MaxEnt and RF models. Standard errors were elevated (SE ~ 0.05) around the base of the Spring and Bird Spring ranges indicating disagreement among the multiple runs of this model in those areas, while the rest of the county had relatively lower error values throughout (Figure A.25.2). Habitat predictions indicated strong habitat predictions throughout the riverine systems along the county's eastern border, but with substantial inland habitat predicted along the lower bajadas of the Spring range, the Lucy Gray mountains, Avi, and the Las Vegas metropolitan area, which had quite a few localities (Figure A.25.1).

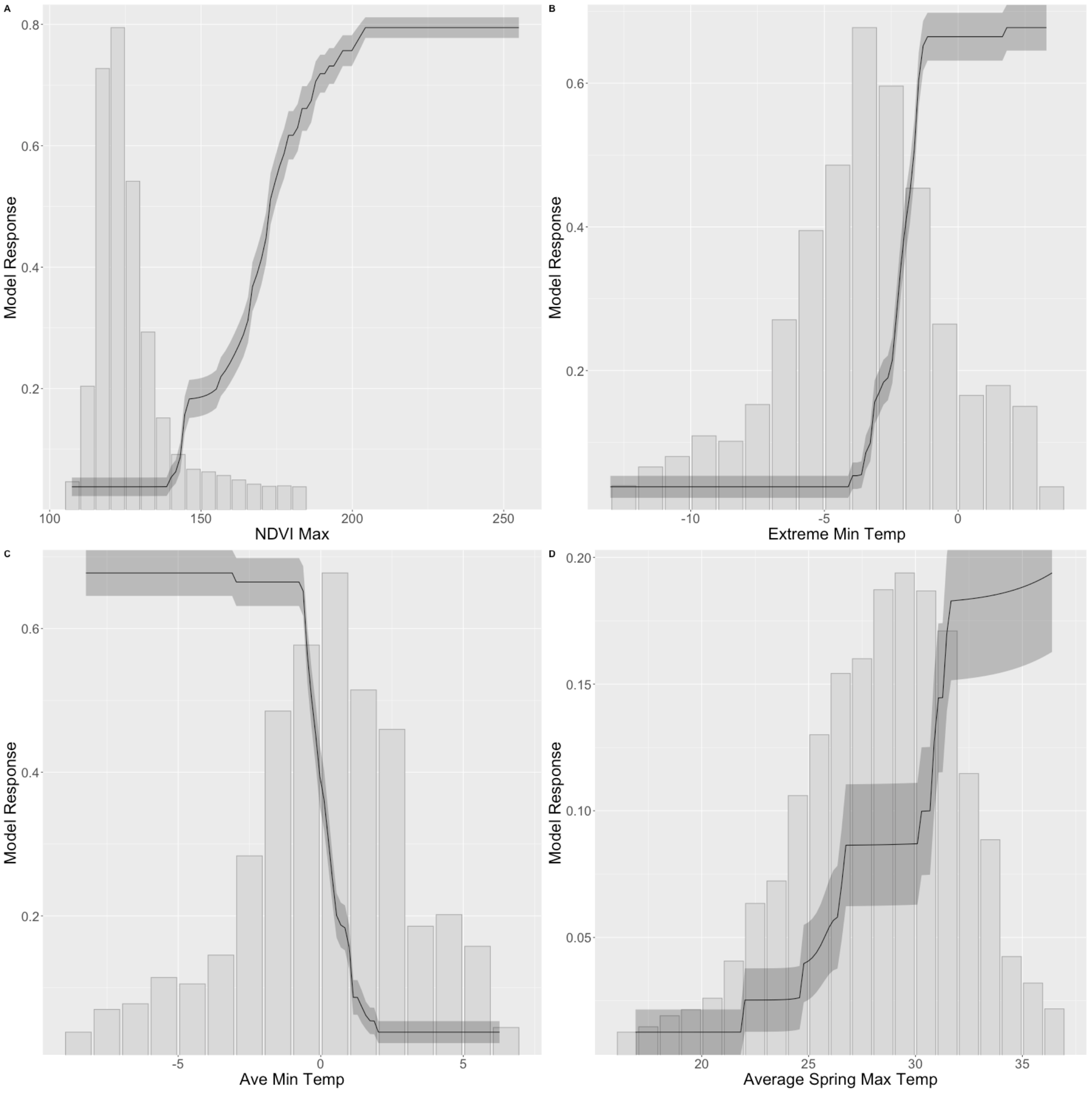
Figure A.25.4. GAM partial response curves for the top four variables in the Arizona Bell's vireo model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.25.4.2 MaxEnt Model

The MaxEnt models was most influenced by the timing of the Maximum value for NDVI (Table A.25.2), which was shared across all three models. The abiotic variables Average Spring Maximum temperature, Average Minimum temperature, and Extreme Minimum temperature were also among the top four most influential variables (Table A.25.2). Performance curves indicated higher predicted habitat values for areas with NDVI Maximum occurring after 150 days, at which point habitat values increase dramatically and plateau as NDVI Maximum increases (Figure A.25.5) – which was a similar response to that seen in the GAM and RF models (Figure A.25.4; Figure A.25.6). Higher habitat values were also predicted in areas with higher Average Spring Maximum temperatures, with higher habitat scores when values for that variable increase (Figure A.25.4). The response curves for the Extreme Minimum temperature showed higher habitat values with increased Extreme Minimum temperature, while lower habitat values occurred when Average Minimum temperature increased (Figure A.25.4). This seemingly counterintuitive response may be explained by the microclimate in the areas that the species occurs having generally cooler temperatures (Average Minimum temperature) in areas such as river valleys (and elsewhere).

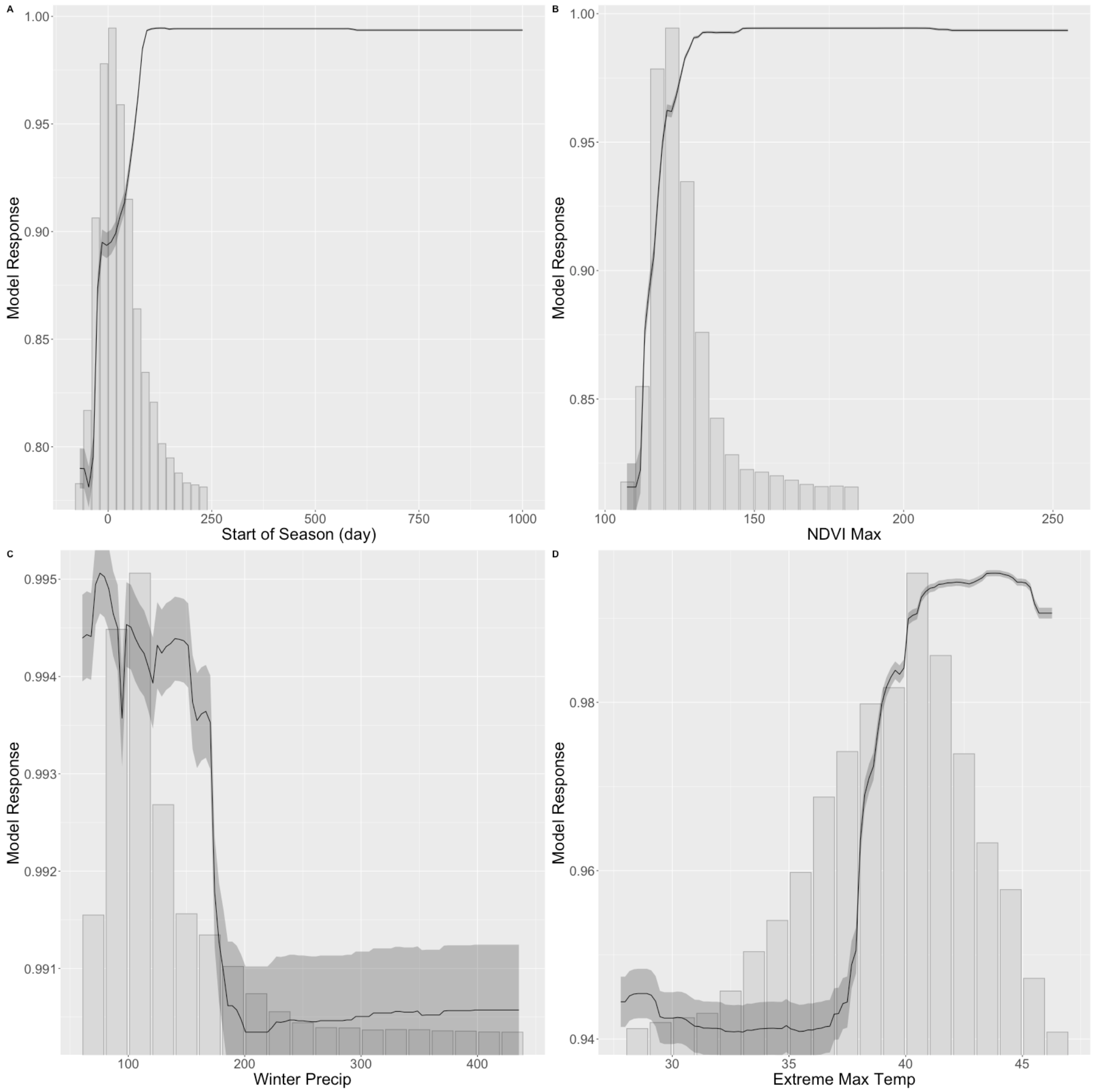
Figure A.25.5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for Arizona Bell's vireo. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.25.4.4 Random Forest Model

The Random Forest predicted similar habitat areas as that seen in the GAM model (Figure A.25.1). Influential habitat variables included NDVI Maximum, Start of Season, Extreme Maximum temperature, and Winter Precipitation. Similar to the GAM and MaxEnt models, performance curves indicated higher habitat values where NDVI Maximum occurred after 100-150 days (Figure A.25.4; Figure A.25.5; Figure A.25.6). Higher habitat was also predicted in areas Start of Season later than the mean of the environment overall (after 125 days) where the values rapidly increase to a maximum. Habitat values increases and reached a plateau as the Extreme Maximum temperature increased (Figure A.25.6). Winter Precipitation showed lower habitat values with increasing Winter Precipitation. This pattern was similar to that which was available in the environment (Figure A.25.6). Performance metrics indicated strong model predictive performance (Table A.25.1), and discrimination among habitat levels (Figure A.25.3).

Figure A.25.6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for Arizona Bell's vireo. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.25.4.5 Model Discussion

Arizona Bell's vireo are predicted to occupy the riverine and larger drainage systems located along the Muddy and Virgin rivers, the immediate shorelines of Lake Mead, down the Colorado river extending to Avi at the southern end of the county (Figure A.25.7). A large expanse of predicted habitat also occurs along the Las Vegas wash, the general metropolitan area, and, to a lesser extent, the foothills of the Spring range (Figure A.25.7). The largest numbers of sightings were located along the Virgin river, but there were substantial numbers of observations inland that supported the habitat predictions in the center of the county. There were also several localities in the lower areas near Laughlin, although this did not result in substantial predicted habitat area there excepting the riparian area along the river (Figure A.25.7).

The locality data for this species consisted of 373 records within the buffered modeling area, which had a high degree of overlap (e.g. the Virgin river points). Spatial thinning of the data reduced the number of localities used for training and testing to 271 records.

A.25.4.6 Standard Error

The standard error map for the Ensemble model indicated areas of higher error (SE ~ 0.04) near the base Spring, Bird Spring, and northwestern portion of the Sheep ranges, the Lucy Gray mountains, and throughout the Las Vegas valley (Figure A.25.8). Areas of marginal error (SE 0.03) included areas along Lake Mead and the Colorado River.

Figure A.25.7. SDM map for Arizona Bell's vireo Ensemble model in Clark County, NV.

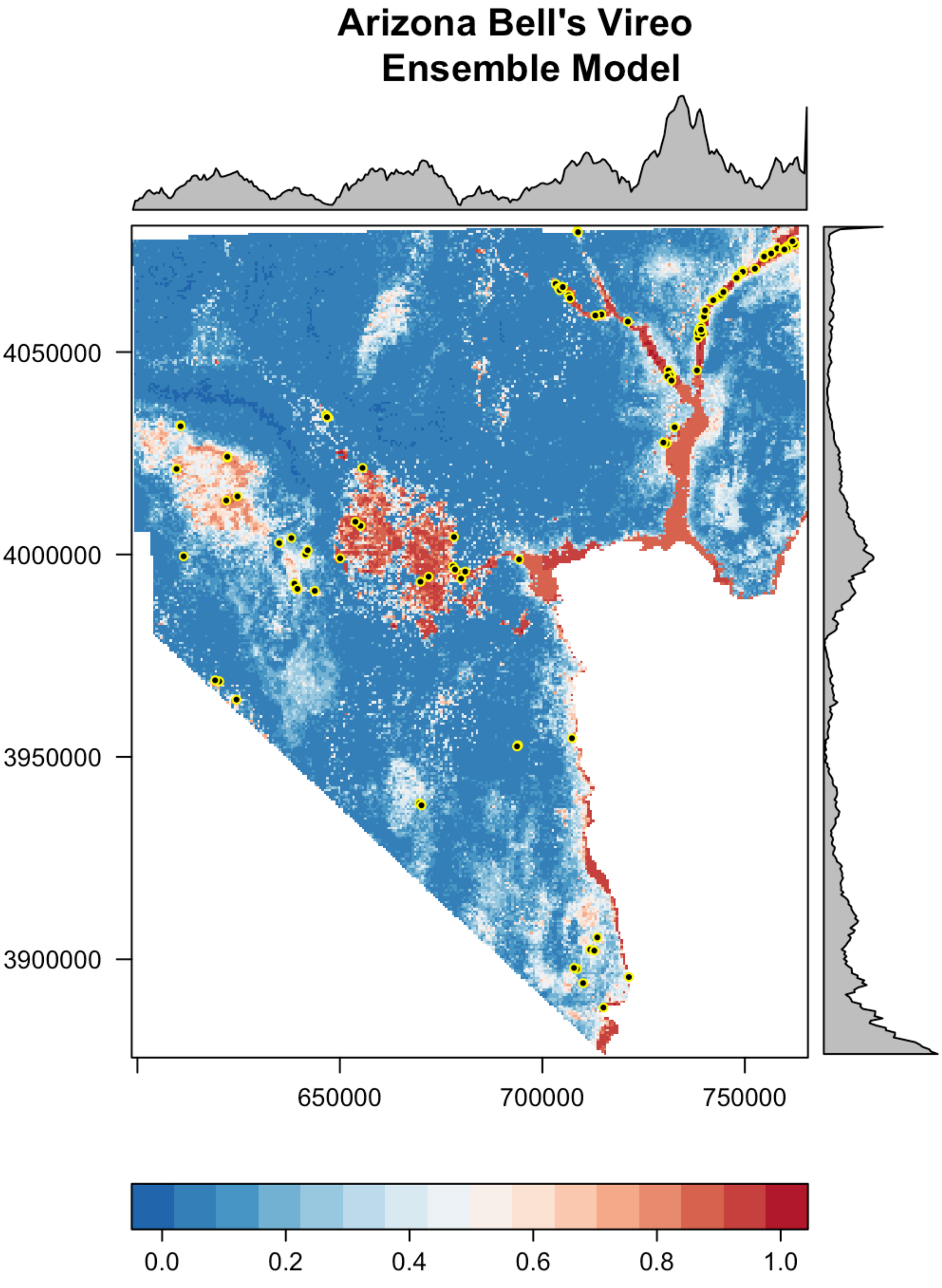
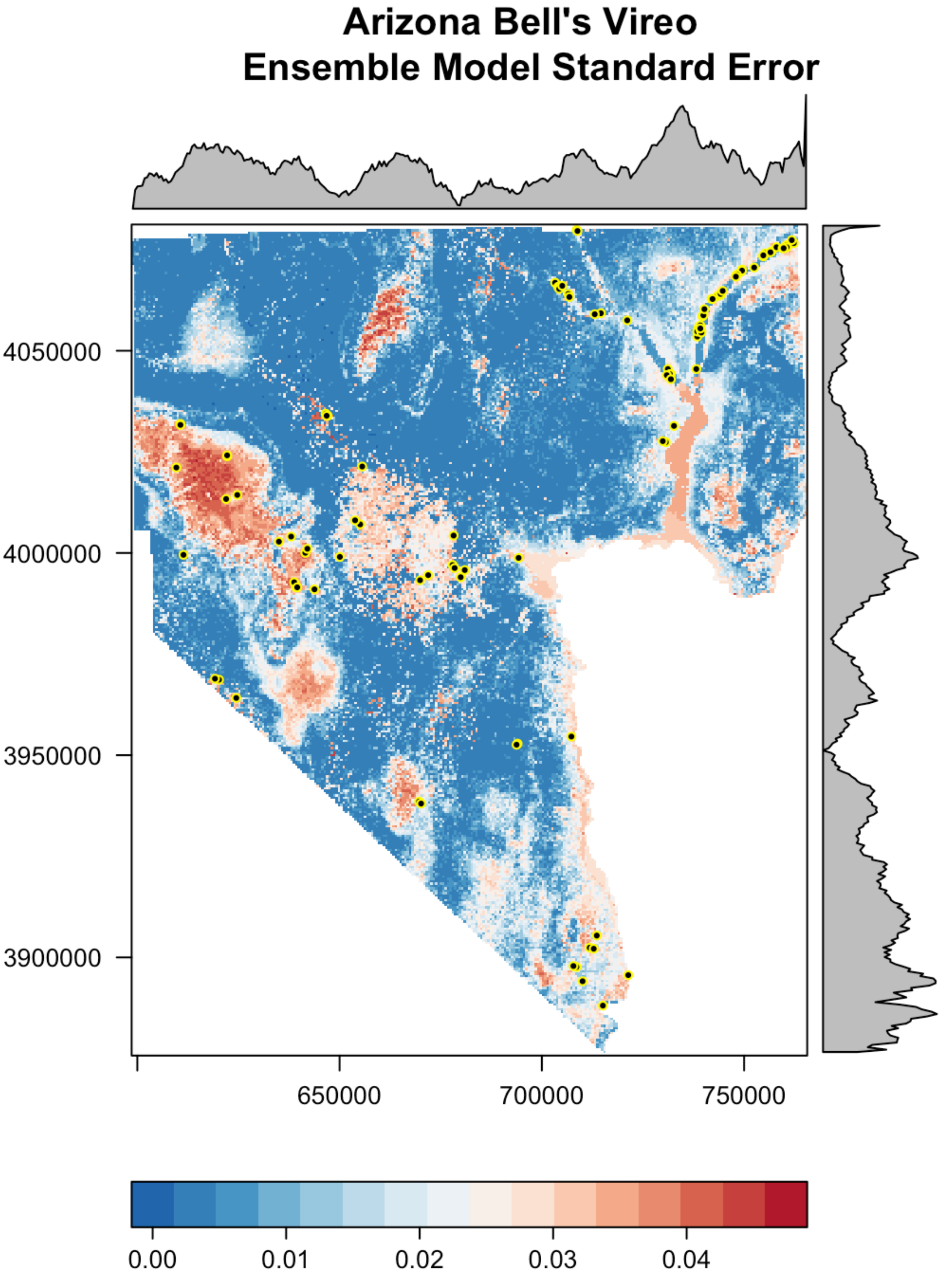


