Covered Species Analysis Support –Final Report

2013-UNR-1460E

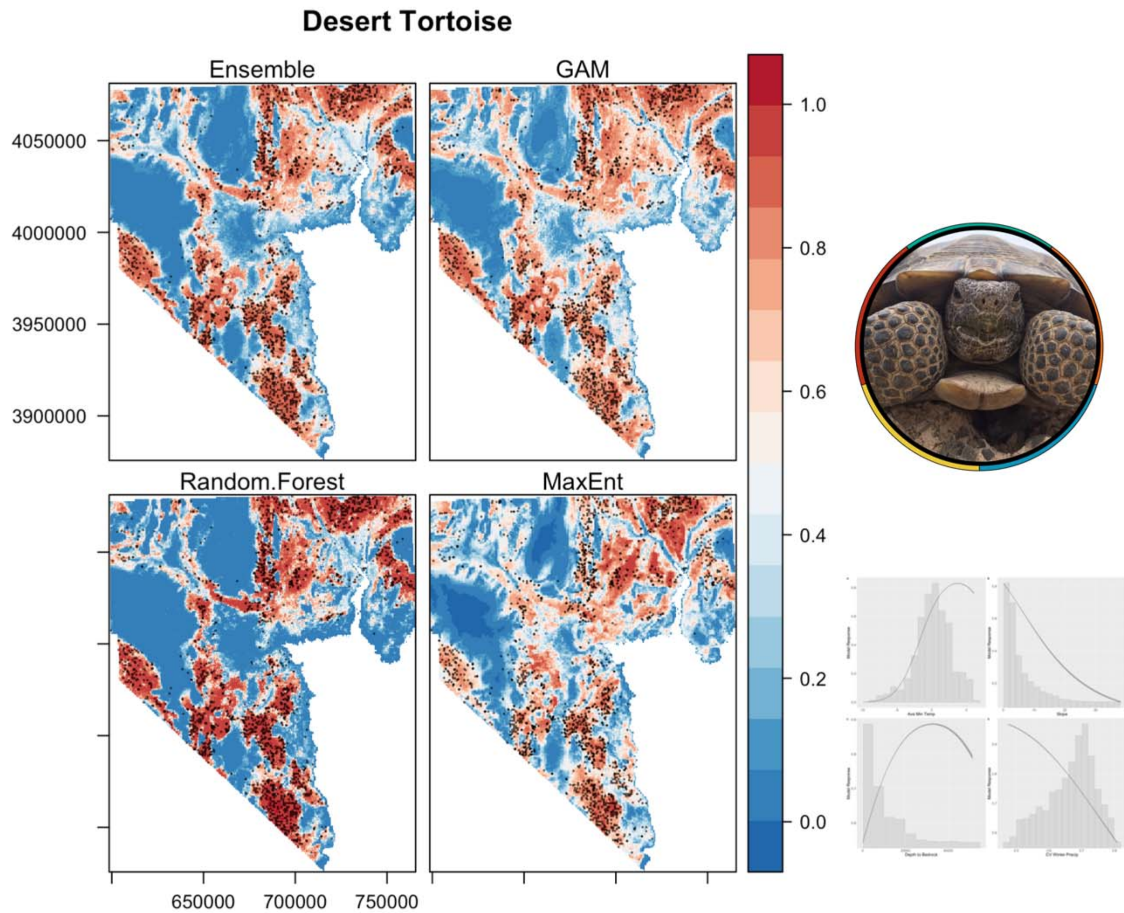

Photo by Ken Nussear

Draft Final report for 2013-UNR-1460E – Submitted to Clark County Desert Conservation Program. January 2020 by Ken Nussear, and Eric Simandle, University of Nevada, Reno

Executive Summary

Clark County is currently in the process of updating its permit with the US Fish and Wildlife Service (USFWS) to allow for continued development, while planning for the management and conservation of species of concern that reside within the county. The original Clark County Multi-Species Habitat Conservation Plan (MSHCP) included 79 Covered Species, 103 Evaluation Species, and 51 Watch List species (Clark County 2000). The goal of this project was to create habitat models for 17 species that were absent, or that had models reviewed by a previous research effort (by Southwest Ecology LLC; for which the author here was the Principal). Models were incorporated into the previous species accounts from that effort to create a cohesive product with respect to each species. Collectively, this information was in the form of 1) species accounts, which give general species information on biology, 2) status and trends, and 3) habitat considerations produced in the prior effort; and 4) species habitat models –produced under this project – to provide an understanding on the amount and extent of potential habitat for these species.

Our approach was to use the species accounts that were produced to drive conceptual models that were used to choose appropriate environmental covariates to use in building species distribution models (SDMs). We received localities for many of the species from the Clark County Desert Conservation Program (DCP), and acquired more localities from a variety of sources to allow for the most accurate modeling possible - given the data. We used three commonly used modeling algorithms to create SDMs; Maximum Entropy (MaxEnt), General Additive Models [GAM], and Random Forest [RF]. Within each of these modeling algorithms performed assessments on variable inclusion and model accuracy. We used weighted input from the best models in each algorithm to create an Ensemble model that is meant to overcome assumptions shortcomings of any one algorithm (Araujo and New 2006).

Habitat models were re-classified into predictions of High, Medium and Low suitability, and these classes were intersected with the ecosystems recognized within the county to give an approximate area of predicted habitat within each. These suitability classes were also intersected with areas to be conserved, those that may be impacted in future development, and those likely already disturbed to quantify the current and future status of conservation and potential impact to each species.

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Introduction

Habitat suitability models are frequently used as a species management tool for tasks such as the design of conservation and monitoring programs, species richness assessments, and the evaluation of potential changes in species distributions as a result of climate change and anthropogenic disturbance. (Araújo and Williams 2000, Elith et al. 2006). Species distribution models (SDMs) can be valuable tools for use in planning efforts toward the conservation of species (Johnson et al. 2004, Kremen et al. 2008, Leathwick et al. 2008). Models that include relevant information matching species needs and limitations (e.g., physiological tolerances) are more likely to accurately reflect species distributions as well as their reactions to changing conditions (Guisan et al. 2006).

For this project, species distribution models [SDMs] were created for 17 species (Table 1). Prior to modeling locality data for each species were acquired, screened, and thinned to reduce spatial biases associated with high densities of points within any location. SDMs were created using an ensemble framework which combined 50 iterations of three frequently used modeling algorithms, and creating a weighted average of the best models from each framework. Performance metrics were analyzed for randomly withheld data, and for data that were not used in modeling to provide unbiased performance metrics.

Response curves for covariate relationships were analyzed to evaluate potential drivers of SDM results, and to evaluate whether the relationships were realistic.

Methods

Species data

This report summarizes habitat distribution modelling conducted for 17 species that occur within Clark County, Nevada and are covered under the MSHCP (Table 1). 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 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 25 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]).

Table 1. Species addressed in this project.

SPECIES CODE	COMMON NAME	SCIENTIFIC NAME
ANLE	Sticky Ringstem	*Anulocaulis leiosolenus*
ARCA	Las Vegas Bearpoppy	*Arctomecon californica*
CHPE	Desert Pocket Mouse	*Chaetodipus penicillatus*
COAM	Yellow-Billed Cuckoo	*Coccyzus americanus*
COCH	Gilded Flicker	*Colaptes chrysoides*
EMTR	Southwestern Willow Flycatcher	*Empidonax traillii extimus*
ERBI	Pahrump Valley Buckwheat	*Eriogonum bifurcatum*
ERCO	Las Vegas Buckwheat	*Eriogonum corymbosum var. nilesii*
ERVI	Sticky Buckwheat	*Eriogonum viscidulum*
GOAG	Mojave Desert Tortoise	*Gopherus agassizii*
LALU	Loggerhead Shrike	*Lanius ludovicianus*
PEAL	White-margined Beardtongue	*Penstemon albomarginatus*
PHPA	Parish’s Phacelia	*Phacelia parishii*
RAOB	Ridgway's rail	*Rallus obsoletus yumanensis*
TOBE	Bendire's Thrasher	*Toxostoma bendirei*
TOLE	Le Conte's Thrasher	*Toxostoma lecontei*
VIBE	Arizona Bell's Vireo	*Vireo bellii arizonae*

Table 2. Environmental covariate names and their source.

Name	Source
Ave Max Temp	Average of the maximum monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Ave Min Temp	Average of the maximum monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Clay	Downloaded from the Soil Grids 250m project. Hengl et al. 2017
Coarse fragments	Downloaded from the Soil Grids 250m project. Hengl et al. 2017
CV Max Temp	Coefficient of Variation of the maximum monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
CV Min Temp	Coefficient of Variation of the maximum monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Dist to cliffs	Distance of Cliffs - from Inman et al. 2014
Extreme Max Temp	Extreme Maximum of monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Extreme Min Temp	Extreme Minimum of monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Flow Accum	Inman et al. 2014
NDVI Amplitude	USGS Phenology network - https://www.usgs.gov/land-resources/eros/phenology/science/deriving-phenological-metrics-ndvi?qt-science_center_objects=0#qt-science_center_objects
NDVI Length of Season	USGS Phenology network - https://www.usgs.gov/land-resources/eros/phenology/science/deriving-phenological-metrics-ndvi?qt-science_center_objects=0#qt-science_center_objects

Name	Source
NDVI Max	USGS Phenology network - https://www.usgs.gov/land-resources/eros/phenology/science/deriving-phenological-metrics-ndvi?qt-science_center_objects=0#qt-science_center_objects
Sand	Downloaded from the Soil Grids 250m project. Hengl et al. 2017
Silt	Downloaded from the Soil Grids 250m project. Hengl et al. 2017
Slope	Calculated from USGS National Map. https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map
Start of Season (day)	USGS Phenology network - https://www.usgs.gov/land-resources/eros/phenology/science/deriving-phenological-metrics-ndvi?qt-science_center_objects=0#qt-science_center_objects
Winter Precip	Average of the cumulative annual winter precipitation (October - March) for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
CV Winter Precip	Coefficient of Variation for the cumulative annual winter precipitation (October - March) for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Surface roughness	Inman et al. 2014
Average Spring Max Temp	Average of the maximum monthly temperatures for March - May for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
CV Average Spring Max Temp	Coefficient of Variation for the maximum monthly temperatures for a 30-year normal period between 1988 and 2018 calculated from monthly PRISM data at 800m resolution and downscaled to a 250 m resolution with bicubic spline interpolation using gdal-warp in python.
Percent washes	Calculated from USGS National Map. https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map
Absolute depth to bedrock	Downloaded from the Soil Grids 250m project. Hengl et al. 2017

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 *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 version 3.5.3 (R Core Team 2019).

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

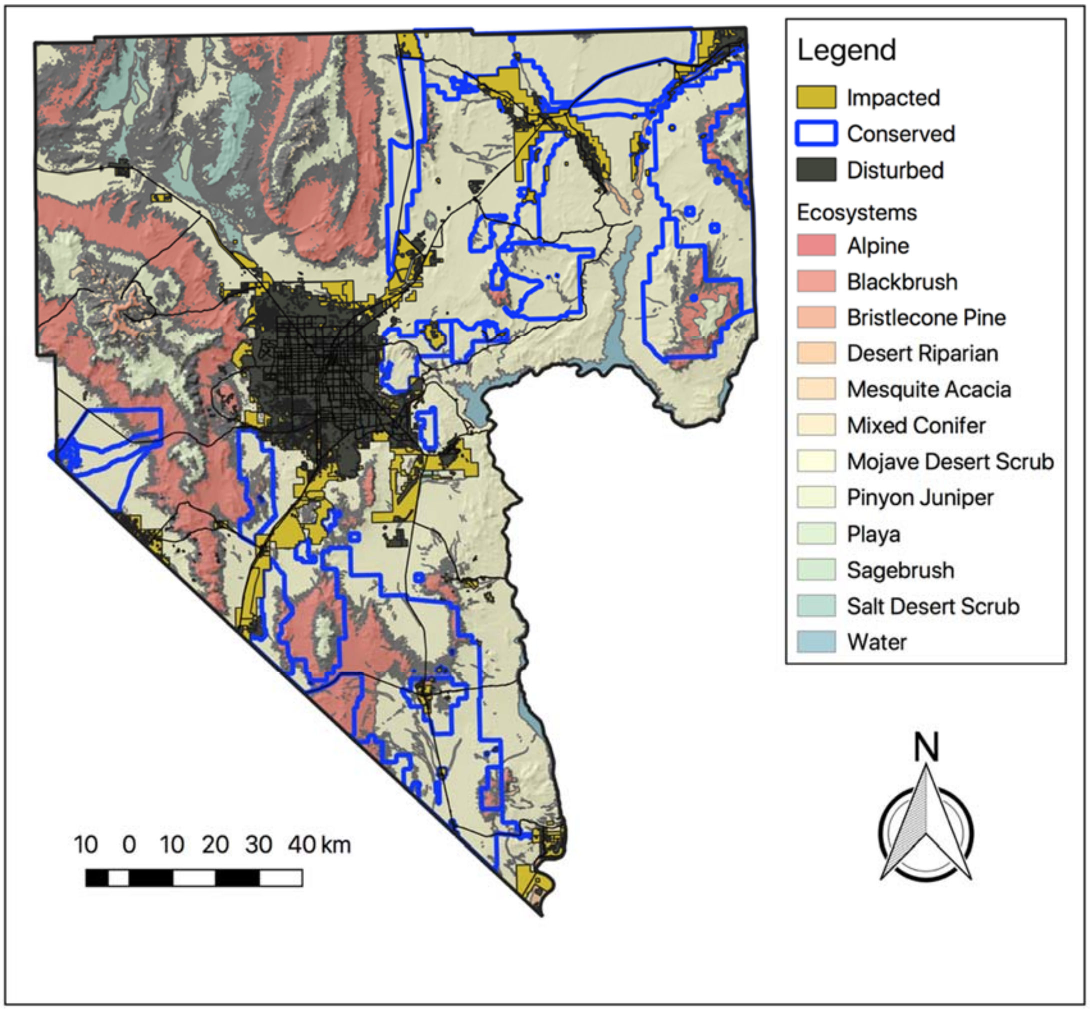
To facilitate biological interpretations of the ensemble models, we calculated the relative importance of environmental predictors across candidate models for each algorithm in biomod2.

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.

Ecosystem and Impact 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. Shapefiles provided by the Clark County Desert Conservation Program (DCP) representing Impacts, Conservation layers (ACECs etc.), and Disturbed layers (e.g. urban areas, power plants, landfills, etc.) were converted to rasters at a
as these layers had inconsistencies in topography that hindered habitat intersects. The

categorical Ecosystem raster provided by the Clark County Desert Conservation Program (DCP) developed by Heaton et al. (2011) (Intro Figure 1) 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 Impact and Ecosystem assessment layers was calculated using standard raster algebra techniques. Tables and summaries of these intersections are included in each species account.



Intro Figure 1. Disturbed areas (charcoal), and projected areas that will be impacted (mustard), conserved (blue outline), and ecosystems located within Clark County, Nevada.

Species Accounts and Distribution Models

ANLE - Sticky Ringstem (Anulocaulis leiosolenus)

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 var. *leiosolenus* had been done, but moths have been visiting flowers, and are thought be pollinators (TNC 2007). Pollinators that have been reported to visit other *A. leiosolenus* 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.

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

Range

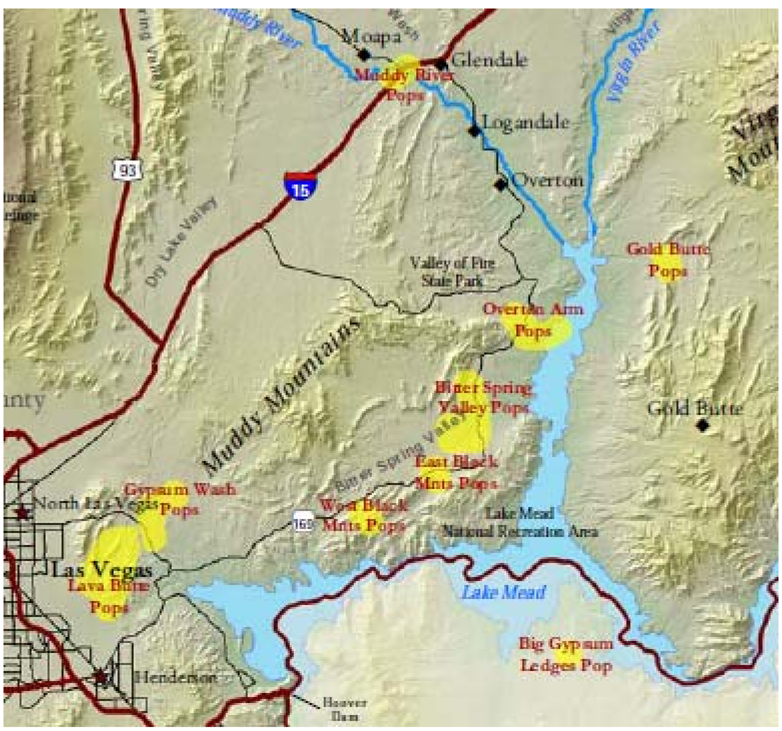
Sticky Ringstem is endemic to arid regions of the southwestern U.S and adjacent Mexico. *Anulocaulis leiosolenus* var. *leiosolenus* has the largest range out of all of the varieties of Sticky Ringstem and also occurs in extreme western Texas, south-central New Mexico, north-central Arizona, and northern 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).

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).

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 (ANLE Table 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).

Distribution and Habitat Use within Clark County

A. leiosolenus var. *leiosolenus* 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) (ANLE Figure 9, TNC 2007).

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 (ANLE Figure 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 (ANLE Table 1).

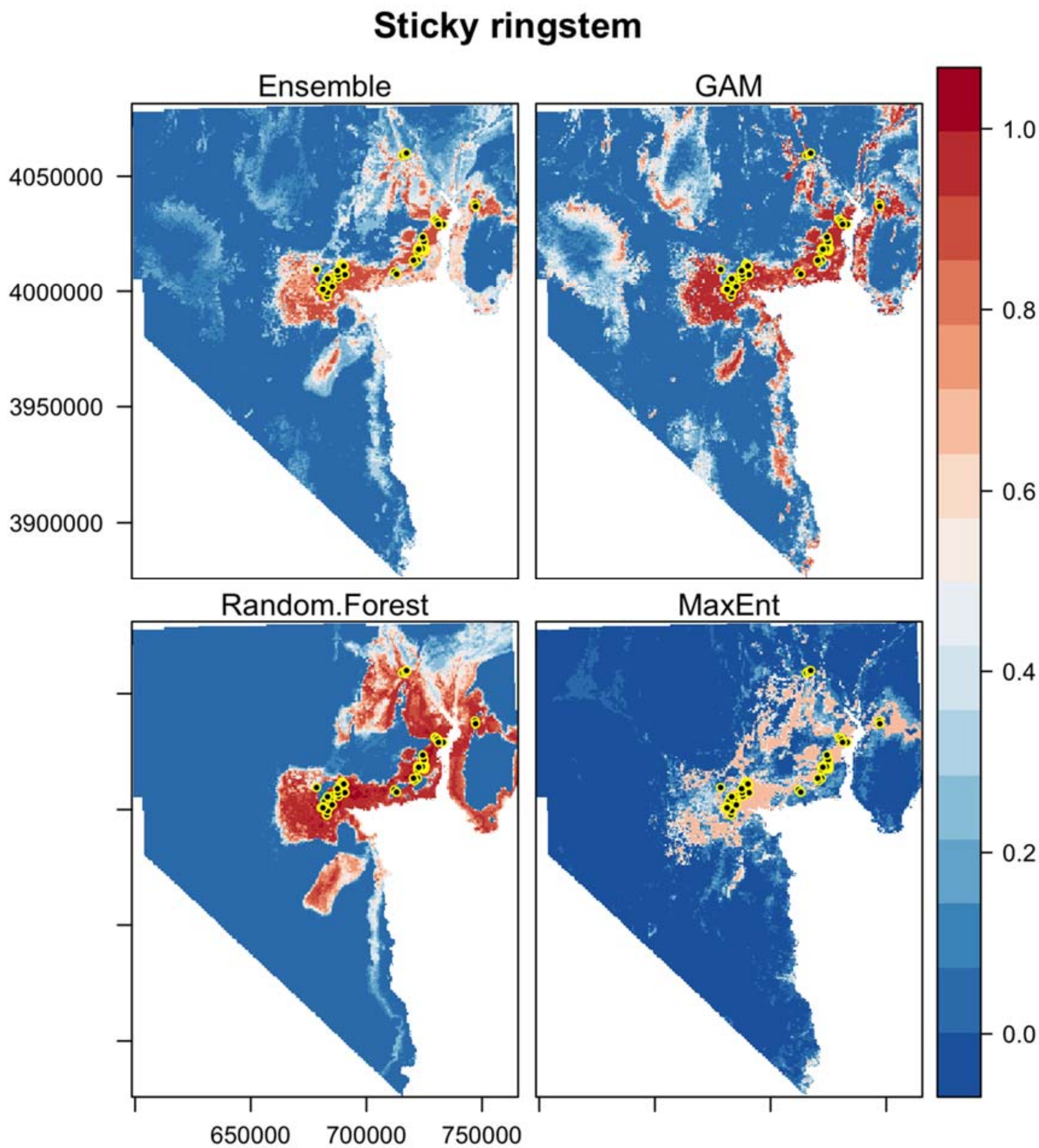
The GAM and RF models shared Average Maximum temperature as a top influential variable (ANLE Table 2). The MaxEnt and RF, models shared two of the top four influential environmental variables, where the Extreme Minimum temperature, and the Soil Gypsum Content were among the largest contributors (ANLE Table 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 (ANLE Figure 2). The Continuous Boyce Indices showed good model performance in all algorithms (ANLE Figure 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.

ANLE Table 1. Model performance values for Anulocaulis leiosolenus 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.

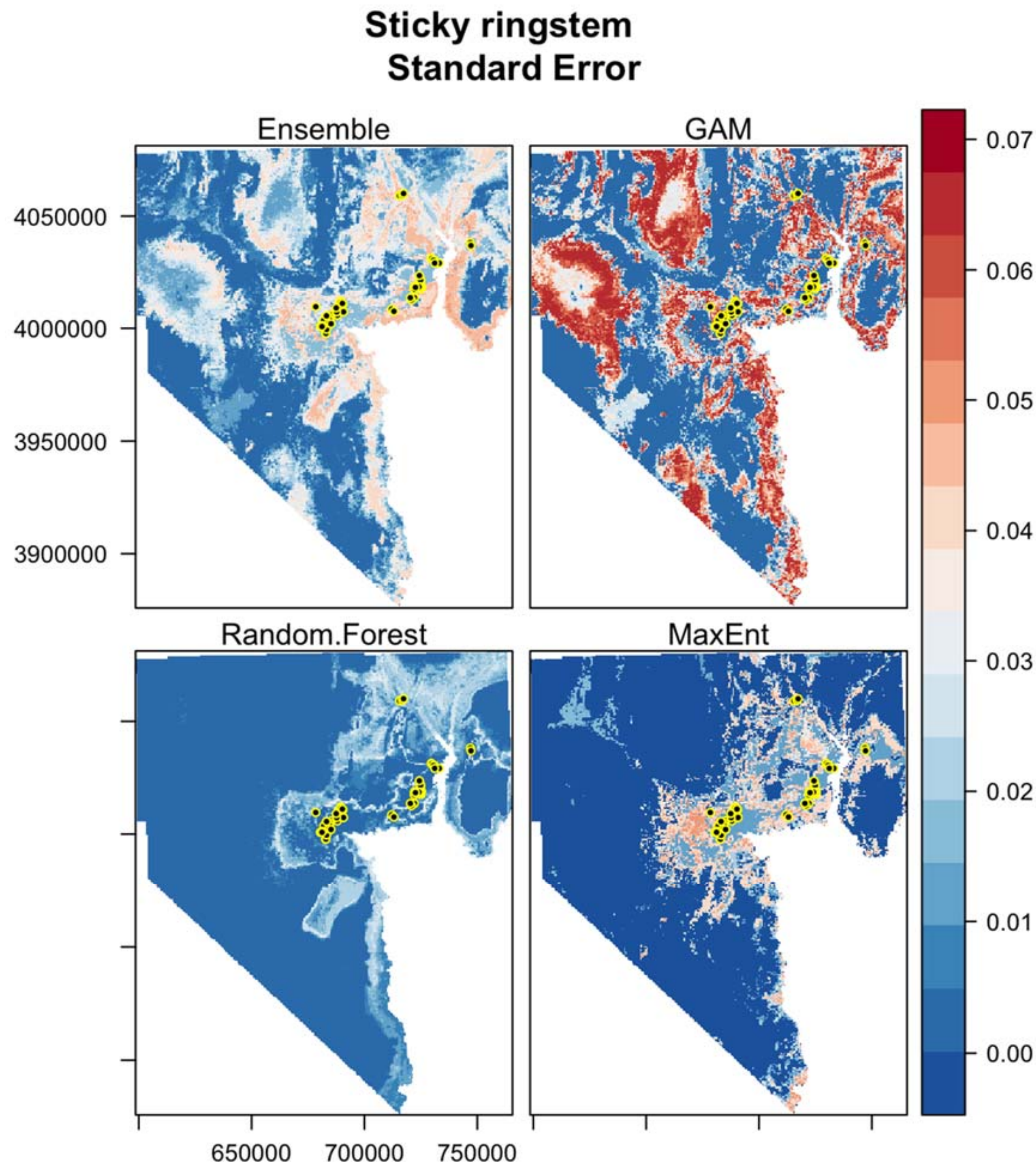
Model	AUC	BI	TSS	PRBE
Ensemble	1	0.91	1	0.37
GAM	1	0.82	1	
Random Forest	0.99	0.33	0.98	
MaxEnt	1	0.76	0.84	

ANLE Table 2. Percent contributions for input variables for *Anulocaulis leiosolenus* 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.

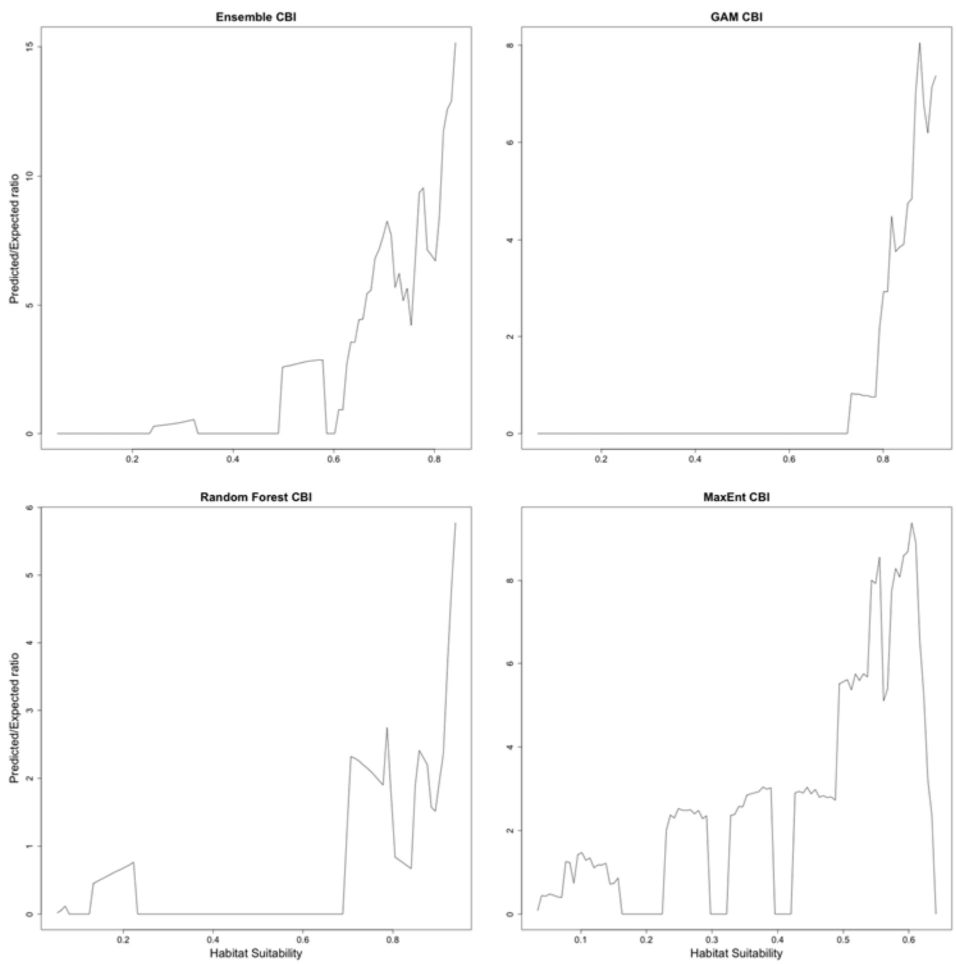
Variable	GAM	RF	MaxEnt
Ave Max Temp	21.4	11.4	0.5
Ave Min Temp	7.2	12.8	4.5
Ave Spring Max Temp	13.6	3.9	0.2
CV Ave Spring Max Temp	11.9	7.9	0
CV Max Temp	6.5	10.7	6.2
Extreme Max Temp	10.9	10.8	0.5
Extreme Min Temp	8.4	18.9	12.8
Soil gypsum	1.6	18.3	43.7
NDVI Amplitude	10.9	2.9	23.3
Silt	7.5	2.4	8.3



ANLE Figure 1. SDM maps for *Anulocaulis leiosolenus* 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.



ANLE Figure 2. Standard error maps for Anulocaulis leiosolenus 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).

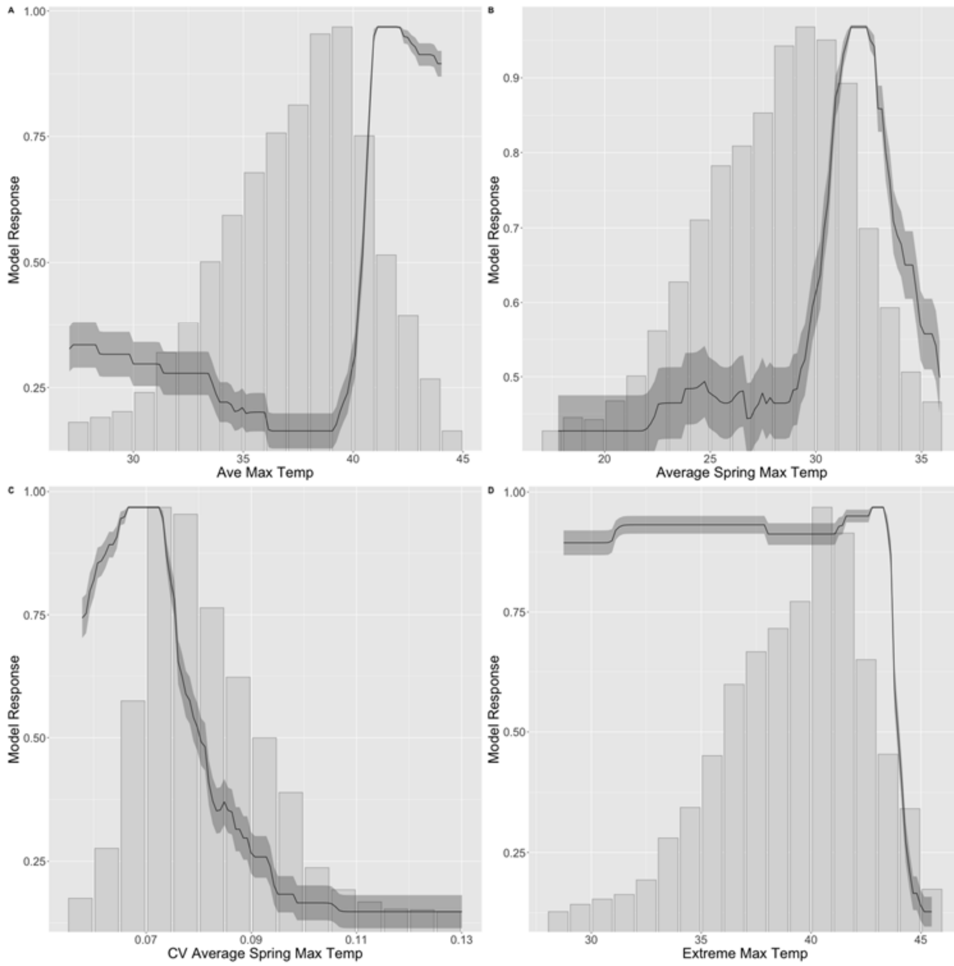


ANLE Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Anulocaulis leiosolenus* models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

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 (ANLE Table 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 (ANLE Figure 4). Model scores peaked with an Average Spring Maximum temperature of ca. 33 ºC, but habitat values decrease rapidly at higher and lower temperatures (ANLE Figure 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 (ANLE Figure 4). Model scores were consistently very high with low Average Maximum temperatures, and declines precipitously when Average Maximum temperature exceeds 44 ºC (ANLE Figure 4).

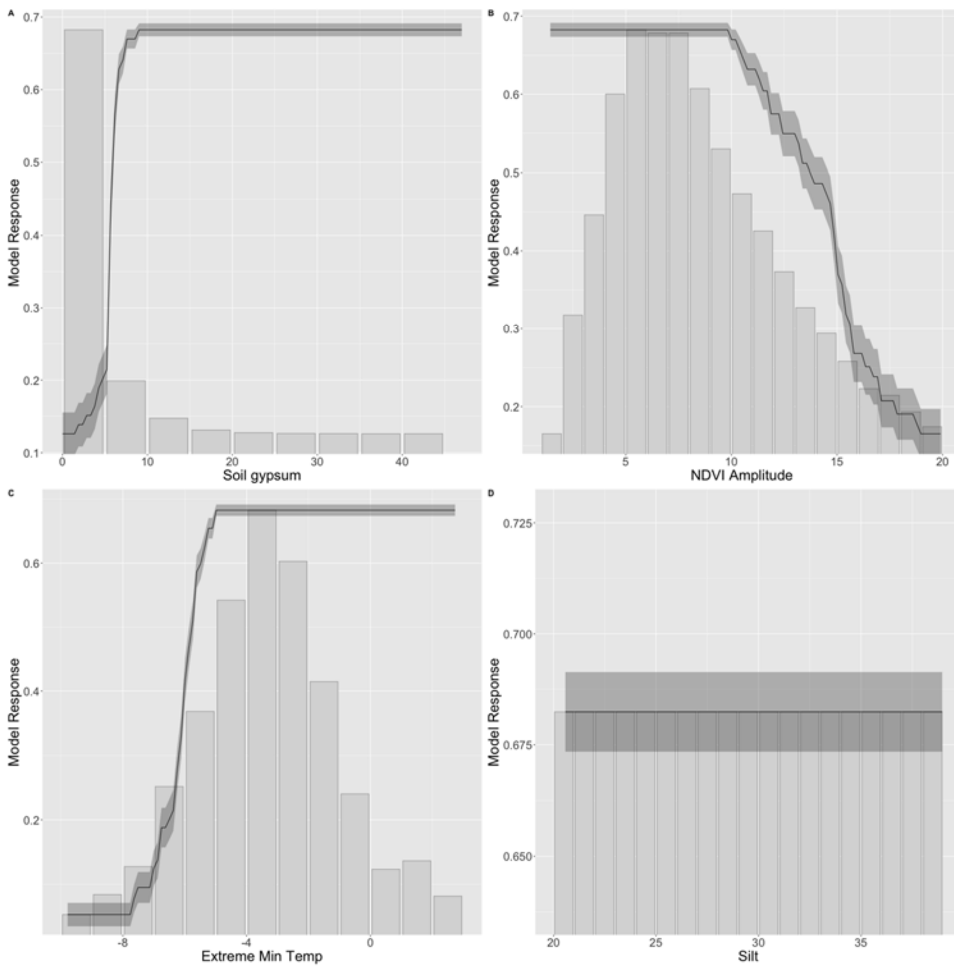
The GAM models had higher standard error values, indicating dissimilar predictions among the 50 model cross-validation runs (ANLE Figure 3).



ANLE Figure 4. GAM partial response curves for the top four variables in the *Anulocaulis leiosolenus* 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.

Maxent Model

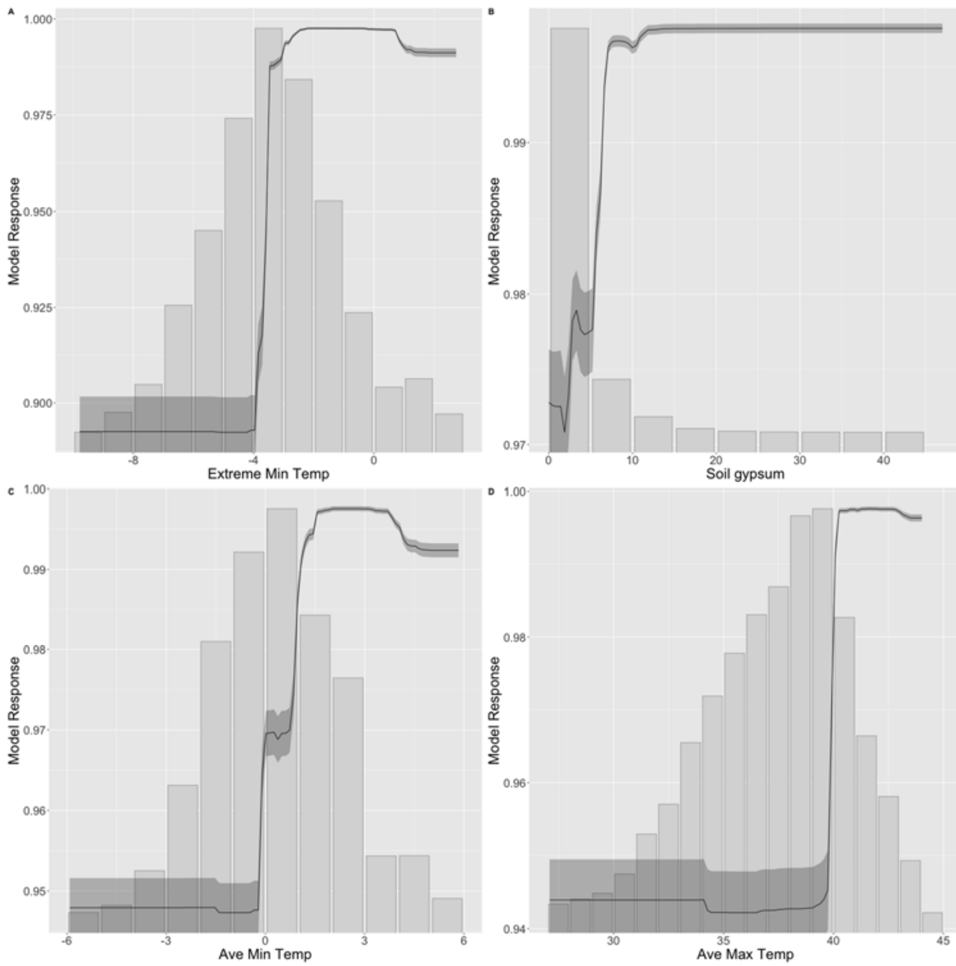
The MaxEnt models relied heavily on the two of the same four top variables as the RF models (Extreme Minimum temperature and Gypsum soil content). NDVI Amplitude, and Silt content of the soil were also an important contributor in the MaxEnt models. In total, these four variables accounted for 88.1% of total model contribution (ANLE Table 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 (ANLE Figure 5, ANLE Figure 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. (ANLE Figure 5, ANLE Figure 6). The similarity of these response curves in different algorithms indicating relatively robust model selection (ANLE Figure 5, ANLE Figure 6). The predicted response for the NDVI Amplitude showed a threshold response with suitability at high values only when NDVI Maximum was low (< 7; ANLE Figure 5, ANLE Figure 6). The Silt variable, while important in the models, did not vary significantly across the narrow range of Silt content present in the environment.



ANLE Figure 5. Partial response curves for the top environmental variables included in the Maxent ensemble model for *Anulocaulis leiosolenus.* 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.

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%; ANLE Table 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 (ANLE Figure 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 (ANLE Figure 4, ANLE Figure 6).



ANLE Figure 6. Partial response curves for the environmental variables included in the Random Forest ensemble model for *Anulocaulis leiosolenus.* 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.

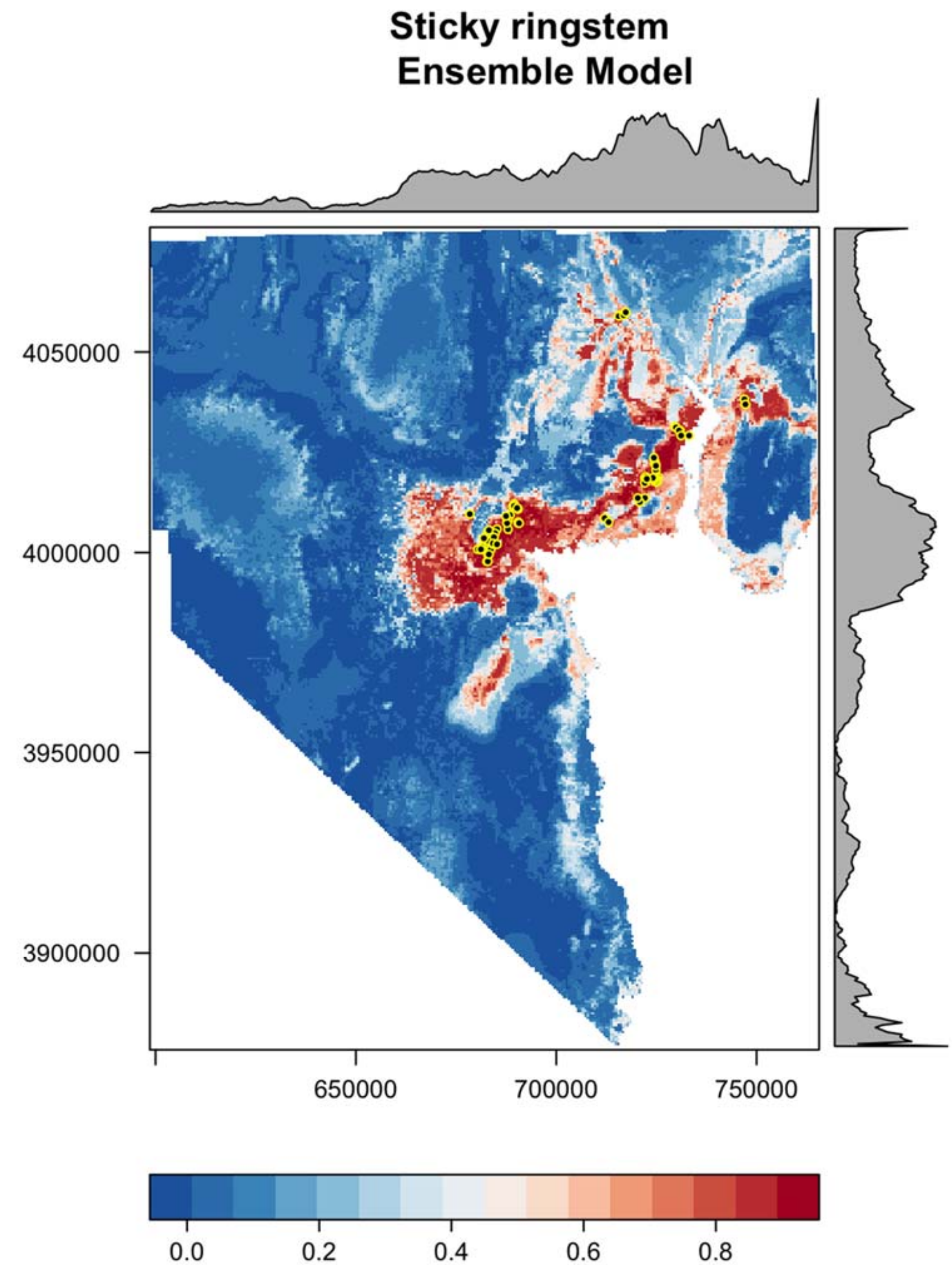
Model Discussion

Habitat for *Anulocaulis leiosolenus* 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.

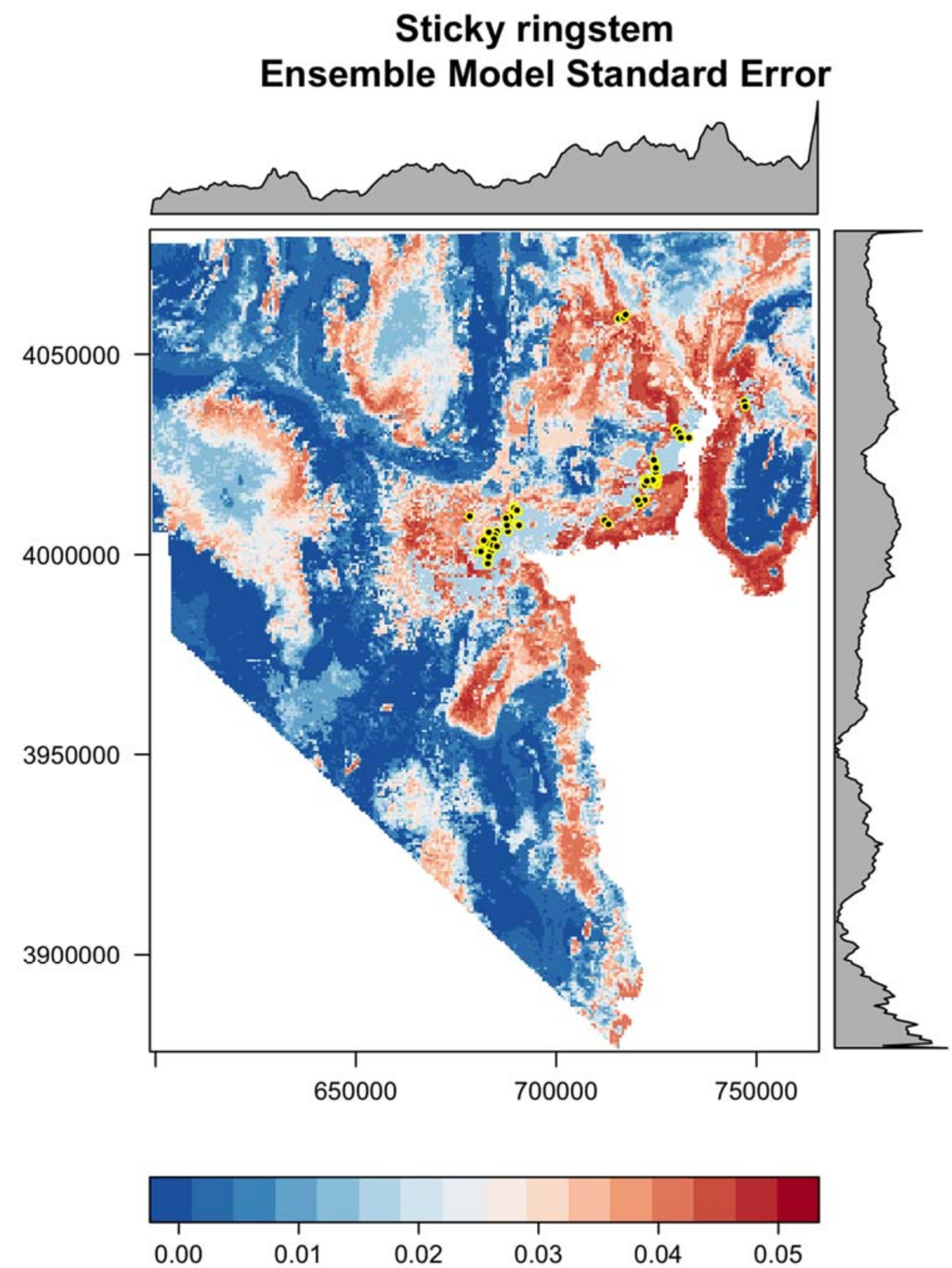
The locality data for this species consisted of 337 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 72 records.

Standard Error

The standard error map for the ensemble model indicated relatively low error (< 0.05) throughout much of the study area (ANLE Figure 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.



ANLE Figure 7. SDM map for *Anulocaulis leiosolenus* Ensemble model for Clark County, NV.



ANLE Figure 8. Standard Error map for the *Anulocaulis leiosolenus* Ensemble model for Clark County, NV.

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 (ANLE Table 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).

ANLE Table 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

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).

Existing Conservation Areas/Management Actions

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 *Anulocaulis leiosolenus* var. *leiosolenus.* 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.

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).

Summary of Direct Impacts

Because Sticky Ringstem often occurs on gypsum soils (TNC 2007, Hamilton and Kokos 2011), gypsum mining poses a direct threat, which has the potential to affect other species that occur on gypsum soil including Las Vegas Bearpoppy. Forty seven of the 1964 km^2 of predicted highly-suitable habitat is located within conservation areas. 919 km^2 of predicted highly suitable habitat is likely to be impacted by future development, while 575 km^2 are already disturbed. Collectively, 789 km^2 of high and moderate habitat will be conserved under the proposed amendment (ANLE Table 4).

ANLE Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	91937	46885	57591	196413
Med	22569	38481	21281	82331
Low	12264	428101	41557	481922

ARCA - Las Vegas Bearpoppy (Arctomecon californica)

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). *A. californica* 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.

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

Range

The Las Vegas Bearpoppy is found in Clark County, Nevada and Mohave County, Arizona (NNHP 2001). *Arctomecon californica* 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).

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).

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 (ARCA Figure 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 (ARCA Figure 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 (ARCA Table 1).

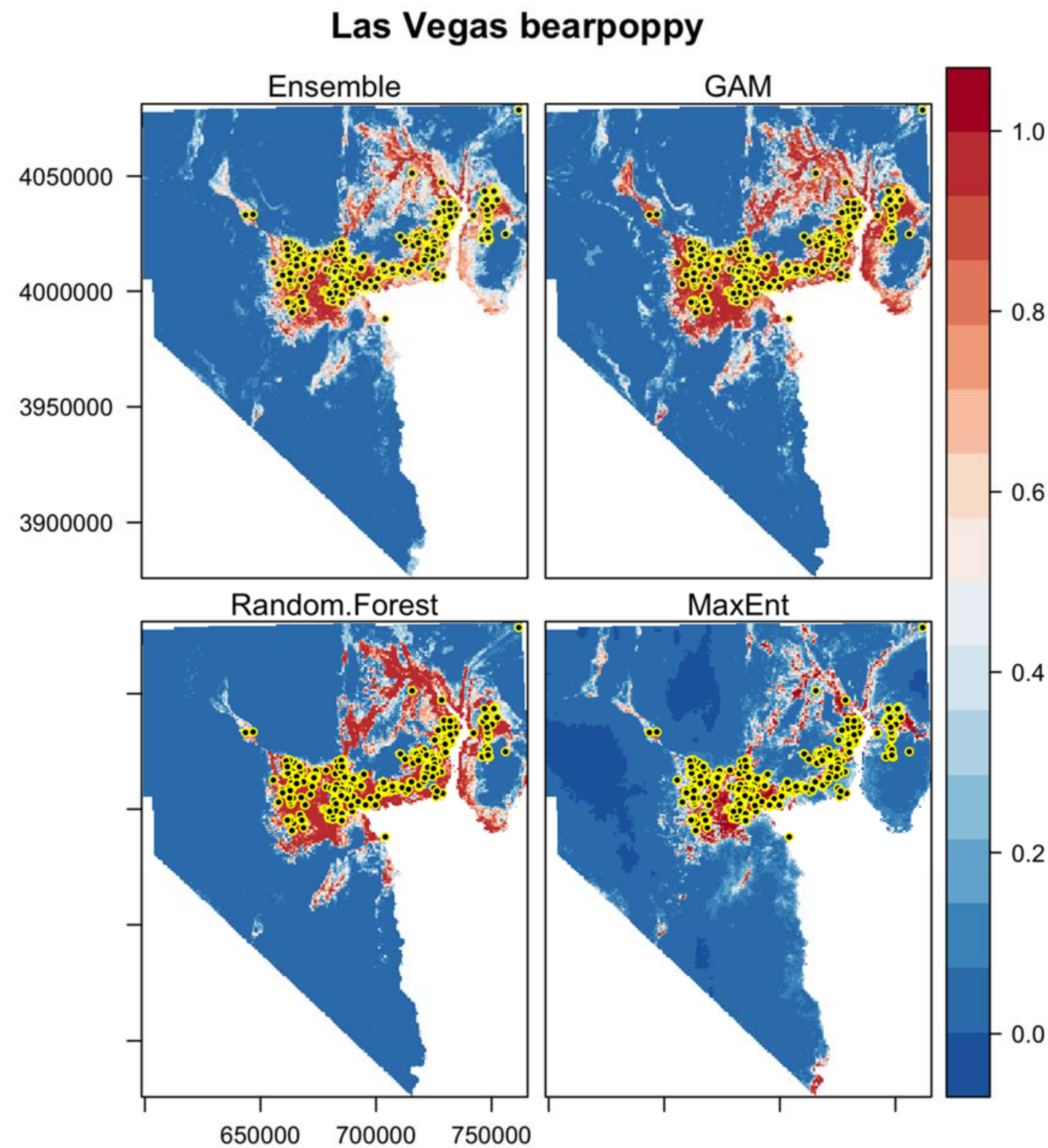
The GAM and MaxEnt models shared Average Maximum temperature, and Average Spring Maximum temperature as top influential variables (ARCA Table 2). The GAM and RF models shared two of the top four influential environmental variables, CV Average Spring Maximum temperature, and CV Winter Precipitation (ARCA Table 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 (ARCA Figure 2). The Continuous Boyce Indices showed good model performance in all algorithms (ARCA Figure 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.

ARCA Table 1. Model performance values for *Arctomecon californica* 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.

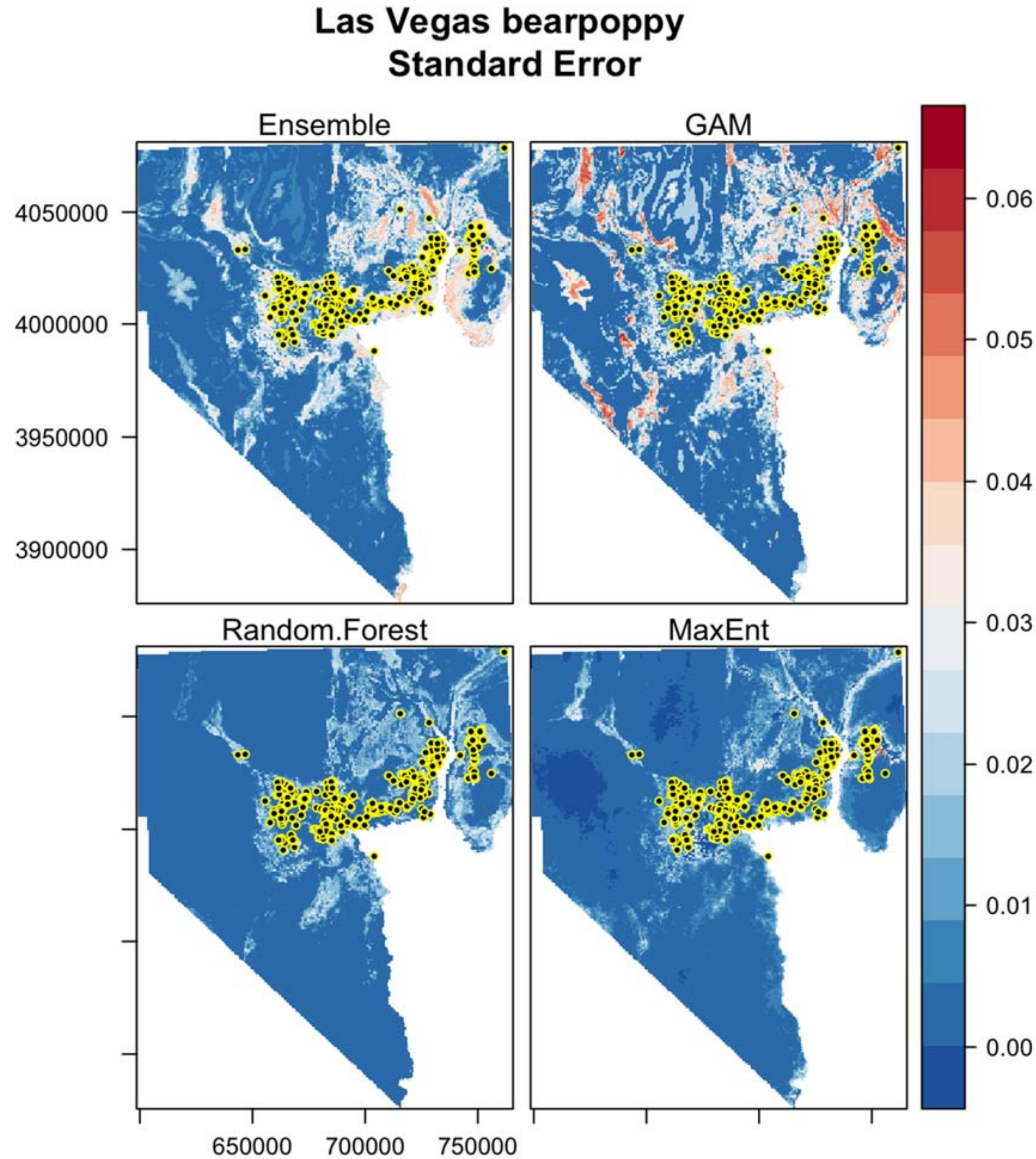
Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.97	0.86	0.54
GAM	0.96	0.92	0.86	
Random Forest	0.97	0.85	0.85	
MaxEnt	0.89	0.77	0.7	

ARCA Table 2. Percent contributions for input variables for *Arctomecon californica* 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.

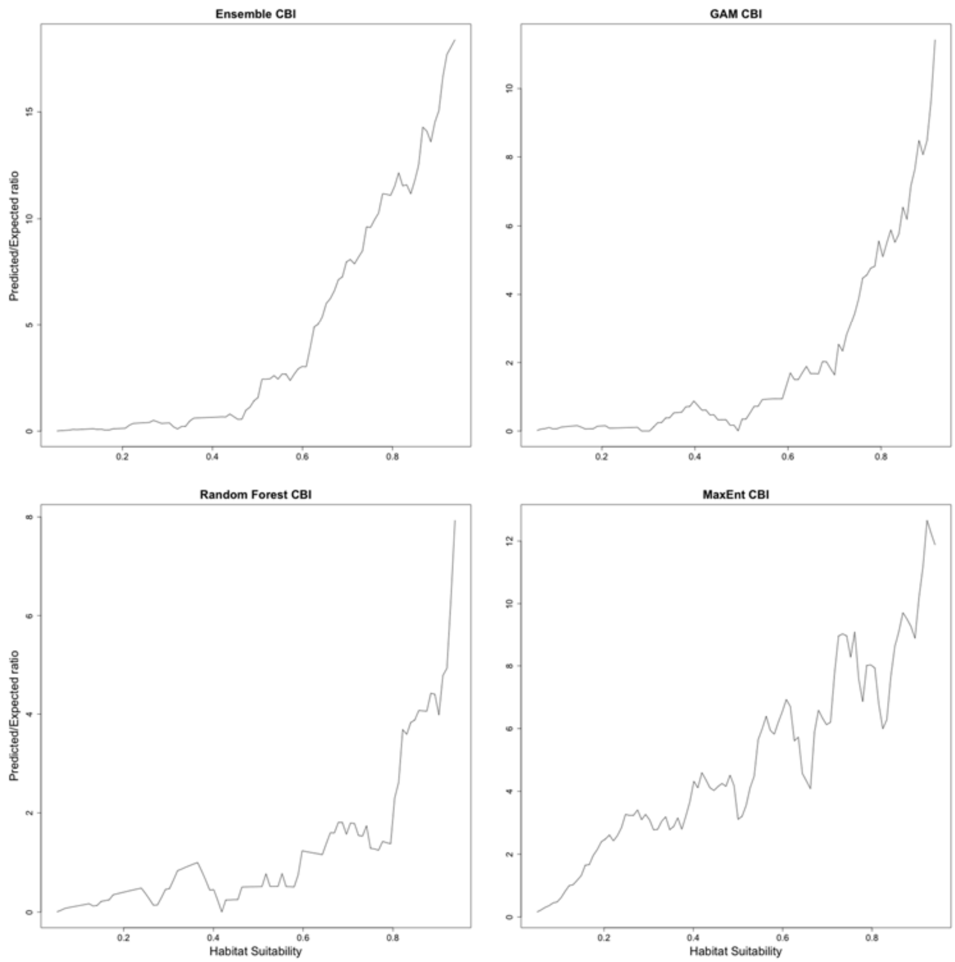
Variable	GAM	RF	MaxEnt
Ave Max Temp	31.5	2.2	21.9
Average Spring Max Temp	9.9	1.5	5
CV Average Spring Max Temp	22.9	13.6	4.5
CV Max Temp	5	12.8	1.3
Extreme Max Temp	8.6	7	0.7
Soil gypsum	3.5	11.6	34
NDVI Amplitude	2.1	10.4	23.6
Sand	5.3	13.5	4.9
Silt	1.8	2.6	3.5
CV Winter Precip	9.4	24.7	0.6



ARCA Figure 1. SDM maps for *Arctomecon californica* 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.



ARCA Figure 2. Standard error maps for Arctomecon californica 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).



ARCA Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Arctomecon californica* 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).

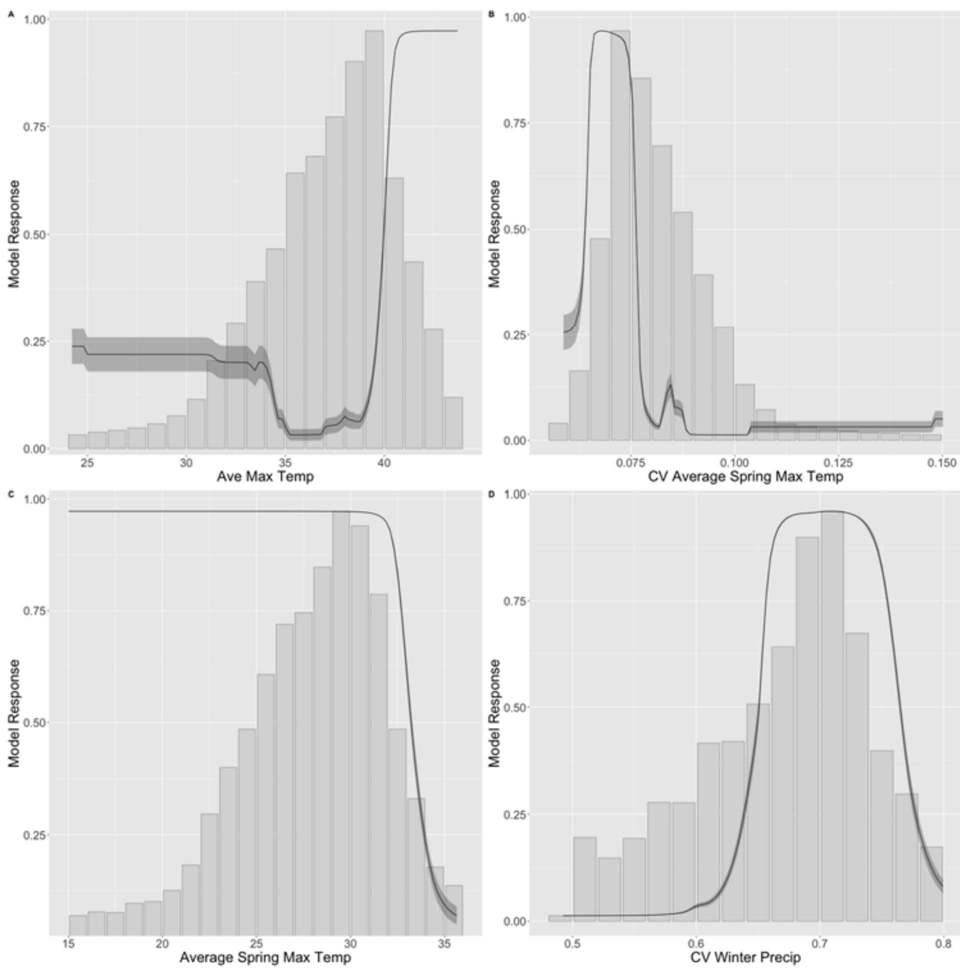
General Additive Model

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 (ARCA Table 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; ARCA Figure 4). A similar response with higher habitat values where Average Maximum temperature is high was shown by the MaxEnt model (ARCA Figure 4, ARCA Figure 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. (ARCA Figure 4). This same peak response, where CV = 0.07, is seen in the RF models (ARCA Figure 6). Model scores peaked with an Average Spring Maximum temperature of ca. 33 ºC, but habitat values decrease rapidly at higher and lower temperatures (ARCA Figure 4). Model scores were consistently very high with low Average Spring Maximum temperatures and declines precipitously when Average Maximum temperature exceeds 31 ºC (ARCA Figure 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 (ARCA Figure 5).

Habitat values for CV Winter Precipitation were very high in the range of 0.68 – 0.73 and lower at all other values (ARCA Figure 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 (ARCA Figure 4).



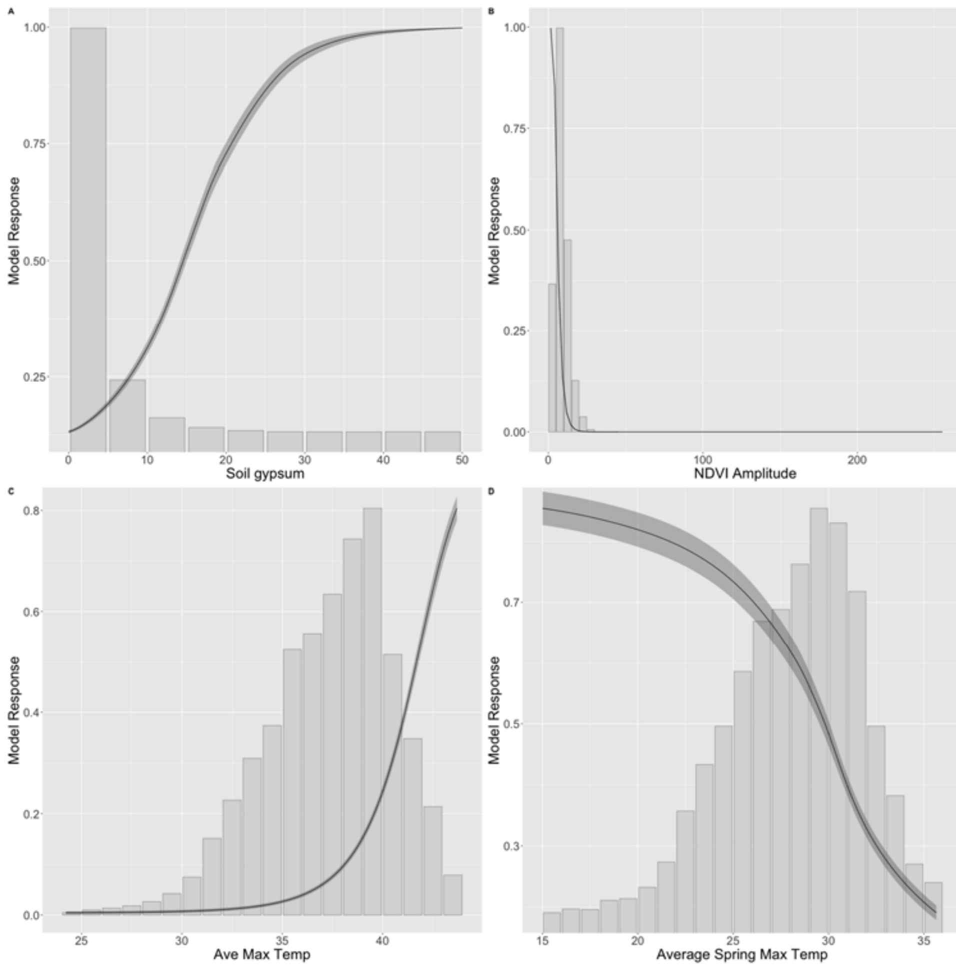
ARCA Figure 4. GAM partial response curves for the top four variables in the *Arctomecon californica* model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative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

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; ARCA Table 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 (ARCA Table 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 (ARCA Figure 4, ARCA Figure 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 % (ARCA Figure 5). The predicted response for the NDVI Amplitude showed a threshold response with suitability at high values only when NDVI Maximum was low (ARCA Figure 5).

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



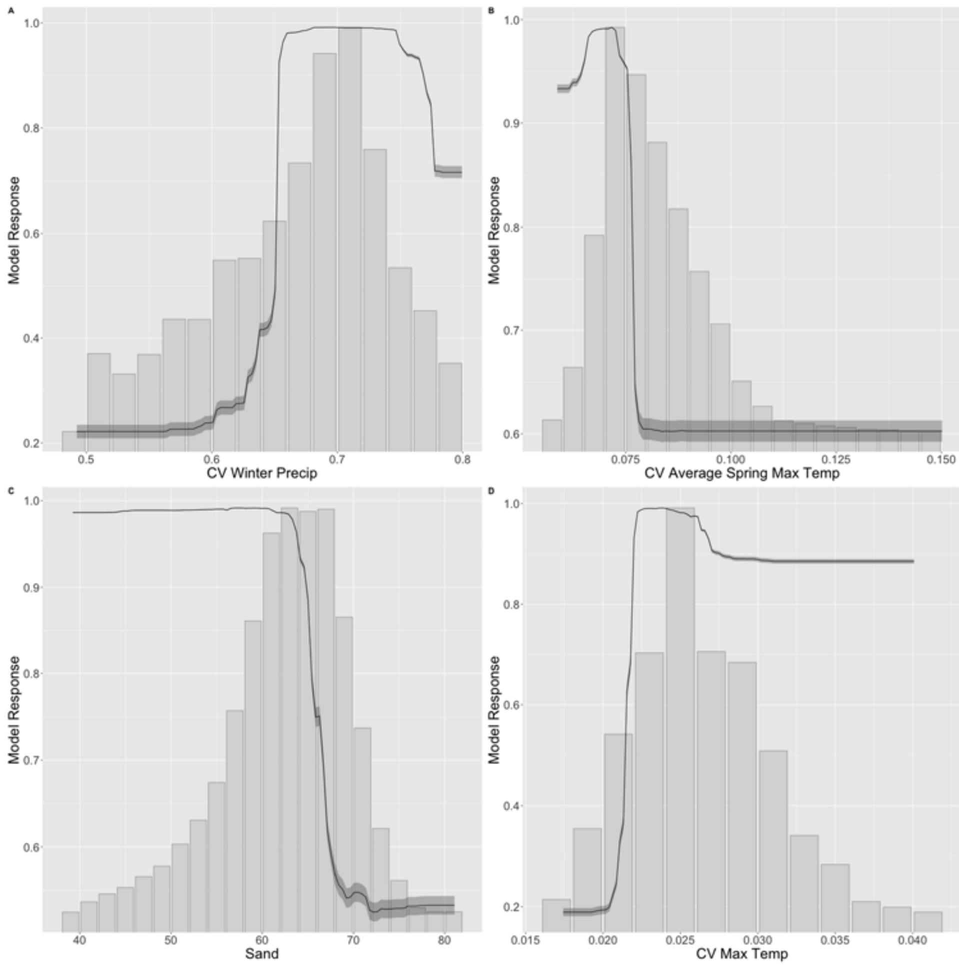
ARCA Figure 5. Partial response curves for the top environmental variables included in the MaxEnt ensemble model for *Arctomecon californica.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

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%; ARCA Table 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 (ARCA Figure 4, ARCA Figure 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 (ARCA Figure 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 (ARCA Figure 3).



ARCA Figure 6. Partial response curves for the environmental variables included in the Random Forest ensemble model for *Arctomecon californica.* 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.

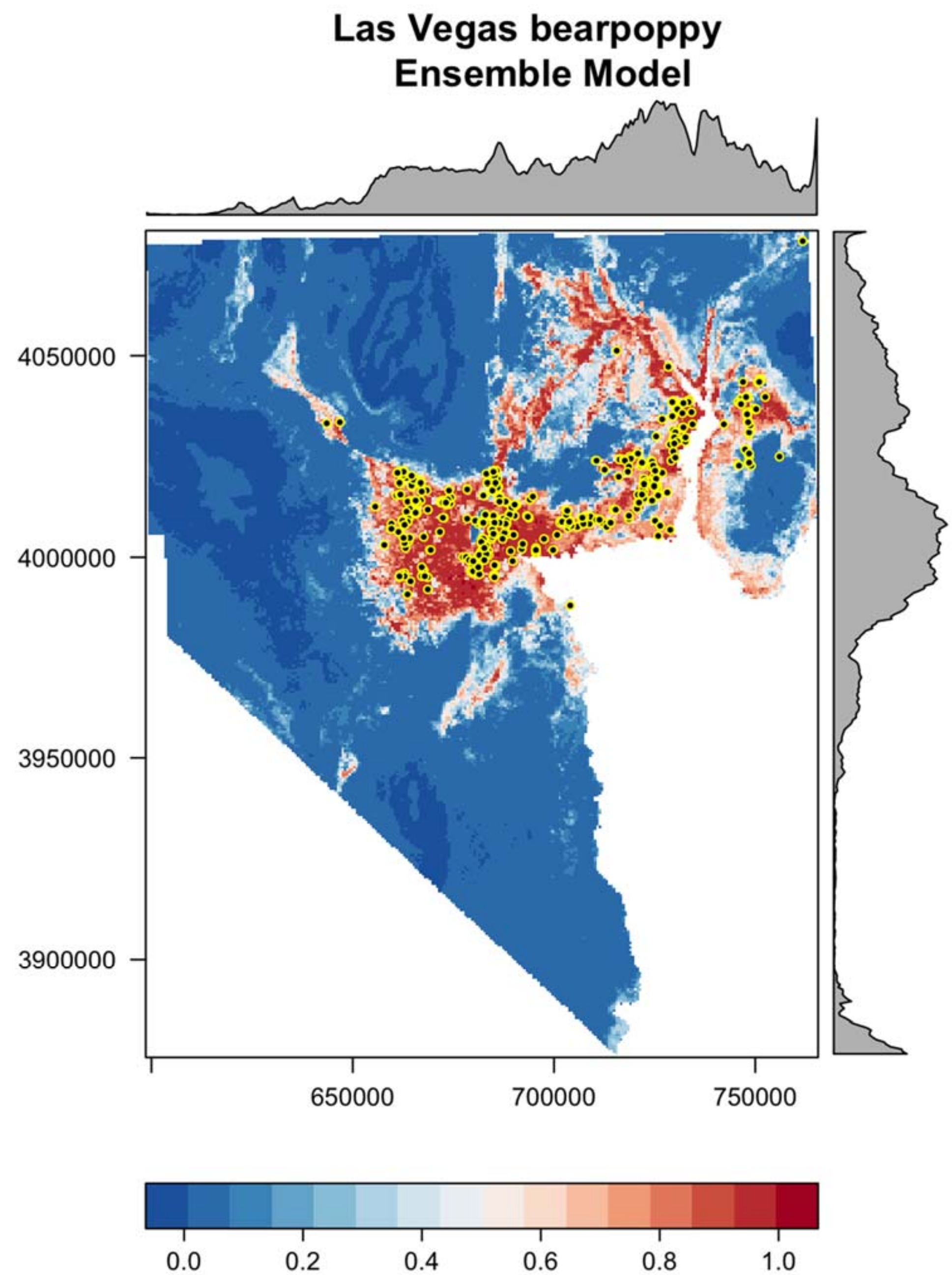
Model Discussion

Predicted habitat for *Arctomecon californica* occurs in Clark County in the areas surrounding the City of Las Vegas, as well as areas to the east and north (ARCA Figure 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.

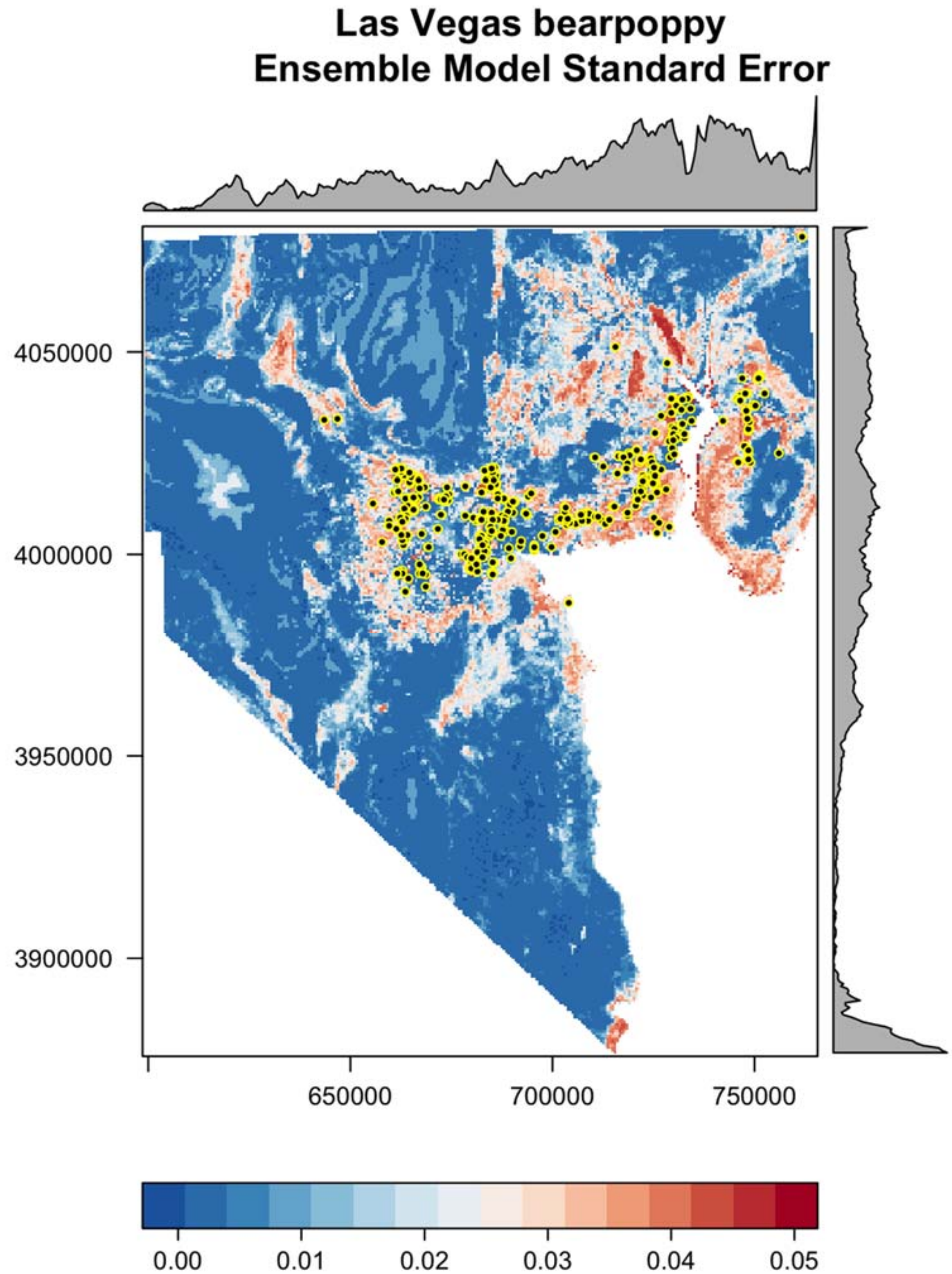
The locality data for this species consisted of 11,537 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 432 records.