Figure A.25.8. Standard Error map for the Arizona Bell’s vireo Ensemble model for Clark County, NV.



A.25.5 Distribution and Habitat Use within Clark County

Distribution within Clark County is largely concentrated in the southern tip of the county, but recent surveys confirmed several breeding pairs in northern Clark County along the Virgin River (Floyd et al. 2007). It is a rare resident of Clark County, Nevada and is a declining resident along the Colorado, Virgin, and Muddy Rivers and isolated springs (AZGFD 2002). This species can be found within rivers and streams, mesquite bosques, and desert washes throughout Clark County (Wildlife Action Plan Team 2012). Modeled habitat within Clark County Ecosystems showed the highest suitability habitat in Mojave Desert Scrub, Mixed Conifer, Pinyon Juniper and Desert Riparian habitats, in addition to Blackbrush, Mesquite Acacia and other ecosystems (Table A.25.3).

Table A.25.3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	16	107	0
Blackbrush	399729	14545	811
Bristlecone Pine	108	4785	2646
Desert Riparian	83	101	11026
Mesquite Acacia	12610	3517	4083
Mixed Conifer	2276	14175	10814
Mojave Desert Scrub	1115726	154836	94251
Pinyon Juniper	71718	34296	9603
Sagebrush	3447	1207	44
Salt Desert Scrub	76237	4100	2239

A.25.6 Ecosystem Level Threats

Threats to this species' habitat include urban and suburban development on floodplains and riparian habitat, the presence of large areas of tamarisk, and off-road vehicular activity (DeSante and George 1994, Wildlife Action Plan Team 2012). Urban development, water diversion, flood control projects, grazing, and the spread of agriculture have destroyed much of the western nesting habitat (Dudley et al. 2000, Krueper et al. 2003, NatureServe 2009). Tamarisk has been shown to reduce insectivorous birds (and many other guilds, Dudley et al. 2000), and is associated with reduced or complete lack of nesting in this species, which preferred willow thickets, or stands of honey mesquite for nesting (Serena 1986).

A.25.7 Threats to Species

Brood parasitism by brown-headed cowbirds (*Molothrus ater*) is considered a significant threat to some populations of this species and has resulted in reductions in breeding populations in the southwestern US (Serena 1986, Brown 1993, DeSante and George 1994). While nest abandonment was once considered a compensating mechanism, research indicates that this behavior results in lower fitness relative to birds that raise parasitic cowbird chicks (Kus 2002).

A.25.8 Existing Conservation Areas/Management Actions

The Arizona Bell's vireo is protected under the Migratory Bird Treaty Act. In addition, recommended conservation actions specific to this subspecies and subspecies habitat are included in the Nevada Wildlife Action Plan (NWAP)(Wildlife Action Plan Team 2012). The NWAP's recommended conservation actions are: to preserve mesquite bosques through private landowner consultation and responsive development planning for the Arizona Bell's Vireo; conserve the habitat that this species occurs in by expanding protected status for riparian habitat that this species occurs in; increasing the linear extent of multi-stored native riparian habitat on floodplains; maintaining this species habitat at its current distribution in stable or increasing condition trend; and sustaining stable or increasing populations of wildlife in key habitats (Wildlife Action Plan Team 2012).

In addition, this subspecies is also covered under the Lower Colorado River Multi-Species Conservation Program. The goal of this program is to conserve habitat of threatened and endangered species and reduce any additional species being listed; accommodate present water diversions and power production; and provide the basis for incidental take authorizations (Lower Colorado River Multi-Species Conservation Program 2004).

The species is also included in the Partners in Flight North American Landbird Conservation Plan (Rich et al. 2004), where it is designated as a Watch List species that warrants immediate action. Additionally, it has recently been included in the Great Basin Bird Observatory six-year inventory and monitoring program on land birds of Clark County (initiated in 2008), and is on the USFWS list of Birds of Conservation Concern 2008 (USFWS 2008).

A.26 DESERT POCKET MOUSE (*CHAETODIPUS PENICILLATUS*)

The desert pocket mouse (*Chaetodipus penicillatus*) is a medium-sized, bipedal rodent, with a long tail that is mostly naked, but for a crest of hairs along the dorsal edge and a tufted tip (Mantooth and Best 2005). It is among a subgroup of pocket mice known as the coarse-haired pocket mice (Nowak 1991). This species is one of three pocket mouse species occupying southern Nevada. The little pocket mouse (*Perognathus longimembris*) is smaller, and the long-tailed pocket mouse (*C. formosus*) is about the same size (Burt and Grossenheider 1976). Pocket mice eat green vegetation, seeds and insects (Hoffmeister 1986). While earlier work recognized a sub species (*C. penicillatus sobrinus*) in Clark County (Lee et al. 1996), subsequent genetic analysis recognized only two distinct groups (1 Mojave and 1 Sonoran) of Pleistocene origin separated by the Colorado River, thus invalidating the formerly recognized subspecies within this genus (Jezkova et al. 2009, Wood et al. 2013).

A.26.1 Species Status

The IUCN Redlist – lists this as a species of least concern with a current stable population, and with abundant habitat, wide distribution and presumed large population (Lindzey et al. 2008). Although this species has no federal or state status, rapid growth and natural habitat loss in Clark County in concert with local interest in the species may result in listing over the permit term.

US Fish and Wildlife Service Endangered Species Act: Not listed

US Bureau of Land Management (Nevada): No Status

US Forest Service (Region 4): No Status

State of Nevada (NAC 503): No Status

NV Natural Heritage Program: Global Rank G5; State Rank S1S2

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Least Concern

CITES: No Status

A.26.2 Range

The desert pocket mouse is found in shrubland habitats of the Mojave Desert in California, Nevada, Utah, and northwest Arizona. It also occurs in shrubland habitats of the Sonoran Desert in Arizona, and the Chihuahuan Desert of southeast Arizona, and throughout much of Sonora Mexico (Mantooth and Best 2005, Hoffmeister 1986). The desert pocket mouse is found throughout Clark County, neighboring southwest Utah, and extreme northwest Arizona (Williams et al. 1993, Hall 1981). The elevational range for this species is 36–1,585 m (Lowe 1964).

A.26.3 Population Trends

Desert pocket mouse populations are stated to be stable by NatureServe (2009) and the IUCN; however, population trends for this subspecies are unknown.

A.26.4 Habitat Model

Habitat models for this species were based on a limited number of input localities (N=66) which caused some difficulty in modeling. While the three model algorithms generally predicted similar habitat arrangements throughout the county their relative performance differed greatly. The Random Forest model was best able to handle the smaller sample sizes, and had satisfactory performance, while the GAM was only able to perform a single model without the internal splitting for training and testing data, and the MaxEnt models ran, but performed very poorly. The Random Forest model had high AUC, BI, and TSS scores, however the Ensemble model still had slightly better performance (increased TSS) with the inclusion of information from the other models (Table A.26.1). The GAM and Random Forest models generally predicted more habitat (although the GAM had no models for averaging), while the MaxEnt model predicted lower level habitat values over a much constricted range (Figure A.26.1).

Relative variable importance highlighted the importance of Extreme Maximum temperatures, Average Maximum temperatures and Winter Precipitation for the GAM and RF models, while the MaxEnt Model shared only Extreme Maximum temperatures in its top four contributing variables (Table A.26.2). The Standard error resulted in relatively low error for the Random Forest models, and with moderate standard error values (SE 0.04 – 0.05) on the periphery of predicted habitat for the MaxEnt models (Figure A.26.3). There was no error estimate calculable for the GAM model, as only one model could be produced. The resulting standard error for the Ensemble model yielded moderate error (SE = 0.03) with a similar footprint as the RF model (Figure A.26.3). The Continuous Boyce Indices showed relatively good model performance in for the RF and resulting Ensemble model, while the MaxEnt model exhibited very poor discriminatory ability (Figure A.26.3).

Table A.26-1. Model performance values for desert pocket mouse models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given in the last column.

Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.87	0.85	0.39
GAM	0.69	NA	0.38	
Random Forest	0.96	0.88	0.77	
MaxEnt	0.86	0.04	0.69	

Table A.26-2. Percent contributions for input variables for desert pocket mouse for Ensemble models using GAM, Maxent and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding sections below.

Variable	GAM	RF	MaxEnt
Extreme Max Temp	24.8	29.1	38.8
Ave Max Temp	15	18.1	2
Winter Precip	11.4	16.5	2.9
Start of Season (day)	4.6	8	10.2
PPT Clay	6.9	4.2	9.8
CV Winter Precip	10.6	7.1	9.5
PCT Coarse frags	0	4.6	6.5
Ave Min Temp	12.5	5.7	6.9
NDVI Max	4.1	1.4	9.4
PPT Silt	10	5.2	4

Figure A.26-1. SDM maps for desert pocket mouse model Ensemble (upper left), and for averaged models of each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right). Hotter colors indicate higher predicted habitat values, and black circles indicate the presence points used in training and testing the models.

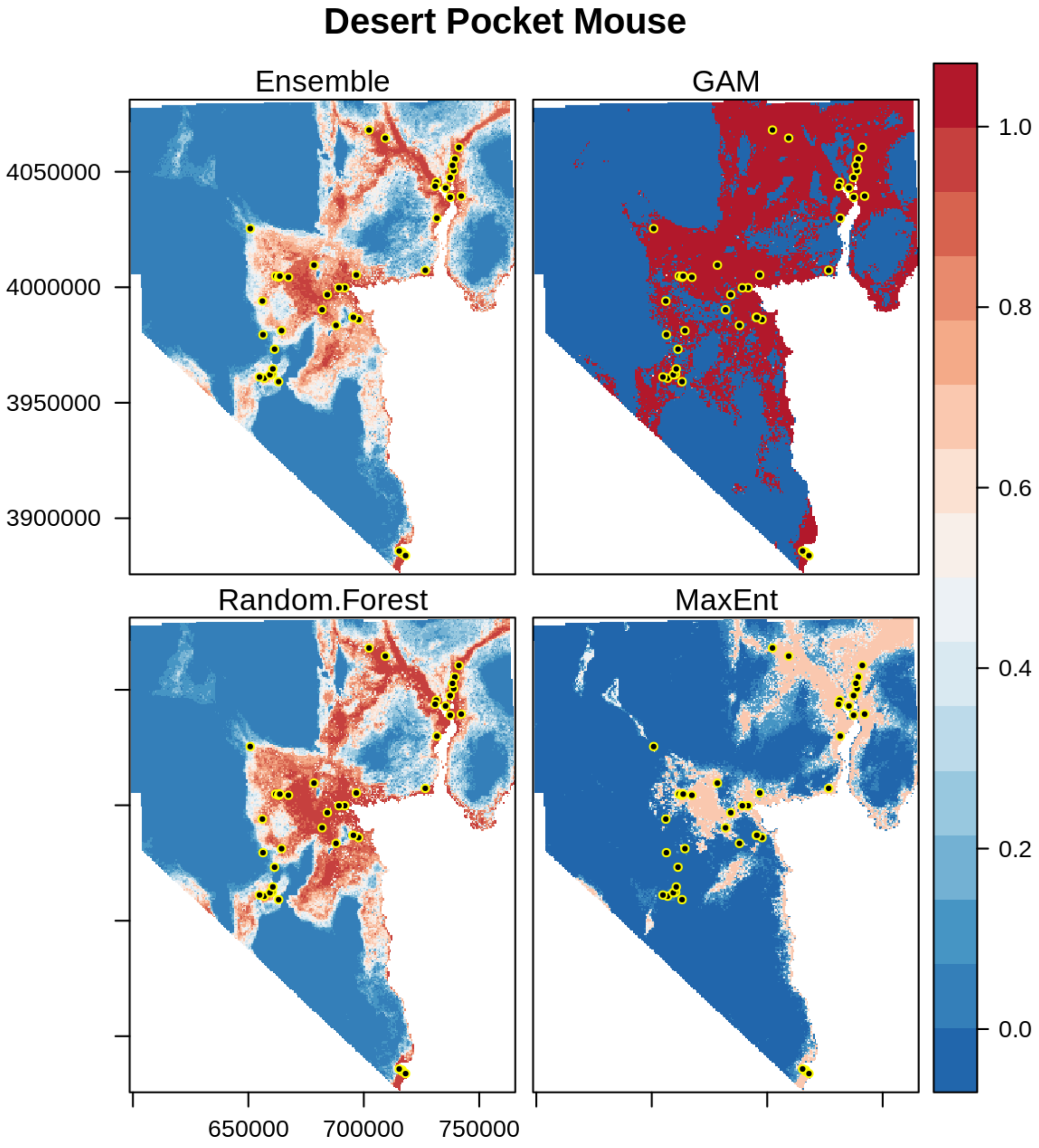


Figure A.26-2. Standard error maps for desert pocket mouse models for each of the modeling algorithms used (Random Forest - lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left). The GAM algorithm could only be calculated using the combined internal and external evaluation data sets, and thus, standard error calculations were not possible.

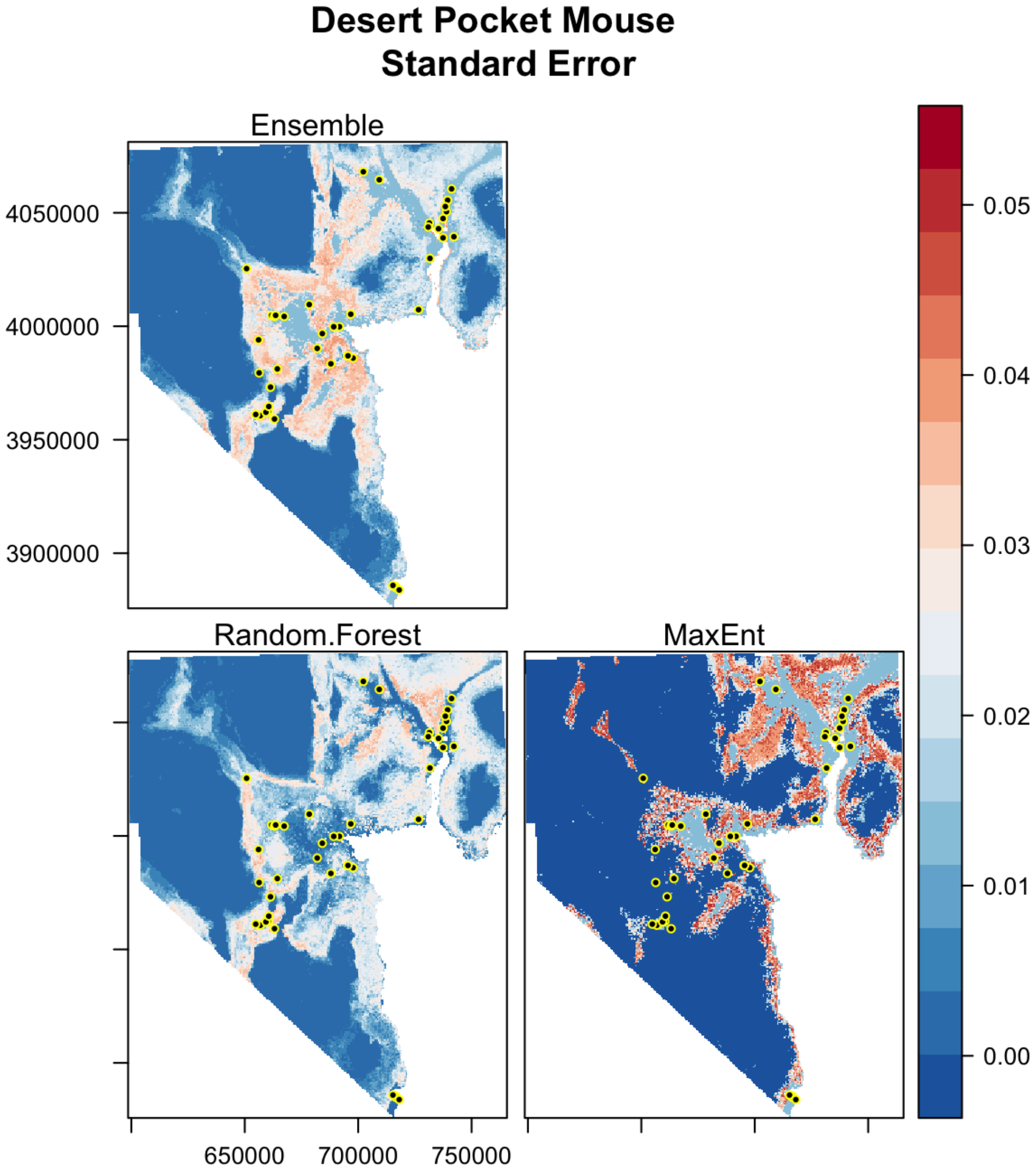
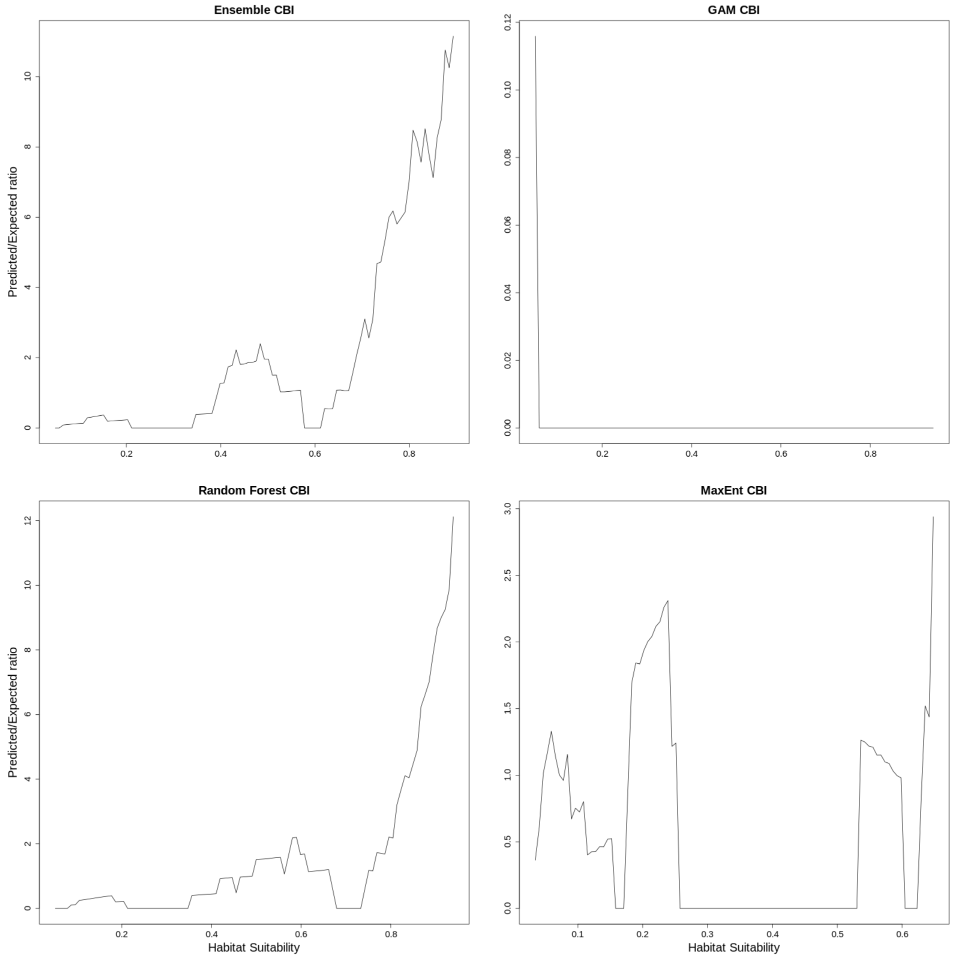


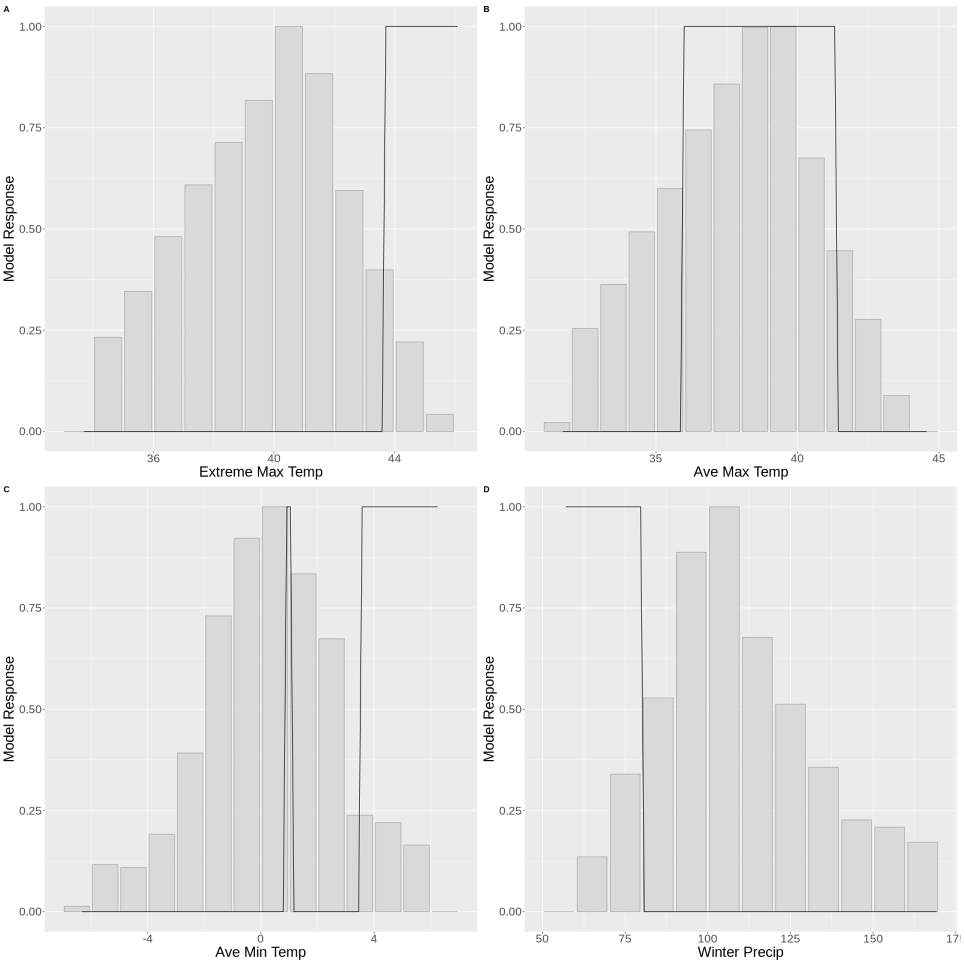
Figure A.26-3. Graphs of Continuous Boyce Indices [CBI] for desert pocket mouse models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right [failed], Random Forest – lower left, and MaxEnt - lower right).



A.26.4.1 General Additive Model

The top four contributing environmental layers were climate based metrics: Extreme and Average Maximum temperatures, Winter Precipitation, and Average Minimum temperature (Table A.26.2). Model scores were higher in areas with higher Extreme Maximum temperatures, but with Average Maximum temperatures consistent with that available in the habitat (Figure A.26.4). Habitat predictions were higher is areas with higher Average Minimum temperatures, and with areas with lower Winter Precipitation than found in the greater study area generally (Figure A.26.4). This algorithm could only be calculated using the combined internal and external evaluation data sets and thus standard error calculations were not possible.

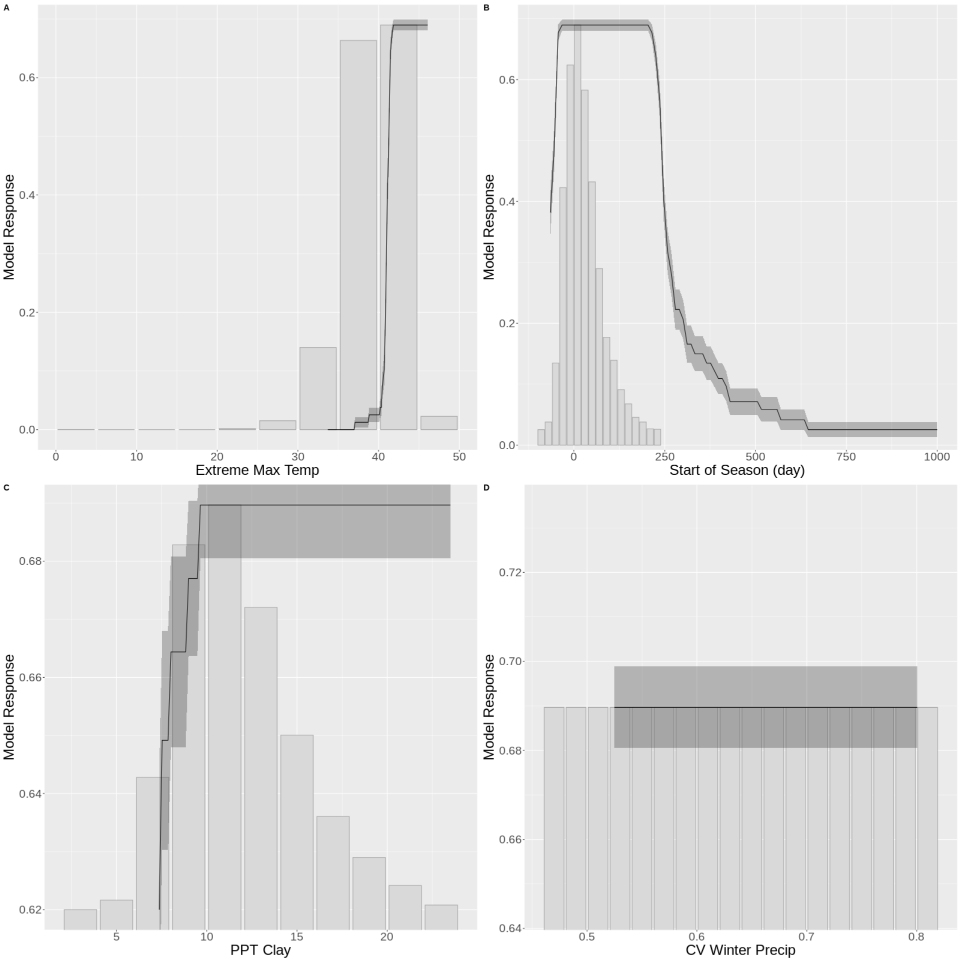
Figure A.26-4. GAM partial response curves for the top four variables in the desert pocket mouse model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.26.4.2 MaxEnt Model

The MaxEnt models were most influenced by Extreme Maximum temperature (39% contribution alone), followed by the Start of Season, Soil Clay content and the CV of Winter Precipitation. Response curves for these variables indicated higher habitat values predicted in areas with higher Maximum temperatures, as a thresholded response (Figure A.26.5) as was seen in the GAM model (Figure A.26.4) and Random Forest models (Figure A.26-6 below). The relationship with Winter Precipitation variability did not have a discernable trend. Model performance was relatively poor for these models (Figures A.26.1-3), however habitat predicted was largely restricted to the watershed areas of the Muddy and Virgin rivers, and the Las Vegas wash (Figure A.26.1). Localities along the I-15 corridor were not afforded predicted habitat.

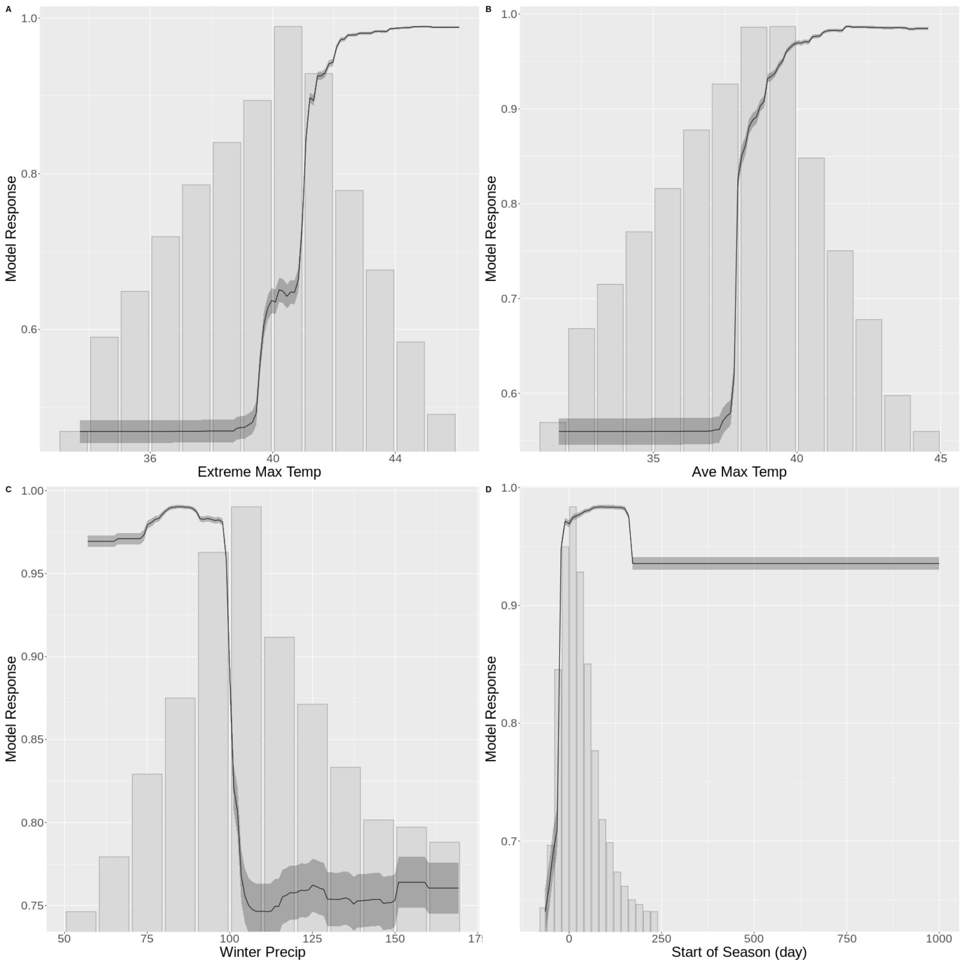
Figure A.26-5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for desert pocket mouse. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.26.4.3 Random Forest Model

The Random Forest model for this species had three of the top four input variables as the GAM models (Table A.26.2), but also included Start of Season collectively accounting for 71% of model influence. Performance curves for these variables indicated higher predicted habitat values in areas with higher Extreme and Average Max temperatures (Figure A.26-6). Models predicted higher model scores in areas with lower Winter Precipitation (falling sharply at the average values for the study area), and where the Spring Season (SOST) started later. Performance metrics (Table A.26.1) as well as the Continuous Boyce plots indicated high model performance (Figure A.26.3). Areas of moderate error among models (SE 0.04) were along the Mormon Mesa and the Moapa area. Lower error rates were otherwise seen in and around habitat prediction areas (Figure A.26.2).