Standard Error

The standard error map for the ensemble model indicated relatively low error (< 0.05) throughout much of the study area (ARCA Figure 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.



ARCA Figure 7. SDM map for *Anulocaulis leiosolenus* Ensemble model for Clark County, NV.



ARCA Figure 8. Standard Error map for the *Anulocaulis leiosolenus* Ensemble model for Clark County, NV.

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 (ARCA Table 3).

ARCA Table 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

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).

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.

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).

Summary of Direct Impacts

The habitat and extent for high suitability habitat for this species approximately 1606 km^2, of this 264 km^2 are estimated to have already been disturbed, and another 725 km^2 are estimated to be impacted. A combined 1044 km^2 of high and moderate habitat are estimated to be within the conservation areas (ARCA Table 4).

ARCA Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	72530	61717	26436	160683
Med	21215	42722	17565	81502
Low	33019	409014	76458	518491

CHPE - 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 (*Chaetodipus 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 (*Chaetodipus 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).

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): 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

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.

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).

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.

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 (CHPE Table 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 (CHPE Figure 1).

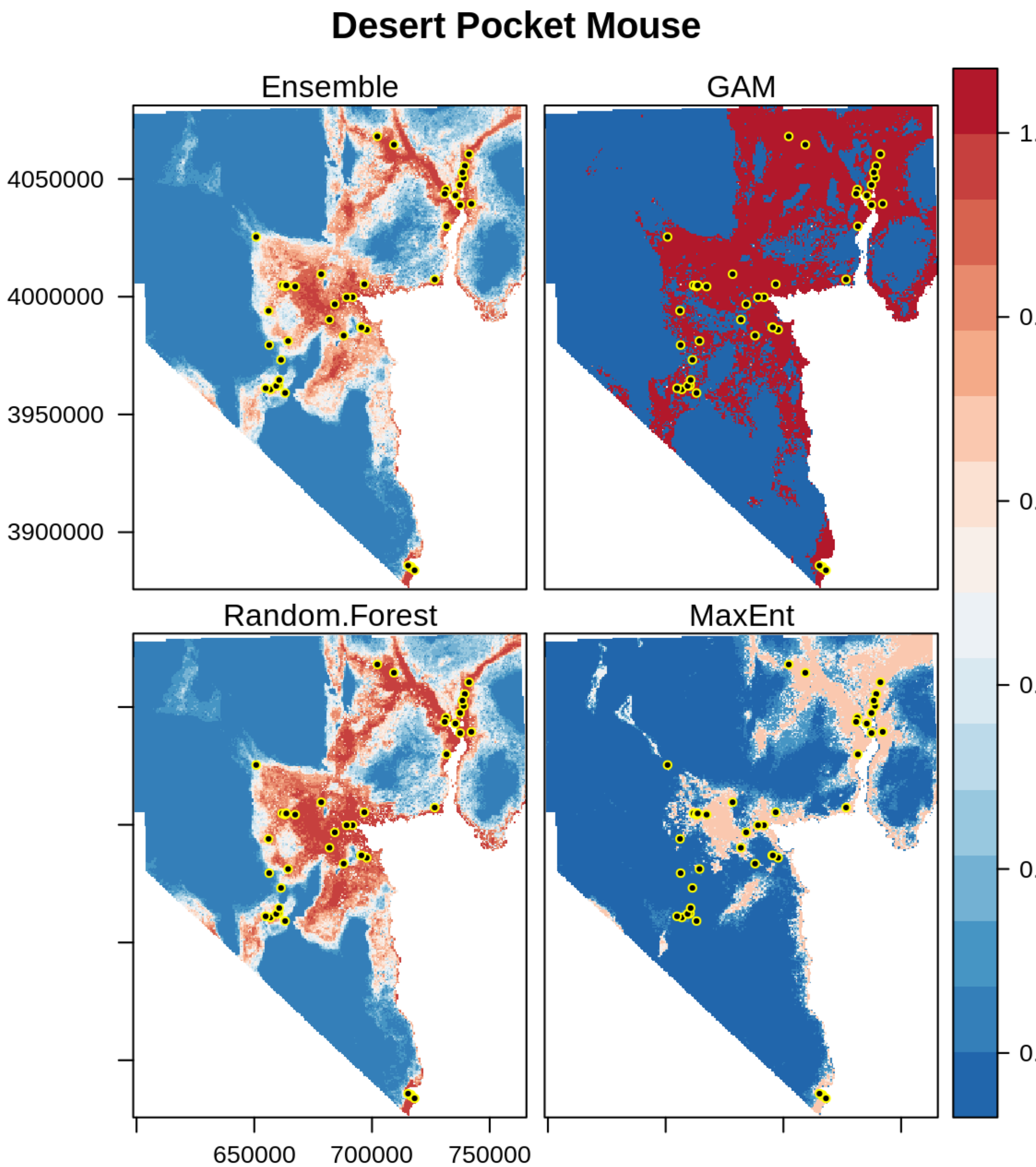
Relative variable importance highlighted the importance of Extreme Maximum temperatures, Average Maximum temperatures and Winter Precipitation for the GAM and RF models, while the MaxEnt Model shared only Extreme Maximum temperatures in its top four contributing variables (CHPE Table 2). The Standard 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 (CHPE Figure 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 (CHPE Figure 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 (CHPE Figure 3).

CHPE Table 1. Model performance values for *Chaetodipus penicillatus* 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.

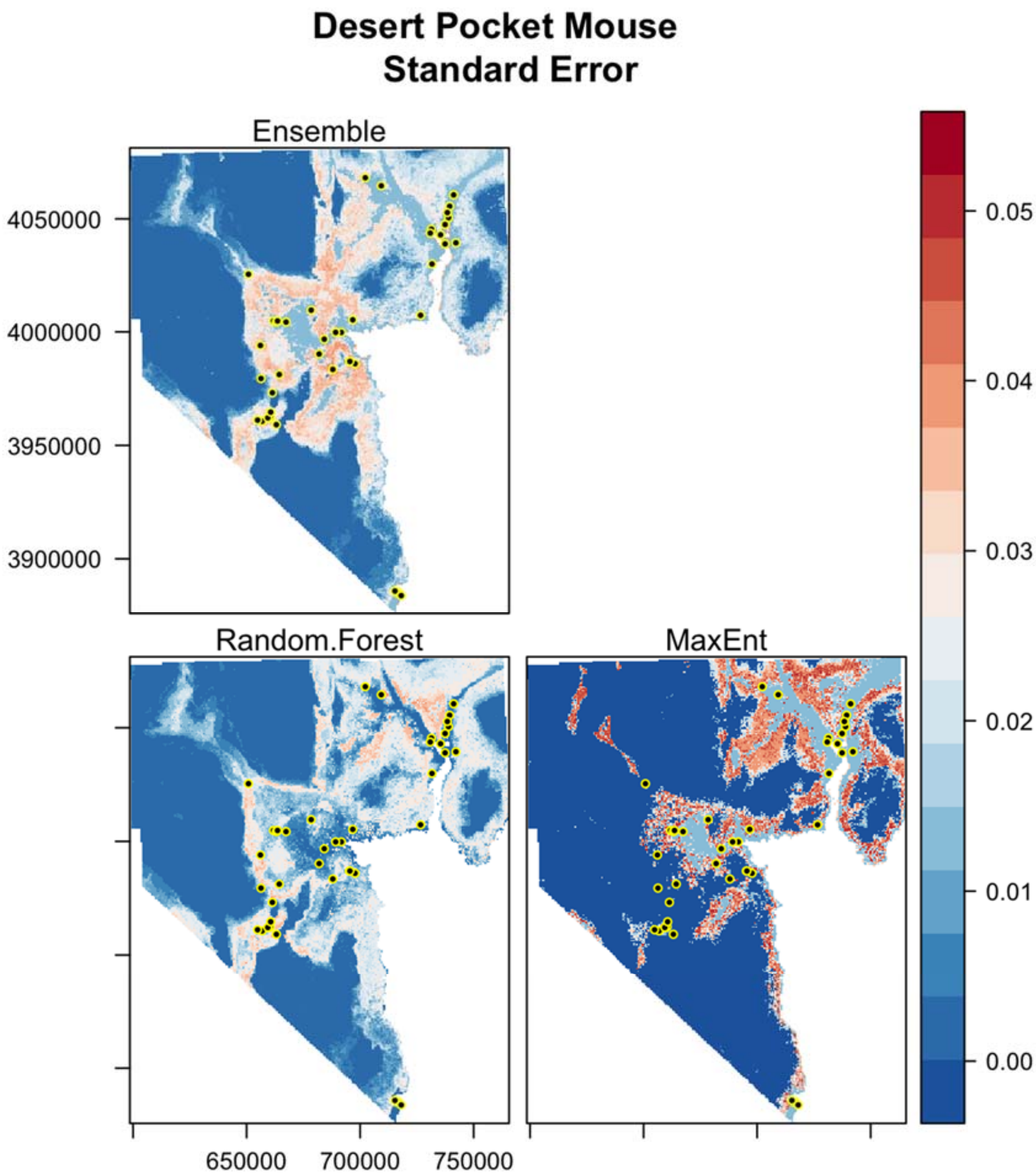
Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.87	0.85	0.39
GAM	0.69	NA	0.38	
Random Forest	0.96	0.88	0.77	
MaxEnt	0.86	0.04	0.69	

CHPE Table 2. Percent contributions for input variables for *Chaetodipus penicillatus* 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.

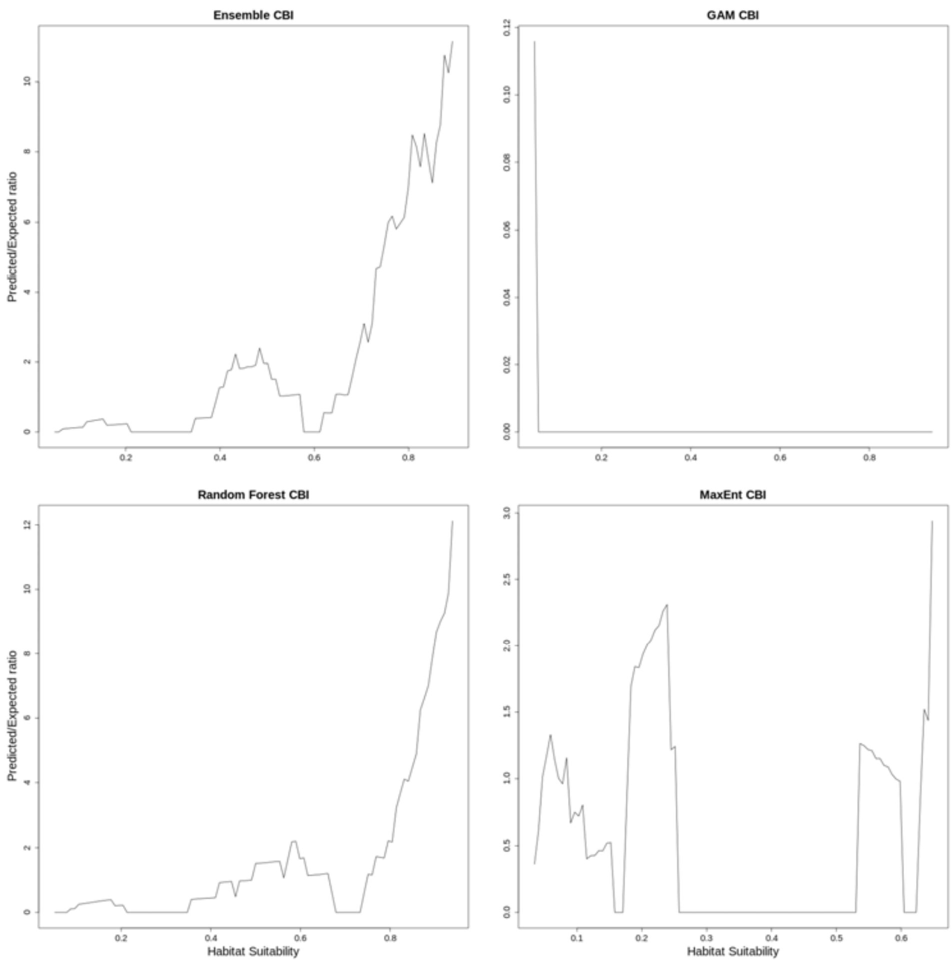
Variable	GAM	RF	MaxEnt
Extreme Max Temp	24.8	29.1	38.8
Ave Max Temp	15	18.1	2
Winter Precip	11.4	16.5	2.9
Start of Season (day)	4.6	8	10.2
PPT Clay	6.9	4.2	9.8
CV Winter Precip	10.6	7.1	9.5
PCT Coarse frags	0	4.6	6.5
Ave Min Temp	12.5	5.7	6.9
NDVI Max	4.1	1.4	9.4
PPT Silt	10	5.2	4



CHPE Figure 1. SDM maps for *Chaetodipus penicillatus* 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.



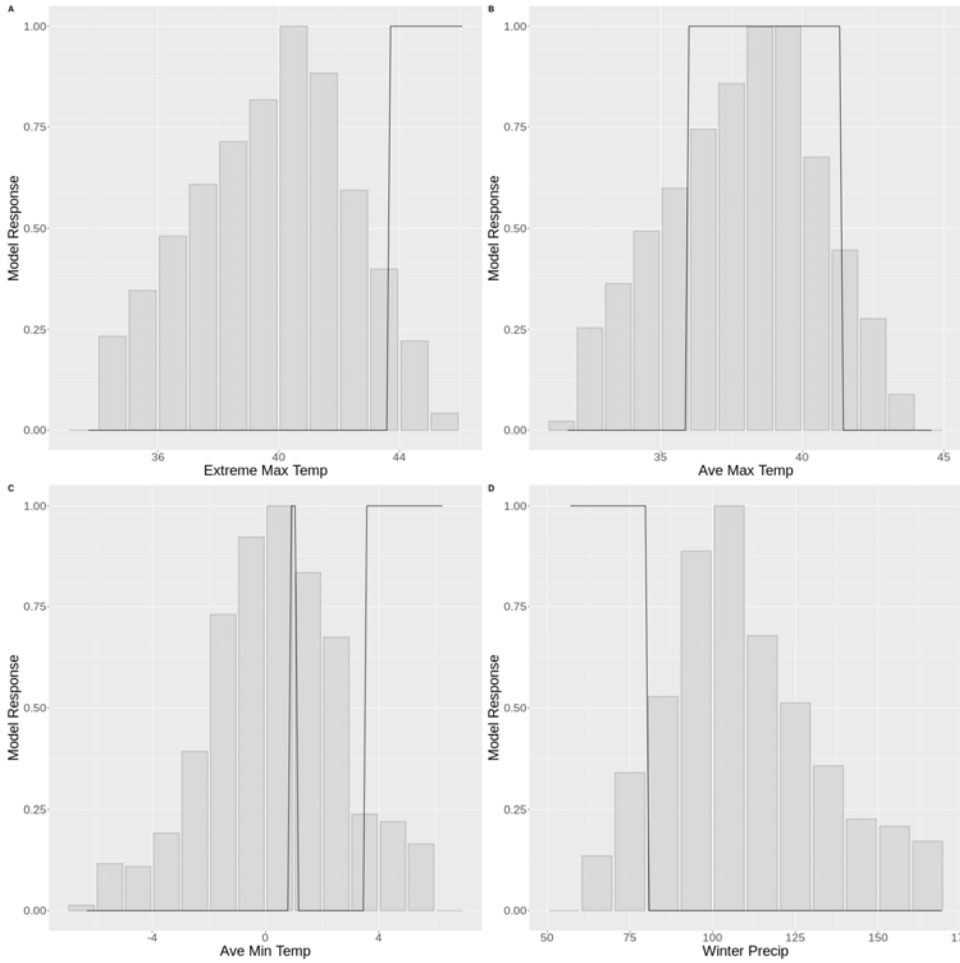
CHPE Figure 2. Standard error maps for *Chaetodipus penicillatus* models for each of the modeling algorithms used (Random Forest - lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left). The GAM algorithm could only be calculated using the combined internal and external evaluation data sets, and thus, standard error calculations were not possible.



CHPE Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Chaetodipus penicillatus* 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).

General Additive Model

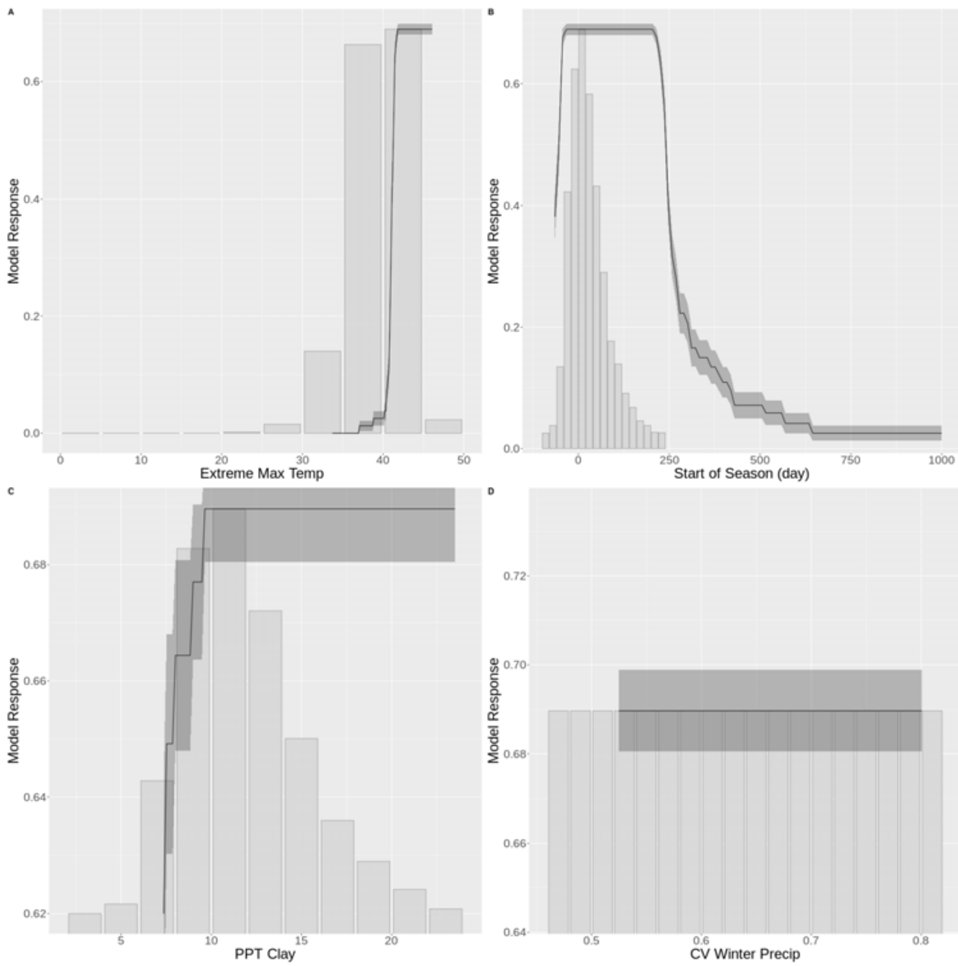
The top four contributing environmental layers were climate based metrics: Extreme and Average Maximum temperatures, Winter Precipitation, and Average Minimum temperature (CHPE Table 2). Model scores were higher in areas with higher Extreme Maximum temperatures, but with Average Maximum temperatures consistent with that available in the habitat (CHPE Figure 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 (CHPE Figure 4). This algorithm could only be calculated using the combined internal and external evaluation data sets and thus standard error calculations were not possible.



CHPE Figure 4. GAM partial response curves for the top four variables in the *Chaetodipus penicillatus* 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.

MaxEnt Model

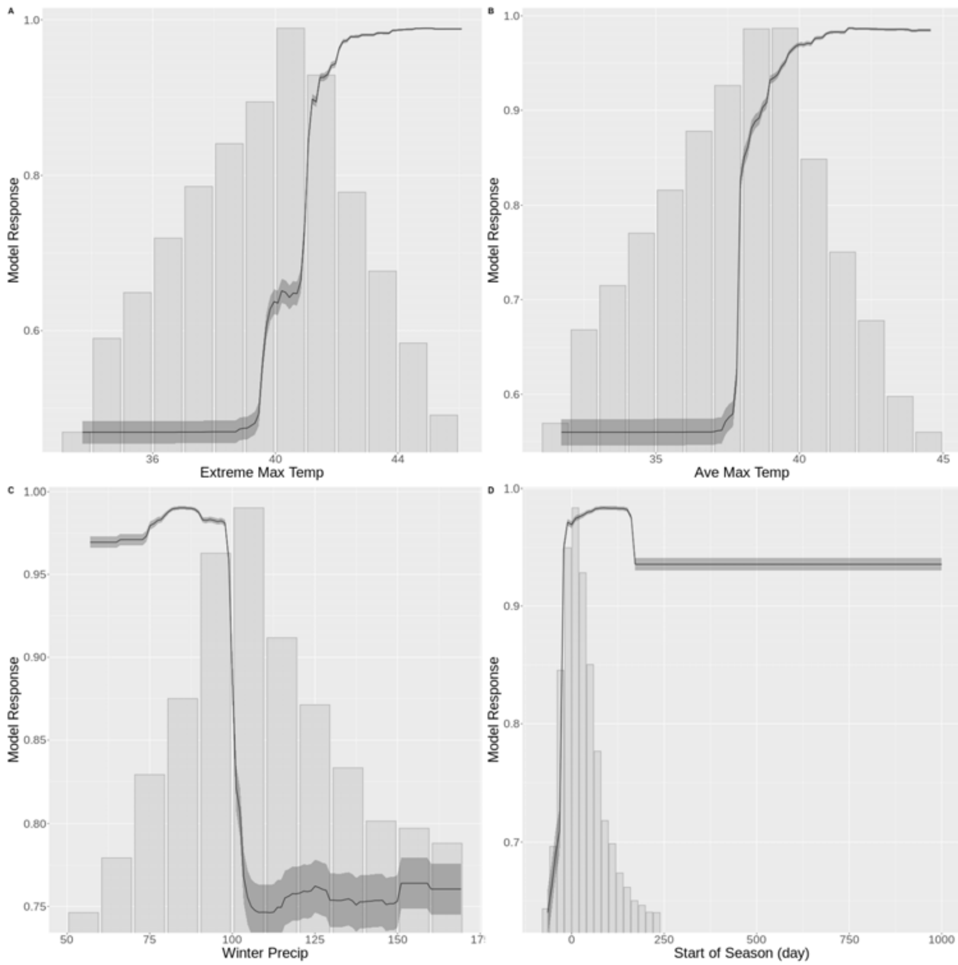
The MaxEnt models were most influenced by Extreme Maximum temperature (39% contribution alone), followed by the Start of Season, Soil Clay content and the CV of Winter Precipitation. Response curves for these variables indicated higher habitat values predicted in areas with higher Maximum temperatures, as a thresholded response (CHPE Figure 5) as was seen in the GAM model (CHPE Figure 4) and Random Forest models (CHPE Figure 6 below). The relationship with Winter Precipitation variability did not have a discernable trend. Model performance was relatively poor for these models (CHPE Figures 1-3), however habitat predicted was largely restricted to the watershed areas of the Muddy and Virgin rivers, and the Las Vegas wash (CHPE Figure 1). Localities along the I-15 corridor were not afforded predicted habitat.



CHPE Figure 5. Response surfaces for the top environmental variables included in the MaxEnt ensemble model for *Chaetodipus penicillatus.* 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.

Random Forest Model

The Random Forest model for this species had three of the top four input variables as the GAM models (CHPE Table 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 (CHPE Figure 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 (CHPE Table 1) as well as the Continuous Boyce plots indicated high model performance (CHPE Figure 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 (CHPE Figure 2).



CHPE Figure 6. Partial response surfaces for the environmental variables included in the Random Forest ensemble model for *Chaetodipus penicillatus.* 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.

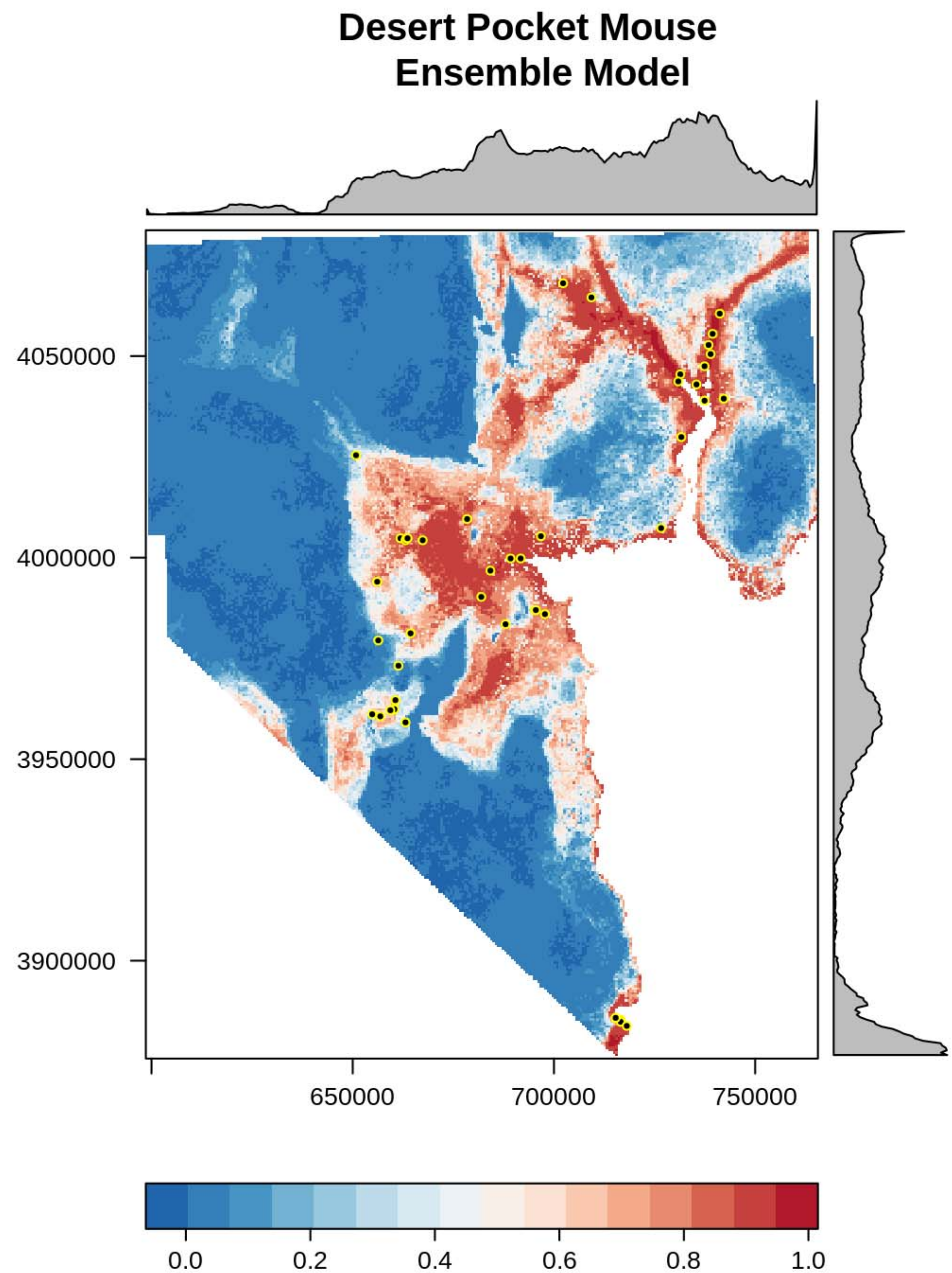
Model Discussion

Chaetodipus penicillatus 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 (CHPE Figure 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 (CHPE Figure 7).

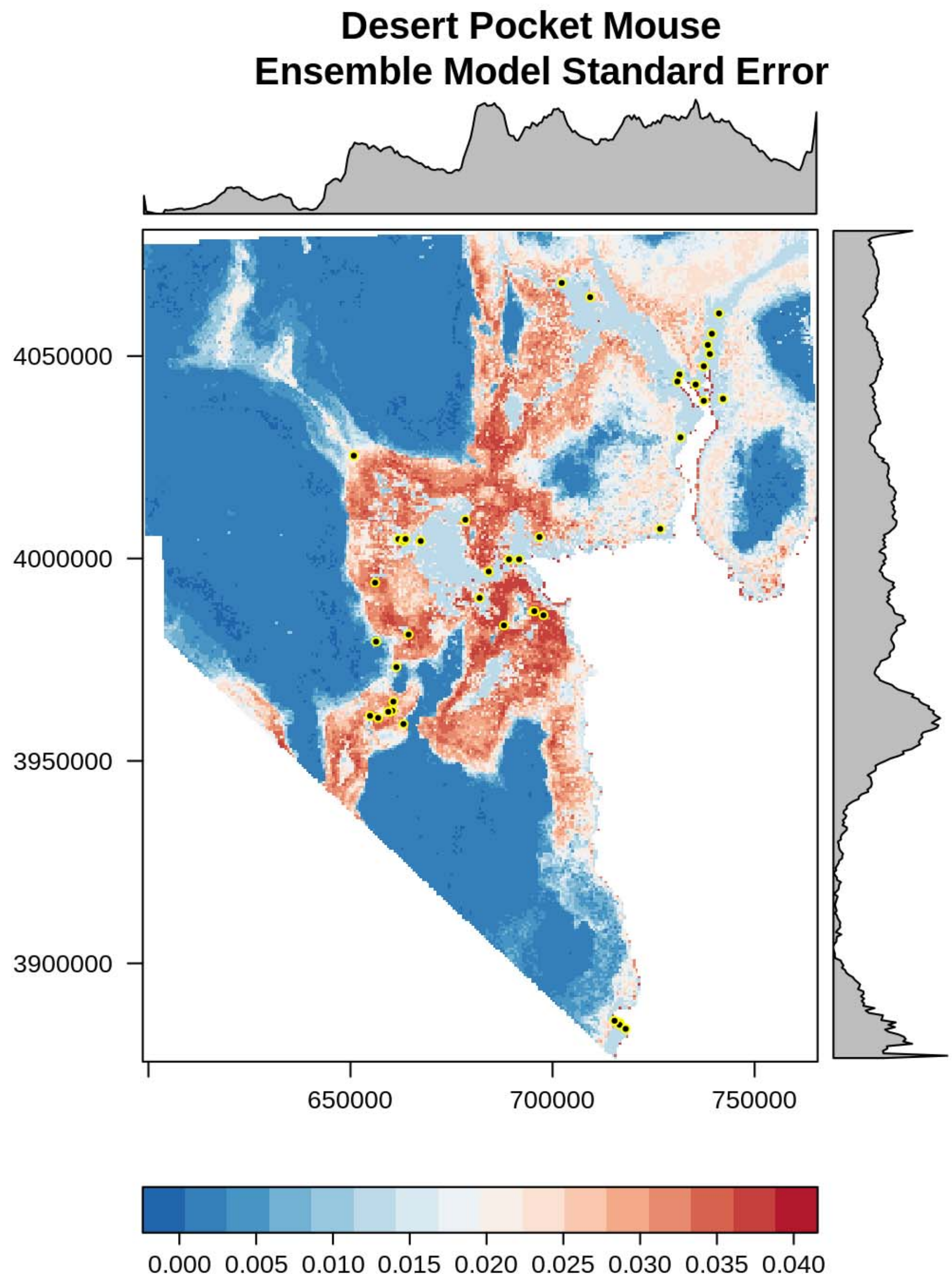
The locality data for this species consisted of 117 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data to lessen sample bias, and removal of duplicates reduced the number of localities used for training and testing to 66 records.

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 (CHPE Figure 8).



CHPE Figure 7. SDM map for *Chaetodipus penicillatus* Ensemble model.



CHPE Figure 8. Standard Error map for the *Chaetodipus penicillatus* Ensemble model for Clark County, NV.

Distribution and Habitat Use within Clark County

Chaetodipus penicillatus sobrinus 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 (CHPE Table 3).

CHPE Table 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

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).

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).

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).

Summary of Direct Impacts

The Desert Pocket Mouse is a moderately common to rare year-round resident of Clark County. Approximately 2008 km^2 of high suitability modeled habitat occurs within the county (CHPE Table 4). Approximately 33% of this may be impacted by proposed development, and 24% is located within proposed conservation areas (CHPE Table 4).

CHPE Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	66563	47941	86349	200853
Med	35479	79626	28810	143915
Low	24373	385641	5214	415228

COAM - Yellow-Billed Cuckoo (Coccyzus americanus)

The Yellow-Billed Cuckoo 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. *Coccyzus americanus* 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 *C. americanus* 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 *C. americanus* 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).

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

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.

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).

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 (COAM Figure 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 (COAM Table 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 (COAM Figure 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. (COAM Figure 2). This was associated with some of the lower level habitat scores evident in the MaxEnt predictive map (COAM Figure 1).

The GAM and Random Forest models had very similar performance metrics to one another (COAM Table 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 (COAM Figure 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 (COAM Table 2).

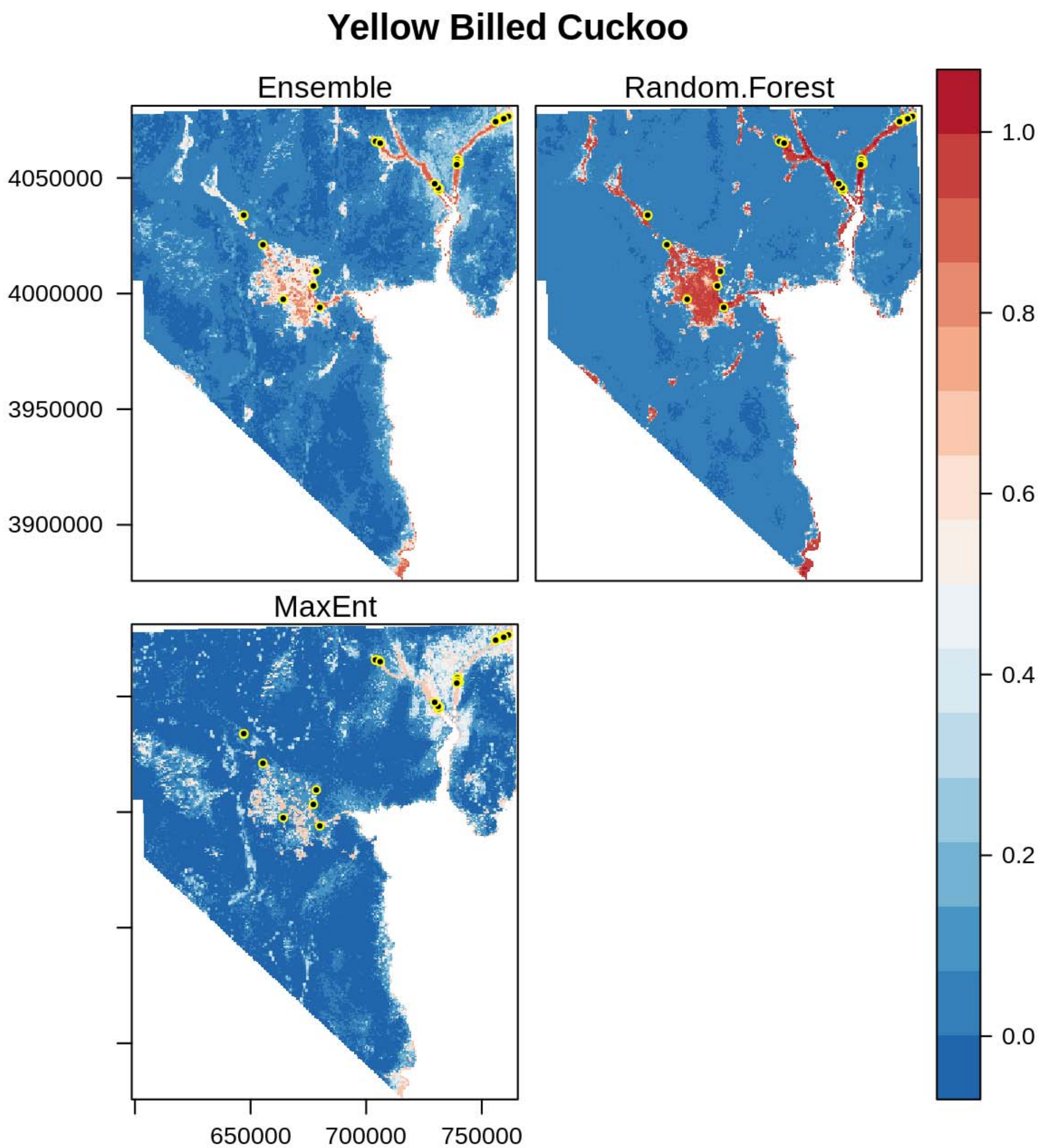
The Continuous Boyce Indices showed some irregularities, especially in the MaxEnt models, where there was a peak at the lower end of habitat suitability where there was increased prevalence (COAM Figure 3). This indicated a potentially under predicting model. The Random Forest model had good performance 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 (COAM Figure 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 (COAM Table 2).

COAM Table 1. Model performance values for *C. americanus* 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.