Figure A.26-6. Partial response surfaces for the environmental variables included in the Random Forest ensemble model for desert pocket mouse. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



A.26.4.4 Model Discussion

Desert pocket mouse are predicted to occupy lower elevation, and lower areas within the drainages in the eastern portion of the county, including the Moapa valley, Muddy and Virgin rivers, the Las Vegas wash, and the shorelines of Lake Mead and the Colorado river (Figure A.26-7). Areas of higher habitat corresponded well with the localities collected but also highlighted potential habitat along the I-15 corridor from Moapa to Las Vegas, continuing down through Ivanpah Valley. Eldorado valley also contained larger portions of predicted habitat, although there are few observations to support this prediction (Figure A.26-7).

The locality data for this species consisted of 117 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data to lessen sample bias, and removal of duplicates reduced the number of localities used for training and testing to 66 records.

A.26.4.5 Standard Error

There are several areas of relatively higher error rates (SE ~ 0.03 - 0.04), although these are relatively moderate error rates. These are located for the most part in areas with sparse localities at the periphery of habitat predicted throughout the Moapa Valley and I-15 corridor the periphery of the Las Vegas Valley, and the Eldorado valley areas (Figure A.26.8).

Figure A.26-7. SDM map for desert pocket mouse Ensemble model.

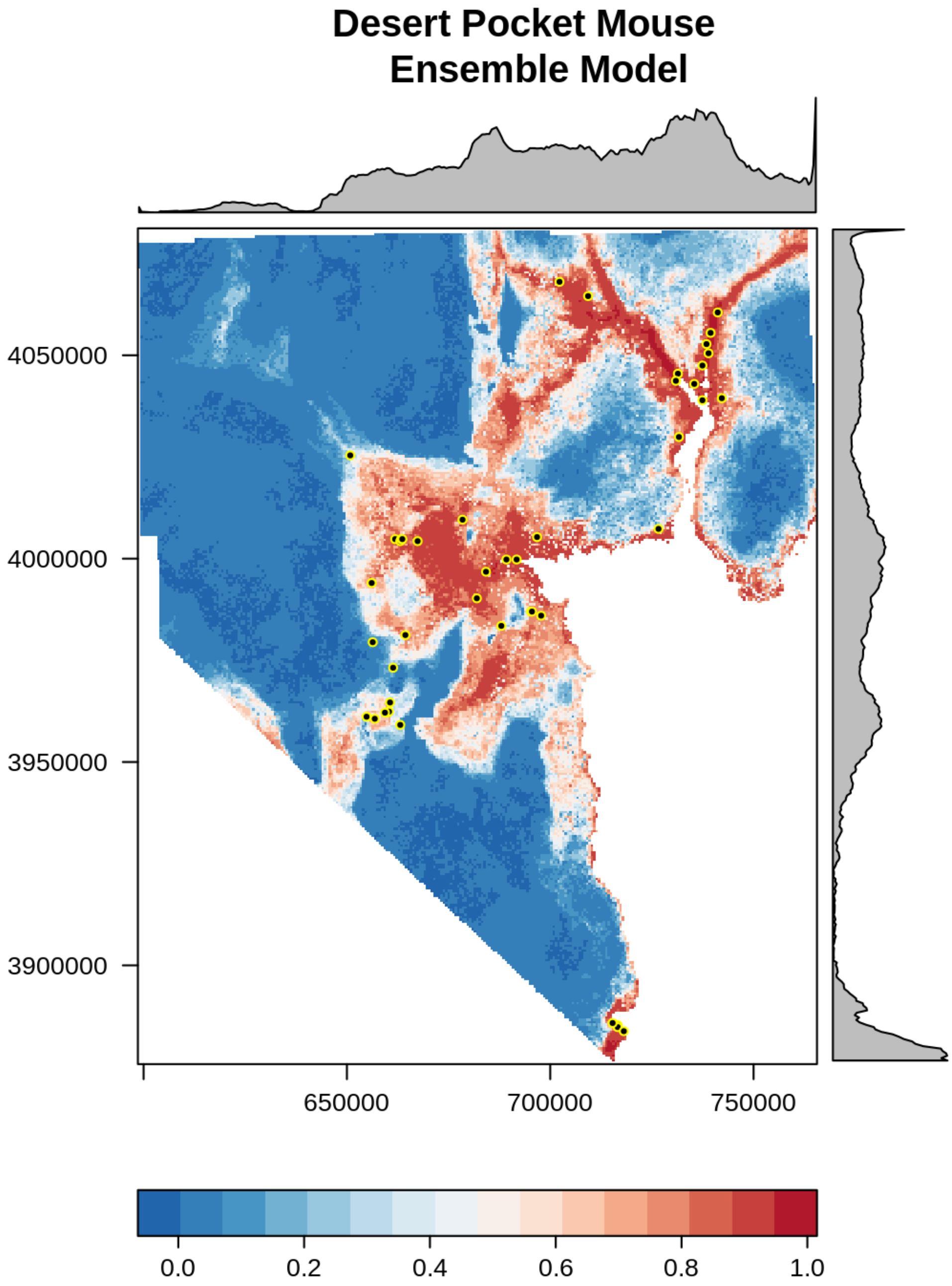
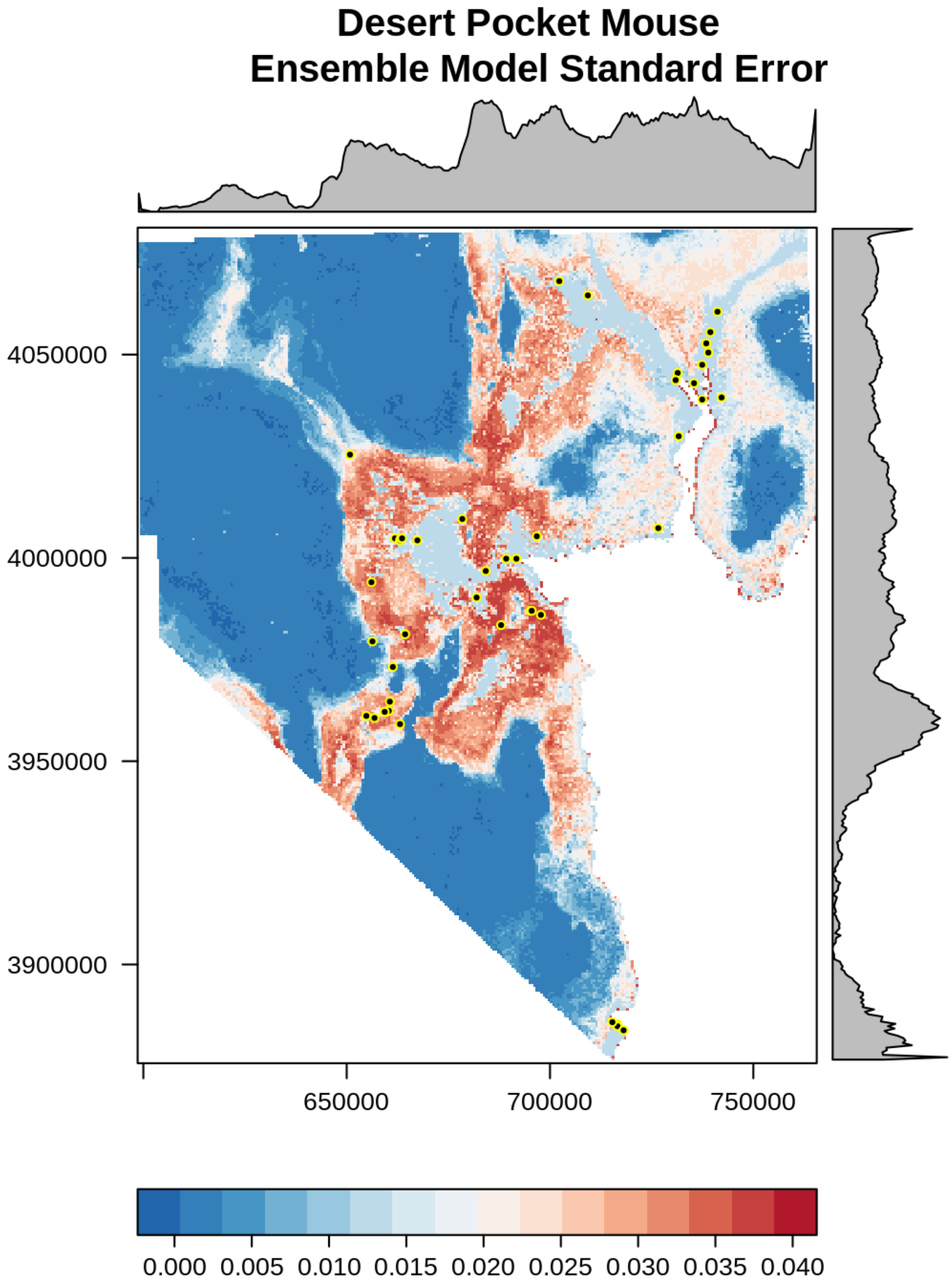


Figure A.26.8. Standard Error map for the desert pocket mouse Ensemble model for Clark County, NV.



A.26.5 Distribution and Habitat Use within Clark County

Desert pocket mouse occurs throughout Clark County from the Arizona and Utah borders and south to the southern tip of Clark County and southern Lincoln County (Wildlife Action Plan Team 2012). This desert pocket mouse inhabits sandy soils in creosote bush (*Larrea tridentata*) and saltbush (*Atriplex* spp.) communities (Mantooth and Best 2005), mesquite bosques, and desert washes, and Mojave-Sonoran warm desert scrub (Wildlife Action Plan Team 2006). This species prefers rock-free bottoms of creeks and rivers (NatureServe 2009). Habitat within the lower Colorado drainage system is considered to be highly fragmented, reducing resilience to disturbance and extirpation. Remnant populations may exist within urban areas, but with limited dispersal habitats they are unlikely to articulate with surrounding populations (Micone 2002). Ecosystems within Clark County that contain larger areas of high suitability modeled habitat include Mojave Desert Scrub, Desert Riparian, Salt Desert Scrub, and Mesquite/Acacia (Table A.26.3).

Table A.26-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	124	0	0
Blackbrush	415247	22	0
Bristlecone Pine	7565	0	0
Desert Riparian	0	2	10178
Mesquite Acacia	11455	1991	6779
Mixed Conifer	27339	0	0
Mojave Desert Scrub	663830	310247	382508
Pinyon Juniper	115868	0	0
Sagebrush	4706	0	0
Salt Desert Scrub	71654	1958	8970

A.26.6 Ecosystem Level Threats

Threats to desert pocket mouse habitats include conversion of habitat through urban and suburban development, invasive species, off-highway vehicle use, and recreational activities (Wildlife Action Plan Team 2006). Additionally, off-highway vehicle activity can result in structural damage to shrubs and soil disturbance can lead to accelerated erosion, reducing habitat suitability for desert pocket mouse (Wildlife Action Plan Team 2012). Concern has been expressed for the viability of the Nevada population of desert pocket mouse (Marshall et al. 2004) because its narrow habitat preference has resulted in fragmentation of local populations. Densities of this species are generally concordant with increasing shrub cover and diversity (Brown et al. 1997, Micone 2002).

A.26.7 Threats to Species

Invasive species and fire present a threat to habitat degradation that destroys important food and cover vegetation, increases erosion, and soil instability thus affecting important soil substrates for burrowing. Off-highway vehicle activity can result in direct mortality, and potentially reduced fitness due to hearing loss and subsequent vulnerability to predation (Brattstrom and Bondello 1983, Bowles 1995).

A.26.8 Existing Conservation Areas/Management Actions

Recommended conservation actions specific to this species and species habitat are included in the NWAP. The NWAP recommended approach is to develop a conservation plan based on outcome of research needs and candidacy for the Nevada state conservation list. Further, the recommended conservation strategies to conserve the habitat that this species occurs in include: maintaining this species habitat at its current distribution in stable or increasing condition trend; expand protected status for mesquite bosques and desert wash habitats, maintaining the disturbance in sand dune and badland habitats without compromising the sustainability of vegetation and wildlife communities; and sustaining stable or increasing populations of wildlife in key habitats (Wildlife Action Plan Team 2012).

This species is also covered under the Lower Colorado River Multi-Species Conservation Program. The goal of this program is to conserve habitat of threatened and endangered species and reduce any additional species being listed; accommodate present water diversions and power production; and provide the basis for incidental take authorizations (Lower Colorado River Multi-Species Conservation Program 2004).

A.27 TOWNSEND'S BIG-EARED BAT (*CORYNORHINUS TOWNSENDII*)

Townsend's big-eared bat (*Corynorhinus townsendii*) is a medium-sized bat (90 to 100 millimeters in length) with large ears (30 to 39 millimeters) that inhabits most of the western United States, north through British Columbia, Canada, and south into Mexico. They migrate only short distances (greater than 30 kilometers) between seasons (Kunz and Martin 1982, Dobkin et al. 1995), and typically roost in large open caves and other suitable areas (e.g. abandoned mines, tunnels, and buildings), and inhabit a wide variety of habitats from pine woodlands, to desert scrub ecosystems, but are not common in extreme desert habitats (Kunz and Martin 1982, Pierson and Rainey 1998). They are insectivorous, eating principally small moths, and forage late in the day. Females form small maternity colonies, typically with fewer than 100 individuals, and males are solitary at this time. They typically mate in the fall and winter, and females store sperm and embryos are fertilized in the spring, with one pup produced in late spring or early summer. Young fly within three weeks and are weaned by six weeks (Kunz and Martin 1982).

A.27.1 Species Status

Townsend's big-eared bat is thought to be declining throughout its range, with noted declines in Arizona, Colorado, and New Mexico in the late 1960's and continuing through the end of the 20th century in Washington, Oregon, and California (Pierson and Rainey 1998). Distributions in California are restricted by available roosting sites, and declines are largely attributed to anthropological factors, as these animals are particularly sensitive to disturbance in their roosting sites, and many roosting sites have been lost due to vandalism or conversion to other uses.

Townsend's big-eared bat was formerly a Category 2 species in consideration for federal listing under the Endangered Species Act, however these categorical listings were dissolved in 1996 due to insufficient information (USFWS 1996). A petition to list all populations of Townsend's big-eared bat in California was filed in 2012 by the Center for Biological Diversity (CBD 2012) citing widespread population declines throughout the state due to a combination of disturbance of cave and mine sites, loss of mine and cave habitat to mining, logging and urban development, white-nose syndrome and other factors (Pierson and Rainey 1998). The California Fish and Game Commission recommended acceptance of the petition, and acknowledged that the petitioned listing may be warranted (CFW 2013), and at this time is under consideration by the Commission for listing. Townsend's big-eared bat is considered a Species of Concern in the state of Nevada due to rarity (Bradley et al. 2006).

US Fish and Wildlife Service Endangered Species Act: No Status

Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): Sensitive

State of Nevada: Sensitive

NV Natural Heritage Program: Global Rank G3G4, State Rank S2 NV

Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Least Concern

CITES: No Status

A.27.2 Range

Townsend's big-eared bat is found in suitable habitat throughout central Mexico, the western United States and southwestern British Columbia, Canada (Arroyo-Cabrales and Álvarez-Castañeda). The habitats in Nevada where Townsend's big-eared bats occur include juniper-mountain mahogany, sagebrush, desert scrub (Rahn 2000), agricultural areas, and occasionally urban areas. Suitable roosting habitat includes caves, cliffs, lava tubes, buildings, and especially mines, all of which are limiting factors in distribution (Bradley et al. 2006, Dalquest 1947, 1948; Graham 1966, Pearson et al. 1952, Kunz and Martin 1982, Pierson et al. 1991, Dobkin et al. 1995). Townsend's big-eared bats have also been found to night roost in clear-span bridges and tree cavities.

During hibernation, Townsend's big-eared bats typically prefer habitats with relatively cold (but above freezing) temperatures in quiet, undisturbed places. These areas are often in the deeper, more thermally stable portions of caves and mines (Barbour and Davis 1969, Dalquest 1947, Humphrey and Kunz 1976, Pearson et al. 1952, Zeiner et al. 1990). Hibernating bats are also often found in ceiling pockets (Pierson et al. 1991). In central California, solitary males and small clusters of females are also known to hibernate in buildings (Pearson et al. 1952, Kunz and Martin 1982). Females may roost in colder places than males during these periods (Pearson et al. 1952).

A.27.3 Population Trends

Townsend's big-eared bat is rare throughout its range in North America. The species is thought to be declining in abundance throughout its range; a number of recent studies show decreases in overall population status and abandonment of traditional roost sites (Pierson 1988, Perkins 1994, Gruver and Keinath 2006). In all regions where it is found, the species is considered a high priority by the Western Bat Species Working Group regional priority matrix (Western Bat Species Working Group 2007). Declines have been documented statewide in California (Pierson and Rainey 1998, CBD 2012), and also in Nevada (Bradley et al. 2006). Little trend information exists for Clark County, although recent surveys along the Colorado River corridor indicate the species was rare, the survey effort may not have overlapped with the typical foraging habitat for this species (Williams et al. 2006).