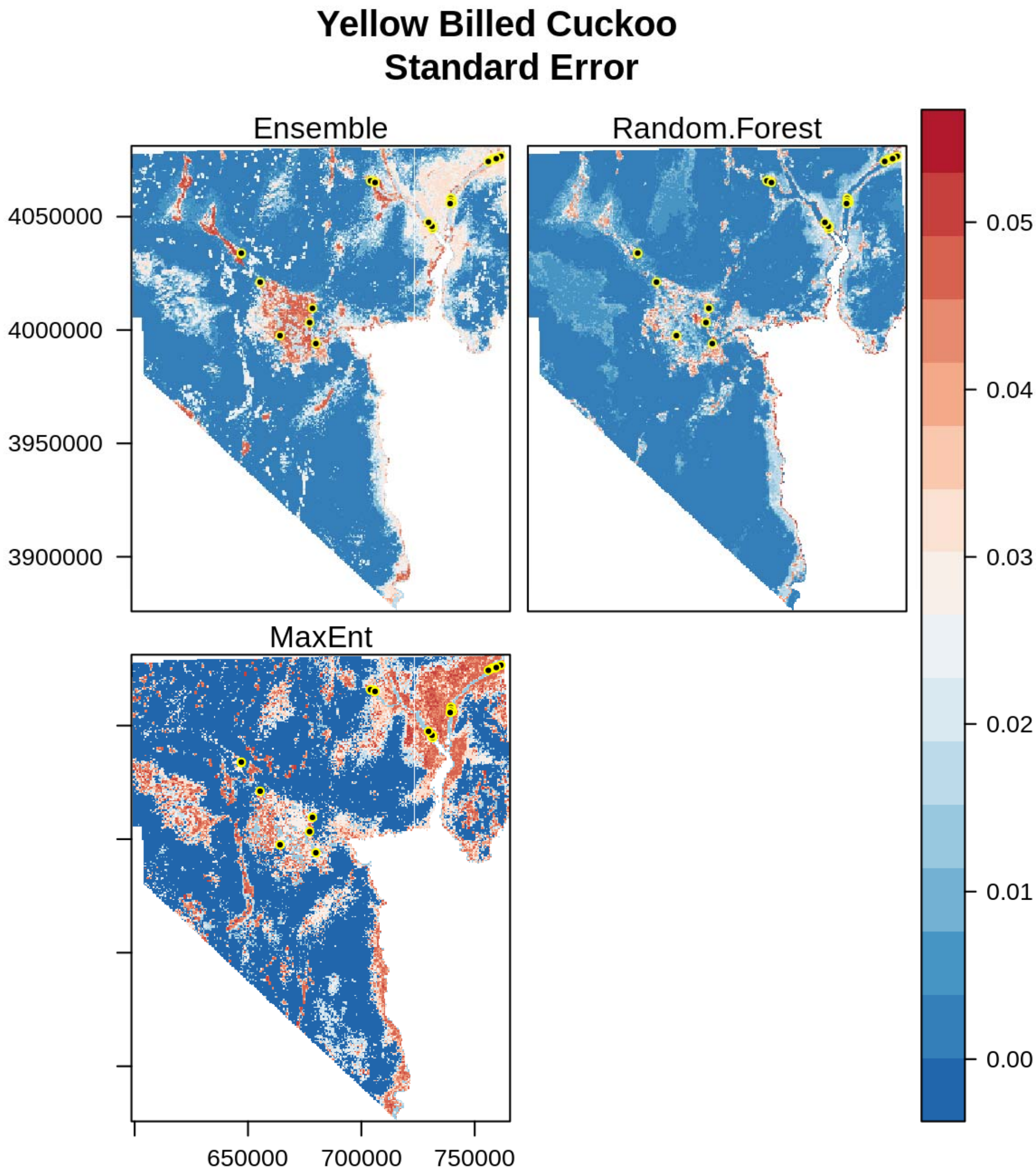
Model	AUC	BI	TSS	PRBE
Ensemble	0.92	0.65	0.8	0.41
Random Forest	0.9	0.82	0.9	
MaxEnt	0.87	0.97	0.8	

COAM Table 2. Percent contributions for input variables for *C. americanus* 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.

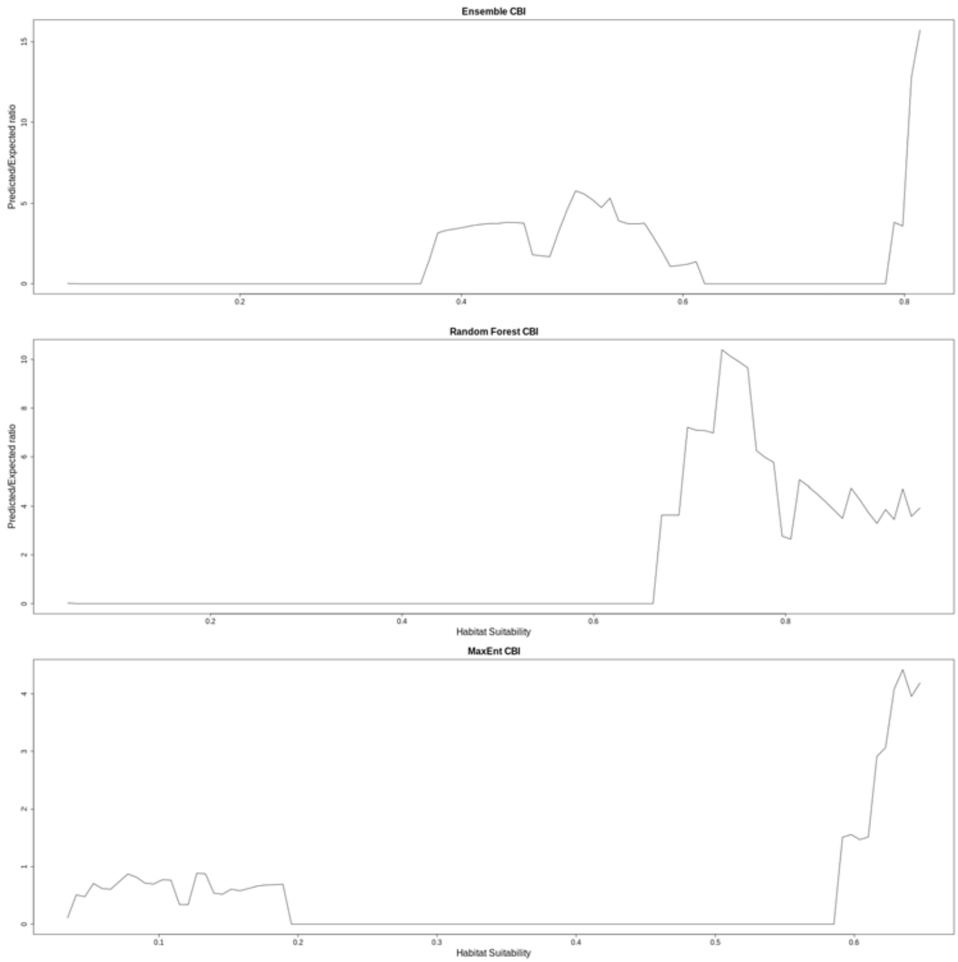
Variable	RF	MaxEnt
Extreme Max Temp	14.1	21.7
NDVI Max	2.1	29.8
PPT Silt	26	4.6
PPT Sand	17.4	2.3
Start of Season (day)	6.6	12.6
Ave Max Temp	9.9	8
PCT Coarse frags	3.6	5
Winter Precip	6.4	0.6
CV Min Temp	2.8	3.4
NDVI Amplitude	0.9	3.9



COAM Figure 1. SDM maps for *C. americanus* 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.



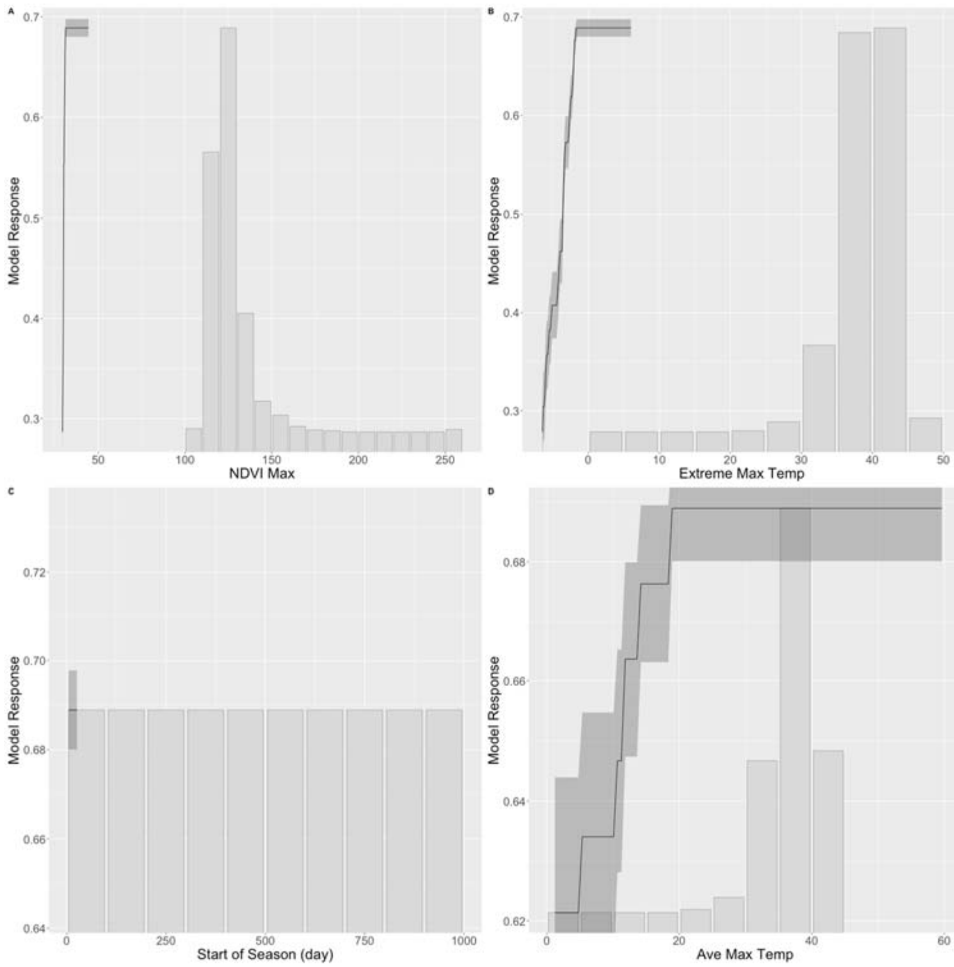
COAM Figure 2. Standard error maps for *C. americanus* models for each of the modeling algorithms used (Random Forest - upper right, MaxEnt - lower left), and an Ensemble model averaging the three (upper left).



COAM Figure 3. Graphs of Continuous Boyce Indices [CBI] for *C. americanus* models for the Ensemble model prediction (upper) and for each of the modeling algorithms used (Random Forest – middle, and MaxEnt - lower).

MaxEnt Model

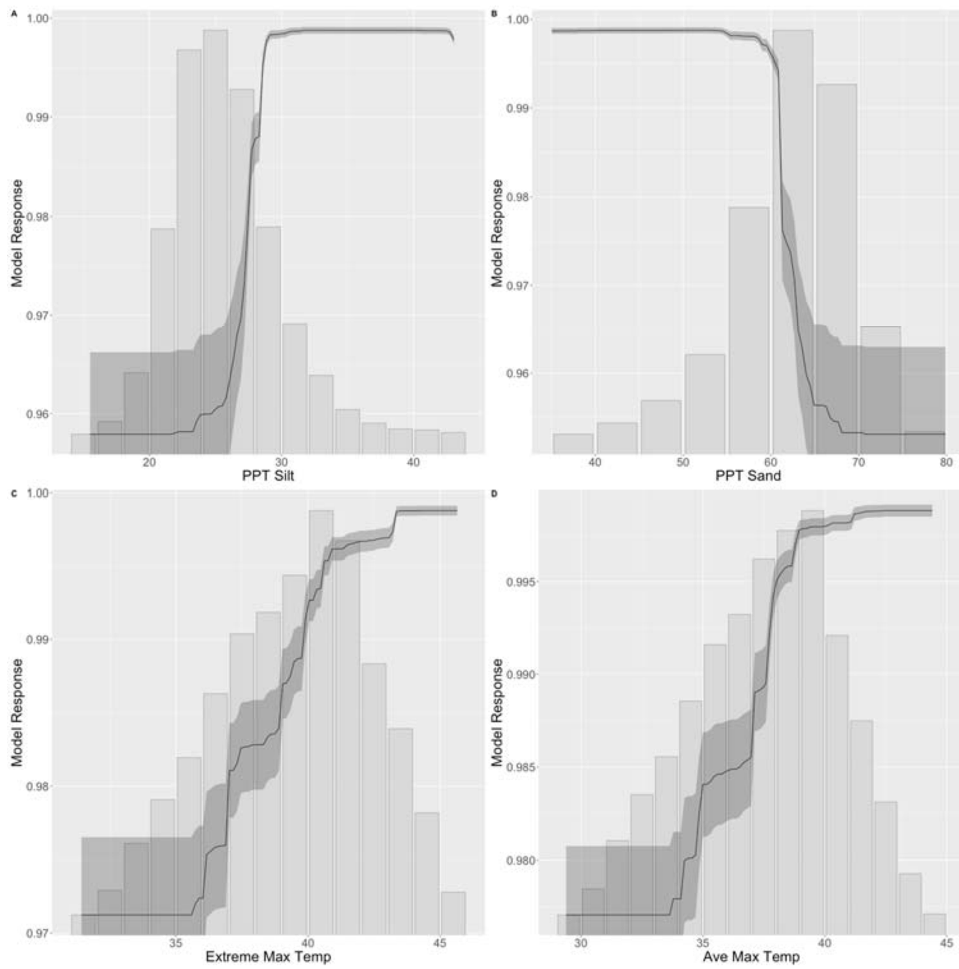
The MaxEnt models were most influenced by the NDVI Maximum value, and the Extreme Maximum temperatures (comprising 42% of influence; COAM Table 2). These variables exhibited peaked threshold responses at lower values relative to their presence in the study area (COAM Figure 4). The Start of Season as 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 (COAM Figure 1), and widespread error (COAM Figure 2) did not reflect strong performance. The CBI curves also showed some discrepancy in the relative strength of the MaxEnt models (COAM Figure 3).



COAM Figure 4. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *C. americanus.* 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.

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; COAM Table 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 (COAM Figure 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 (COAM Table 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 (COAM Figure 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 (COAM Figure 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 (COAM Figure 2)



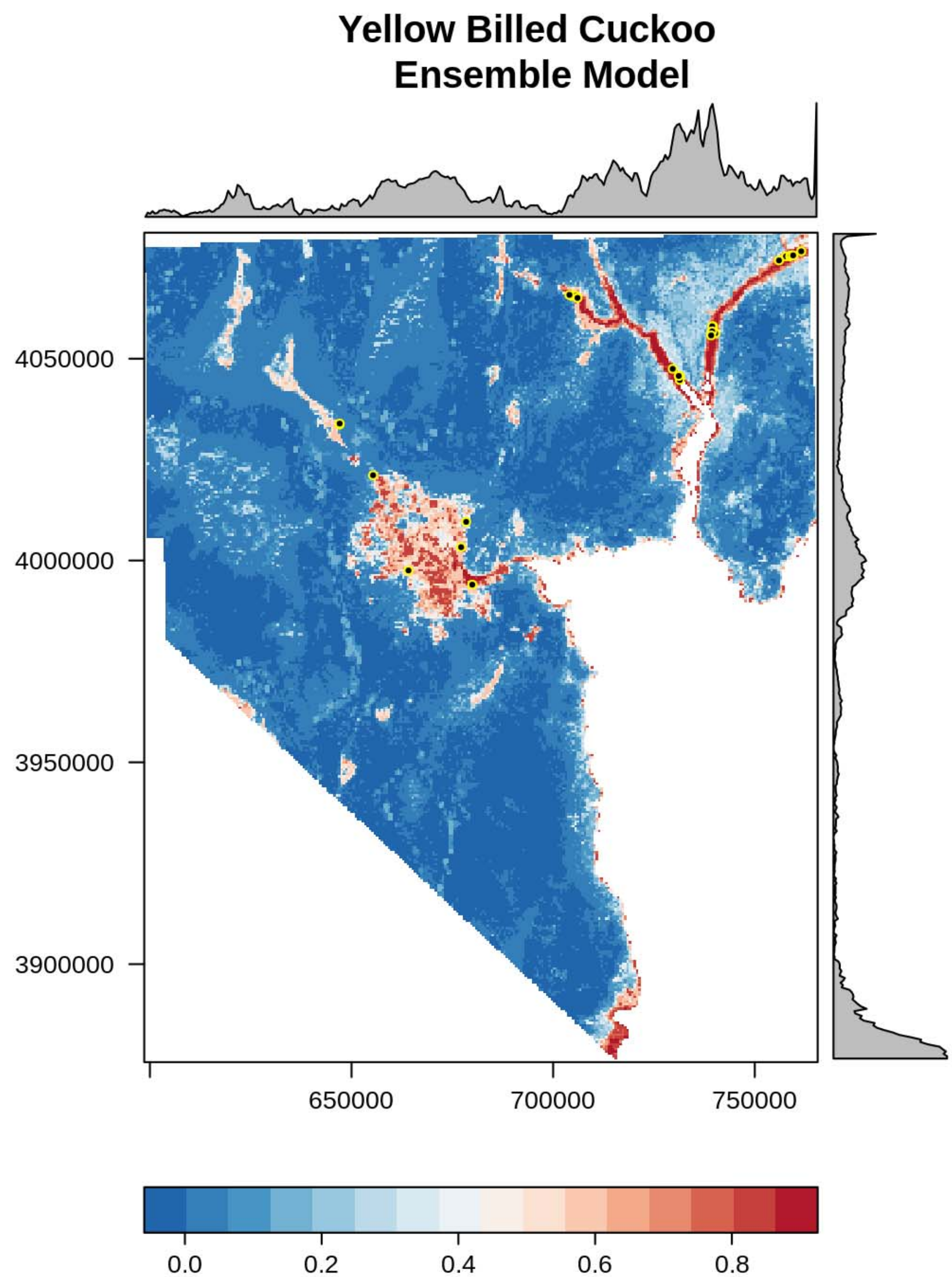
COAM Figure 5. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *C. americanus.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

Model Discussion

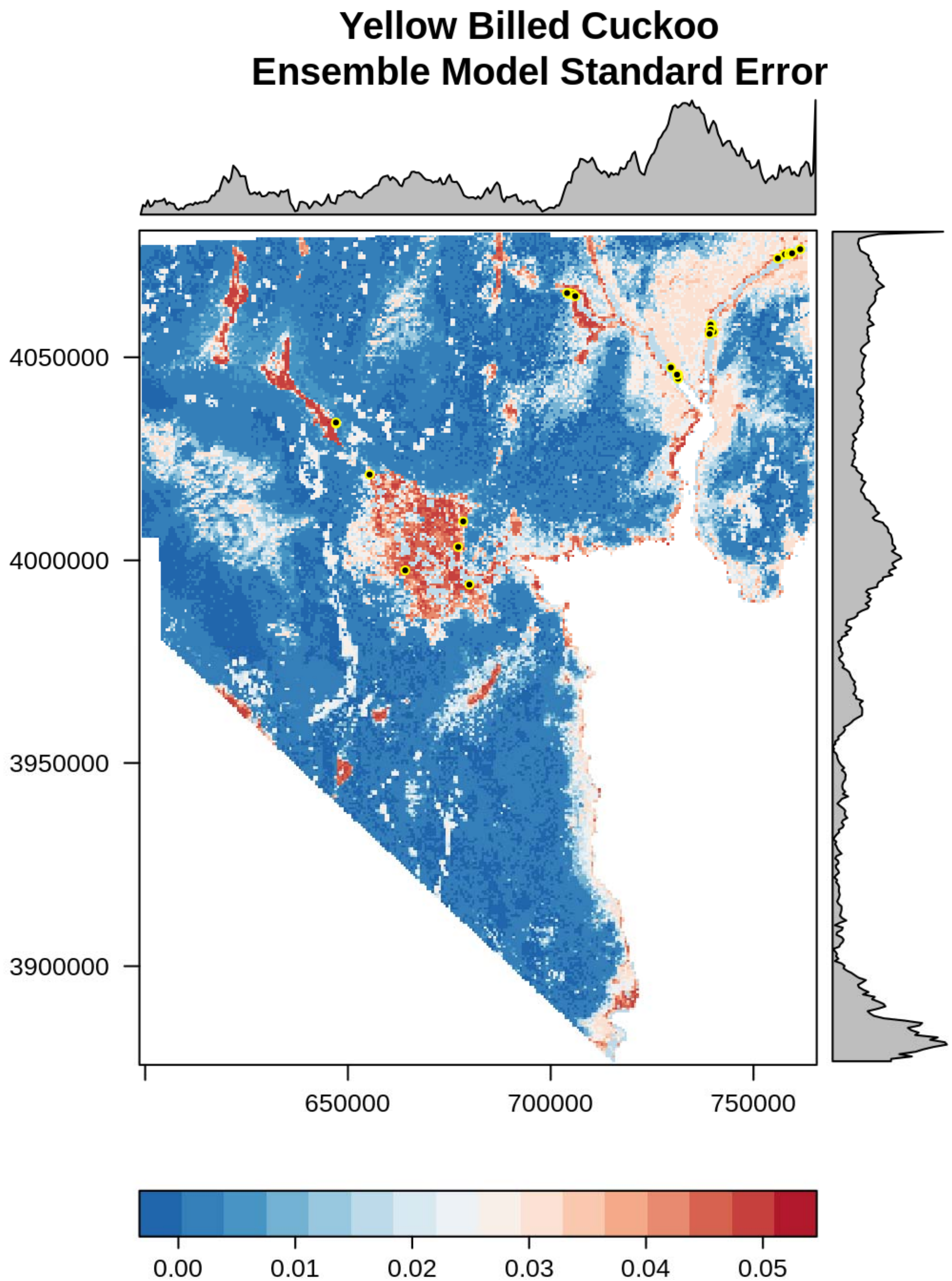
C. americanus largely occupy the riverine and larger drainage systems located along the Muddy and Virgin rivers. There are also several localities in and around the Las Vegas valley and to the northwest near the USFWS refuge. The Ensemble model predicted the highest habitat values in the immediate Virgin and Muddy river drainages, near Laughlin and the flatter areas near Avi, and along the Las Vegas wash and throughout the Las Vegas Valley (COAM Figure 6). Model performance for the Ensemble model was high for all metrics (COAM Table 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.

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 (COAM Figure 7). The Mormon mesa area had widespread areas of moderate standard error (SE 0.02 - 0.03; COAM Figure 7).



COAM Figure 6. SDM map for *C. americanus* Ensemble model for Clark County, NV.



COAM Figure 7. Standard Error map for the *C. americanus* Ensemble model for Clark County, NV.

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 (COAM Table 3).

COAM Table 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

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.

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.

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.

Summary of Direct Impacts

The Yellow-Billed Cuckoo is a very rare summer resident of Clark County that nests in riparian habitat. Approximately 515 km^2 of higher suitability modeled habitat exists within Clark County, although the proportion that is suitable for cuckoo nesting is estimated to be much less. This species occurs rarely in the plan area, although covered activities have the potential to impact species habitat. It is estimated that approximately 21% of this species' modeled habitat within Clark County could be impacted by activities covered under the Amendment, while 69% is already disturbed, and 9% is located within proposed or existing conservation areas (COAM Table 4).

COAM Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	10937	4779	35836	51552
Med	17074	8129	40299	65502
Low	98504	500772	44142	643418

COCH - 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. Frémont 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.

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

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.

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.

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 (COCH Figure 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 (COCH Figure 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 (COCH Table 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 (COCH Table 2).

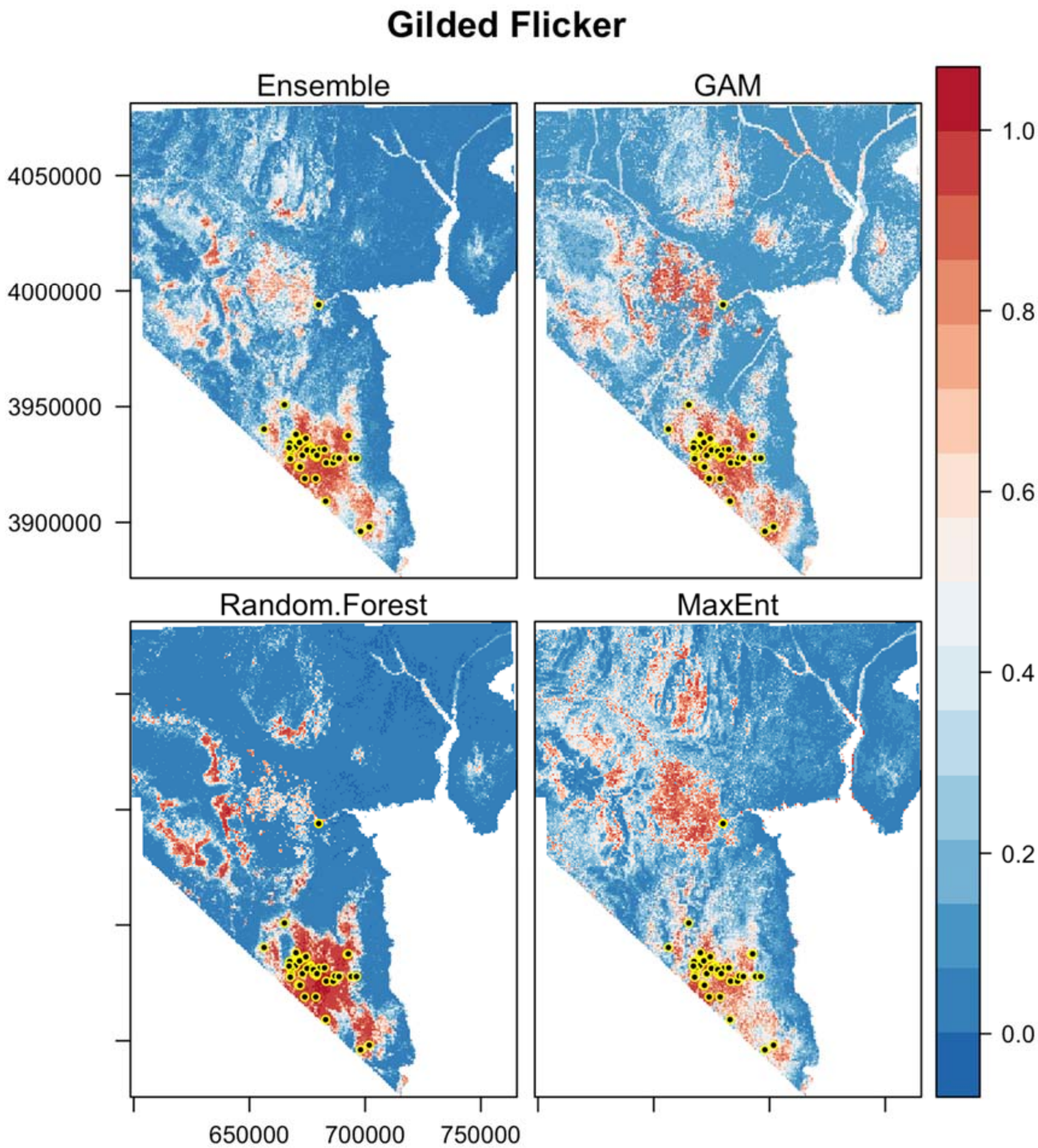
Standard error maps indicated maximum SEs of approximately 0.07, and that these were widespread in the GAM models, with more moderate error among models in the MaxEnt outputs in localized areas around the Spring and Sheep Ranges. The Random Forest had the lowest overall standard error, and the Ensemble Model, had moderate error (~0.04) near the Las Vegas Valley (COCH Figure 3). The Continuous Boyce Indices showed good model performance in all algorithms, where all but the MaxEnt models had sharply increasing performance curves (COCH Figure 3).

COCH Table 1. Model performance values for *C. chrysoides* 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.

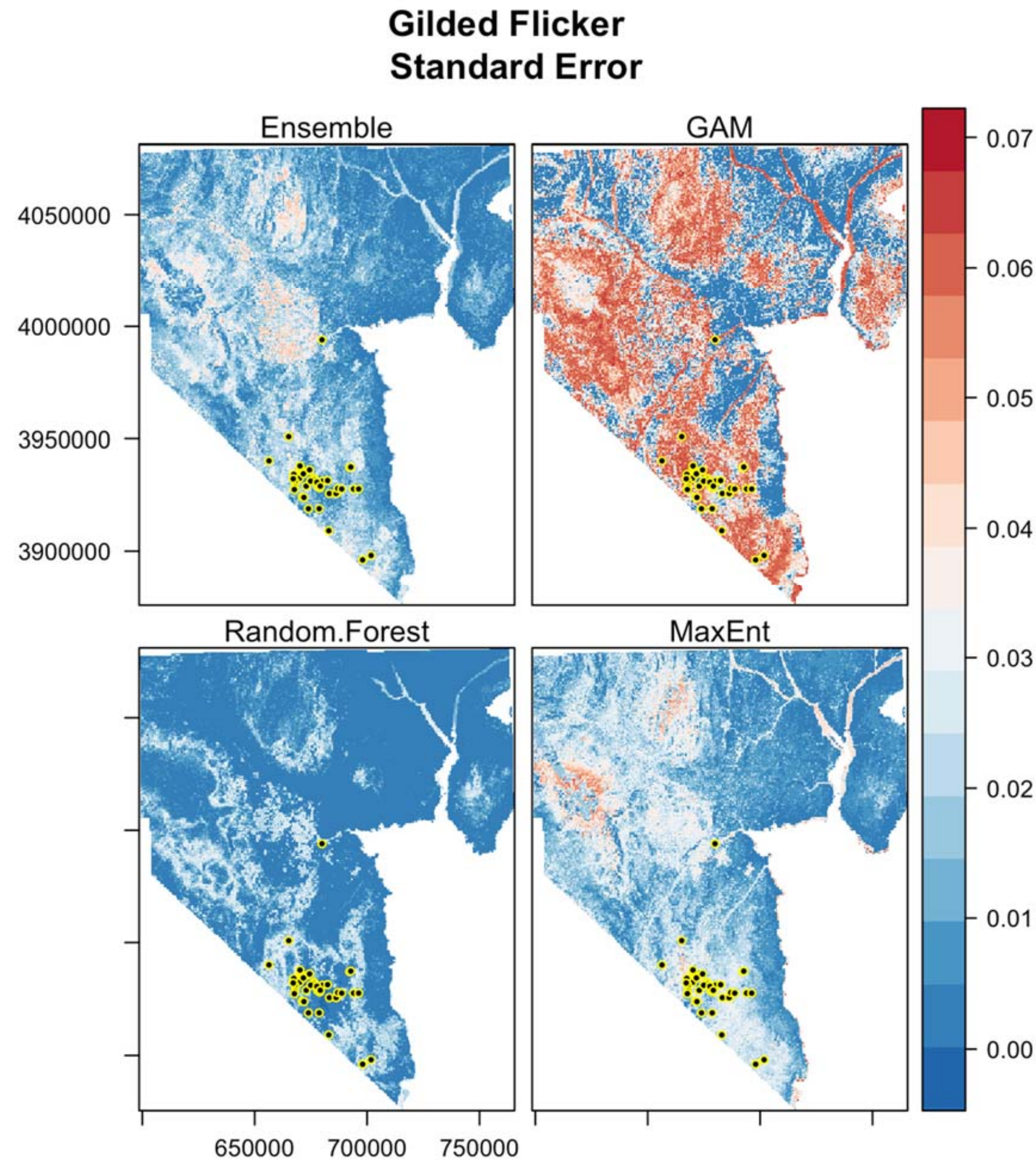
Model	AUC	BI	TSS	PRBE
Ensemble	0.95	0.94	0.84	0.52
GAM	0.91	0.89	0.72	
Random Forest	0.94	0.66	0.84	
MaxEnt	0.91	0.81	0.64	

COCH Table 2. Percent contributions for input variables for *C. chrysoides* 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.

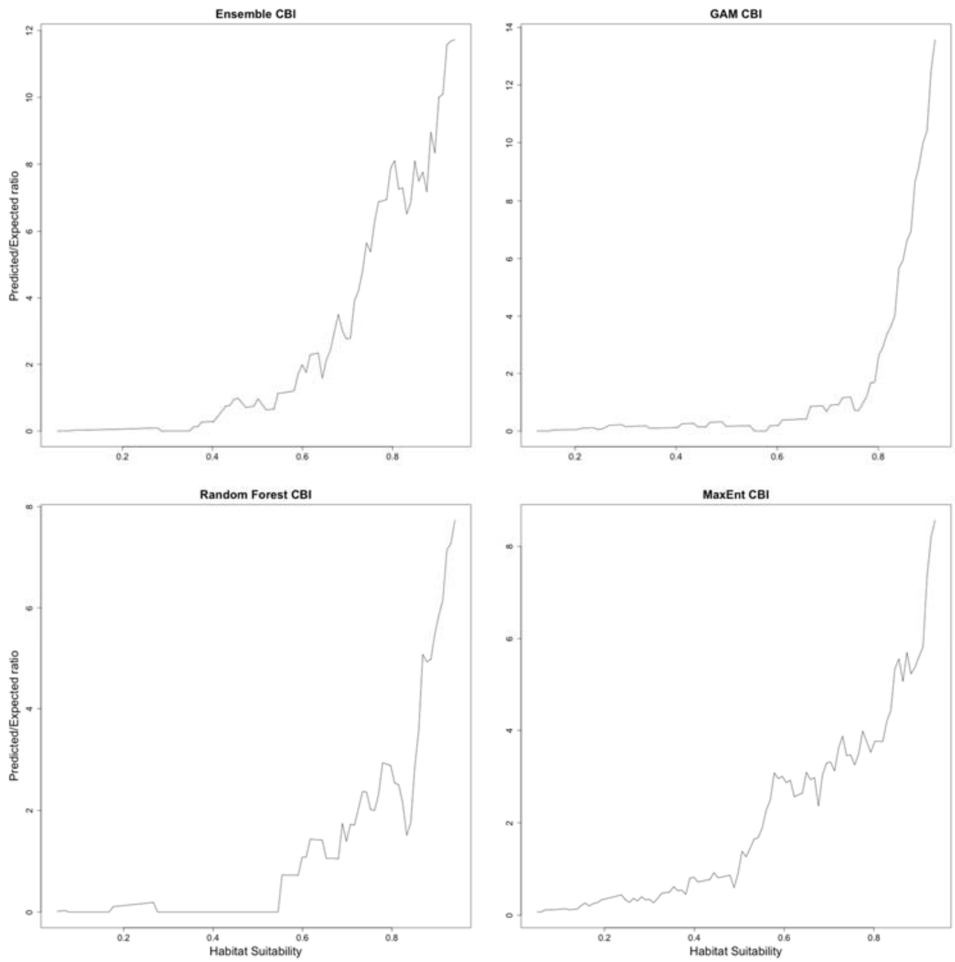
Variable	GAM	RF	MaxEnt
Dist to cliffs	4	0.7	2.2
NDVI Amplitude	9.3	1.9	2.8
NDVI Length of Season	6.7	1.9	1.2
NDVI Max	15.8	20.6	2.3
Winter Precip	6.1	5.2	4.3
CV Winter Precip	10.3	40.6	10.2
Average Spring Max Temp	16.7	13.8	36.8
CV Average Spring Max Temp	11.4	2.2	11.5
Slope	9.6	7.7	16.1
NDVI Start of Season	7.3	2.4	10.5
Flow Accum	2.6	3.2	2.1



COCH Figure 1. SDM maps for *C. chrysoides* 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.



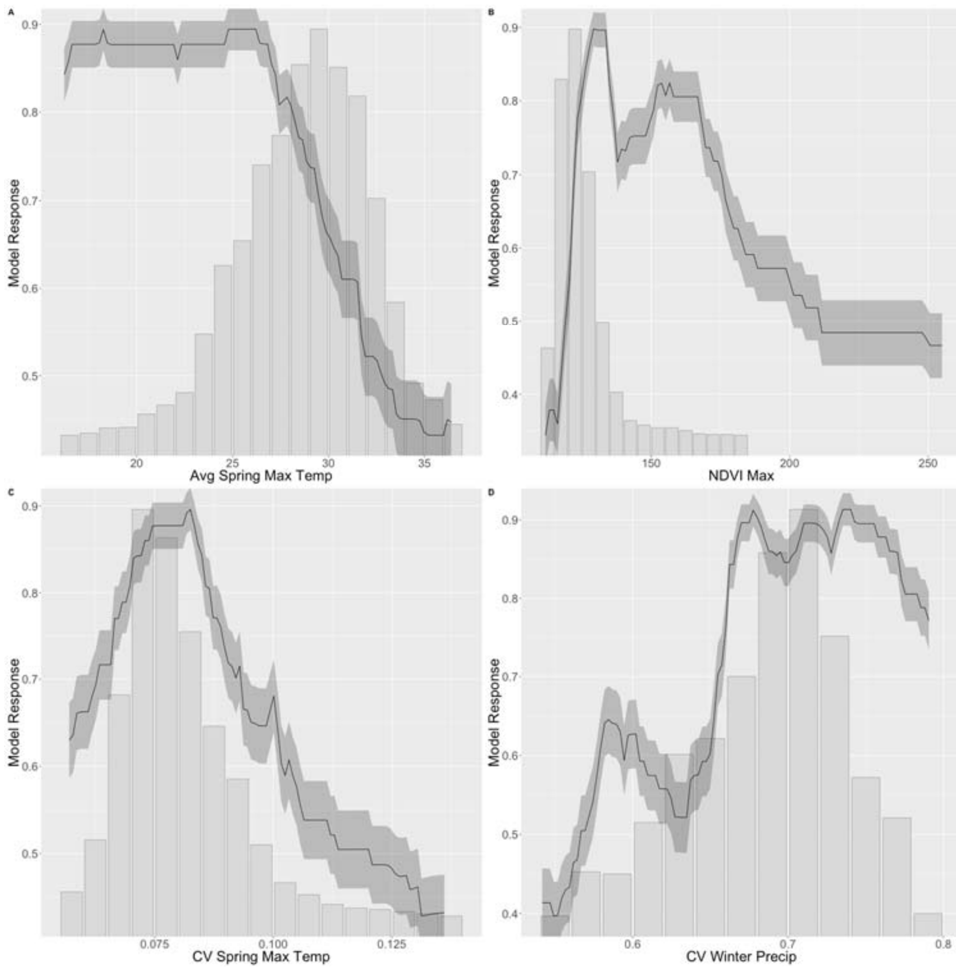
COCH Figure 2. Standard error maps for *C. chrysoides* models for each of three modeling algorithms used (Ensemble - upper left, GAM - upper right, RF - lower left, and MaxEnt - lower right).



COCH Figure 3. Graphs of Continuous Boyce Indices [CBI] for *C. chrysoides* 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).

General Additive Model

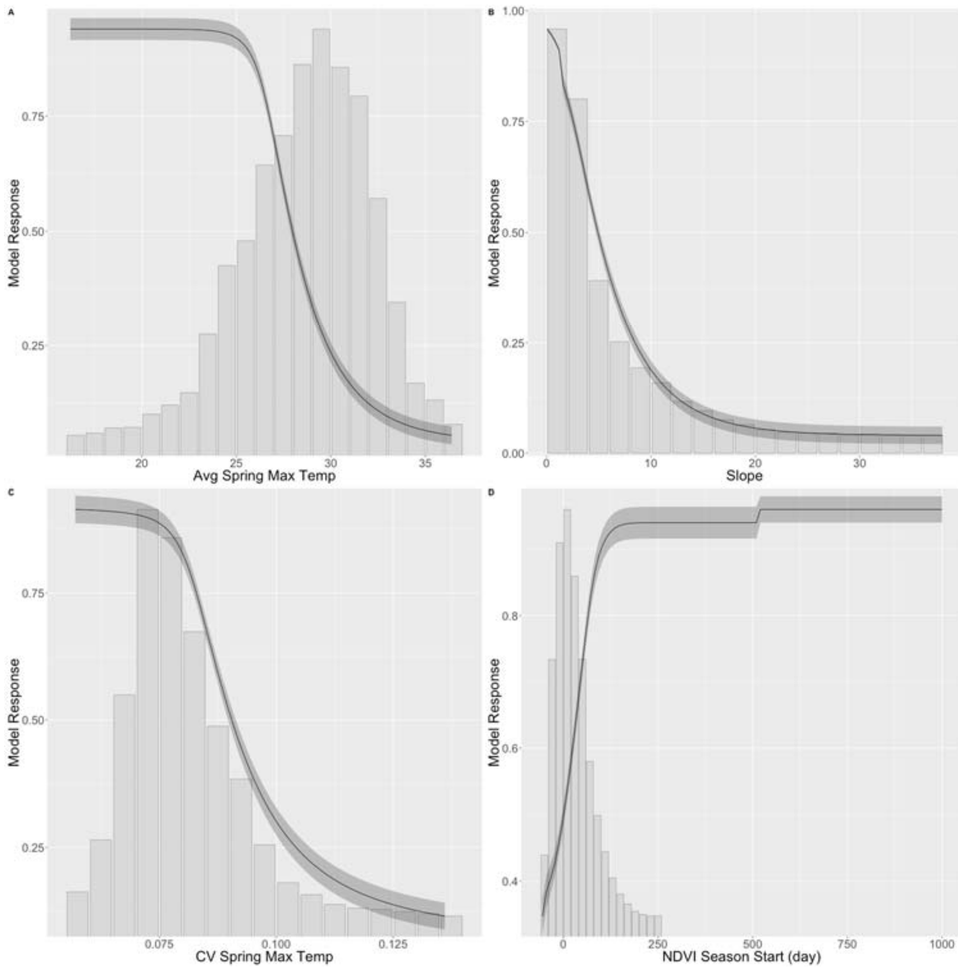
The top four contributing environmental layers were Average Spring Maximum temperature and its coefficient of variation, NDVI Maximum, the CV of Average Winter Precipitation and the NDVI Maximum value for the year (COCH Table 2). Model scores were higher in areas with lower Spring temperatures, and higher 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 (COCH Figure 4).



COCH Figure 4. GAM partial response curves for the top four variables in the *C. chrysoides* model overlaid over distribution of environmental variable inputs in the study area.

MaxEnt Model

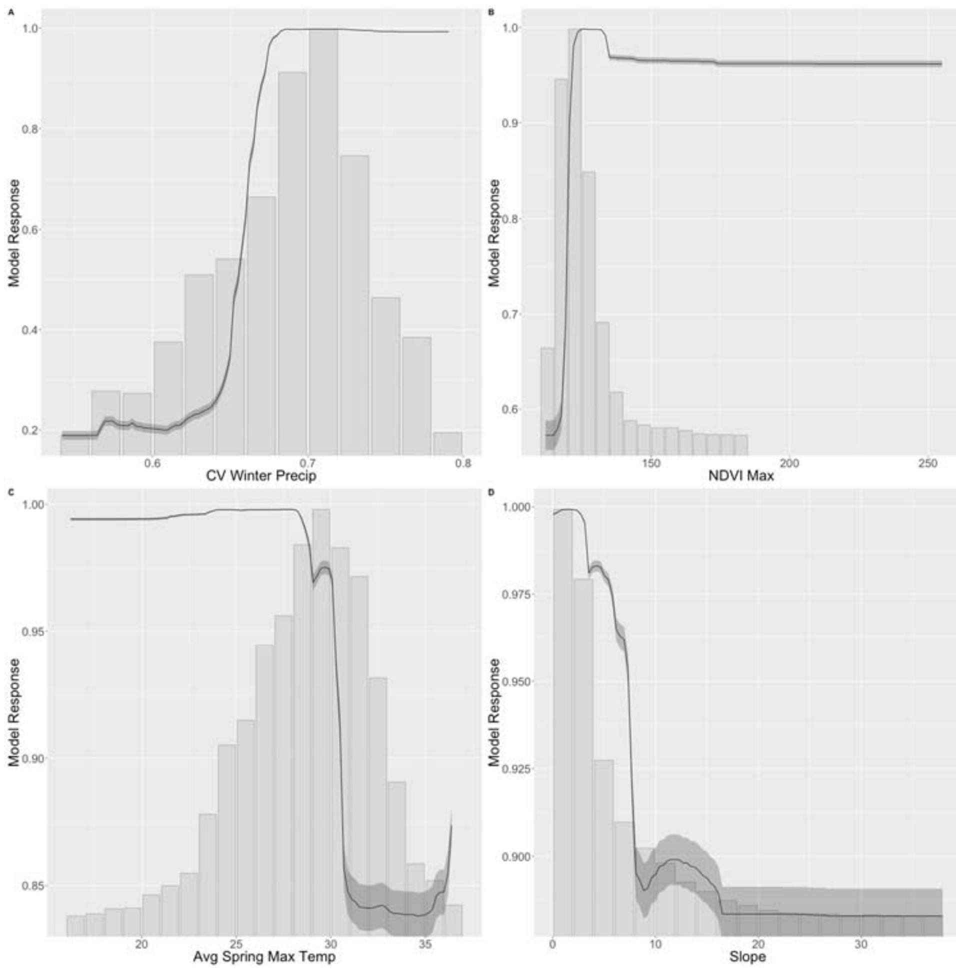
The MaxEnt models was largely driven by three of the four top variables as those in the GAM models, and two of the higher Random Forest models (COCH Table 2). Average Spring Maximum temperature and its Coefficient of Variation were among the top four, with higher habitat scores predicted for cooler areas with lower variability (COCH Figure 5). Habitat was also predicted in areas of later NDVI Start of Season dates, corresponding with later greenup. Finally, there was a negative association with Slope that mirrored its prevalence in the habitat, which may not be an indication of selection (COCH Figure 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 (COCH Figure 1).



COCH Figure 5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *C. chrysoides.*

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 (COCH Table 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 (COCH Figure 5). Slope had a negative association with habitat and largely mirrored its availability, as was seen in the MaxEnt model (COCH Figure 6, COCH Figure 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 (COCH Figure 1). Standard Error values were relatively low throughout the county (COCH Figure 2).



COCH Figure 6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *C. chrysoides.* 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.

Model Discussion

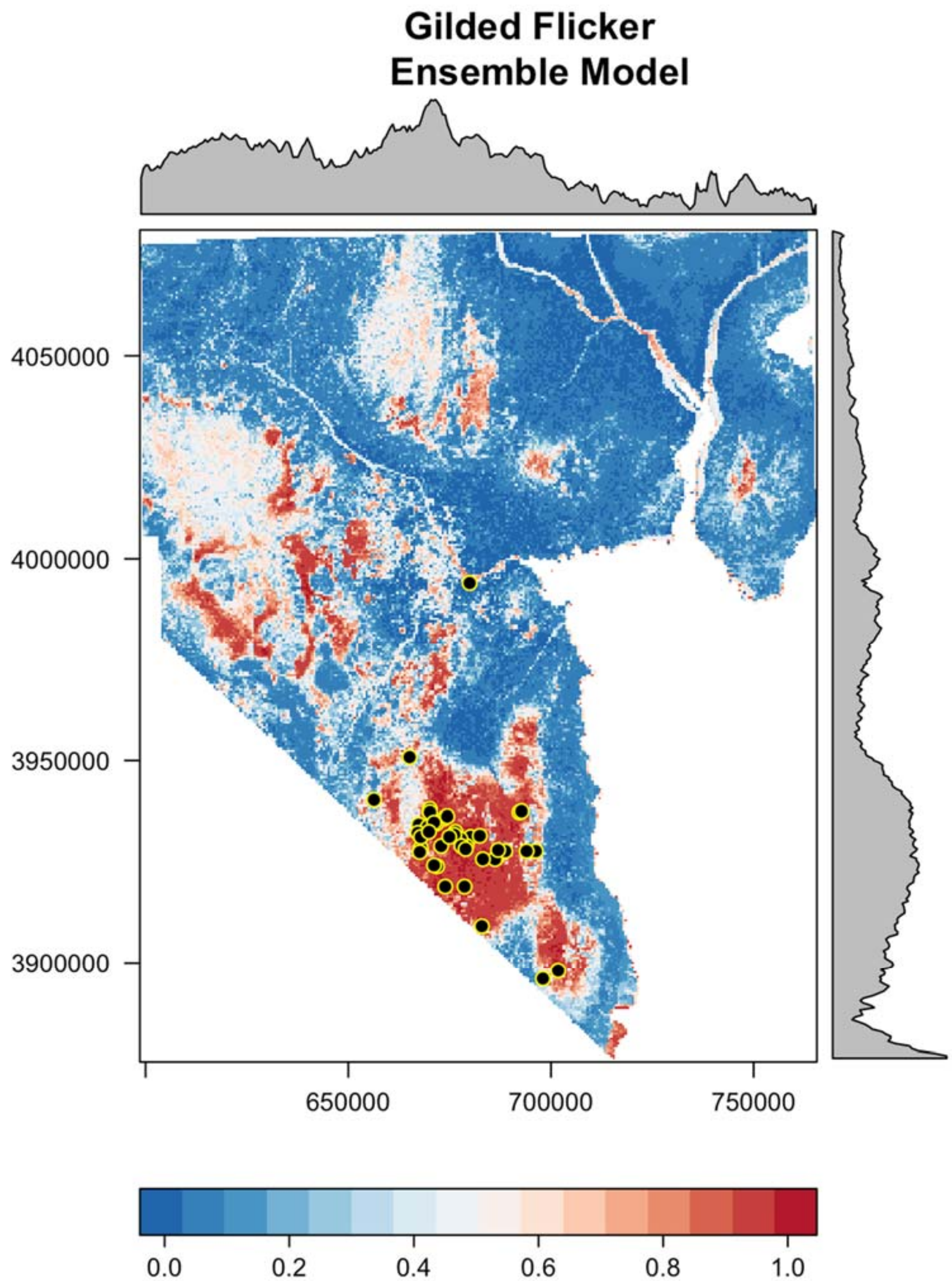
Gilded Flickers largely occupy the southern-most portions of Clark County, NV. While there are additional habitat areas predicted around the Spring range, and the southern extent of the Sheep range, there are no localities in the data collected that far north. Indeed, the farthest north point was located in the Las Vegas wash area (COCH Figure 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.

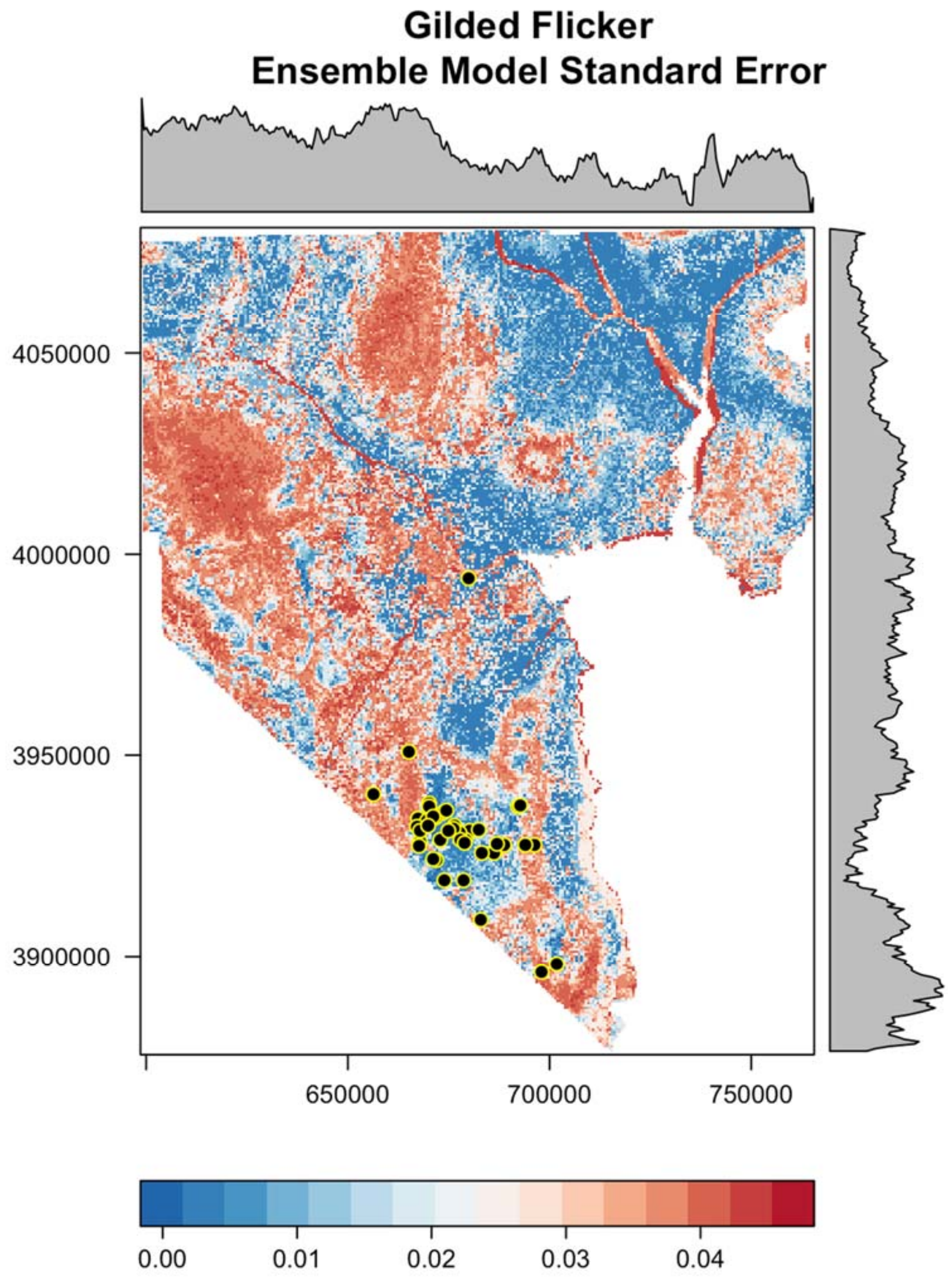
The locality data for this species consisted of 223 records. Spatial thinning of the data reduced the number of localities used for training and testing to 127 records.

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, COCH Figure 8).



COCH Figure 7. SDM map for *C. chrysoides* Ensemble model for Clark County, NV.



COCH Figure 8. Standard Error map for the *C. chrysoides* Ensemble model for Clark County, NV.

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 (COCH 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).

COCH Table 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

Ecosystem Level Threats

Within Clark County the Gilded Flicker is known to occupy Blackbrush and Mojave Desert Scrub ecosystems (COCH Table 3). They may also occupy Mesquite Acacia, and Desert Riparian, with a lesser presence in other ecosystems (COCH Table 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.

Threats to Species

Threats to the species 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.

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).

Summary of Direct Impacts

Direct impacts may include mining activities in the Searchlight, Nevada mining district, invasive grasses and related wildfires, large scale renewable energy development, utility and transportation infrastructure, and military training. Higher densities for this species encompass approximately 1205 km^2 of area within the county, 74% of which is located within conservation areas, while very minimal amounts of high density habitat are likely to be impacted (3%) and 22% is already disturbed (COCH Table 4). Moderate density habitat is similarly extensive, and 46% of this area is located within conservation areas, 41% is already disturbed and only 12% is likely to be impacted under the plan amendment (COCH Table 4).

COCH Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	4017	89738	26837	120592
Med	16444	59539	52658	128641
Low	106030	354238	40751	501019

EMTR - Southwestern Willow Flycatcher (Empidonax traillii extimus)

The Southwestern Willow Flycatcher is one of four recognized subspecies of *Empidonax 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 (*Populous* 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).

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

Range

The breeding range of the Southwestern Willow Flycatcher (subspecies *E. t. extimus*) 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).

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).

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 (EMTR Figure 1).

The GAM and Random Forest models had very similar performance metrics to one another (EMTR Table 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 (EMTR Figure 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 (EMTR Table 2).

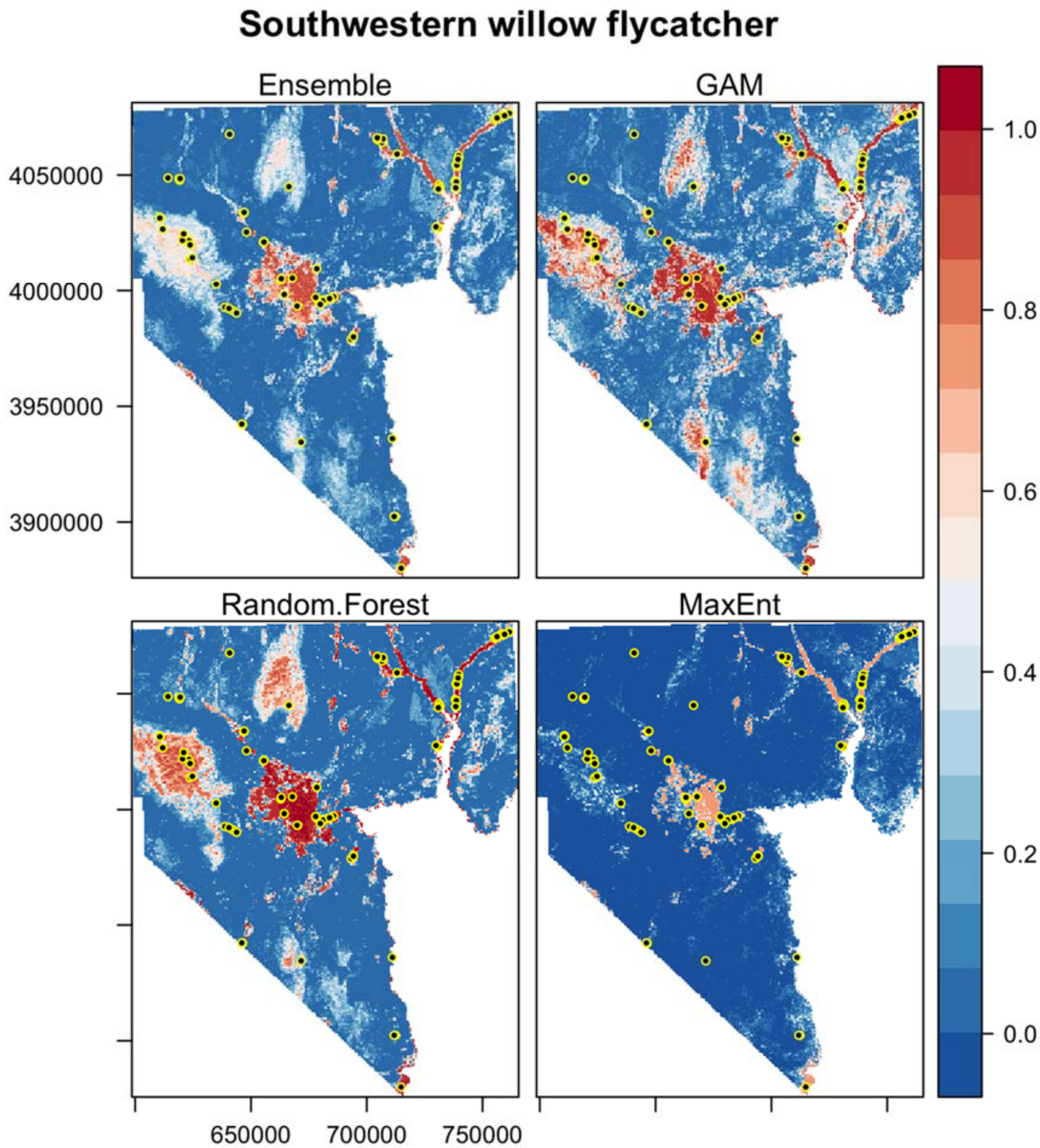
The Random Forest models had the lowest standard error values among the modeling algorithms (EMTR Figure 2), where the areas of moderate error (~ 0.02 – 0.03) were surrounding the habitat predicted in the Spring and Sheep ranges. The GAM model had more areas of higher error (SE 0.04 – 0.06) and these 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 (EMTR Figure 2 and EMTR Figure 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 (EMTR Figure 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. (EMTR Figure 3).

EMTR Table 1. Model performance values for *E. traillii extimus* 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.

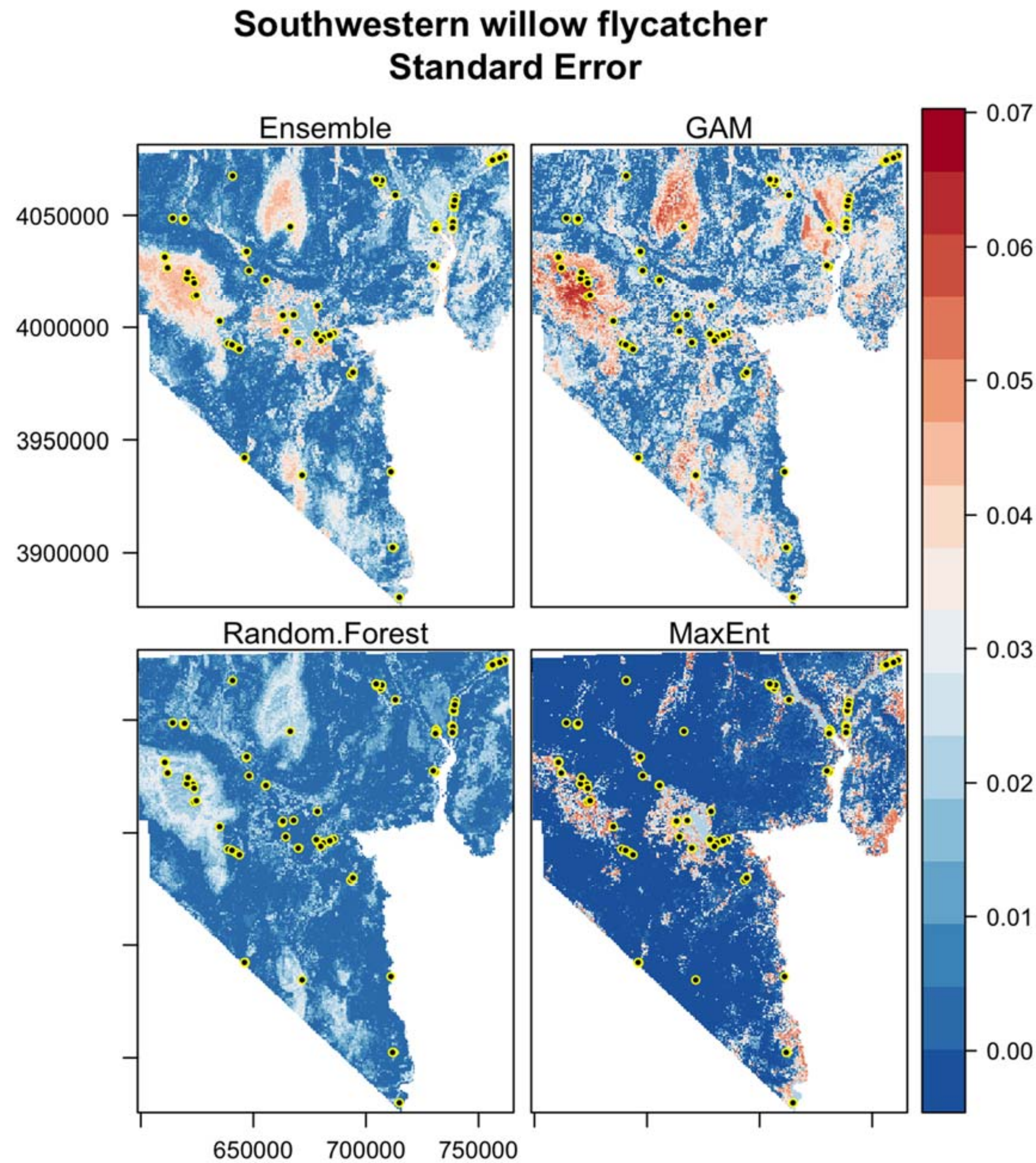
Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.92	0.94	0.77	0.30
GAM	0.92	0.72	0.77	
Random Forest	0.91	0.91	0.79	
MaxEnt	0.87	0.84	0.65	

EMTR Table 2. Percent contributions for input variables for *E. traillii extimus* 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.

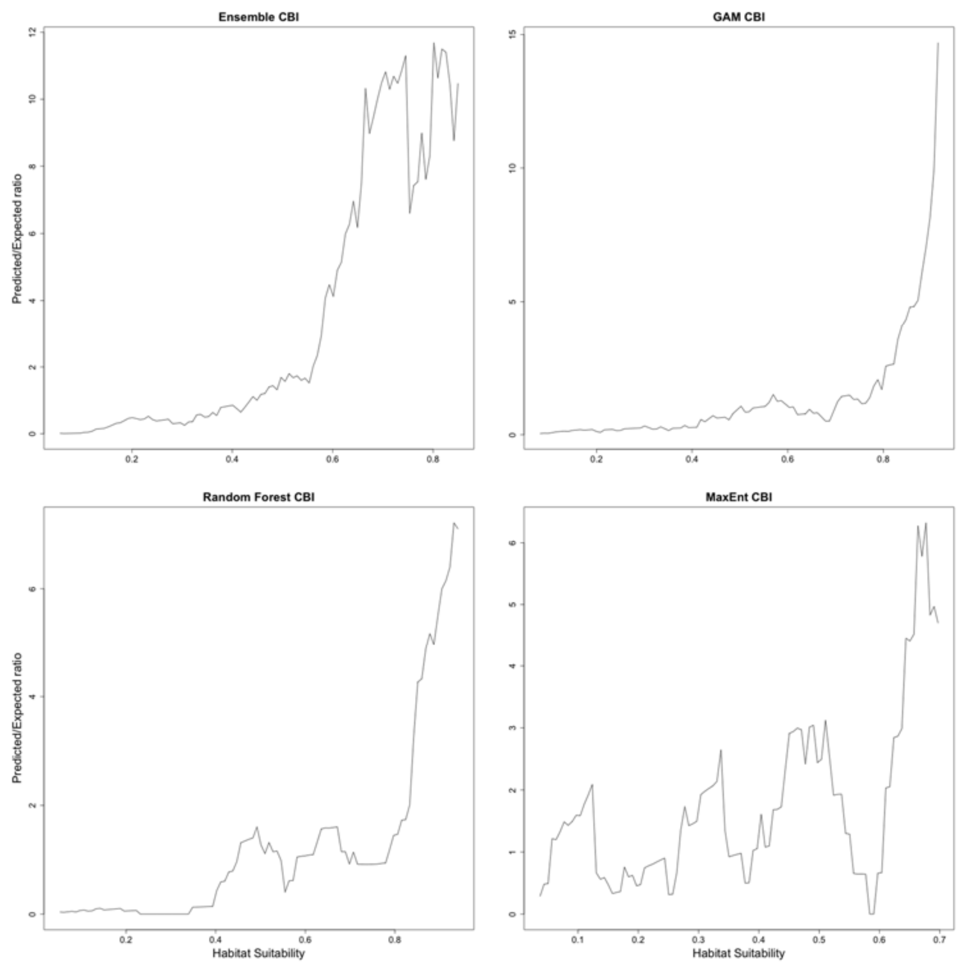
Variable	GAM	RF	MaxEnt
Ave Max Temp	25.9	3.4	4.9
Average Spring Max Temp	9.3	2.8	3.6
Coarse frags	4.3	6.6	18.2
Extreme Max Temp	13.6	4.8	14
NDVI Amplitude	7.7	1.5	9.6
NDVI Max	20.4	7.7	22.6
Sand	2.1	6.7	3.1
Silt	11.2	36.6	5.7
Slope	2.2	2.5	4.6
Start of Season (day)	3.3	27.5	13.7



EMTR Figure 1. SDM maps for *E. traillii extimus* 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.



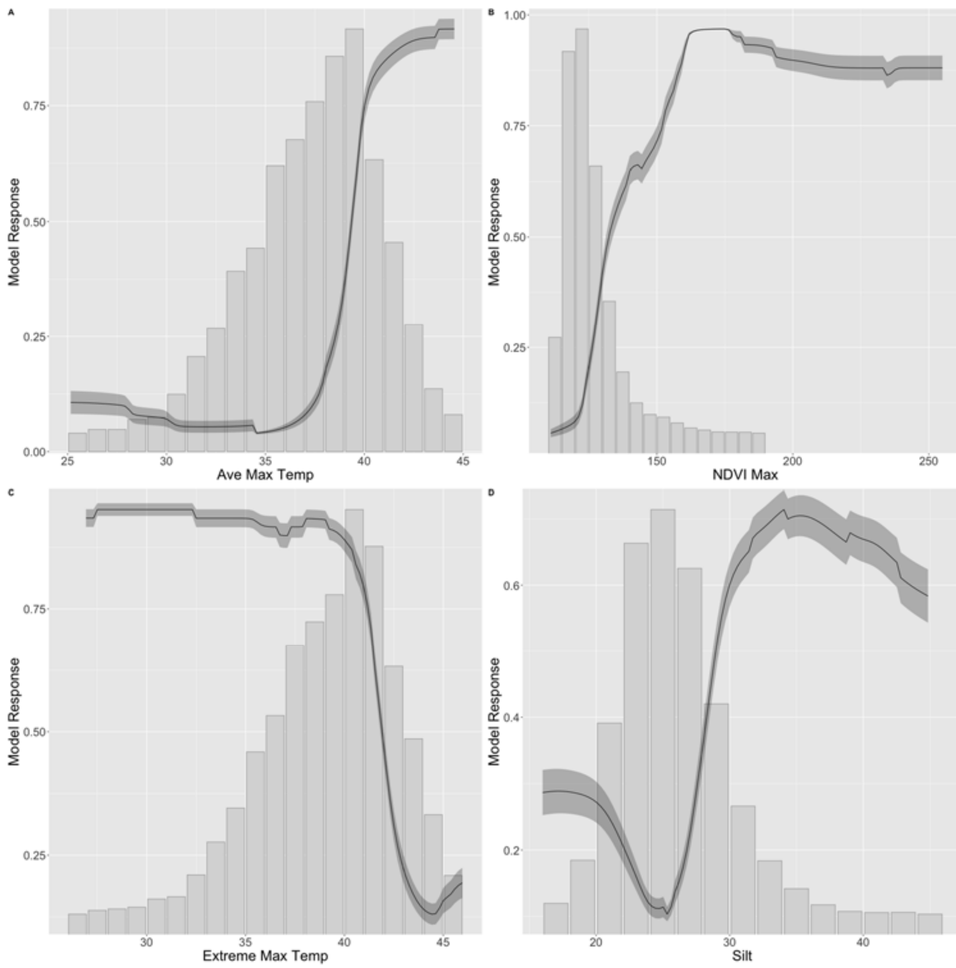
EMTR Figure 2. Standard error maps for *E. traillii extimus* models for each of three modeling algorithms used (Ensemble - upper left, GAM - upper right, RF - lower left, and MaxEnt - lower right).



EMTR Figure 3. Graphs of Continuous Boyce Indices [CBI] for *E. traillii extimus* 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).

General Additive Model

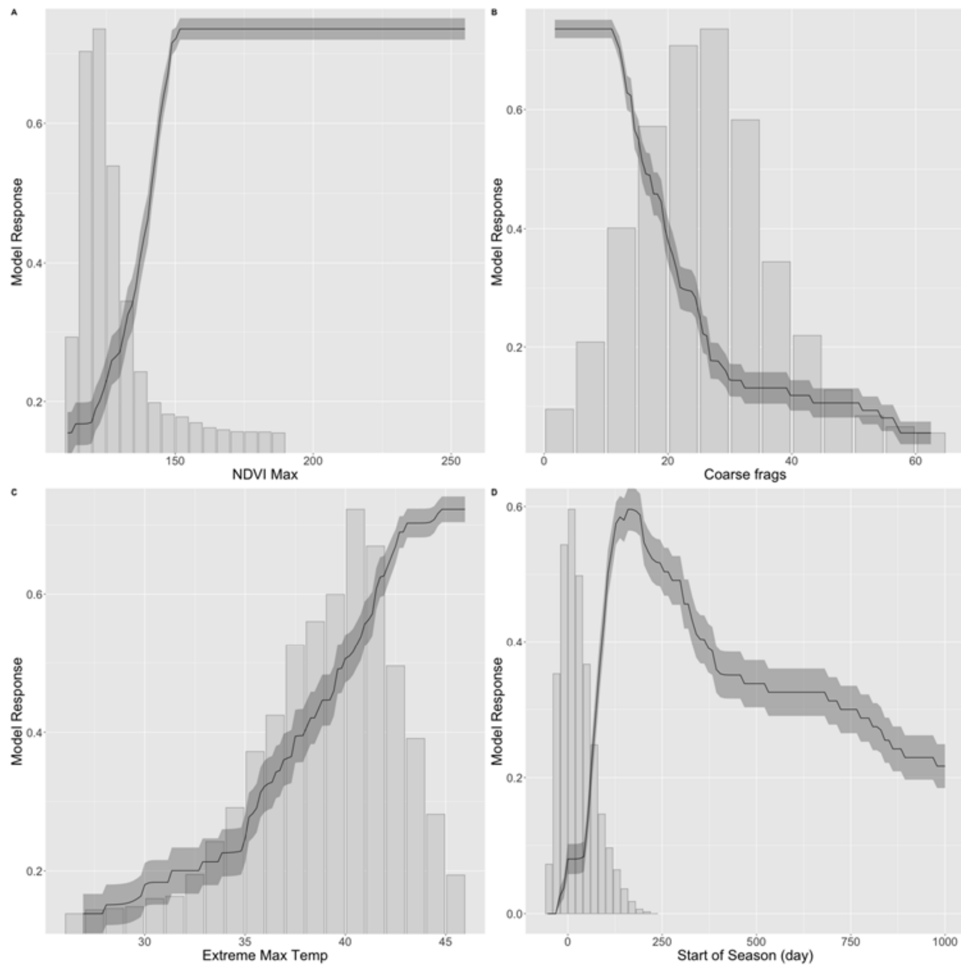
The top four contributing environmental layers were Average Maximum temperature, and NDVI Maximum, followed by the Extreme Maximum temperature, and Silt content of the soil (EMTR Table 2). Model scores were higher in areas with higher Average Maximum temperatures, but lower Extreme Maximum temperature (EMTR Figure 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 (EMTR Figure 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.



EMTR Figure 4. GAM partial response curves for the top four variables in the *E. traillii extimus* 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.

MaxEnt Model

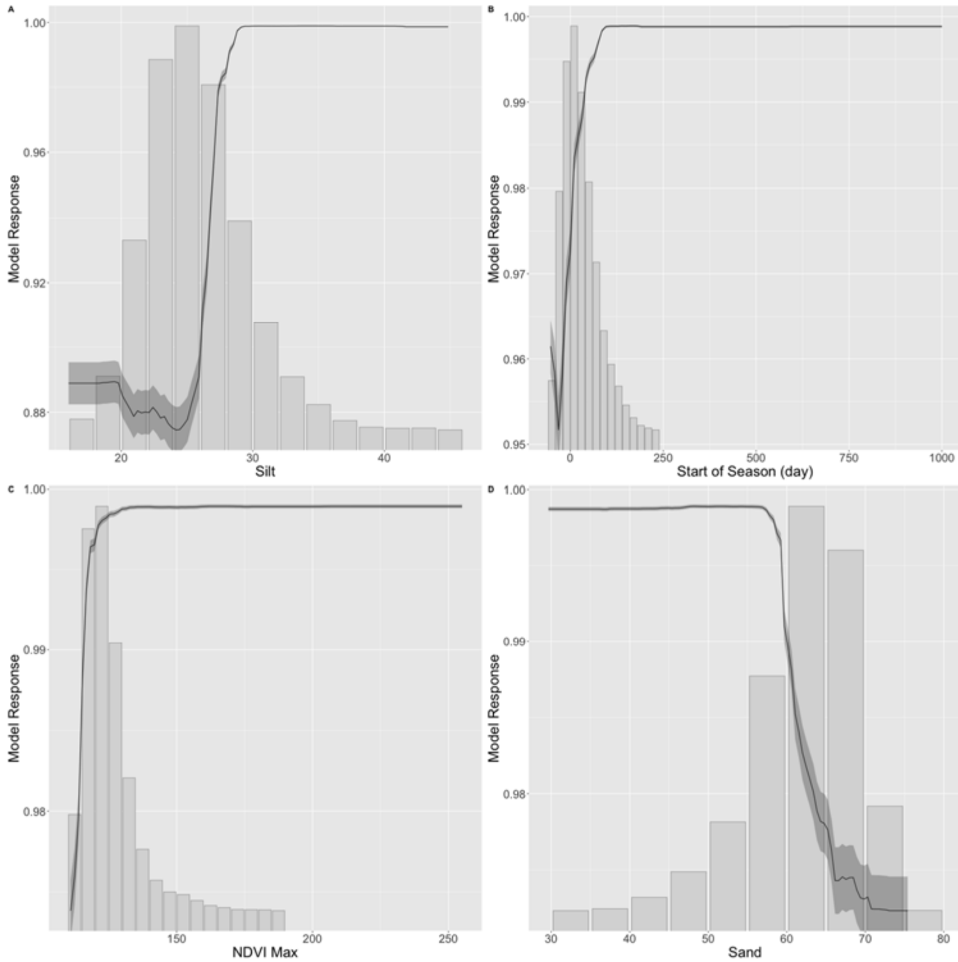
The MaxEnt models had a more even contribution among the input layers used. The most influential contributions were from NDVI Maximum and Coarse Fragments, followed by Extreme Maximum temperature, and the Start of the Spring Season (as indicated by NDVI). (EMTR Table 2). Like the GAM model, habitat values increased with greater NDVI Maximum and plateaued at a high level (EMTR Figure 5). Higher habitat values were predicted when Coarse fragments were lower (< 30%) and declined with higher values (EMTR Figure 5). lowest Maximum temperature values, peaking at 30 C and remaining higher thereafter (EMTR Figure 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 (EMTR Figure 4, EMTR Figure 5). High habitat values were predicted when start of the season occurred at about 240 days, and declined with higher or lower values (EMTR Figure 5).



EMTR Figure 5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *E. traillii extimus.* 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.

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%, EMTR Table 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 (EMTR Figure 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; EMTR Figure 6). Habitat was also higher in areas with a lower concentration of Sand Content (<55%; EMTR Figure 6). The performance metrics were excellent for this model (EMTR Table 1) although the Continuous Boyce plots indicated good model performance with some anomalies (EMTR Figure 3) likely caused by moderate habitat prediction values peaking in areas with lower locality density, such as the Spring Range (EMTR Figure 1).



EMTR Figure 6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *E. traillii extimus.* 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.