A.27.4 Habitat Model

The three modeling algorithms for Townsend's big-eared bat predicted similar areas around prominent higher elevations mountain ranges, centering on the Spring and Sheep ranges, the Virgin Mountains, the southern portion of the McCullough Range in Clark County, and the Newberry Mountains at the southern tip of the state, while they differed in predictions among valleys (Figure A.27-1). The RF model had the highest performance scores among the four performance measures reported, followed by the Ensemble model, which had a higher fixed BI score than the RF model (Table A.27-1).

Model standard error appeared highest in Bajadas and lowland areas in Eldorado Valley, and the Moapa area (Figure A.27-2). Continuous Boyce indices indicated generally good model performance each of the modeling approaches, as well as the ensemble model (Hirzel et al. 2006)(Figure A.27-3). The CBI for the MaxEnt model had some fluctuation at model values of ~ 0.8, and the CBI for the GAM had a later increase than the others. Bins for the ensemble model based on the CBI were 0-0.45 unsuitable, 0.45-0.55 marginal, 0.55-0.8 suitable, and 0.8 -1 optimal habitat; with a suggested cutoff threshold of 0.5 (Figure A.27-3) which corresponded closely with that calculated from ROC statistics for the ensemble model (Table A.27-1).

Table A.27-1. Model performance values for Townsend's big-eared bat models.

Performance	GAM	RF	MaxEnt	Ensemble
AUC	0.79	0.95	0.81	0.90
BI	0.55	0.66	0.62	0.75
TSS	0.56	0.83	0.59	0.75
Correlation	0.50	0.80	0.53	0.70
Cut-off*	0.45	0.62	0.33	0.47

*threshold at which sum of sensitivity (true positive rate) and specificity (true negative rate) is highest

Table A.27-2. Percent contributions for input variables for Townsend's big-eared bat for ensemble models using GAM, MaxEnt and RF algorithms.

Term	GAM	RF	Max	Avg
Winter Min Temp.	44.66	15.53	39.20	33.13
Annual Temp. Range	11.98	16.02	22.98	16.99
Winter Precip.	13.20	8.33	14.95	12.16
NDVI Maximum	11.16	11.83	3.79	8.93
Diurnal Temp. Range	5.31	10.07	3.91	6.43
Distance to Cliffs	5.39	6.33	7.25	6.32
NDVI Amplitude	2.76	6.42	2.73	3.97
Surface Texture (ATI)	1.84	8.95	0.98	3.93
Topographic Position (TPI)	1.84	5.15	3.56	3.52
Annual Temp. Range	24.08	17.87	26.13	22.6

Figure A.27-1. SDM maps for Townsend’s big-eared bat model ensembles for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

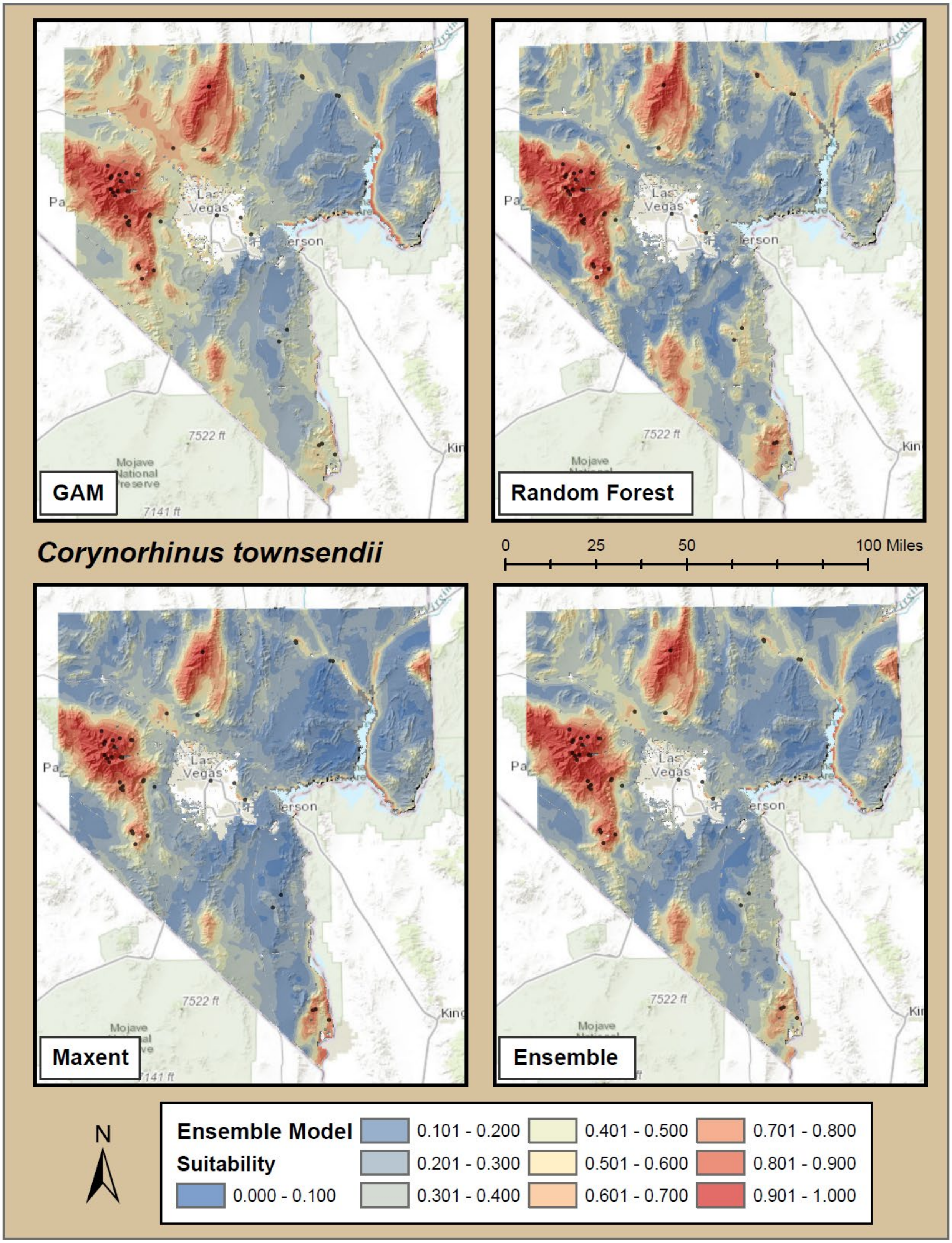


Figure A.27-2. Standard error maps for Townsend’s big-eared bat models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).

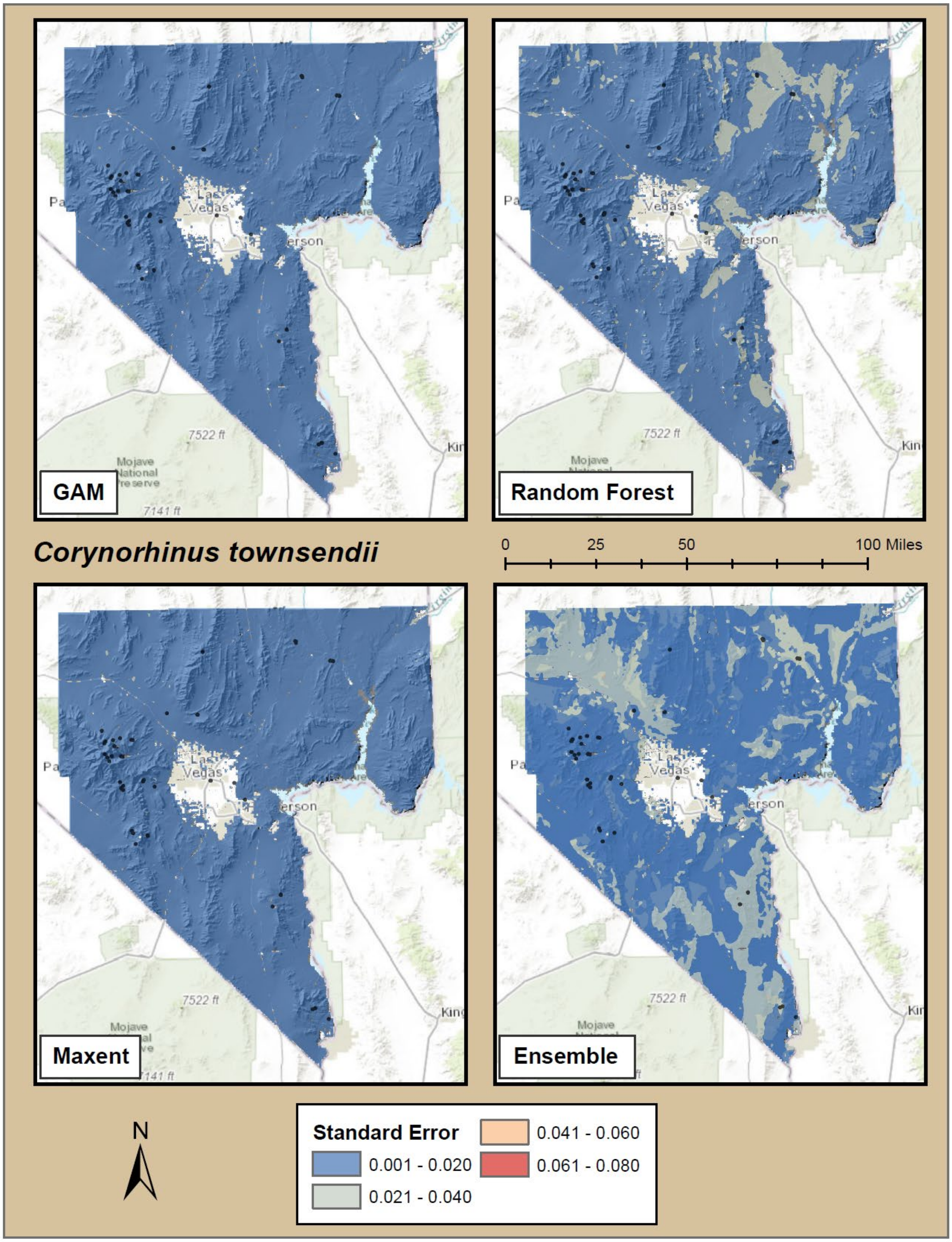
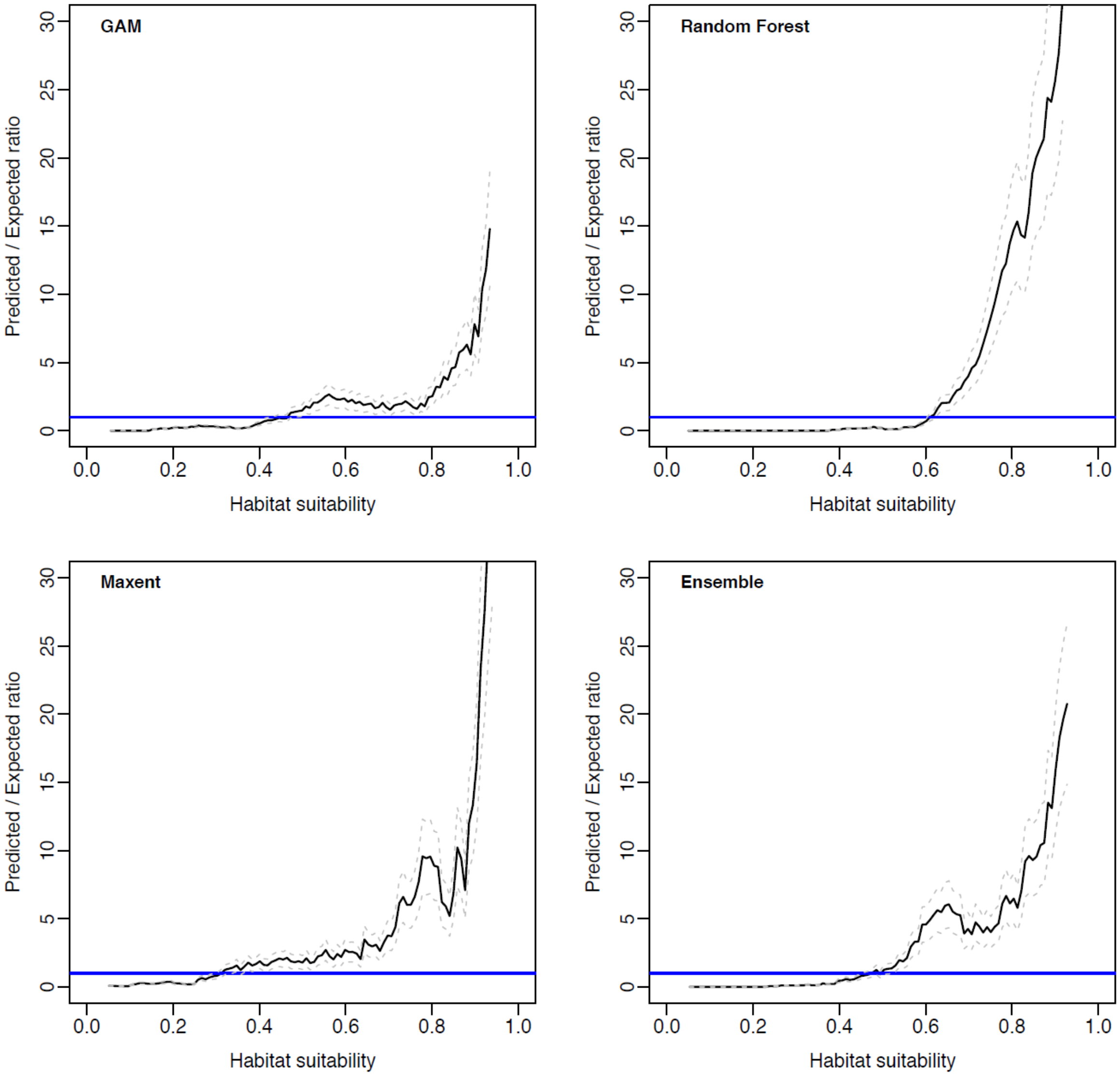


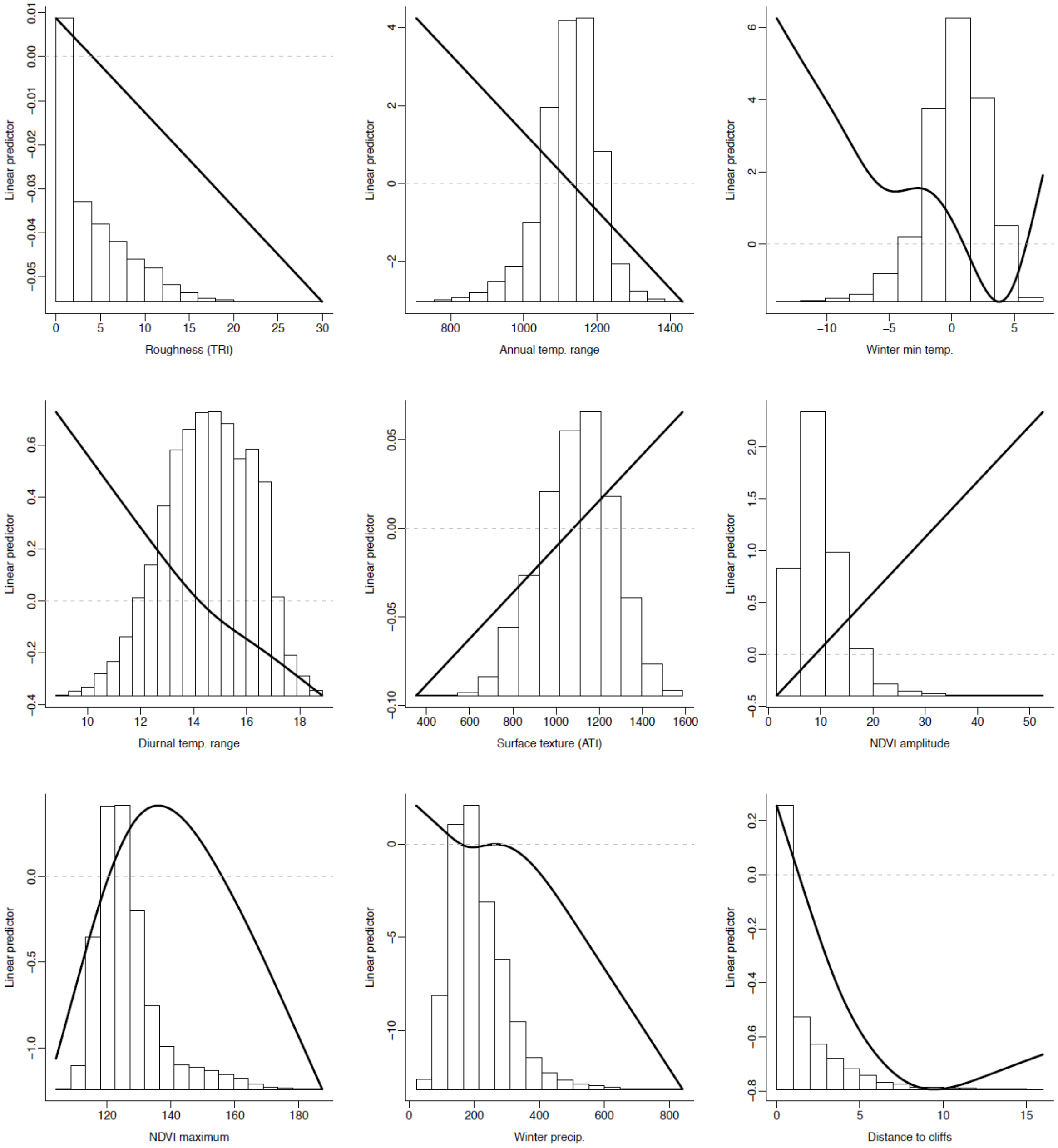
Figure A.27-3. Continuous Boyce Indices for Townsend's big-eared bat models for each of three modeling algorithms used (GAM - upper left, RF - upper right, MaxEnt - lower left), and an ensemble model averaging the three (Lower Right).