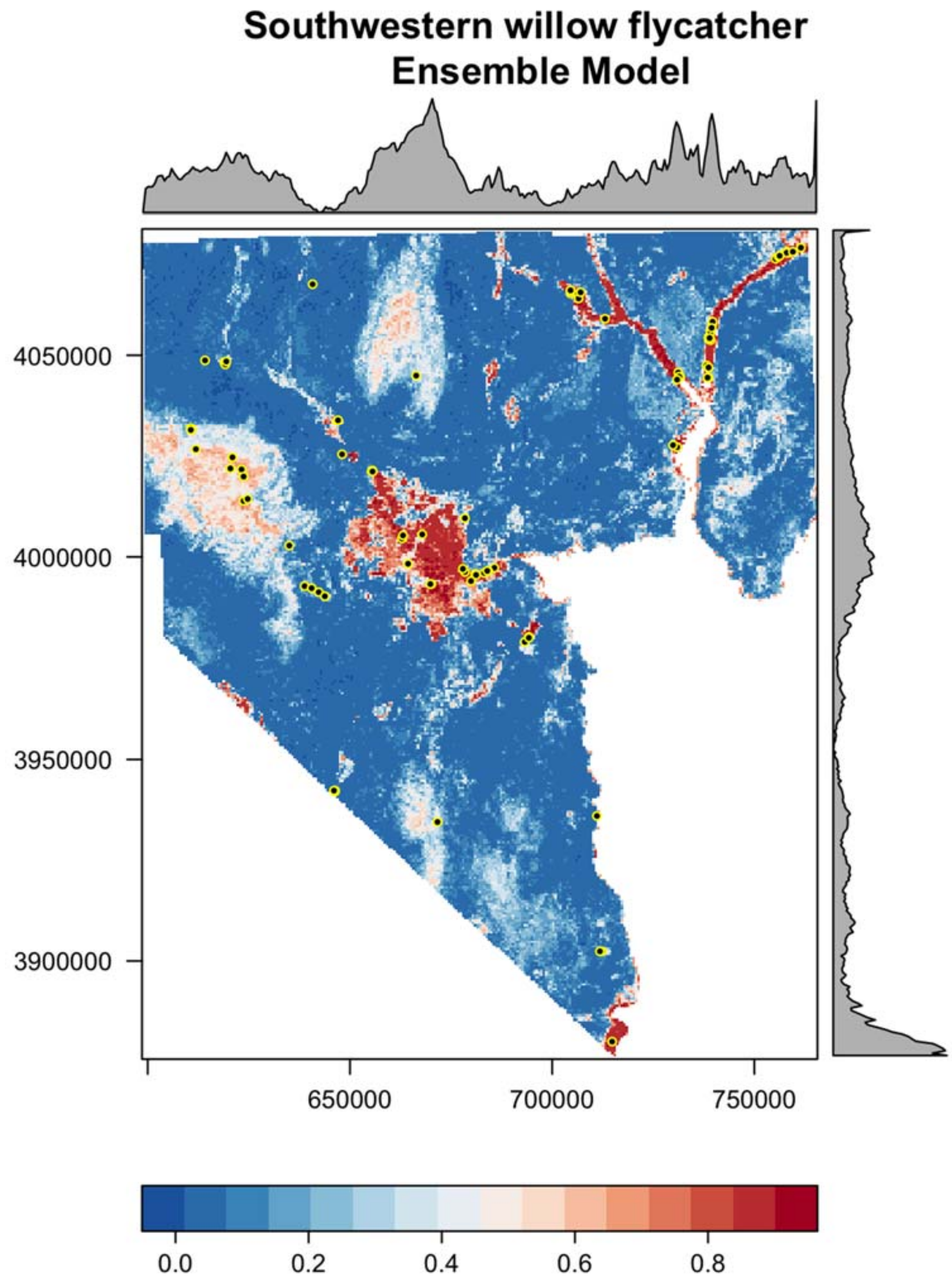
Model Discussion

E. traillii extimus 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 (EMTR Figure 7).

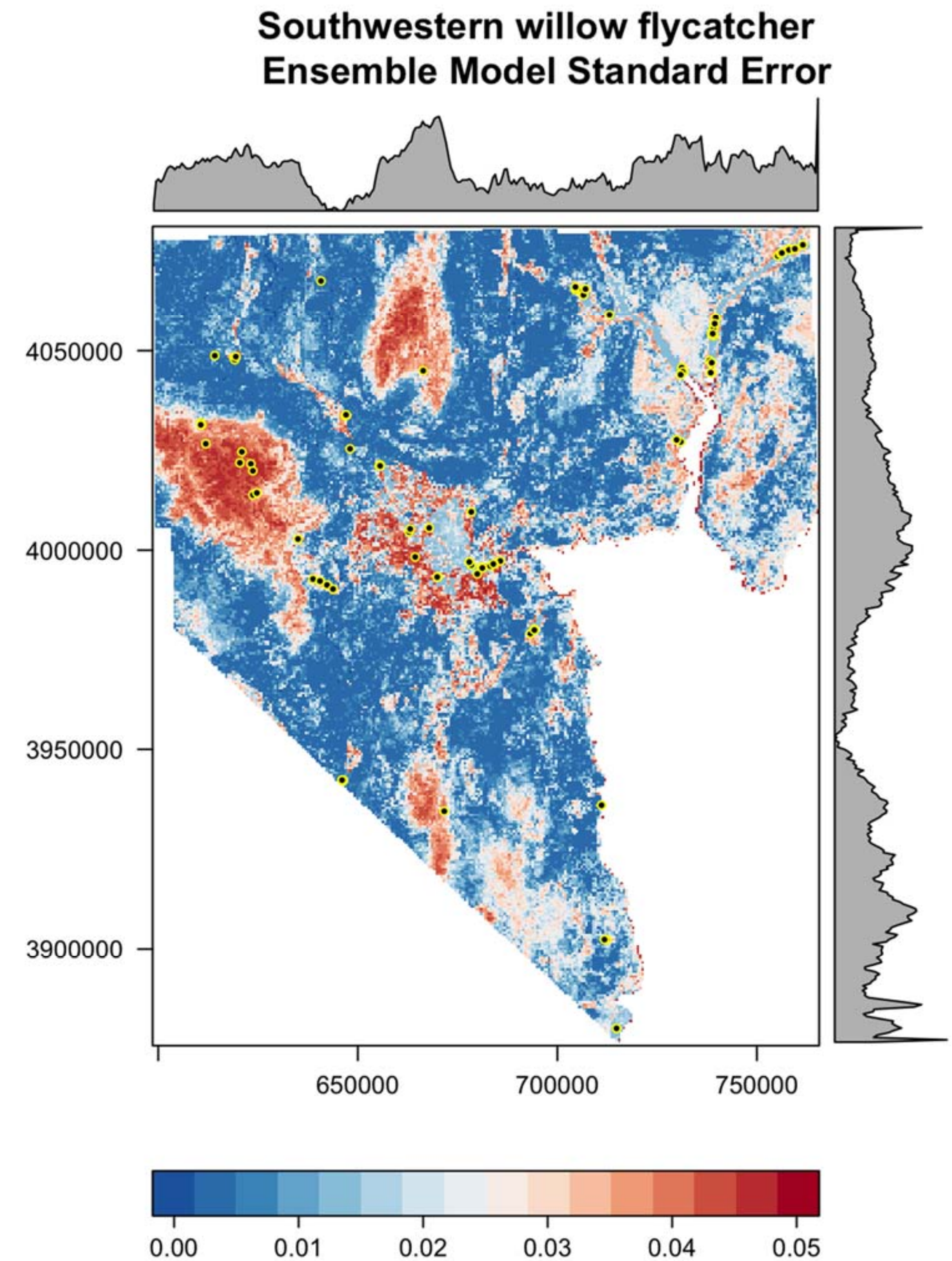
The locality data for this species consisted of 321 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 213 records.

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 (EMTR Figure 8).



EMTR Figure 7. SDM map for *E. traillii extimus* Ensemble model for Clark County, NV.



EMTR Figure 8. Standard Error map for the *E. traillii extimus* Ensemble model for Clark County, NV.

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 (EMTR Table 3), although breeding habitat is likely far more restricted.

EMTR Table 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

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).

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).

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.

Summary of Direct Impacts

The Southwestern Willow Flycatcher is a rare summer resident of Clark County. Approximately 823 km^2 of modeled high suitability habitat exists in the County (EMTR Table 4), although the proportion of this that is suitable for willow flycatcher nesting is estimated to be less. Covered activities have the potential to adversely affect this species in Clark County. It is estimated that approximately 18% of high and moderate suitability within the county could be impacted by activities covered under the Amendment, while 55% is already disturbed, and 27% of the combined habitat is located within conservation areas (EMTR Table 4).

EMTR Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	12786	6149	63423	82358
Med	15211	35196	21046	71453
Low	98542	472087	35912	606541

ERBI - Pahrump Valley Buckwheat (Eriogonum bifurcatum)

Pahrump Valley Buckwheat 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).

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

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).

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).

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 (ERBI Figure 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 (ERBI Figure 1).

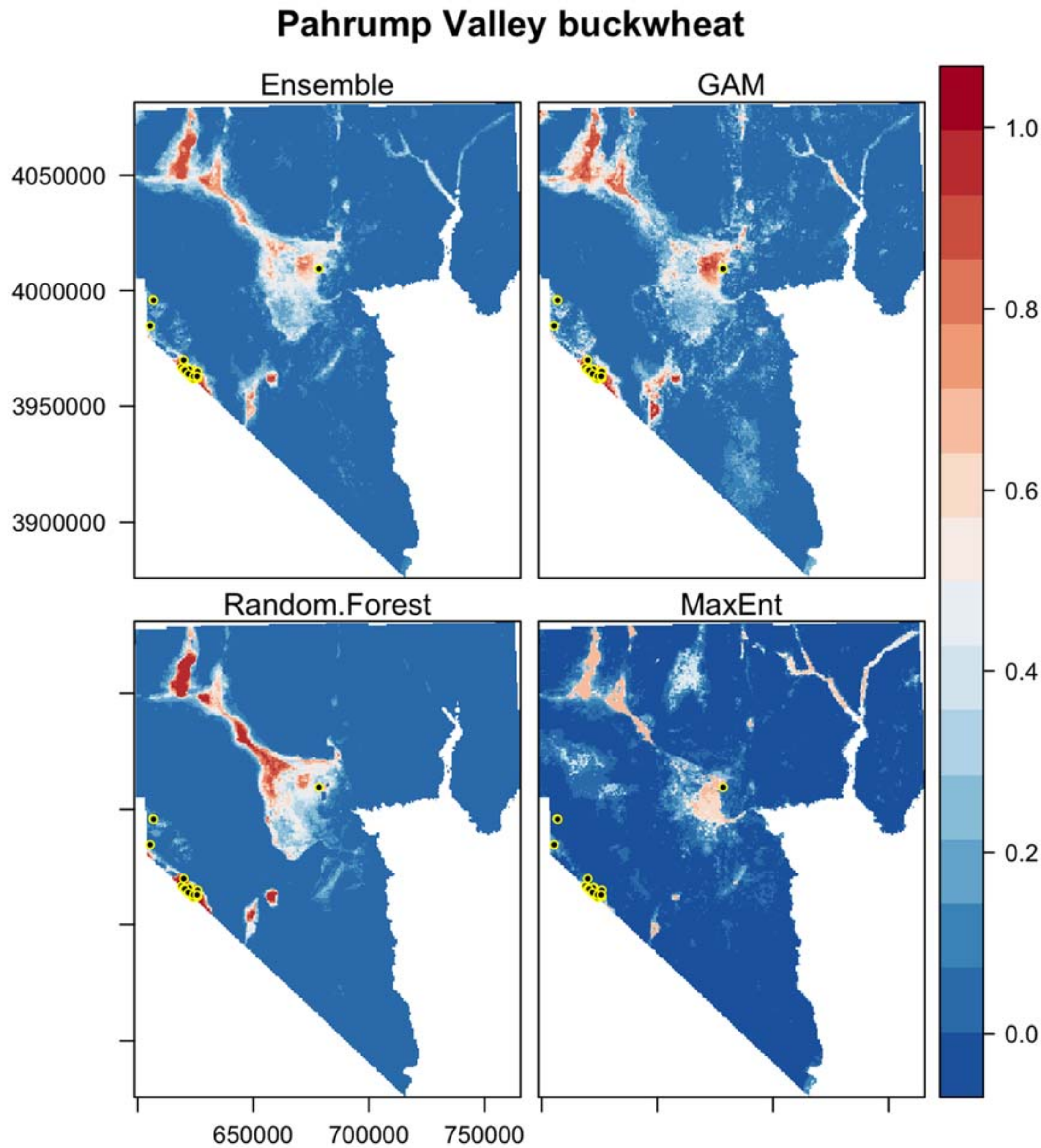
The Ensemble model and GAM models had slightly higher performance relative to the other models, with an equivalent score for AUC, and nearly equivalent scores for BI and TSS. The RF model (ERBI Table 1) performed well but had a lower BI score than both the Ensemble and GAM models. Relative to the other 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 (ERBI Table 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 (ERBI Figure 2). The Continuous Boyce Indices showed good model performance with the exception of the MaxEnt model (ERBI Figure 3). The MaxEnt curve indicated some values of lower performance where point density was higher, indicating less discrimination between high and low habitat (ERBI Figure 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, ERBI Figure 1).

ERBI Table 1. Model performance values for *Eriogonum bifurcatum* 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.

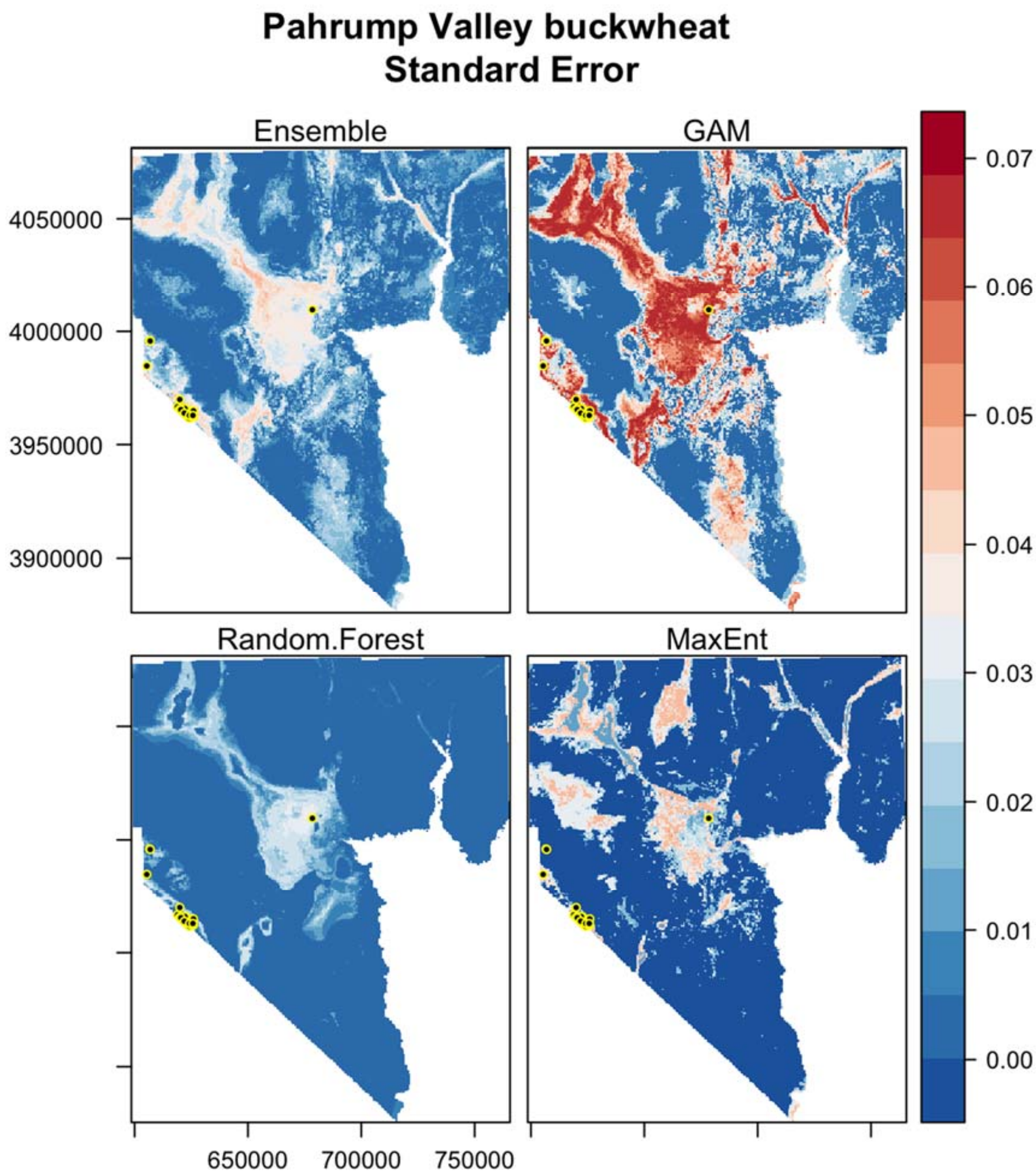
Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.88	0.88	0.39
GAM	0.99	0.84	0.92	
Random Forest	0.99	0.75	0.88	
MaxEnt	0.94	0.57	0.85	

ERBI Table 2. Percent contributions for input variables for *Eriogonum bifurcatum* 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.

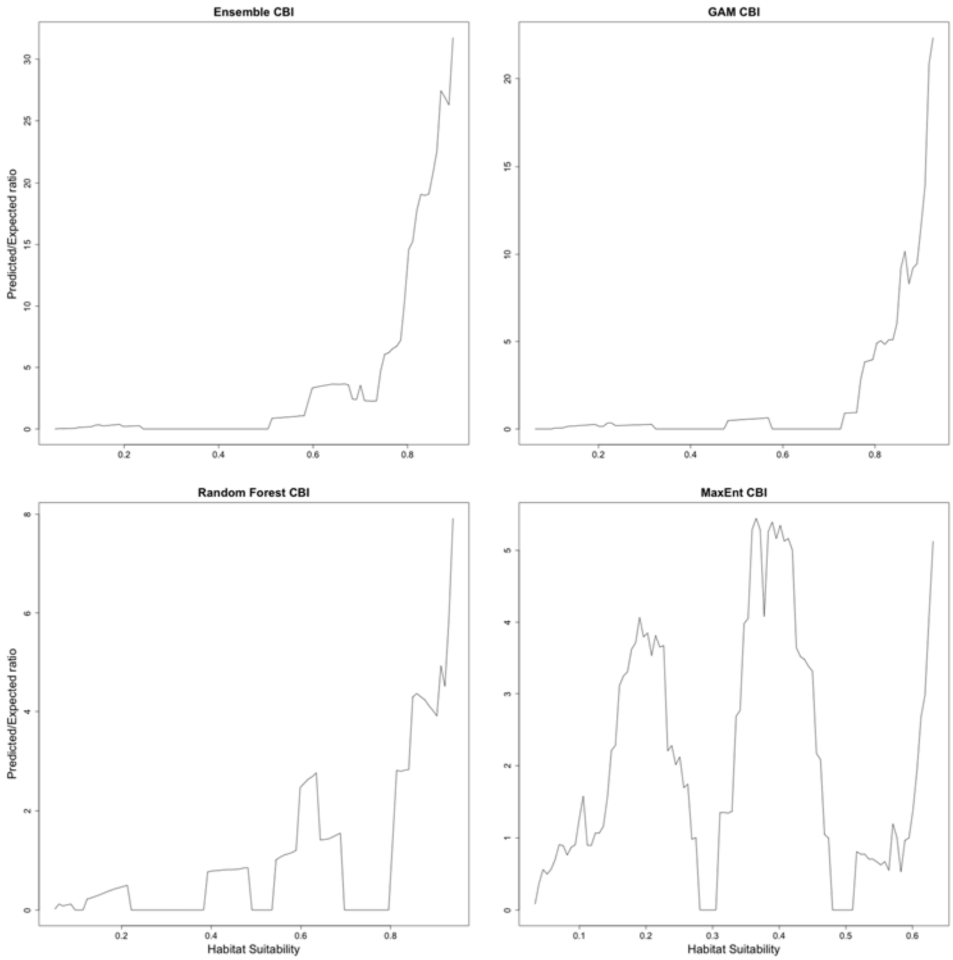
Variable	GAM	RF	MaxEnt
Ave Max Temp	12.9	5.6	2.3
Average Spring Max Temp	11.8	1.2	7
Clay	15.3	3.3	19.9
CV Average Spring Max Temp	11.1	2.9	3.4
Extreme Max Temp	8.9	1.4	1.5
Extreme Min Temp	3.3	2	24.8
Sand	9.9	1.1	4.2
Silt	13.7	0.5	12.9
Slope	5.6	4.6	8
Winter Precip	7.4	77.5	15.9



ERBI Figure 1. SDM maps for *Eriogonum bifurcatum* 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.



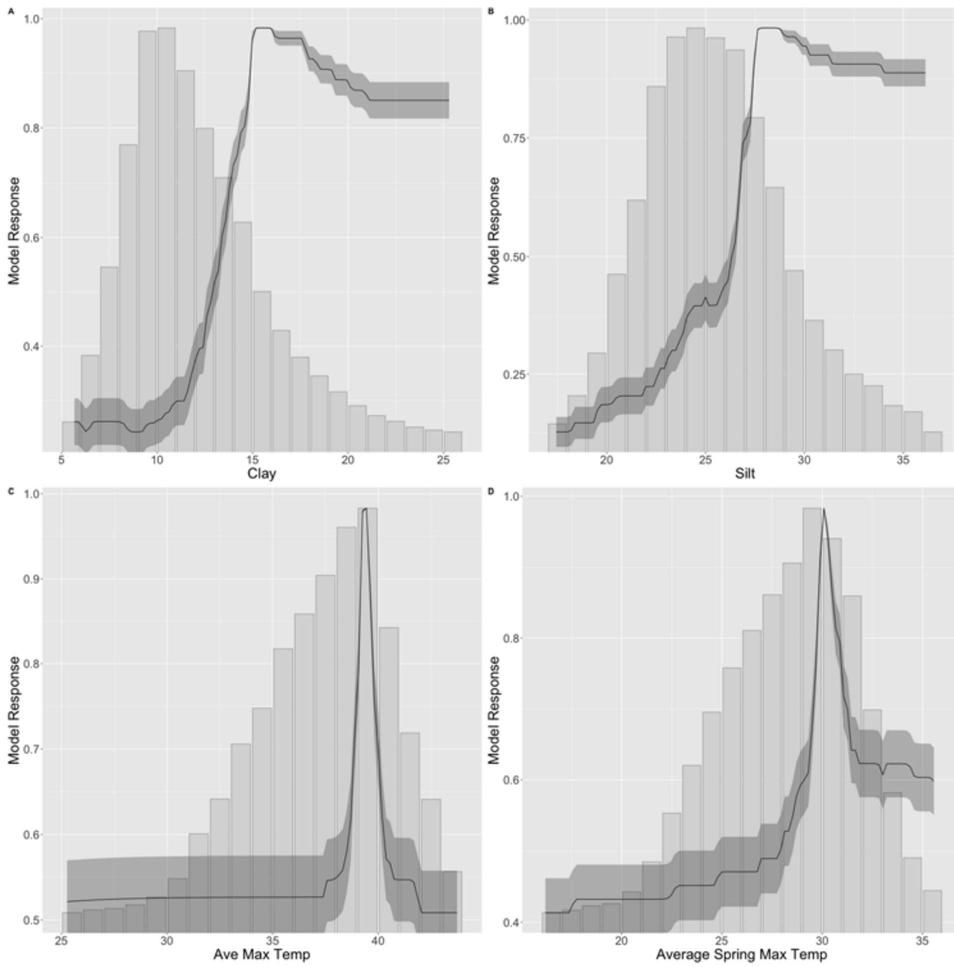
ERBI Figure 2. Standard error maps for *Eriogonum bifurcatum* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



ERBI Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Eriogonum bifurcatum* 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).

General Additive Model

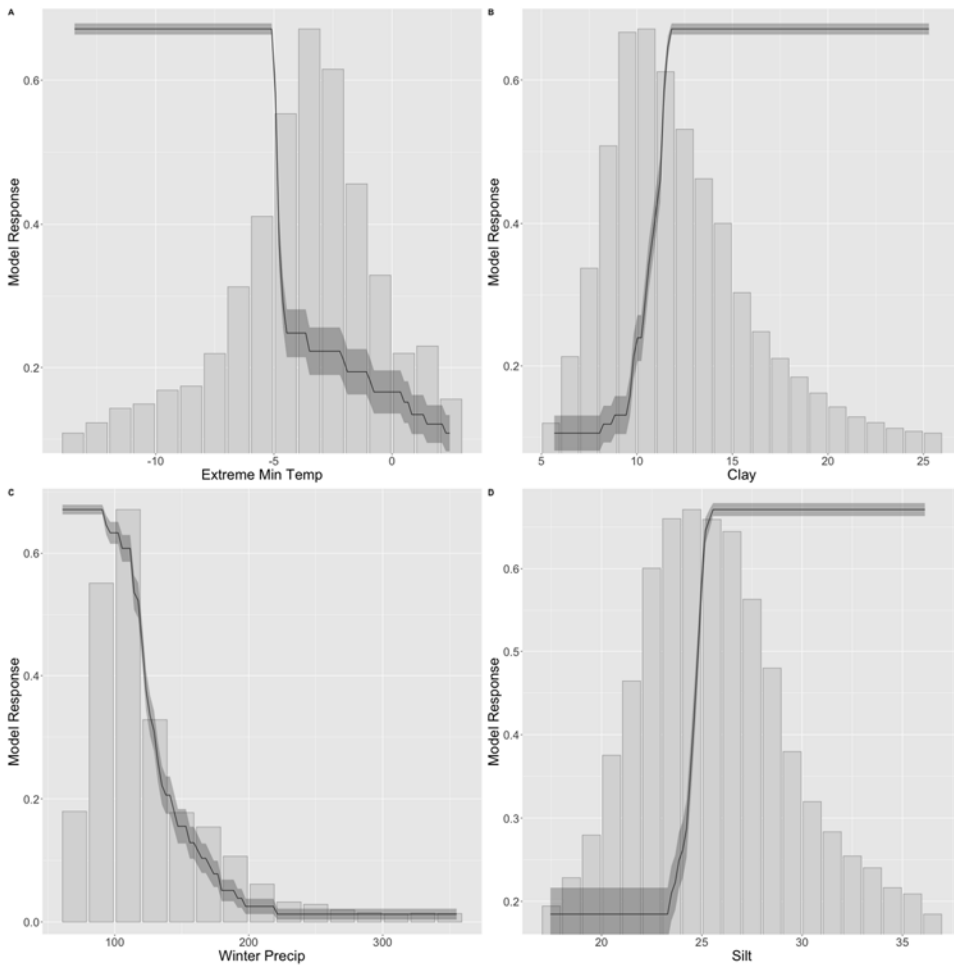
The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, Clay, and Silt components of the soil collectively accounting for 54% of total model contribution (ERBI Table 2). Model scores were higher in areas with Extreme Maximum temperatures at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



ERBI Figure 4. GAM partial response curves for the top four variables in the *Eriogonum bifurcatum* 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.

MaxEnt Model

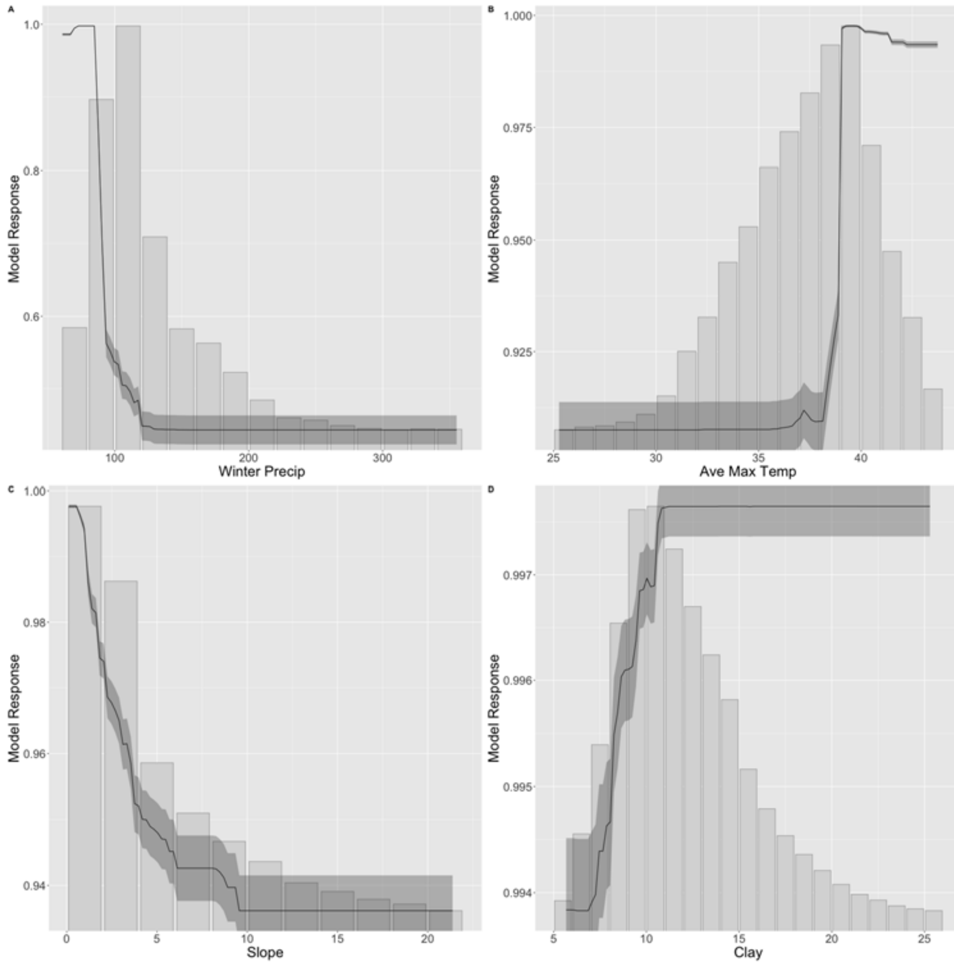
The MaxEnt models relied heavily on the one of the same four top variables as those in the GAM and RF models (Clay Content), shared Winter Precipitation as a variable with the RF models. Extreme Minimum temperature, and Winter Precipitation were also important contributors in the MaxEnt models. In total, these four variables accounted for 73.5% of total model contribution (ERBI Table 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 (ERBI Figure 4, ERBI Figure 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 (ERBI Figure 5).



ERBI Figure 5. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for *Eriogonum bifurcatum.* 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.

Random Forest Model

The Random Forest model was largely driven by Winter Precipitation (77.4%), Average Maximum temperature, Slope, and soil Clay Content (ERBI Table 2). The collective model influence of these four variables was 91%, where very little additional influence was proved by several other input variables (ERBI Table 2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (ERBI Figure 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 (ERBI Figure 6).



ERBI Figure 6. Partial response curves for the environmental variables included in the Random Forest Ensemble model for *Eriogonum bifurcatum.* 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.

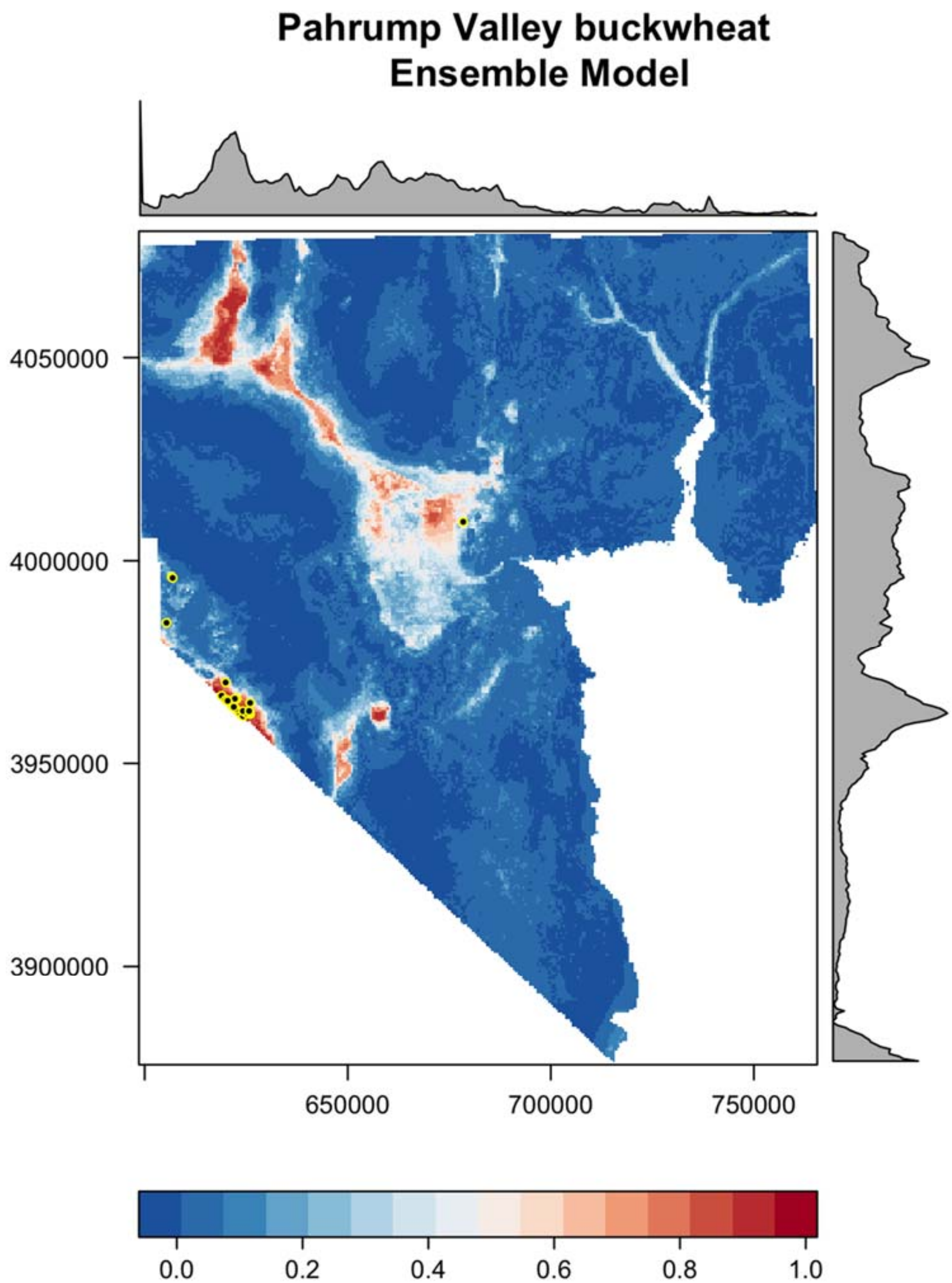
Model Discussion

Eriogonum bifurcatum 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 (ERBI Figure 7). More habitat exists in the California side of the Pahrump valley, and in habitat extending into Nye County.

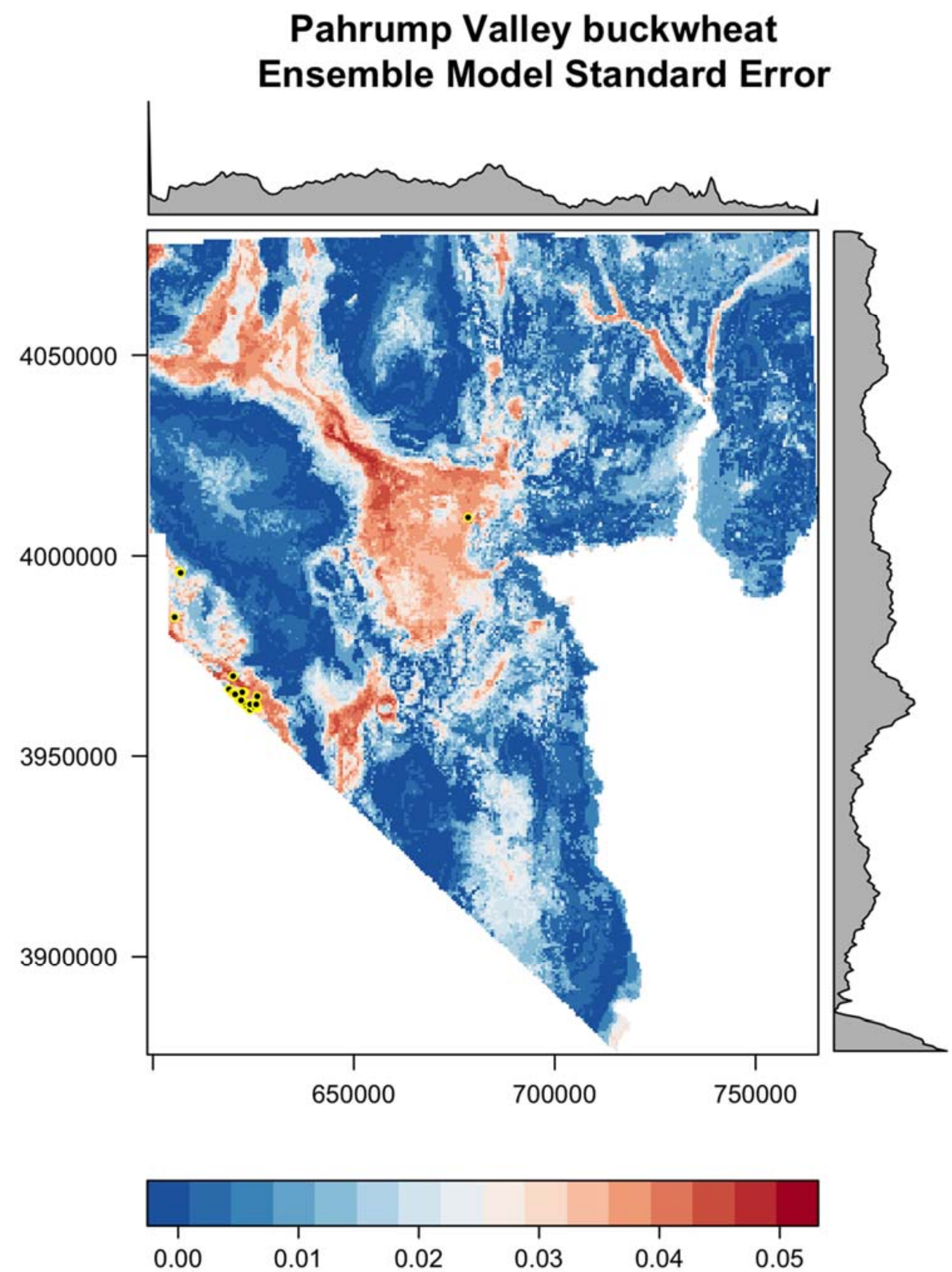
The locality data for this species consisted of 1384 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 128.

Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (ERBI Figure 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.



ERBI Figure 7. SDM map for *Eriogonum bifurcatum* Ensemble model for Clark County, NV.



ERBI Figure 8. Standard Error map for the *Eriogonum bifurcatum* Ensemble model for Clark County, NV.

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 (ERBI Table 3). Moderate habitat includes some Desert Riparian areas as well (ERBI Table 3).

ERBI Table 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

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).

Threats to Species

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

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.

Summary of Direct Impacts

Pahrump Valley Buckwheat is a very rare species throughout its range. Direct impacts indicate that 10% of predicted high suitability habitat is already disturbed, and an additional 89% is in potential impact areas. Relatively little area was identified as within conservation areas (ERBI Table 4).

ERBI Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	99263	764	11560	111587
Med	19023	3153	51693	73869
Low	8537	509811	56987	575335

ERCO - Las Vegas Buckwheat (Eriogonum corymbosum var. nilesii)

The Las Vegas Buckwheat 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).

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

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).

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).

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 (ERCO Figure 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 (ERCO Figure 1).