A.27.4.1 General Additive Model

The top 4 contributing variables to the GAM model were Winter Minimum Temperature, Winter Precipitation, Annual Temperature Range, and NDVI Maximum, collectively representing 80% of the overall environmental contributions to the model (Table A.27-2). Habitat suitability was negatively associated with the two temperature metrics, and winter precipitation, with cooler winter temperatures, with lower temperature difference between summer and winter, and lower precipitation contributing to suitable habitat. The temperature associations with highest habitat suitability were markedly lower than the average habitat values (Figure A.27-4). Habitat suitability relative to NDVI Maximum had the highest values in areas with later greenup than average, but not at the extreme for this variable. The continuous BI curve for the GAM model had a much lower peak at the highest habitat values than those for the other odels (Figure A.27-3).

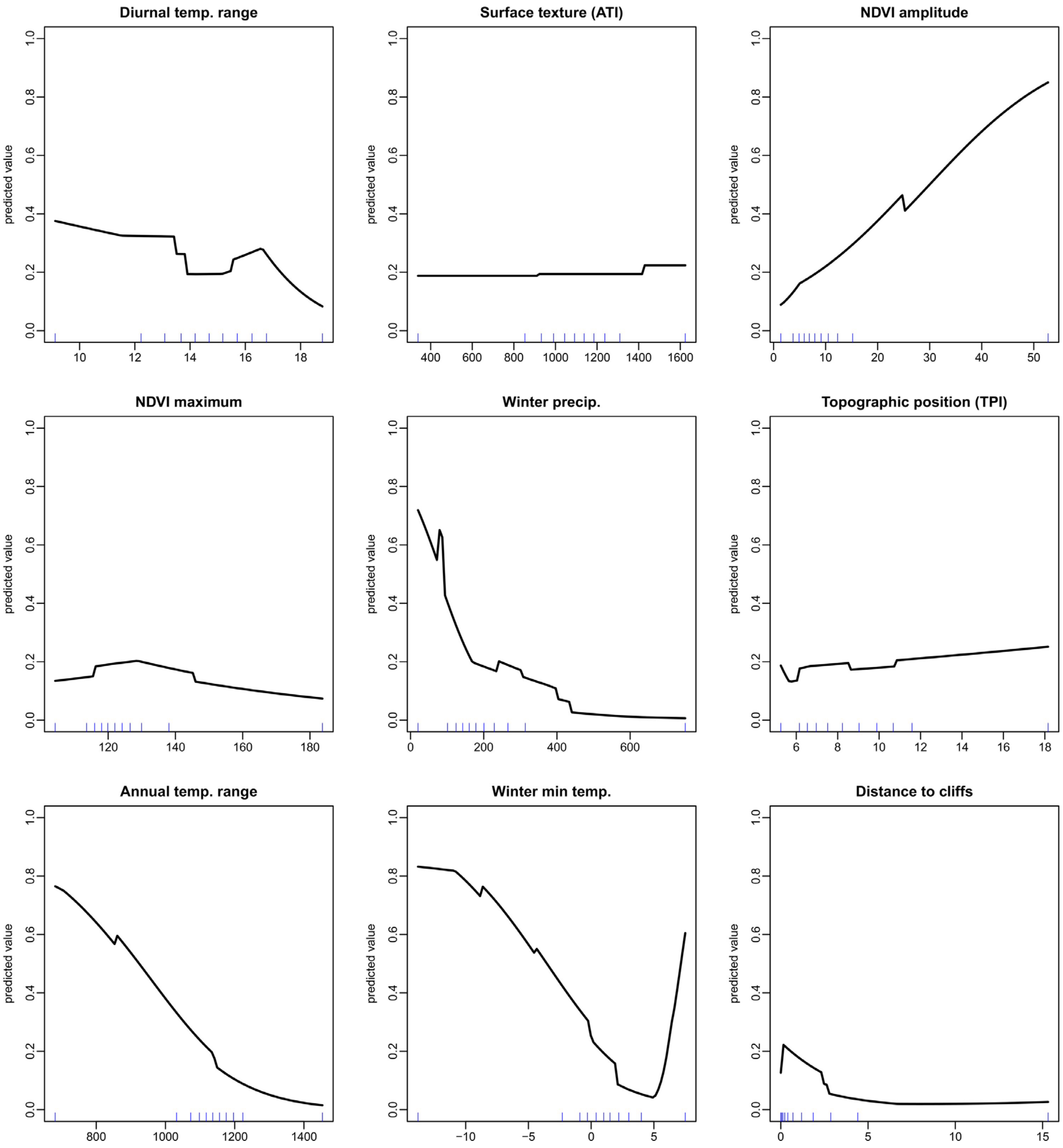
Figure A.27-4. GAM partial response curves for the Townsend’s big-eared bat model overlaid over distribution of environmental variable inputs in the study area.



A.27.4.2 MaxEnt Model

Three variables had the strongest contributions to the MaxEnt models for this species, providing 77% of the overall environmental contributions (Table A.27-2). These were: Winter Minimum Temperature, Annual Temperature Range, and Winter Precipitation, which were also the top three in the GAM models. The partial response curves depicting the relationships of these variables were all similar to those for the GAM models, which was not surprising given the similarities in predicted habitat (Figure A.27-5). Differences between the two were most prominently visible along the US 95 corridor northwest of Las Vegas (predicted to have relatively higher suitability by the GAM model), and in the Newberry mountains (predicted to have relatively higher suitability by the MaxEnt model) (Figure A.27-1).

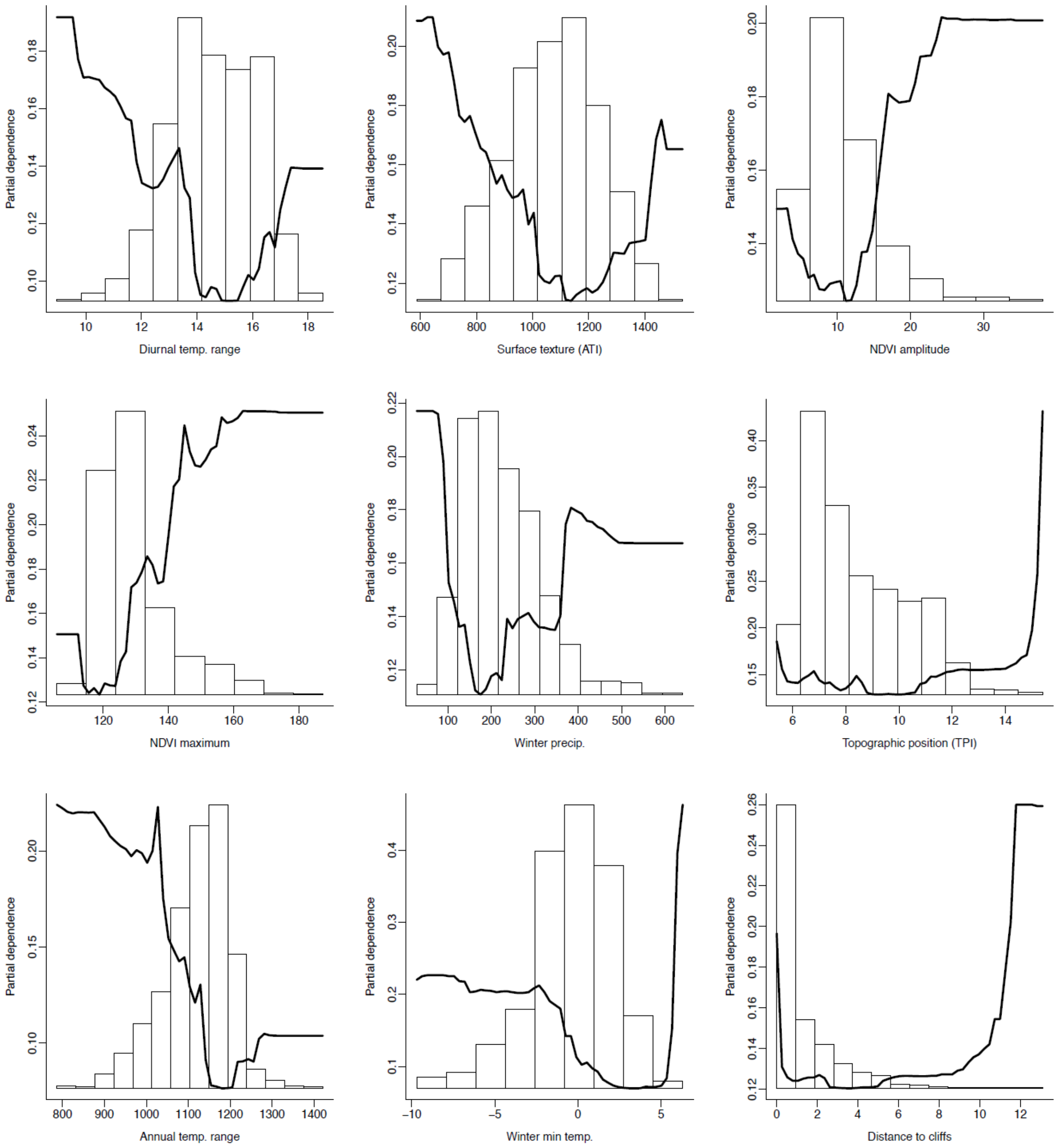
Figure A.27-5. Response surfaces for the top 9 environmental variables included in the MaxEnt ensemble model for Townsend's big-eared bat.



A.27.4.3 Random Forest Model

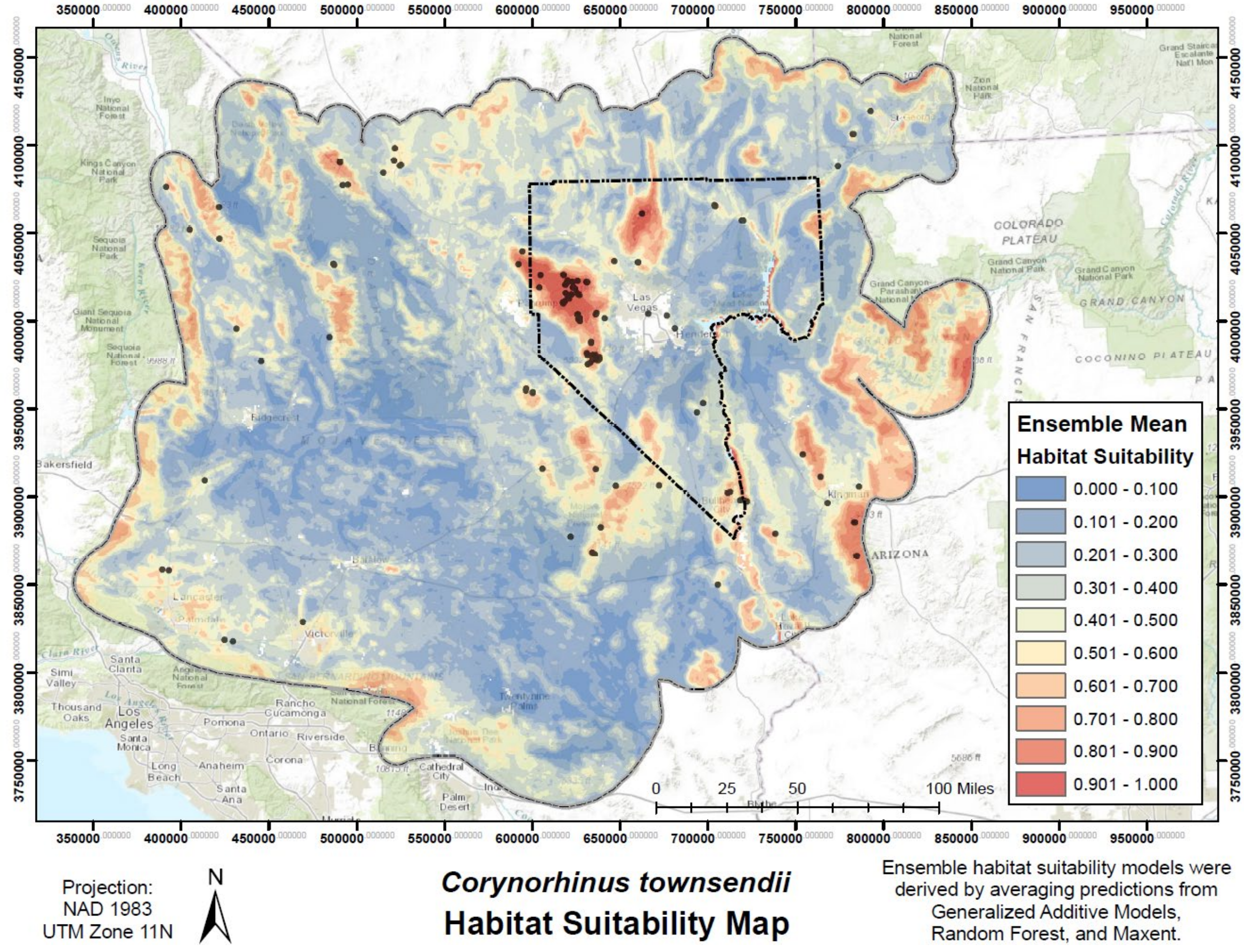
The RF models had a much more diverse influence of environmental variables, with six variables contributing to achieve 70% of environmental variable influence, and without a sharp reduction to the last four (Table A.27-2). Highest contributions were from Annual Temperature Range, Winter minimum temp, NDVI Maximum, Diurnal Temperature Range, Surface Texture, and Winter Precipitation (Table A.27-2). There were differences in the pattern of influence indicated by the RF response curves from the other two models. For example, habitat suitability was high for both low and high values of Annual Temperature Range, with the lowest suitability for moderate values. Habitat suitability was highest in areas with lower Winter Minimum Temperatures, but the response was non-linear, and had a negative sigmoidal relationship. Diurnal Temperature Range was positively associated with habitat suitability for all three of the modeling approaches. Suitable habitat for this species was associated with lower Surface Texture values – indicating rockier areas (Figure A.27-6). The Continuous Boyce Index had the best relationship for this algorithm (Figure A.27-3).

Figure A.27-6. Response surfaces for the environmental variables included in the RF ensemble model for Townsend’s big-eared bat. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.



850000 900000 950000

Figure A.27-7. Mojave wide SDM map for the Townsend's big-eared bat ensemble model

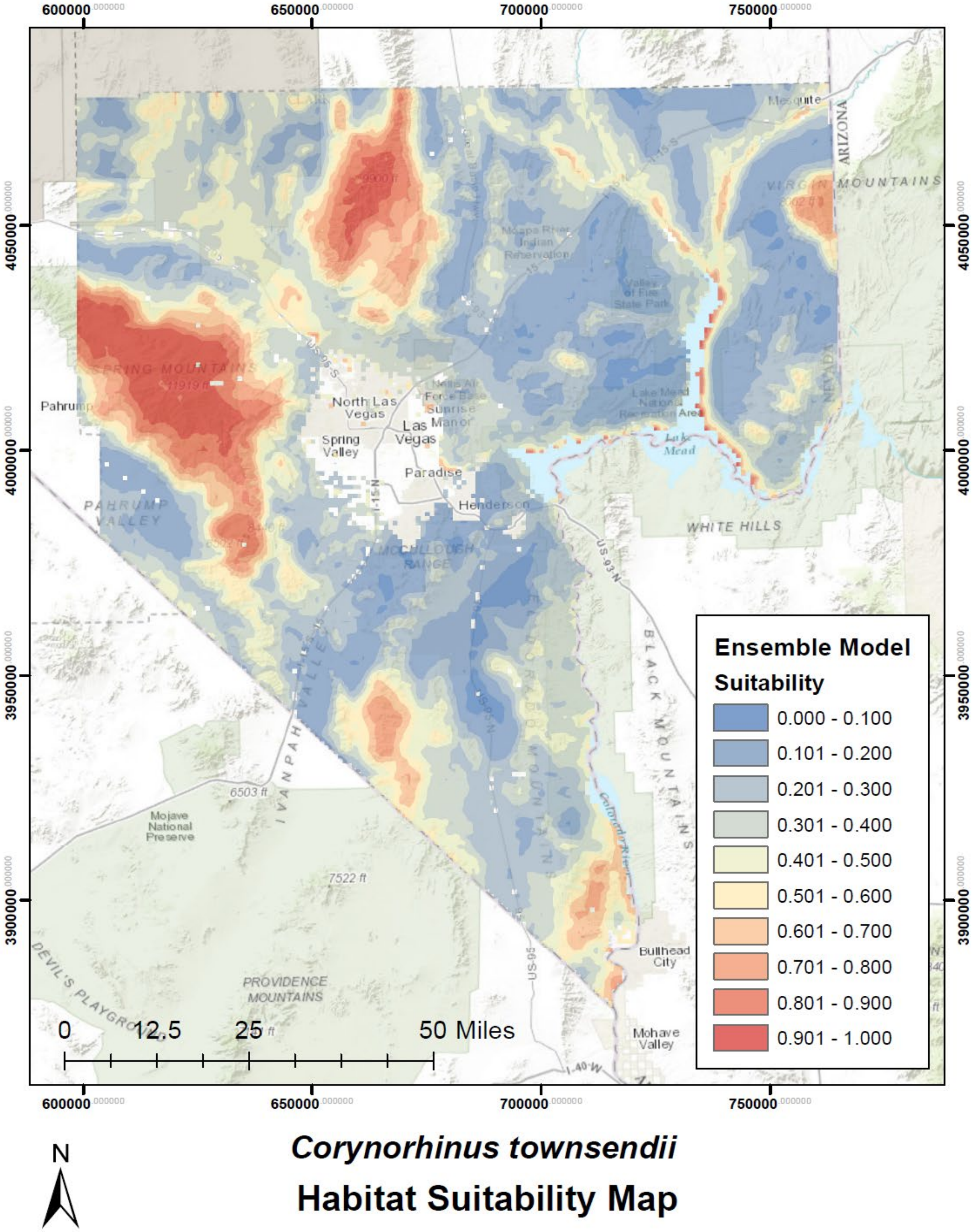


Projection:
NAD 1983
UTM Zone 11N

Corynorhinus townsendii
Habitat Suitability Map

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and Maxent.

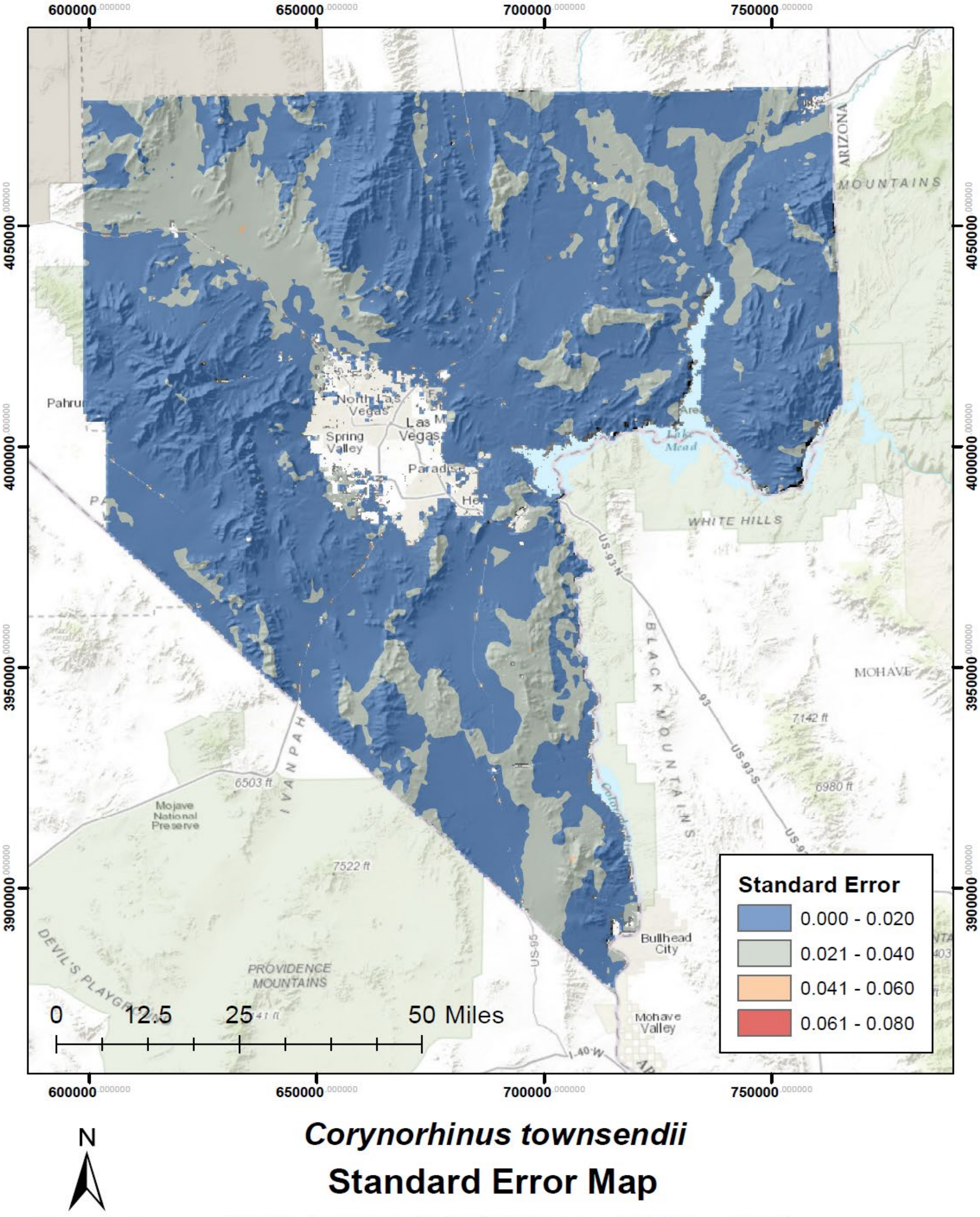
Figure A.27-8. SDM map for the Townsend's big-eared bat ensemble model.



Projection:
NAD 1983
UTM Zone 11N

Ensemble habitat suitability models were derived by averaging predictions from Generalized Additive Models, Random Forest, and MaxEnt.

Figure A.27-9. Standard Error map for the Townsend’s big-eared bat ensemble model



Corynorhinus townsendii

Standard Error Map

Standard error in habitat suitability was calculated across all selected GAM, Random Forest, and Maxent models used in deriving the ensemble estimates.

A.27.4.4 Locality Distribution

Townsend's big-eared bats are known to occur across the Mojave Desert Ecoregion, but specifics of their habitat are poorly known with few verified locality points (Figure A.27-7). The locality database used in this modeling exercise had the fewest locality points of any of the bat species we have modeled. Townsend's big-eared bat are equally widespread throughout Nevada from low desert to high mountain habitats. As an example of its ecological amplitude, it has been observed in Krumholz (windblown trees near timberline) bristlecone pines as high as 3,500m in the Snake Range of eastern White Pine County (Bradley et al. 2006). Similar to *Antrozous* and *Tadarida*, *Corynorhinus* is extremely sparse in the western Mojave Desert across most of California's desert without any verified localities in most of the central basin and range there (Figure A.27-7). The greatest concentrations of verified Townsend's Big- eared Bat localities in the Mojave Desert are in the Spring Mountains of western Clark County. While there were many observations in Clark County, Nevada, there were far fewer localities in the urban areas around Las Vegas for this species than either *Antrozous* or *Tadarida*.

A.27.4.5 Standard Error on Habitat Suitability

The standard error analysis for Townsend's big-eared bat models indicates a homogenous pattern of very low error values presenting very little to be concerned about with respect to this model (Figure A.27-9). The pattern is qualitatively similar to *Antrozous* and *Tadarida* however, there is one small patch of moderately high error near the southern margin of the Nellis Bombing Range just north of US Highway 95.

A.27.4.6 Mojave Desert Ecoregion Habitat Suitability

Models of habitat suitability for Townsend's big-eared bats in the Mojave Desert Ecoregion indicate mostly relatively small patches of moderately high habitat suitability across the desert occurring in association with higher elevation areas. The heart of California's Mojave Desert, known as the west Mojave in the context of the whole desert is nearly void of suitable habitat with the exception of a very small patch east of Barstow in San Bernardino County, between the I40 and I15 highways (Figure A.27-7). This small patch is also ranked as moderately high suitability for *Antrozous* and *Tadarida* to the exclusion of most of the surrounding landscapes. The few other patches of moderately high suitability occur in montane environments such as the Panamint Range, and the White Mountains. On the east side of the Mojave Desert, both rims of the Grand Canyon, as well as the Cerbat and Hualapai mountains on the north and south of Kingman; respectively, in Mohave County, Arizona also supports moderately high habitat suitability. The only habitat ranked as the highest quality habitat in the Mojave Desert Ecoregion is in Clark County, Nevada. As noted for other bat species there are many small and intermittent patches of moderate habitat suitability on the very periphery of the Mojave Desert habitat suitability model. Those habitat patches should probably not be considered solely on the basis of this model due to the behavior of the modeling algorithms on the periphery of their boundaries, although the metric most likely to have edge effects (distance to cliffs) was not among the higher contributing environmental variables.

A.27.5 Distribution and Habitat Use within Clark County

This species has been observed at fewer than 50 locations throughout Clark County. In Clark County, Townsend's big-eared bats have been observed near the eastern end of Lake Mead and in the Newberry Mountains (RECON 2000), physically captured and acoustically recorded in the upper Muddy River (Williams et al. 2006), and acoustically recorded at several sites within the Spring Mountains. While this species is widespread throughout the county, predicted higher suitability habitat occurs in the uplands near Blackbrush, Pinyon Juniper, Mixed Conifer, and Alpine Ecosystems (Table A.27-3). Its occurrence in lowlands is thought to be primarily for foraging, and thus the presence of moderate habitat in Mojave Desert Scrub, Mesquite Acacia, Desert Riparian, as well as the upland ecosystems (Table A.27-3).

Clark County, Nevada hosts the largest contiguous area of predicted highest suitability rating in the Spring Mountains. An almost equally high level of predicted suitability habitat exists on the Sheep Range, although this area is smaller in size (Figure A.27-8). Townsend's big-eared bats are probably widespread among the low desert to montane habitats of these high mountain ranges. In those areas, these moth specialists likely inhabit pinyon/juniper and mountain mahogany woodlands, and forests of ponderosa pine, white fir, aspen and cottonwood (Bradley 2000). The only other areas where the models identify high suitability habitat patches occur along the eastern shoreline of the Overton Arm of Lake Mead and small intermittent patches along the main stem of the Colorado River. There are patches of moderately high suitability in both the Virgin and McCullough mountains, though less extensive areas than the Spring Mountains and Sheep Range.

Table A.27-3. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	0	124
Blackbrush	77481	227031	109806
Bristlecone Pine	0	0	7565
Desert Riparian	104	5863	4760
Mesquite Acacia	7599	9967	2218
Mixed Conifer	0	0	27339
Mojave Desert Scrub	825987	433242	26165
Pinyon Juniper	199	5573	110101
Sagebrush	19	631	4055
Salt Desert Scrub	16532	61719	1352

A.27.6 Ecosystem Level Threats

In addition to urbanization, activities that can result in significant disturbance or loss of habitat include mine reclamation, renewed mining, water impoundments, recreational caving, rock climbing, loss of building roosts, and bridge replacement (Kunz and Martin 1982, Pierson et al. 1999). Additional threats to the species include the loss of foraging habitat through timber harvesting and development and the reduction of prey base through the use of pesticides (Piaggio 2005).

A.27.7 Threats to Species

Townsend's big-eared bats are very sensitive to roost disturbance and may abandon roosts after human visitation. Disturbance of roosts, including recreational caving and mine exploration and resumed mining are the primary threats to Townsend's Big- eared Bats (Piaggio 2005). Pesticide contamination may also threaten this species in agricultural areas (Geluso et al. 1976). There is some evidence that predation from rats could be suppressing certain populations (Fellers 2000).

White-nosed fungus (*Pseudogymnoascus destructans* or Pd*)* has the potential to impact the species (Gargas et al. 2009). Although incidence of white-nosed fungus – a cold-loving fungus that affects hibernating bat species -- has not been reported in Nevada, this disease has the potential to affect all hibernating bat species, including Townsend's big-eared bats. Colonies of hibernating bats exposed to the fungus can suffer mortality rates of 81-97 percent (http://www.fort.usgs.gov/wns/).

Renewable energy development can threaten bat habitat in a couple of ways. First there is the direct habitat disturbance. In this regard, solar arrays may be the most destructive to foraging areas for desert bats in Clark County, while wind farms have a smaller surface area disturbance. In contrast, wind turbines can have direct impacts to bats through collisions or barotrauma (Cryan and Barclay 2009, Cryan 2011).

Gates have been installed to protect some mines from human disturbance and people from mine hazards, however many gates installed are not bat friendly and may interfere with local colony survivorship (Pierson and Rainey 1998), as there is some evidence of collisions of this species with bat gates, particularly with younger animals (Diamond and Diamond 2014).

Nevada has an abundance of former mining sites that are suitable roosts for this species. As the species is known to abandon roosts when disturbed by human visitation, threats are likely a result of recreational use of known or potential roost sites. Closure of sites, and of routes leading to these sites, could be considered as a mitigation strategy to reduce disturbance. Further, renewed starts on formerly closed mines are also documented to disturb this species. The potential effects on the species by permitting for renewed mining activities should be considered.

A.27.8 Existing Conservation Areas/Management Actions

The Nevada Wildlife Action Plan sets a strategic vision for wildlife conservation at the landscape level in Nevada, and identifies the species of greatest conservation need within the state (2012). The plan designates Townsend's big-eared bat a Species of Conservation Priority because of its patchy distribution, range-wide population status concerns, and possible susceptibility to white-nose syndrome (Wildlife Action Plan Team 2012). Plan objectives relevant for this species include: maintaining stable or increasing populations, conducting 200 bat surveys within mines per year, and installing 50 bat-friendly closure structures per year through 2022. Research and conservation actions recommended for Townsend's big-eared bat include: mapping and monitoring winter, maternity, bachelor, lekking, and night roosts; developing and implementing temporal and spatial use recommendations in known roost areas in order to minimize human disturbance; supporting and advocating technological research to develop non-lethal wind turbine designs to minimize collision mortality; using alternative mine closure methods such as hazard signs, fencing, and/or bat gates in order to retain habitat; and monitoring for white-nose syndrome (Wildlife Action Plan Team 2012).

The Nevada Bat Conservation Plan assesses the state of bat conservation in Nevada and suggests strategies, actions, and research needed to promote healthy bat populations and habitats (Bradley et al. 2006). The plan considers Townsend's Big- eared Bat populations and habitats a high priority for funding, planning, and conservation actions, and states the species is imperiled or at high risk of imperilment (Bradley et al. 2006).

Townsend's big-eared bat is considered a Very High Priority species in the Spring Mountain Conservation Agreement. This agreement has been developed between various agencies to provide long-term protection for the rare and sensitive flora and fauna of the Spring Mountains National Recreation Area (USFS et al. 1998). Out of the seven species of bats that occur in the Spring Mountains, Townsend's is of greatest concern because it is highly susceptible to disturbance. Conservation actions listed in the plan include: developing a bat monitoring plan, emphasizing roost site and water source monitoring; developing and implementing a plan to protect bat roosts in mines and caves; working with volunteers to provide nest boxes for roosting bats to replace lost habitat; and developing and implementing a monitoring program for assessing effects of recreational use on bats and their habitats (USFS et al. 1998).

The Overton Wildlife Management Area (OWMA) consists of 17,229 acres in the Moapa Valley managed by the Nevada Department of Wildlife. The conceptual management plan for OWMA calls for protecting and enhancing mammal habitats and populations. Recommended management actions are to determine the occurrence and habitat functionality on the OVWMA for warm desert riparian bats, including Townsend's bat-eared bat (NDOW 2014).

Townsend's big-eared bat is an Evaluation species under the Lower Colorado River Multi-Species Habitat Conservation Plan (LCR MSCP 2004). Conservation measures to avoid, minimize, and mitigate impacts include: conducting surveys and research to locate roost sites and better identify habitat requirements; creating habitat near existing roost sites; monitoring and adaptively managing created habitat; and reducing the risk of losing created habitat to wildfire (LCR MSCP 2004). The plan states that created cottonwood-willow and honey mesquite habitat will support a substantially greater density and diversity of plant species that will in turn support a greater abundance of insect prey species.