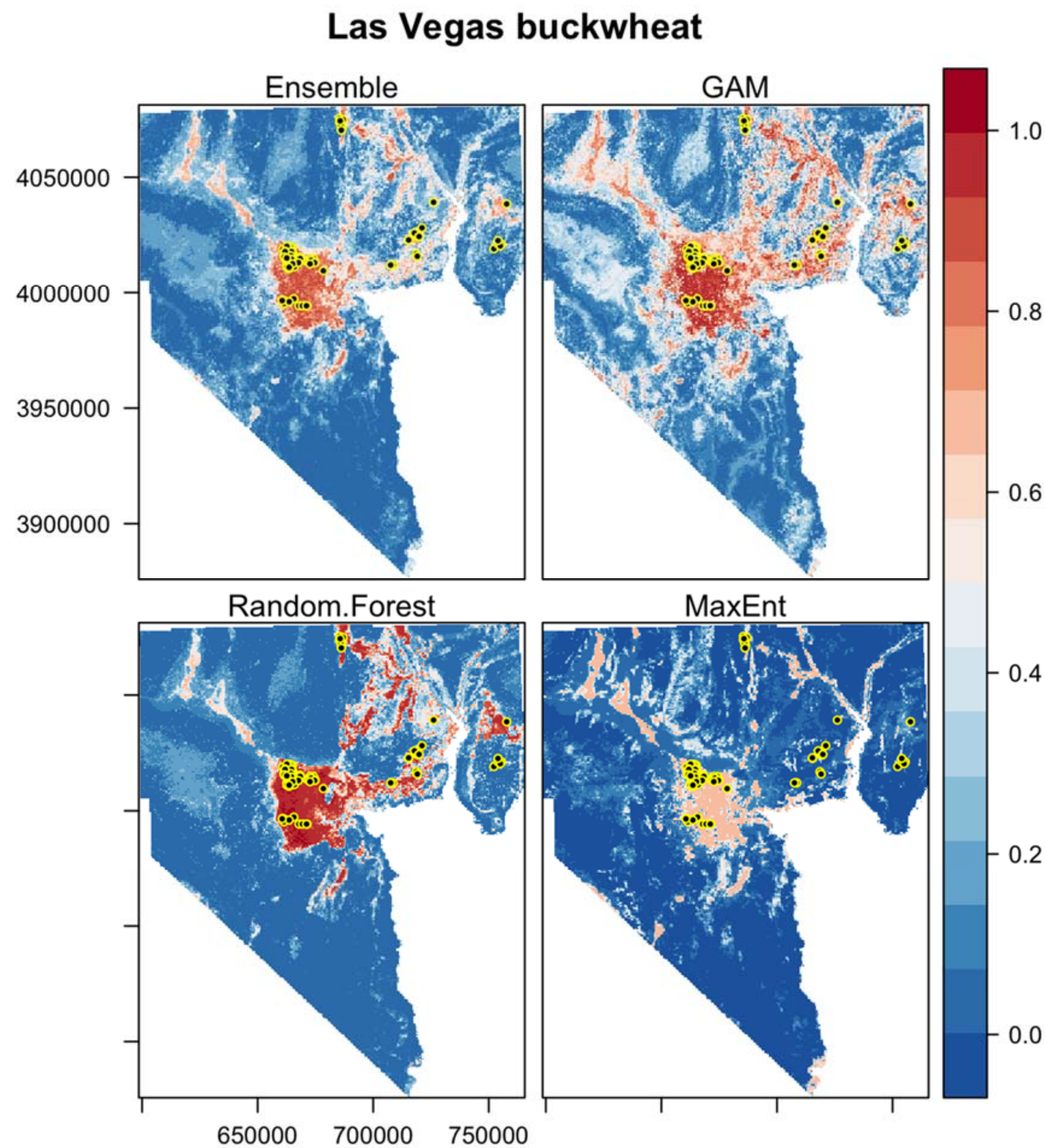
The Ensemble model and GAM models had slightly higher performance relative to the other models, with an equivalent score for AUC and TSS (ERCO Table 1). However, the Ensemble model had a noticeably lower BI score than any other model. The RF model performed well but had a lower BI score than both the GAM models (ERCO Table 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 (ERCO Table 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 (ERCO Figure 2). All other model standard errors were very low (ERCO Figure 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 (ERCO Figure 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.

ERCO Table 1. Model performance values for *Eriogonum corymbosum* var. *nilesii* 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.

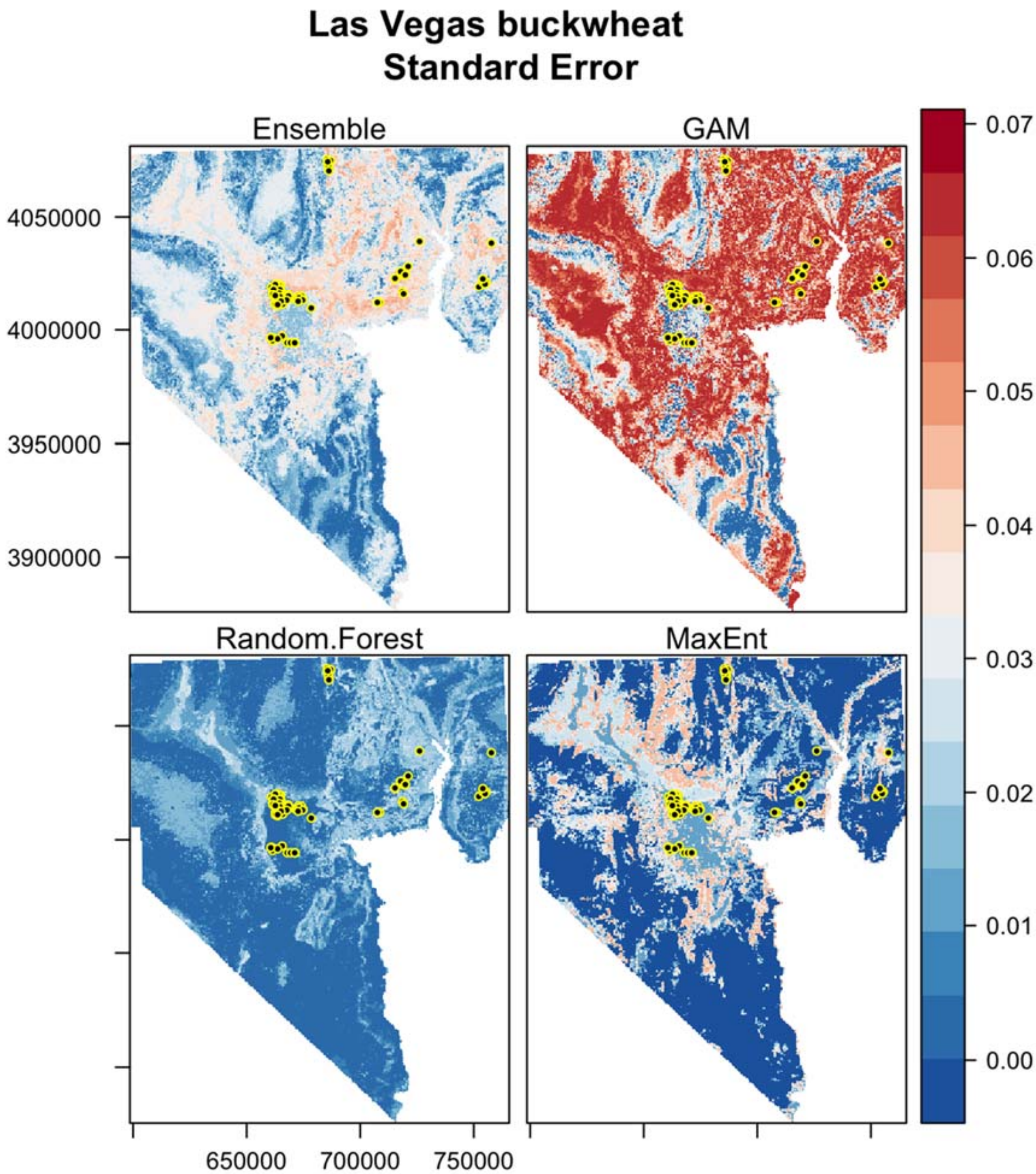
Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.7	0.95	0.39
GAM	0.99	0.98	0.95	
Random Forest	1	0.86	0.95	
MaxEnt	0.95	0.82	0.84	

ERCO Table 2. Percent contributions for input variables for *Eriogonum corymbosum* var. *nilesii* 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.

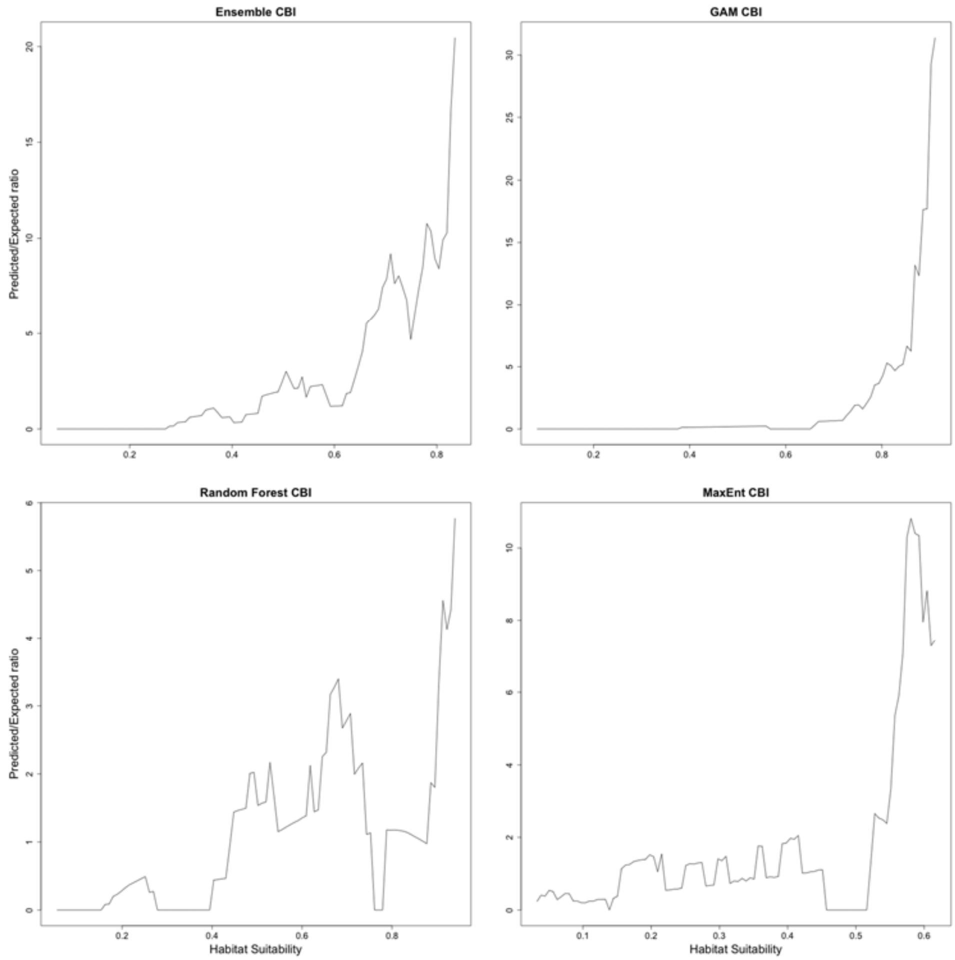
Variable	GAM	RF	MaxEnt
Ave Max Temp	13.3	9.7	6
Average Spring Max Temp	13.5	18	1.2
Soil gypsum	2.6	5.3	3.2
NDVI Amplitude	18.9	15	1.9
NDVI Max	7.7	8.3	20
Sand	7	6.7	36.8
Silt	12.5	8.6	6.8
Start of Season (day)	6.2	11	4.6
Winter Precip	10.1	14.7	15
CV Winter Precip	8.2	2.6	4.6



ERCO Figure 1. SDM maps for *Eriogonum corymbosum* var. *nilesii* 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.



ERCO Figure 2. Standard error maps for *Eriogonum corymbosum var. nilesii* 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).

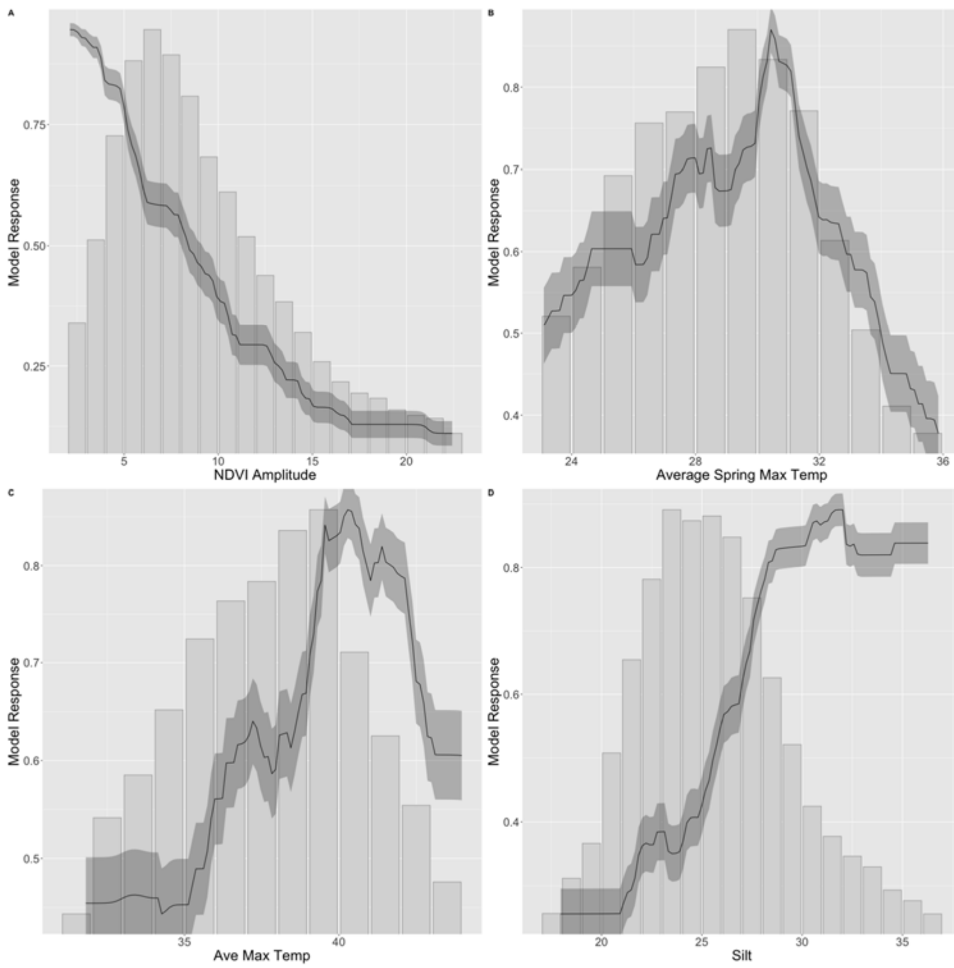


ERCO Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Eriogonum corymbosum* var. *nilesii* models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

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 (ERCO Table 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 (ERCO Figure 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 (ERCO Figure 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 (ERCO Figure 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. (ERCO Figure 4, ERCO Figure 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 (ERCO Figure 4). These areas also represent areas with higher Silt Content than found in the County generally (ERCO Figure 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 (ERCO Figure 3).

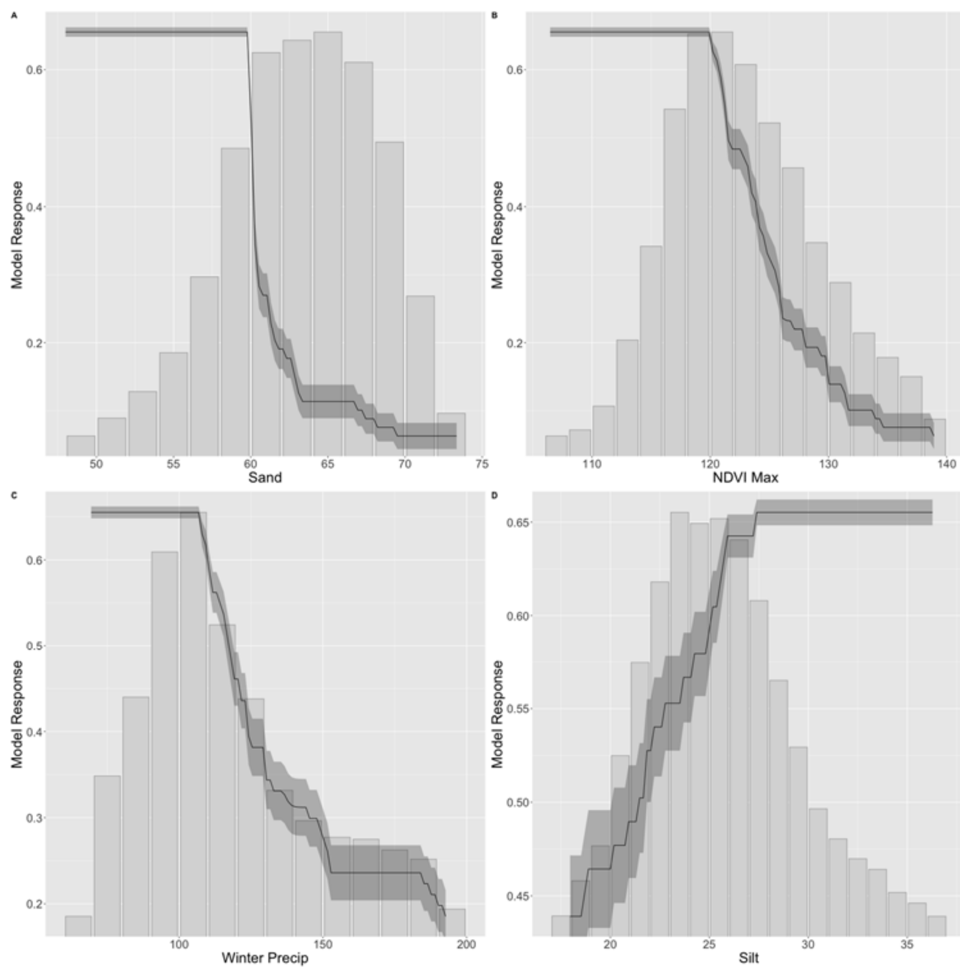


ERCO Figure 4. GAM partial response curves for the top four variables in the *Eriogonum corymbosum* var. *nilesii* model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence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

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 (ERCO Table 2). The models indicated consistently high habitat values when NDVI Maximum was below 120, with a rapid decline thereafter (ERCO Figure 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% (ERCO Figure 4). This model had very similar response curves to the GAM model for the Silt Content variable (ERCO Figure 4. ERCO Figure 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.

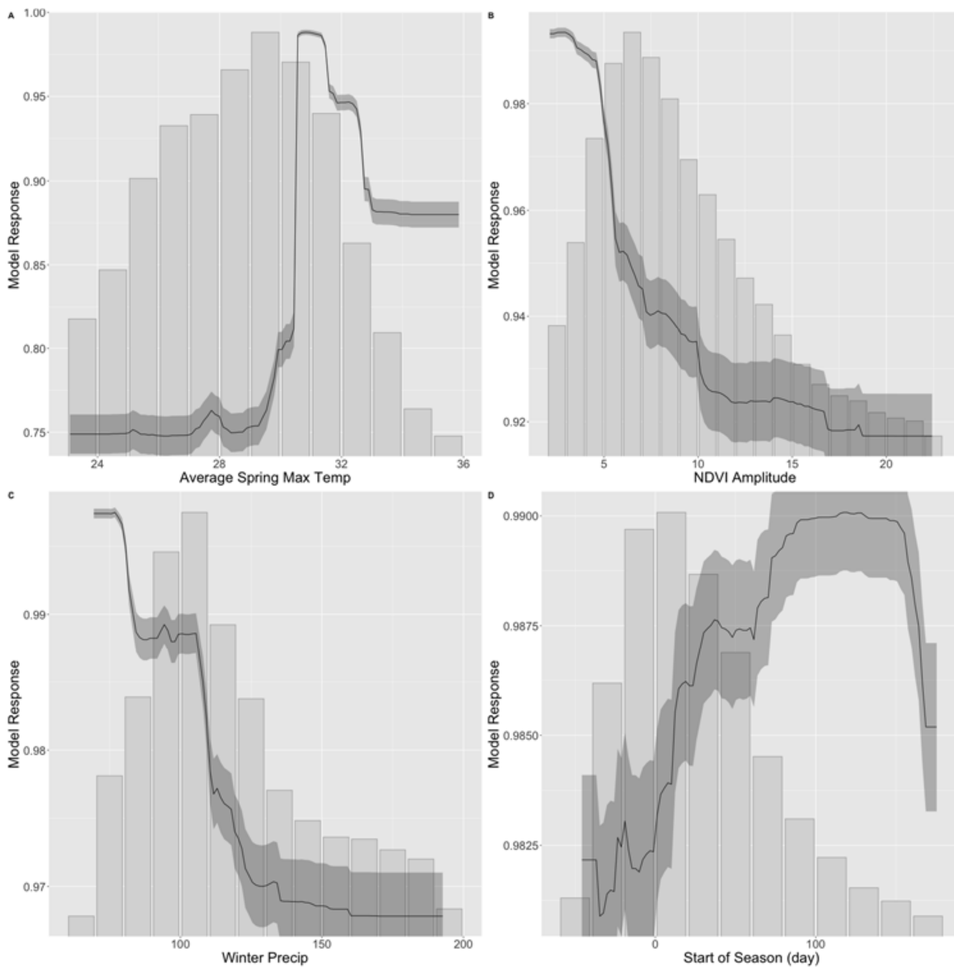
This model had relatively low standard errors, indicating general agreement in the predictions among the 50 model cross-validation runs (ERCO Figure 3).



ERCO Figure 5. Partial response curves for the top four environmental variables included in the MaxEnt Ensemble model for *Eriogonum corymbosum* var. *nilesii.* 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.

Random Forest Model

The Random Forest model was largely driven by Average Spring Maximum temperature, NDVI Amplitude, Start of Season, and Winter Precipitation (ERCO Table 2). The collective model influence of these four variables was 58.7%, where additional influence was proved by several other input variables (ERCO Table 2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (ERCO Figure 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 (ERCO Figure 6).



ERCO Figure 6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for *Eriogonum corymbosum* var. *nilesii.* 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.

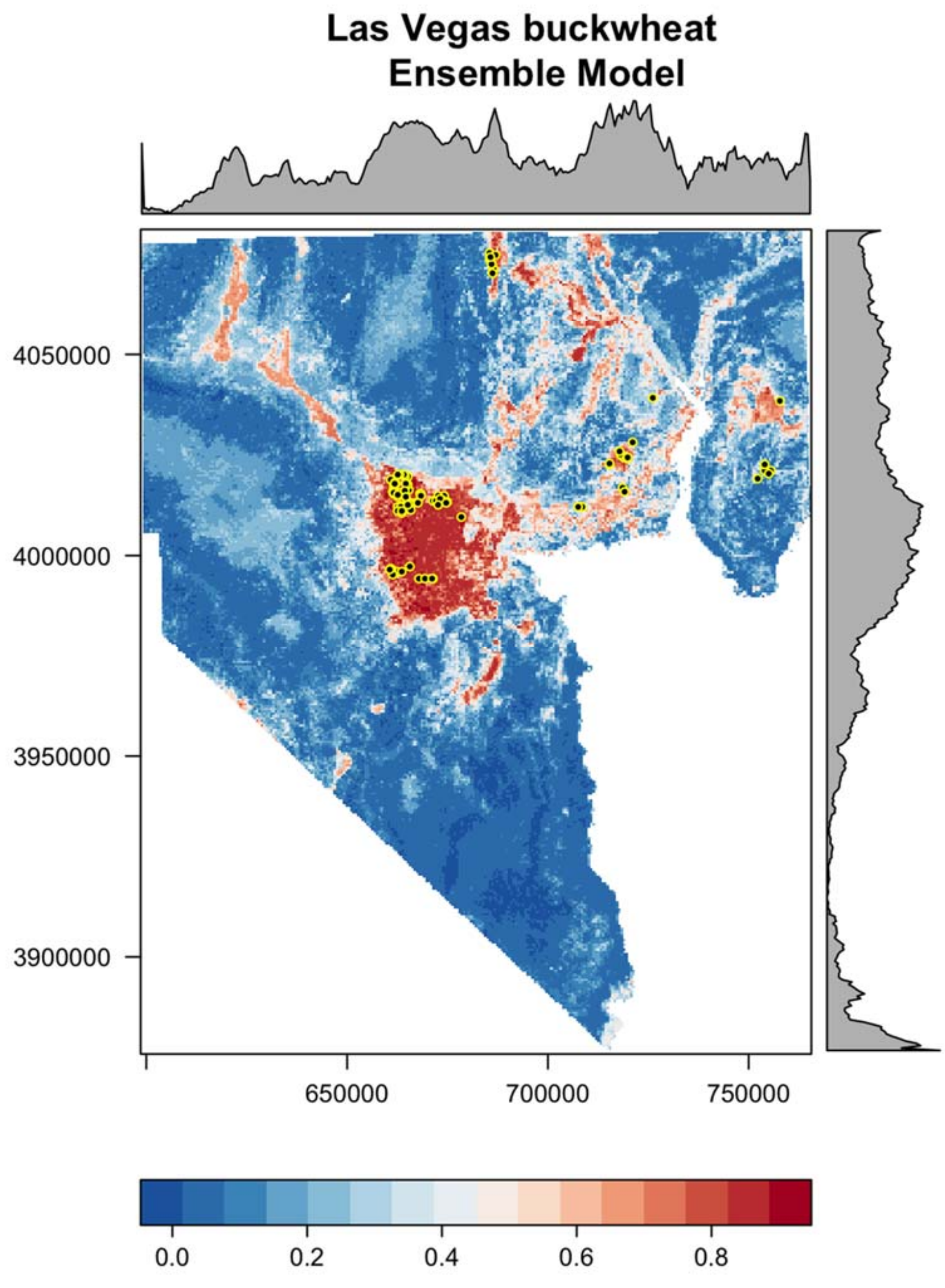
Model Discussion

Eriogonum corymbosum var. *nilesii* primarily occurs in and near the City of Las Vegas, notably concentrated on both the North and South sides (ERCO Figure 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 (ERCO Figure 7)

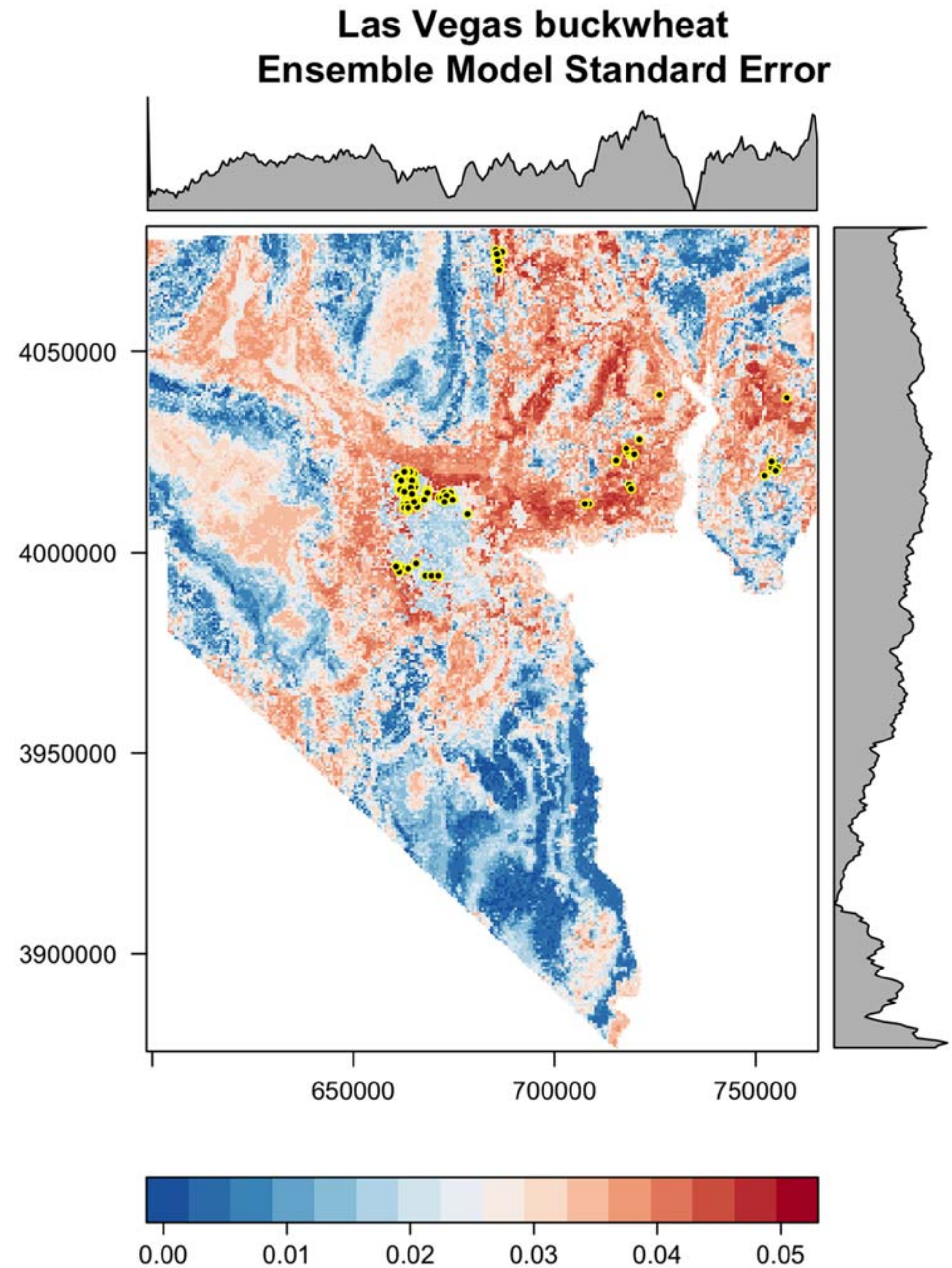
The locality data for this species consisted of 936 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 96 records

Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (ERCO Figure 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.



ERCO Figure 7. SDM map for *Eriogonum corymbosum* var. *nilesii* Ensemble model for Clark County, NV.



ERCO Figure 8. Standard Error map for the *Eriogonum corymbosum* var. *nilesii* Ensemble model for Clark County, NV.

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 (ERCO Table 3), while medium suitability habitat includes areas in Blackbrush, Mesquite Acacia, and Desert Riparian systems (ERCO Table 3).

ERCO Table 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

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).

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.

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.

Summary of Direct Impacts

The Las Vegas Buckwheat is a very rare species within Clark County, although it may be locally abundant. Suitable habitat for this species encompasses 1753 km^2 hectares of high and 1314 km$^{2\ of}$ medium category modeled habitat within Clark County. Of this 705 km^2 of high suitability habitat are estimated to have already been disturbed, and another 741 km^2 are estimated to be impacted. Conservation areas encompass 307 km^2 of high and 705 km^2 of moderate habitat (17.5% and 54% respectively, ERCO Table 4).

ERCO Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	74095	30686	70543	175324
Med	32627	70503	28263	131393
Low	19954	411987	21546	453487

ERVI - Sticky Buckwheat (Eriogonum viscidulum)

Sticky Buckwheat 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).

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

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.

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.

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 (ERVI Figure 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 (ERVI Figure 1).

All three models had similarly high performance for AUC and TSS (ERVI Table 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 (ERVI Table 1). The GAM and RF models shared Average of Maximum temperature as one of the top four influential environmental variables (ERVI Table 2). The GAM and MaxEnt models shared Silt Content as one of the top four influential environmental variables (ERVI Table 2). The RF and MaxEnt model shared CV Average Spring Maximum temperature, and CV Winter

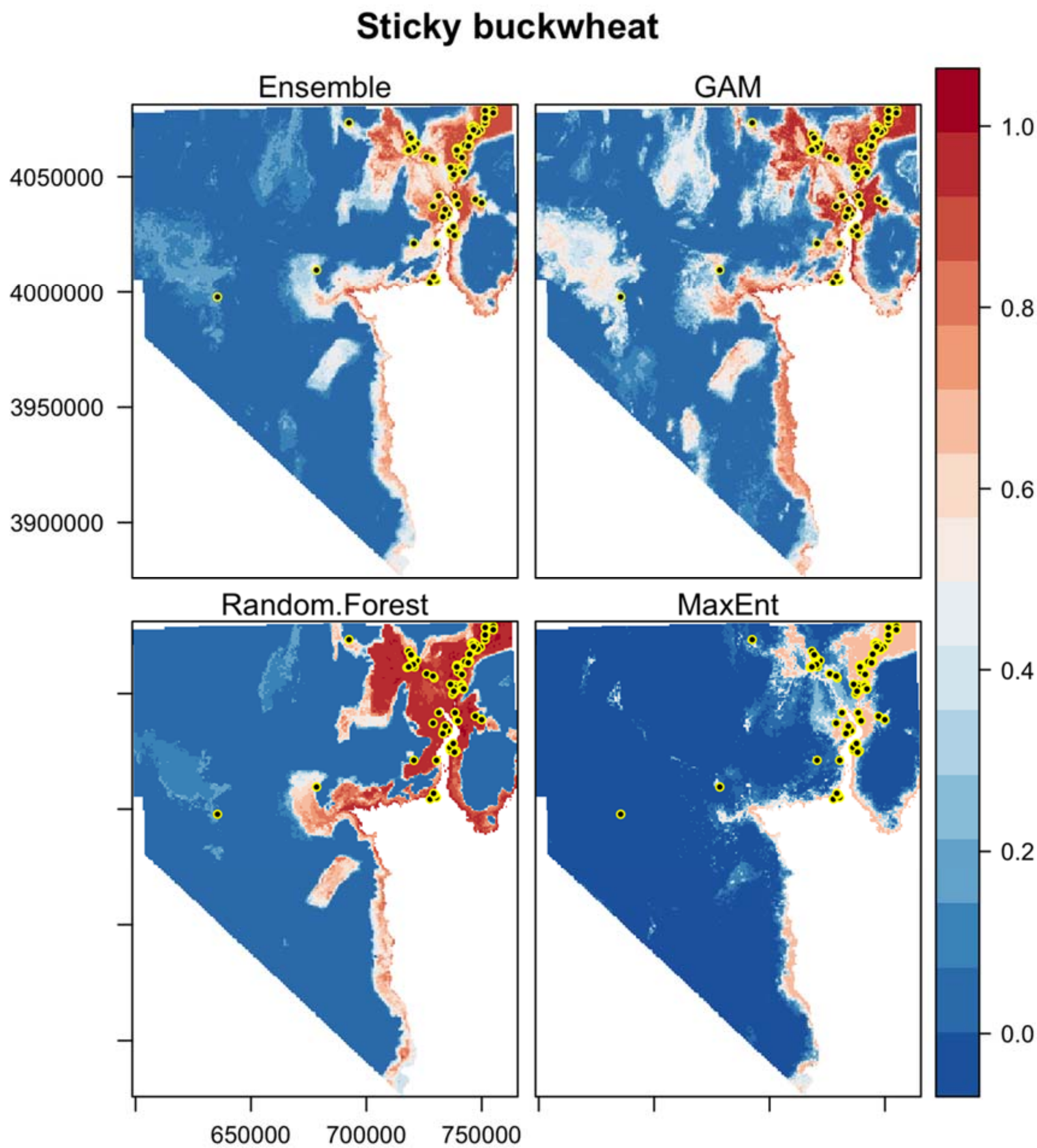
Precipitation as a top influential variables (ERVI Table 2). The standard error was relatively low throughout the County for the RF and MaxEnt models, while the GAM model had values approaching 0.07 in many areas (ERVI Figure 2). The Continuous Boyce Indices showed good model performance for the GAM models, with some irregularity in lower habitat values for the RF models (ERVI Figure 3). The MaxEnt curve indicated some values of higher performance where point density was only moderate, indicating less discrimination between high and low habitat (ERVI Figure 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, ERVI Figure 1), and lack of high scores in areas of highest point density.

ERVI Table 1. Model performance values for *Eriogonum viscidulum* 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.

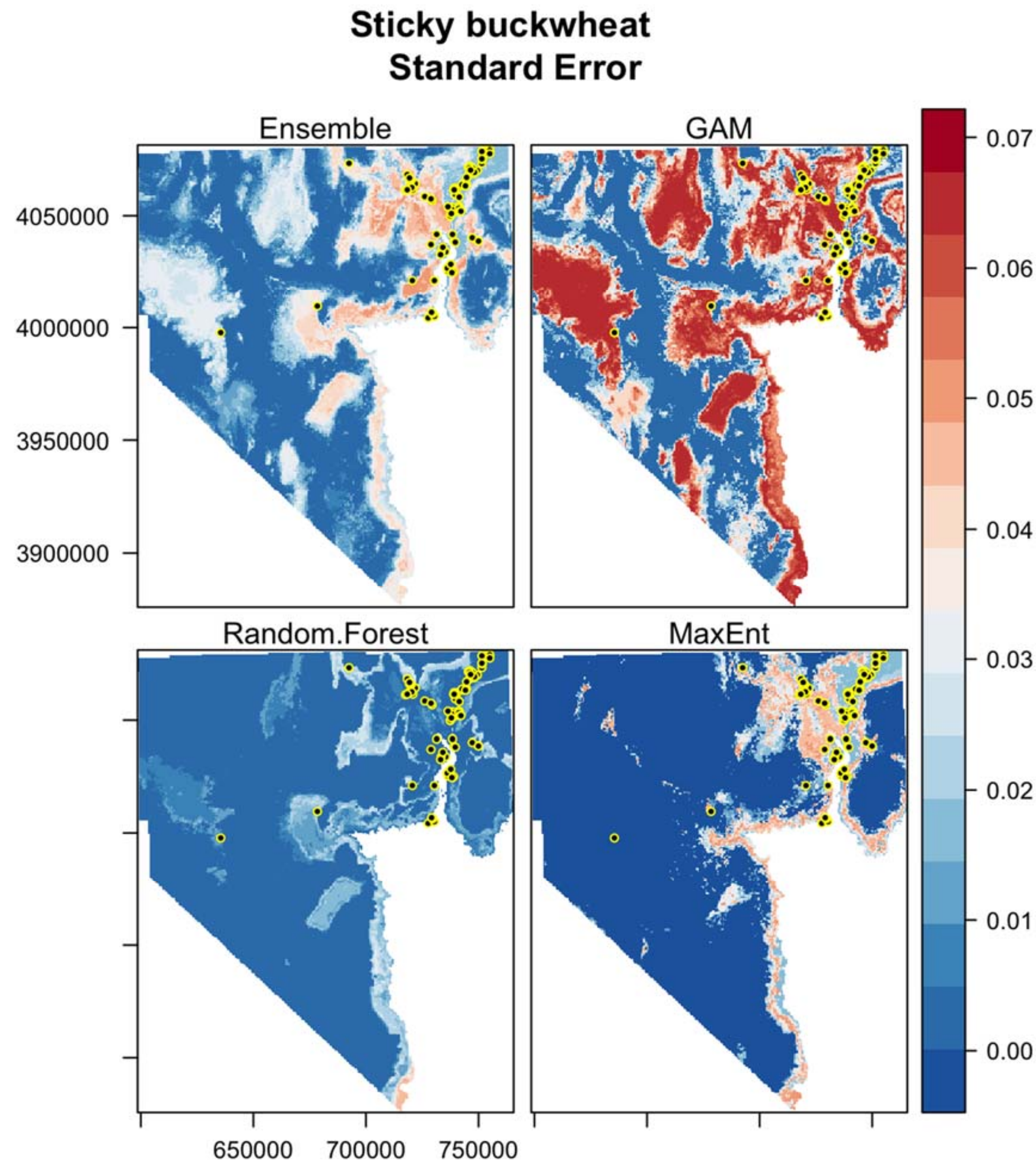
Model	AUC	BI	TSS	PRBE
Ensemble	0.99	0.77	0.9	0.41
GAM	0.97	0.93	0.86	
Random Forest	0.98	0.25	0.86	
MaxEnt	1	0.48	0.95	

ERVI Table 2. Percent contributions for input variables for *Eriogonum viscidulum* 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.