A.28 SPOTTED BAT (*EUDERMA MACULATUM*)

Spotted bats (*Euderma maculatum*) are solitary and widely distributed in western North America. spotted bats, though rarely observed by the public, have a striking coloration pattern, with a pair of white spots on their dorsal sides, against a dark background. They are one of the largest bats in North America, and they roost either singly, or in small groups where there are suitable cliffs and nearby foraging areas and water resources (Chambers et al. 2011).

A.28.1 Species Status

The IUCN Redlist categorizes this species as one of Least Concern because of its wide distribution, presumably large population, occurrence in protected areas, and absence of evidence of declining populations (Arroyo-Cabrales and Álvarez- Castañeda 2008). However, both Great Basin National Park and Lake Mead National Recreation Area list them as Species of Concern.

US Fish and Wildlife Service Endangered Species Act: No Status

US Bureau of Land Management (Nevada): Sensitive

US Forest Service (Region 4): Sensitive

State of Nevada: Threatened

NV Natural Heritage Program: Global Rank G4, State Rank S2

NV Wildlife Action Plan: Species of Conservation Priority

IUCN Red List (v 3.1): Least Concern

CITES: No Status

A.28.2 Range

The spotted bat is a solitary species found in northern Mexico, throughout the western United States, and in British Columbia, Canada (NatureServe 2009). They occur in 11 western states in the United States, and occur throughout Nevada. Thirty-three percent of the known localities in the state occur in the metropolitan areas of Reno and Las Vegas (Geluso 2000). Most Spotted Bat sightings are in the southwestern part of the state. Spotted bats inhabit cliffs in their natural habitat, and are frequently found in dry rough desert terrain (Watkins 2007), but have also been observed roosting in buildings within cities (Geluso 2000, Sherwin and Gannon 2005).

A.28.3 Population Trends

Abundance and population trends are essentially unknown (Arroyo-Cabrales and Álvarez-Castañeda 2008). In Clark County, the species is considered a medium priority by the Western Bat Species Working Group regional priority matrix (Western Bat Species Working Group 2007).

A.28.4 Qualitative Habitat Model Methods

According to our search, the spotted bat has been observed within Clark County only in the Las Vegas urban area and in the Muddy River drainage (Williams et al. 2006). The total number of occurrences (n = 13) were insufficient to pursue a quantitative habitat suitability model. However, the species' broad distribution within North America, along with research finding that spotted bats are a late flyer and roosts singly in isolated locations (Chambers et al. 2011), suggests that this species may occupy a broader range of habitat within Clark County than has previously been observed (Bradley et al. 2006). In particular, the county contains a large area of potential cliff roosting habitat, which appears to be the favored roosting habitat type for spotted bats (Chambers et al. 2011). The species has also been observed foraging in riparian habitat along the Muddy River (Williams et al. 2006), suggesting that similar habitat types within the county (i.e., along the Lake Mead riparian corridor) may also be used. Additionally, radio telemetry tracking in arid portions of Northern Arizona discovered spotted bats foraging in forested habitat as well as desert scrub (Chambers at al. 2011).

Based on the available information, we delineated potentially suitable habitat for spotted bats within Clark County through a GIS overlay of suitable habitat features (Table A.28-1) at a 1 km^2 spatial resolution. Potential cliff roosting habitat was identified as rocky surfaces with a slope > 25 degrees (Inman et al. 2014). Forested and riparian foraging areas, including springs, were identified based on the vegetation classification of Clark County (Heaton et al. 2011) and the National Hydrography Dataset (NHD). Potential watering sites were identified as high resolution NHD waterbodies ((https://nhd.usgs.gov/) along with guzzler locations from the Nevada Department of Wildlife.

Given the large home range size and nightly flight patterns (distances up to 30 km) observed for spotted bats (Chambers et al. 2011), much or all of Clark County is likely within the species' potential flight path, including the urban Las Vegas area where spotted bats reportedly roost. Through distance overlays, we determined that the entire county was indeed within a typical flight distance (20 km) of potentially suitable roosting habitat and / or watering sites, particularly given the species known occurrences within the Las Vegas urban area. For this reason, we considered the entirety of Clark County to be a potential flight area for spotted bats. A base value of “1” was therefore assigned to all grid cells within our qualitative habitat suitability map (extent of Clark County). Other grid cells were assigned values according to the highest priority habitat type that occurred in each cell (Table A.28-1), with roosting habitat given the highest value (e.g., Roosting > Foraging > Watering). We did not mask urban areas from the final layer because urban development is not thought to be a deterrent for spotted bats within Clark County.

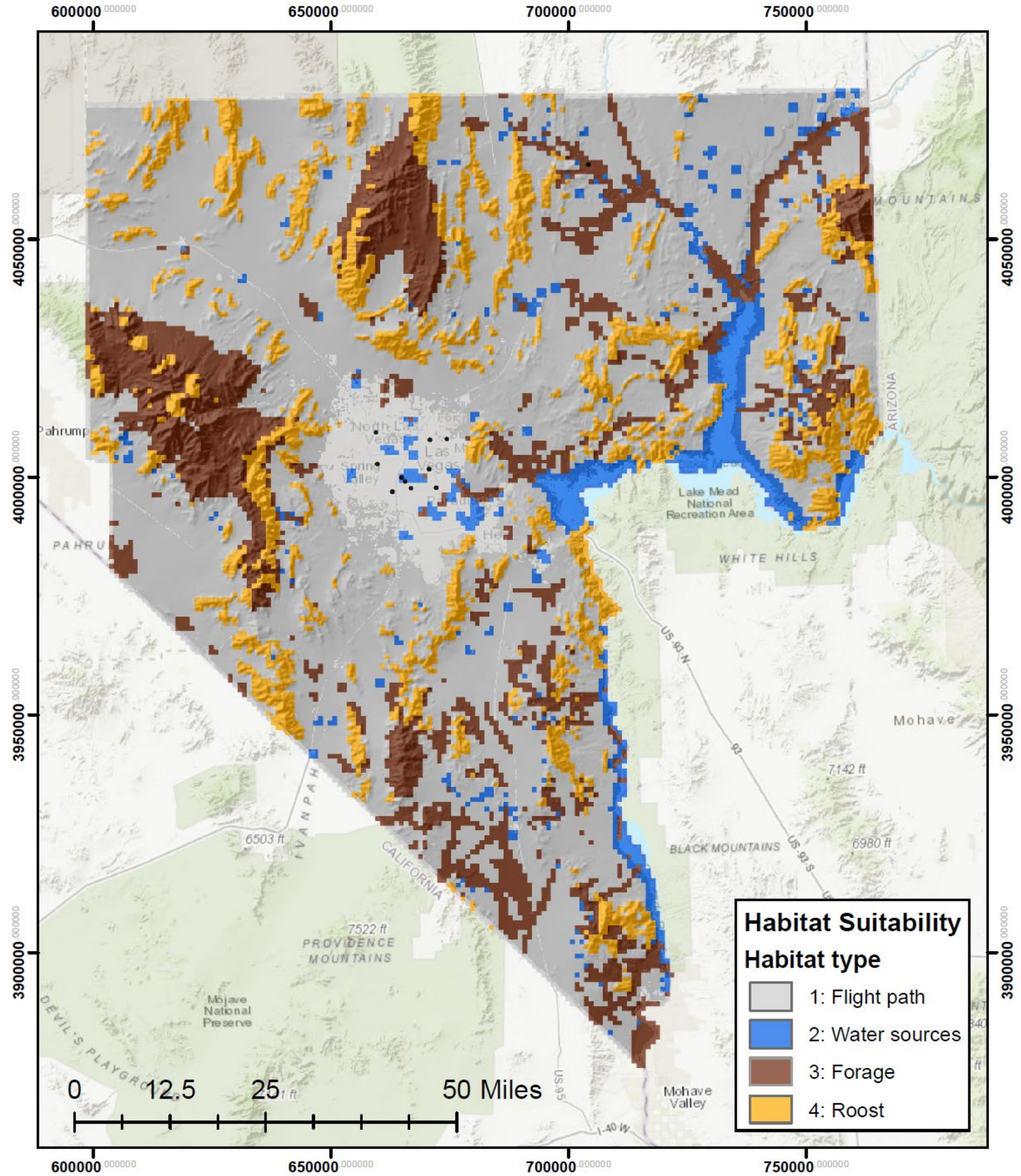
A.28.4.1 Model Discussion

The qualitative habitat model predicts habitat for roosting sites in mountainous areas located throughout the county. Foraging areas are typically located nearby (e.g. the Sheep and Spring ranges and McCullough Mountains, and the north and south Virgin Mountains in Gold butte). Additional foraging areas are located in the more highly vegetated regions of the greater Lake Mead area, including Las Vegas Bay, the Virgin River, the Muddy River, and Moapa Valley (Figure A.28-1).

Table A.28-1. Landscape features used to identify potential spotted bat habitat at a spatial resolution of 1 km2.

Habitat type	Description	Value
Flight Area	Areas within a distance of 20 km from potential roosting sites and water sources.	1
Water sources	Water bodies and springs were identified from the National Hydrography Dataset (https://nhd.usgs.gov/) high-resolution layer for Nevada. Guzzler locations were provided by the Nevada Department of Wildlife. Point features were rasterized to 1 km^2 grid cells.	2
Foraging	Forested and riparian vegetation cover classes extracted from Heaton et al. (2011) vegetation classes.	3
Roosting	Cliffs were identified from a 30 m^2 DEM as cells with a slope > 25 degrees. This layer was aggregated to 1 km^2 such that all 1 km grid cells with at least 10 % cliff habitat were included. This binary slope layer was then clipped to rocky surfaces identified by Inman et al. (2014).	4

Figure A.28-1. Estimated habitat for spotted bat from the qualitative model developed from water sources, potential forage areas, and potential roosting sites (Table A.28-1).



N

Projection:
NAD 1983
UTM Zone 11N

Euderma maculatum

Habitat Suitability Map

Qualitative habitat suitability scores were based on multiple landscape features, including rocky cliffs, riparian and woodland vegetation, and water sources.

A.28.5 Distribution and Habitat Use within Clark County

The Nevada Natural Heritage database contains six records for spotted bat: five in the Las Vegas area and one in the upper Moapa Valley. This species has been studied in the Upper Moapa Valley (Willams et al. 2006). Geluso (2000) reported six records from urban areas in Las Vegas.

Spotted bats occur within a wide variety of habitats including desert scrub, pinyon- juniper woodland, conifer and mixed conifer forests, riparian forests, and sub-alpine meadows (Chambers and Herder 2005). This species is closely associated with dry, rough desert country (Watkins 1977) and will use rocky cliffs, caves and cave-like structures as well as houses and/or urban high-rise buildings that mimic natural cliffs (Geluso 2000, Sherwin and Gannon 2005, Bradley et al. 2006). Along the Muddy River in Upper Moapa Valley, spotted bats were primarily observed foraging over mesquite habitat, and secondarily over riparian marsh (Williams 2001, Williams et al. 2006), and springs and areas of open water also provide important foraging habitat.

They have also been observed foraging in the canyons of the Colorado River drainage system (Chambers et al. 2011). Modeled habitat for High and Moderate habitat classifications was most prominent in Mojave Desert Scrub, Salt Desert Scrub, and Blackbrush, and Pinyon Juniper ecosystems, but this species is also predicted to use higher elevation ecosystems, with high or moderate habitat overlapping much of the available Bristlecone Pine, and the Alpine ecosystems in the county (Table A.28-2).

Table A.28-2. Ecosystems within Clark County, and the area (Ha) of Low Medium and High predicted suitability within each ecosystem.

Ecosystem	Low	Medium	High
Alpine	0	0	124
Blackbrush	199308	124488	91877
Bristlecone Pine	70	4679	2816
Desert Riparian	96	10785	336
Mesquite Acacia	1209	18270	760
Mixed Conifer	0	23699	3640
Mojave Desert Scrub	934049	329738	103221
Pinyon Juniper	20	89359	26523
Sagebrush	542	3429	736
Salt Desert Scrub	60502	12476	9712

A.28.6 Ecosystem Level Threats

Spotted Bats likely occur in habitats such as Blackbrush, Desert Riparian, Mesquite/Acacia, Mixed Conifer, Mojave Desert Scrub, Pinyon-Juniper, Sagebrush, and Salt Desert Scrub. Threats to spotted bat habitats include loss of habitat due to development in areas where cliffs occur, recreational climbing, and mining and quarry operations (Bradley et al. 2006). Spotted bats likely also have had a loss of foraging areas to large developments such as urbanization and large-scale renewable energy. Wind energy development can also be detrimental to Spotted Bats from being stuck by propellers, or due to extreme low pressure gradients that occur near the moving propellers and kill bats. Spotted bats are not on the list of bat species known to be affected by white-nose syndrome (whitenosesyndrome.org 2017), and they may be less susceptible to it, due to their solitary behavior, but this should always be considered a potent risk for bat species.

A.28.7 Threats to Species

Little is known about possible threats to spotted bats because there are so few observations of them in the wild. Spotted bats roost in remote locations making threats to roosts unlikely. However, recreational rock climbing may cause impacts in some areas due to disturbances and damage to habitats. Urbanization in some areas may remove roost sites, although they are known to roost in urban areas. Collection of spotted bats by humans and use of pesticides that may bio-accumulate in bats or kill prey may also be threats. In desert habitats, loss of accessible open water that was previously available in many areas for grazing livestock, but has been eliminated in many areas may impact bats because of their high rates of evaporative water loss. As with most bat species, threats include habitat destruction or alteration, disturbance, sensitivity to pesticides and other pollutants, and overexploitation (Chambers and Herder 1995, Wildlife Action Plan Team 2006). Renewable energy development can threaten bat habitat. First there is the direct habitat disturbance. In this regard, solar arrays may be the most destructive to foraging areas for desert bats in Clark County, while wind farms have a smaller surface area disturbance. In contrast, wind turbines can have direct impacts to bats through collisions or barotrauma (barotrauma results from exposure to extremely low pressure areas around moving propellers that cause severe trauma to the delicate bats; Cryan and Barclay 2009, Cryan 2011). White-nose fungus (*Pseudogymnoascus destructans*) has the potential to impact bat species, but has not been found in spotted bats, or any bats in the desert southwest, to date.

Although incidence of white-nosed fungus – a cold-loving fungus that affects hibernating bat species (whitenosesyndrome.org 2017) -- has not been reported in Nevada, this disease has the potential to affect all hibernating bats, including spotted bats. Possible impacts from white-nosed fungus may be lower than with Townsend’s big-eared bat (on which the fungus has been found, yet infected individuals have not been found), because spotted bat roosts alone or in small groups, which is less conducive to the spread of disease than large hibernacula.

A.28.8 Existing Conservation Areas/Management Actions

The Nevada Wildlife Action Plan sets a strategic vision for wildlife conservation at the landscape level in Nevada, and identifies the species of greatest conservation need within the state (2012). The plan designates the spotted bat as a Species of Conservation Priority because of its rare and patchy occurrences and because it is listed as threatened in the Nevada Administrative Code (Wildlife Action Plan Team 2012). The objective for this species is maintaining populations at detectable levels. Recommended research and conservation actions include: developing random-plot networks where bats are listened for using high performance microphones and recording devices to establish status, population trends, and distribution; promoting snag retention for potential roosting locations; supporting and advocating technological research to develop non-lethal wind turbine designs to minimize collision mortality; and monitoring for white-nose syndrome (Wildlife Action Plan Team 2012).

The Nevada Bat Conservation Plan assesses the state of bat conservation in Nevada and suggests strategies, actions, and research needed to promote healthy bat populations and habitats (Bradley et al. 2006). The plan considers spotted bat populations and habitats a medium priority for funding, planning, and conservation actions, though it states a lack of information about this species is a concern, and prevents an adequate assessment of its status (Bradley et al. 2006). Suggested research priorities are the identification and description of roost sites and breeding range within Nevada.

The spotted bat is covered under the Spring Mountain Conservation Agreement. This agreement has been developed between various agencies to provide long-term protection for the rare and sensitive flora and fauna of the Spring Mountains National Recreation Area (USFS et al. 1998). Conservation actions listed in the plan include: developing a bat monitoring plan, emphasizing roost site and water source monitoring; developing and implementing a plan to protect bat roosts in mines and caves; working with volunteers to provide nest boxes for roosting bats to replace lost habitat; and developing and implementing a monitoring program for assessing effects of recreational use on bats and their habitats (USFS et al. 1998).

The Overton Wildlife Management Area (OWMA) consists of 17229 acres in the Moapa Valley managed by the Nevada Department of Wildlife. The conceptual management plan for OWMA calls for protecting and enhancing mammal habitats and populations. Recommended management actions are to determine the occurrence and habitat functionality on the OVWMA for warm desert riparian bats, including Spotted Bats (NDOW 2014).

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