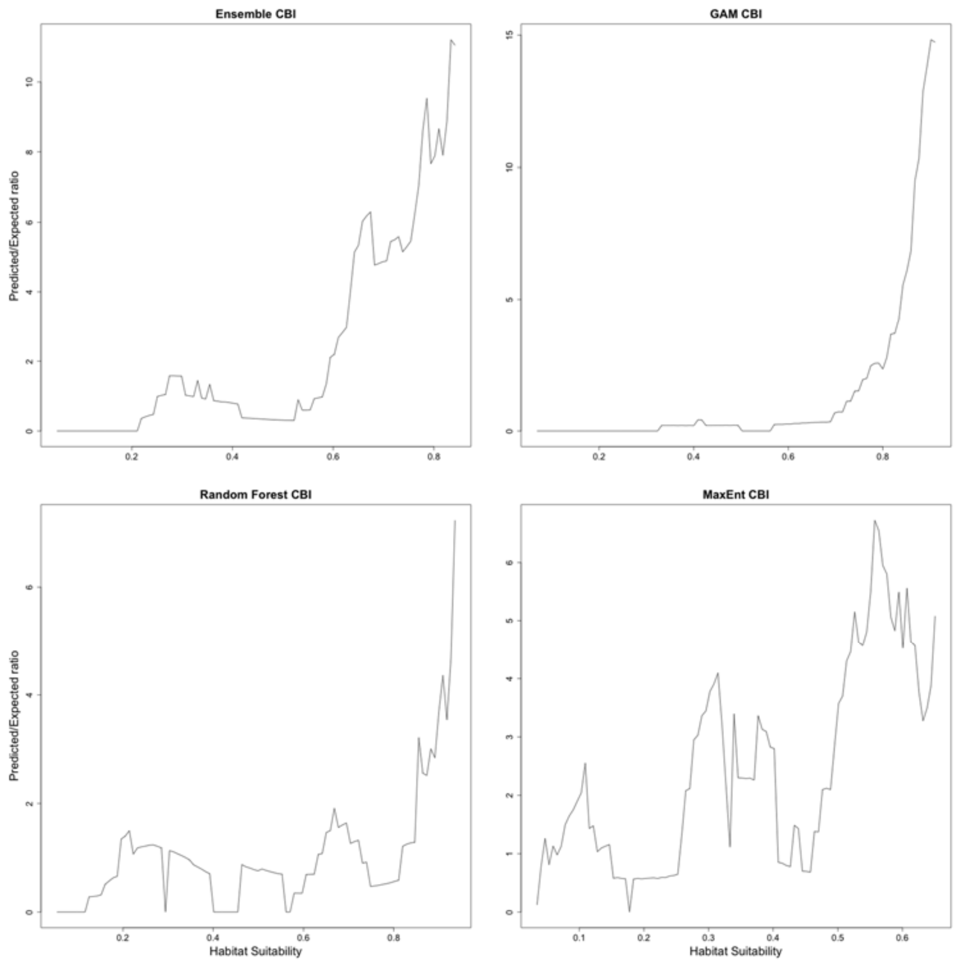
Variable	**GAM**	**RF**	**MaxEnt**
Ave Max Temp	15.9	9.2	1.1
Average Spring Max Temp	12.6	8.1	0.5
Depth to bedrock	4	1.7	5.8
Clay	11.1	0.4	15
Coarse frags	3.2	3.7	3.1
CV Average Spring Max Temp	8.3	16.9	39.6
Extreme Max Temp	11.2	49.9	6.9
Sand	13.6	0.4	0.6
Silt	12.4	0.9	9.2
CV Winter Precip	7.8	8.9	18.1



ERVI Figure 1. SDM maps for *Eriogonum viscidulum* 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.



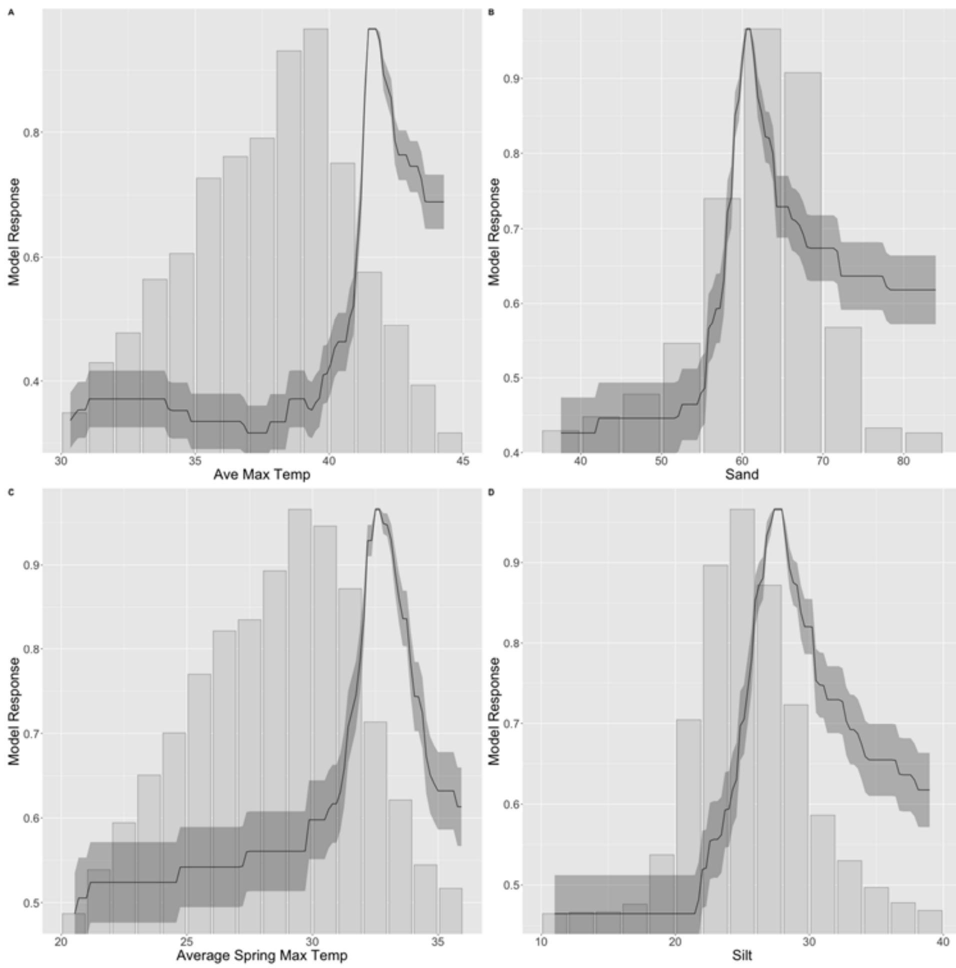
ERVI Figure 2. Standard error maps for *Eriogonum viscidulum* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



ERVI Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Eriogonum viscidulum* 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).

General Additive Model

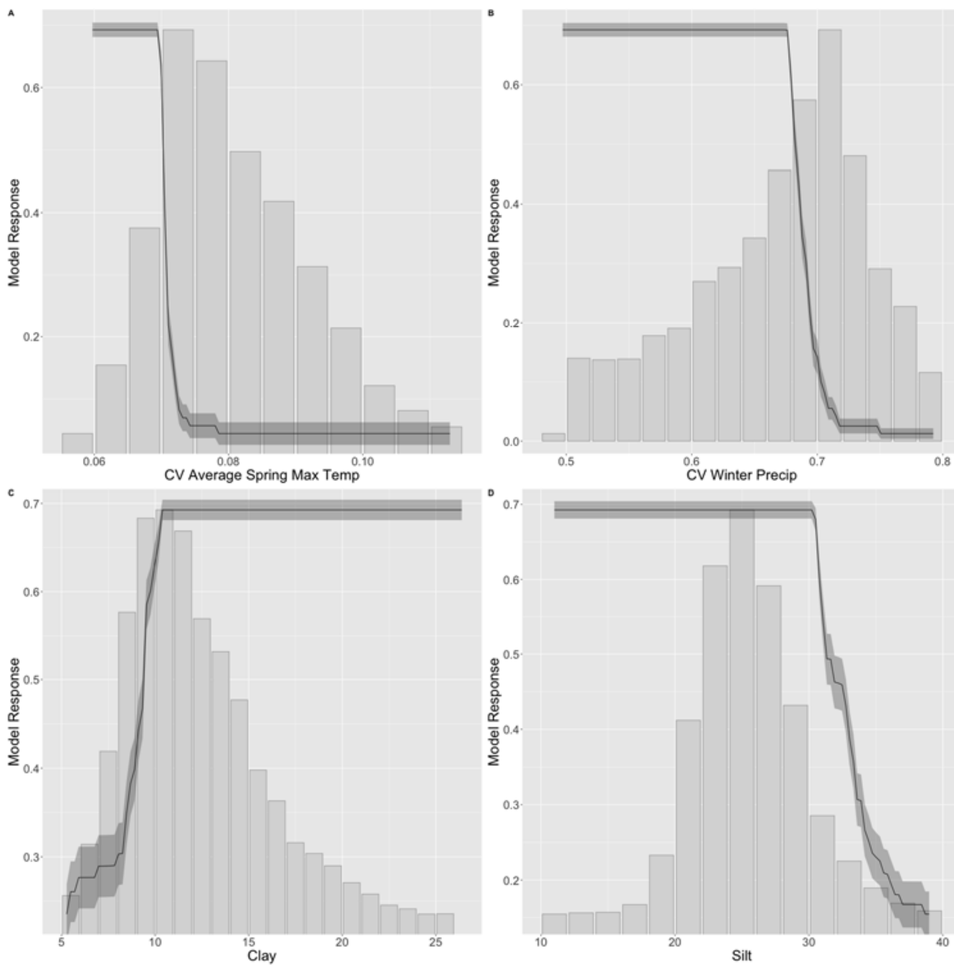
The top four contributing environmental layers were Average Maximum temperature, Average Spring Maximum temperature, Sand, and Silt components of the soil collectively accounting for 54% of total model contribution (ERVI Table 2). Model scores were higher in areas with Average Maximum temperatures at 44 ºC, and lower at all other temperatures. Spring Maximum temperatures showed a peak response at 33 ºC, and were lower elsewhere. (ERVI Figure 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 (ERVI Figure 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 (ERVI Figure 3).



ERVI Figure 4. GAM partial response curves for the top four variables in the *Eriogonum viscidulum* 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.

MaxEnt Model

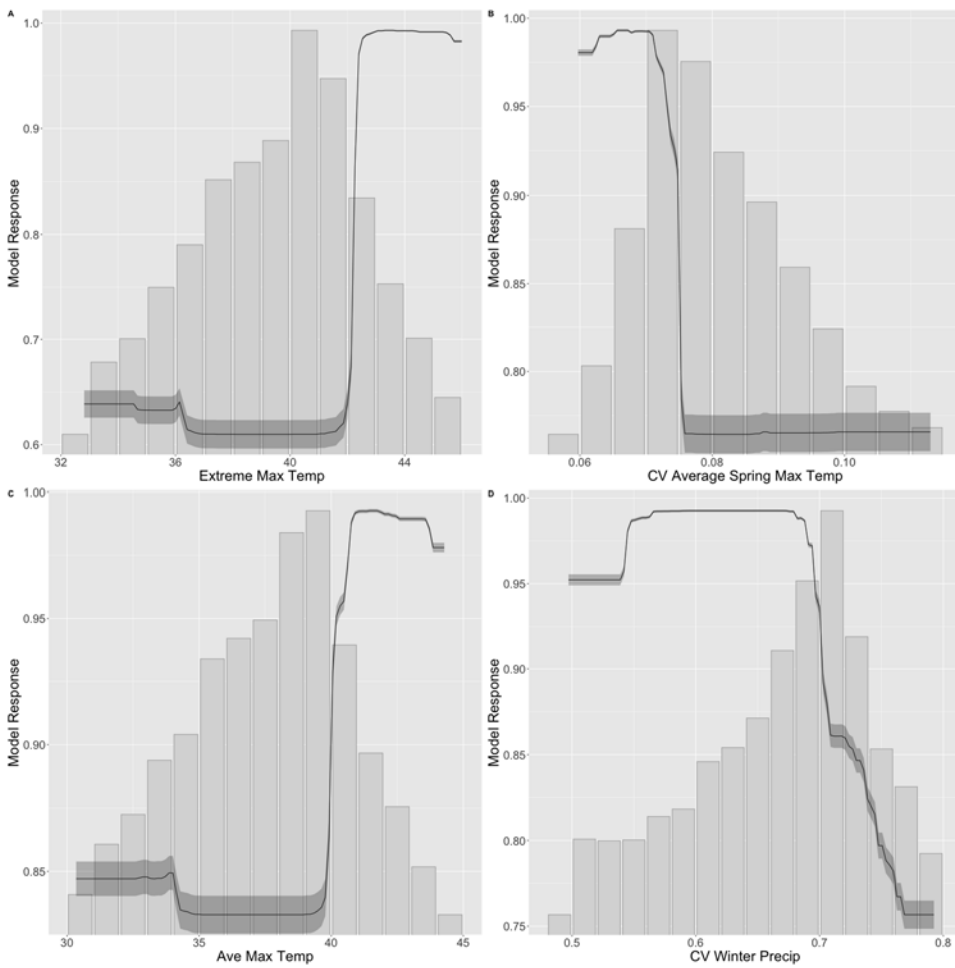
The MaxEnt models relied heavily on the one of the same four top variables as those in the GAM models (Silt Content), and shared CV Winter Precipitation as a variable with the RF models. Clay Content, and CV Spring Maximum temperature were also important contributors in the MaxEnt models. In total, these four variables accounted for 72.7% of total model contribution, where CV of the Spring Maximum temperature was the largest overall contributor (40%. ERVI Table 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 (ERVI Figure 4, ERVI Figure 5). The predicted response for CV Winter Precipitation is nearly the same as the response seen in the RF model (ERVI Figure 5, ERVI Figure 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 (ERVI Figure 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 (ERVI Figure 5, ERVI Figure 6).



ERVI Figure 5. Partial response curves for the top four environmental variables included in the MaxEnt Ensemble model for *Eriogonum viscidulum.* 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.

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 (ERVI Figure 6). The CV of Average Maximum temperatures was the second highest contributor (ERVI Table 2). As described above, the response was similar to the MaxEnt model ERVI Figure 5, ERVI Figure 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 (ERVI Figure 5, ERVI Figure 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 (ERVI Figure 4, ERVI Figure 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 (ERVI Figure 1).



ERVI Figure 6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for *Eriogonum viscidulum.* 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.

Model Discussion

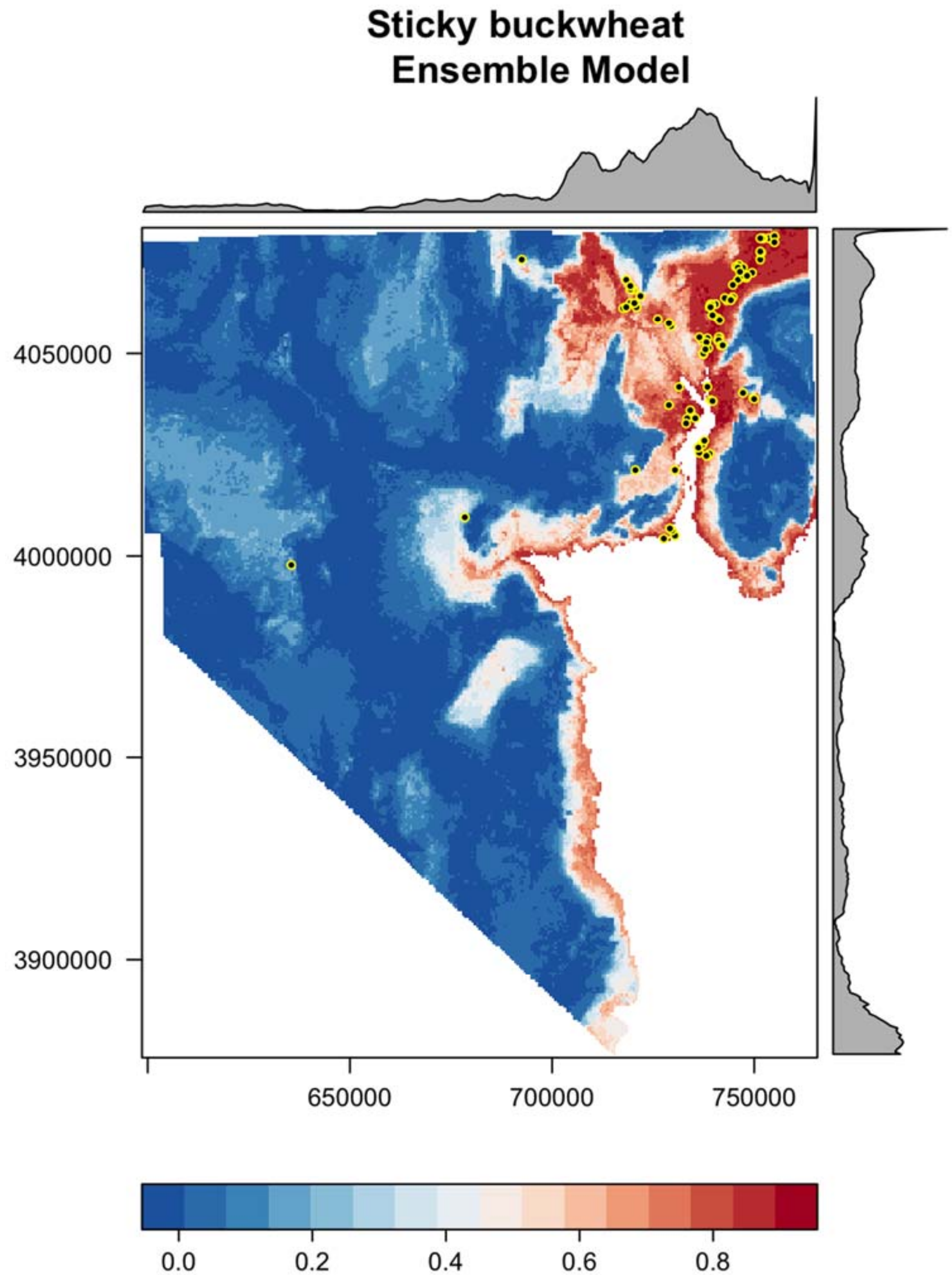
Habitat for *Eriogonum viscidulum* is predicted to occur primarily in the northeastern portion of the County, near the shores of Lake Mead, the Virgin River and Moapa Valley.

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 (ERVI Figure 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 (ERVI Figure 7).

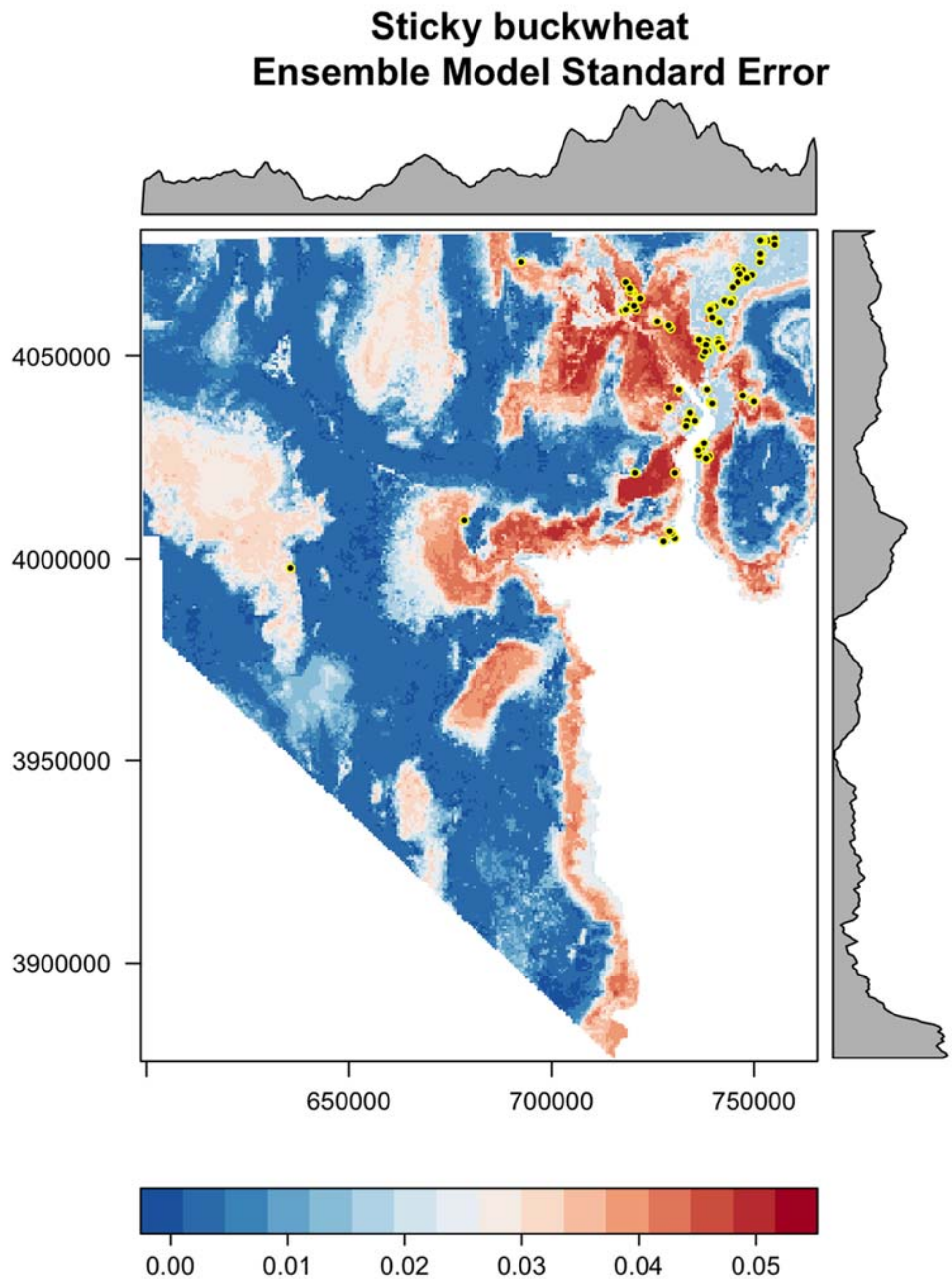
The locality data for this species consisted of 603 records within the buffered modeling area. Spatial thinning of the data reduced the number of localities used for training and testing to 107, as there were many co-located records for this species.

Standard Error

The standard error map for the Ensemble model indicated relatively low error (ca. 0.05) throughout much of the study area (ERVI Figure 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.



ERVI Figure 7. SDM map for *Eriogonum viscidulum* Ensemble model for Clark County, NV.



ERVI Figure 8. Standard Error map for the *Eriogonum viscidulum* Ensemble model for Clark County, NV.

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 (ERVI Table 3). Salt Desert Scrub contains some moderate habitat for this species.

ERVI Table 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

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).

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 *E. viscidulum* 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).

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.

Summary of Direct Impacts

A total of 1335 km^2 of high suitability habitat is estimated within the County. Projected impacts by this plan amendment may affect 60% of the total area for high and moderate habitat, while 34% of the area is located within conserved areas (ERVI Table 4). Very little high suitability habitat (6%) is estimated to be already disturbed.

ERVI Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	79677	45613	8187	133477
Med	20634	48717	25549	94900
Low	26519	419144	86677	532340

GOAG - 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 *G. agassizii* 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.

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

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).

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 (GOAG Figure 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 (GOAG Figure 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 (GOAG Table 1). The continuous Boyce indices all indicated very good performance, (GOAG Figure 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) (GOAG Table 2).

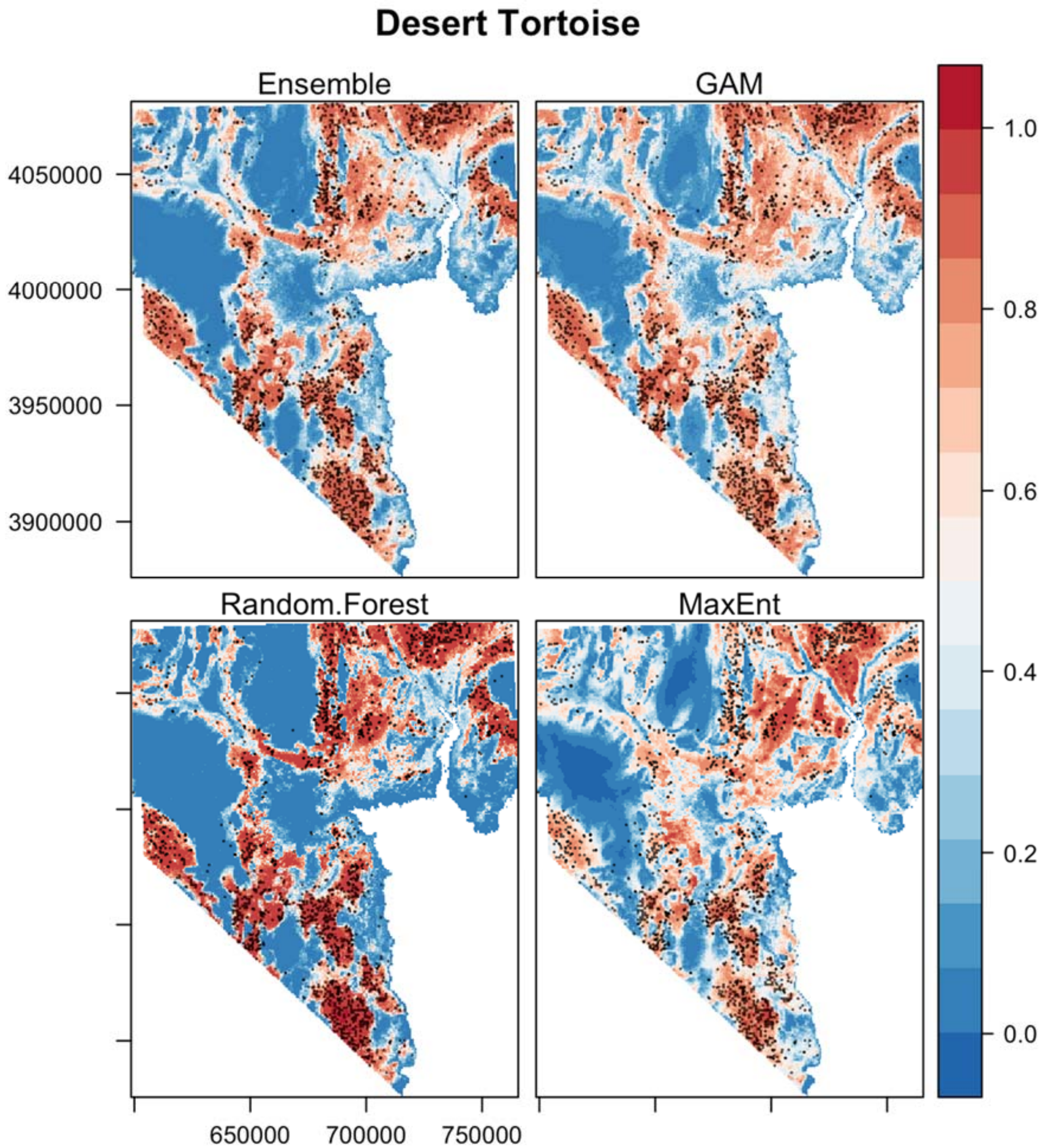
The Standard error maps indicated relatively low standard error among all of the models, ranging from 0 to 0.02 throughout the study area (GOAG Figure 2).

GOAG Table 1. Model performance values for Gopherus agassizii 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.

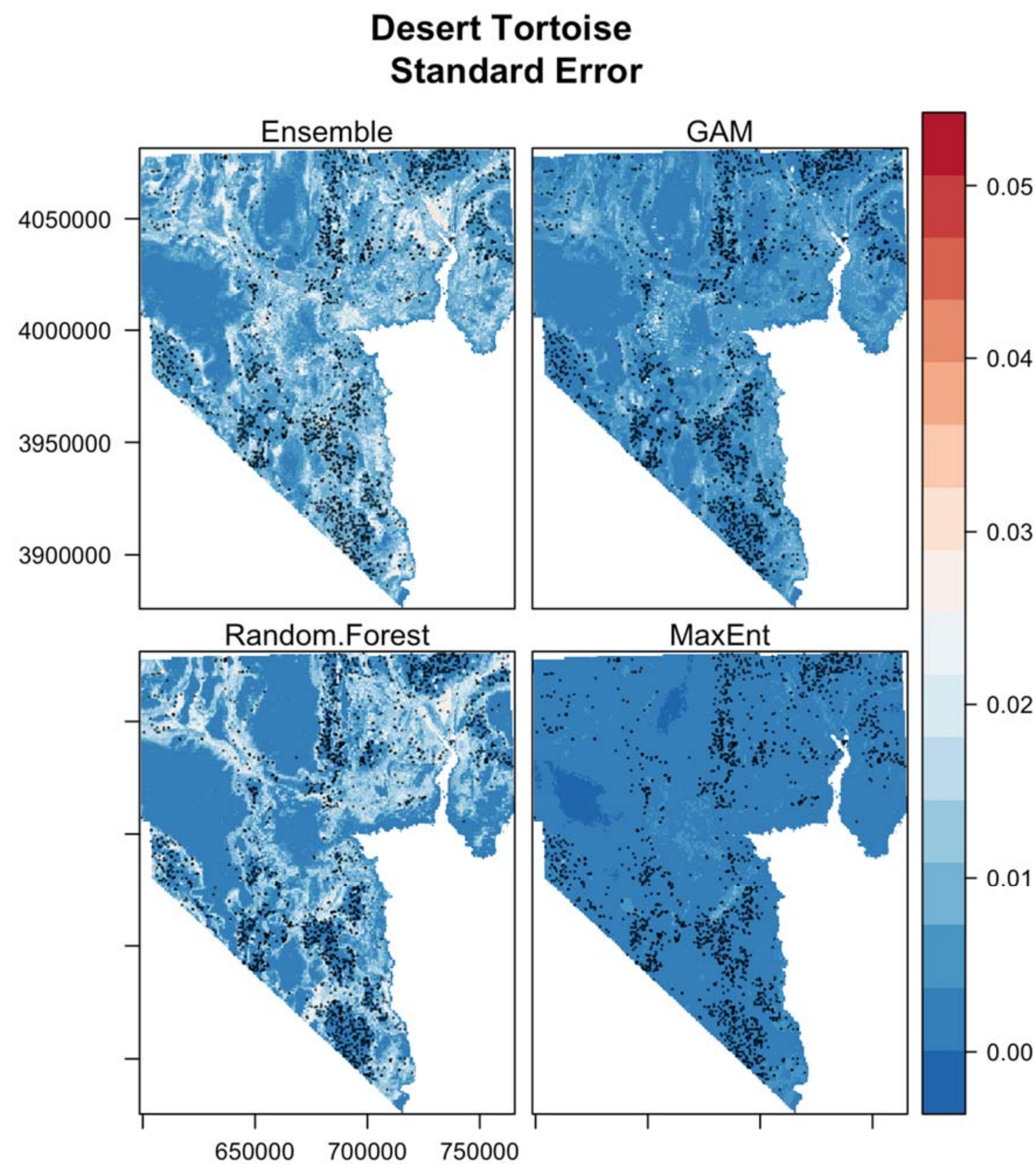
Model	AUC	BI	TSS	PRBE
Ensemble	0.87	0.98	0.64	0.59
GAM	0.81	1	0.5	
Random Forest	0.88	0.98	0.66	
MaxEnt	0.78	1	0.46	

GOAG Table 2. Percent contributions for input variables for *G. agassizii* 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.

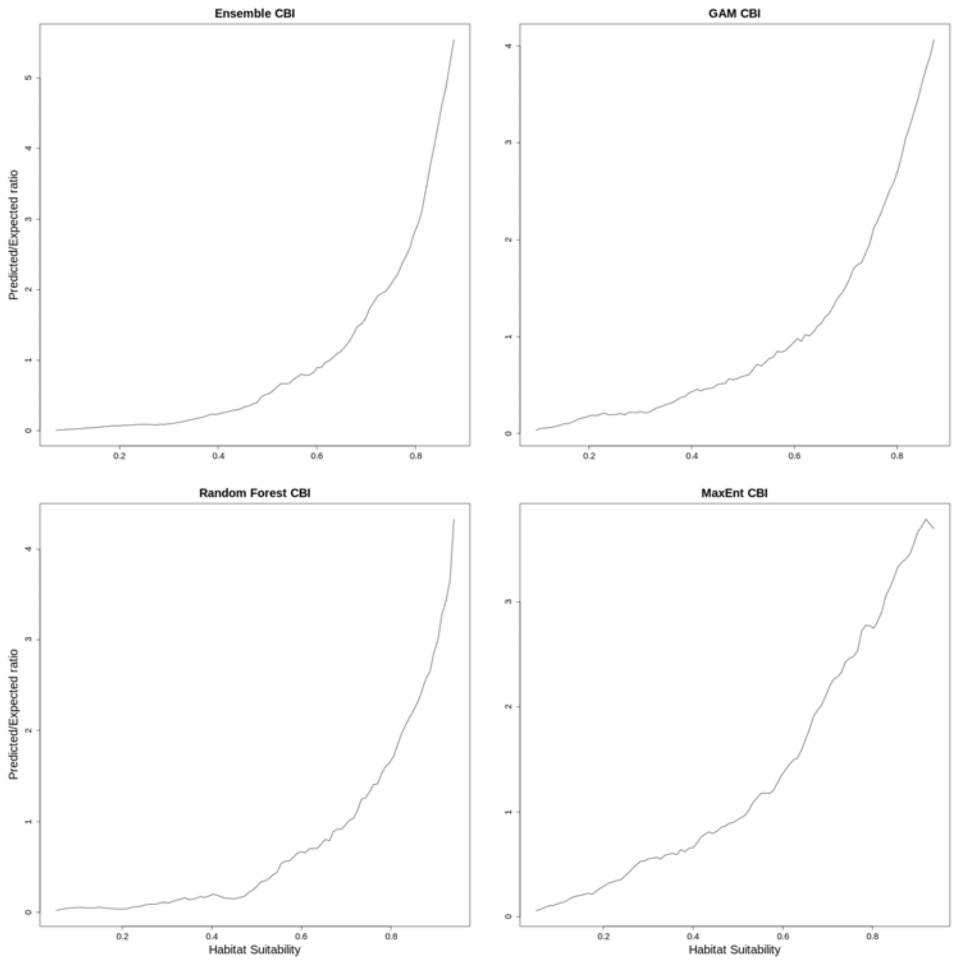
Variable	GAM	RF	MaxEnt
Ave Min Temp	6.9	2.8	36.2
Ave Max Temp	26.8	15.8	0.1
Depth to Bedrock	5.6	18.2	13.5
PPT Sand	19.6	7.1	6
Slope	3.6	9.2	13.6
Extreme Max Temp	17	7.3	0
PPT Clay	2.4	5.3	7.9
Winter Precip	2.9	9	3.4
CV Winter Precip	1.2	3.2	9.7
PPT Silt	3.7	3.3	2.5



GOAG Figure 1. SDM maps for *Gopherus agassizii* 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.



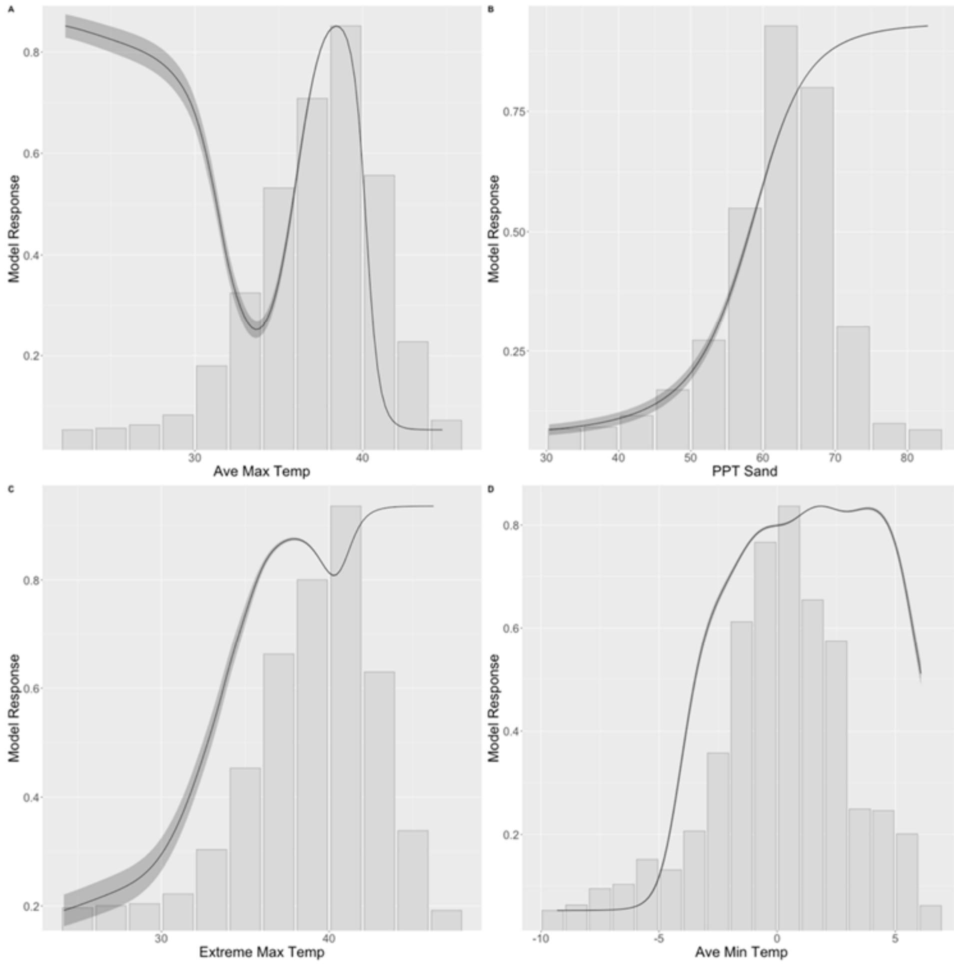
GOAG Figure 2. Standard error maps for *Gopherus agassizii* models for each of three modeling algorithms used (GAM - upper right, Random Forest - lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



GOAG Figure 3. Graphs of Continuous Boyce Indices [CBI] for *G. agassizii* 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).

General Additive Model

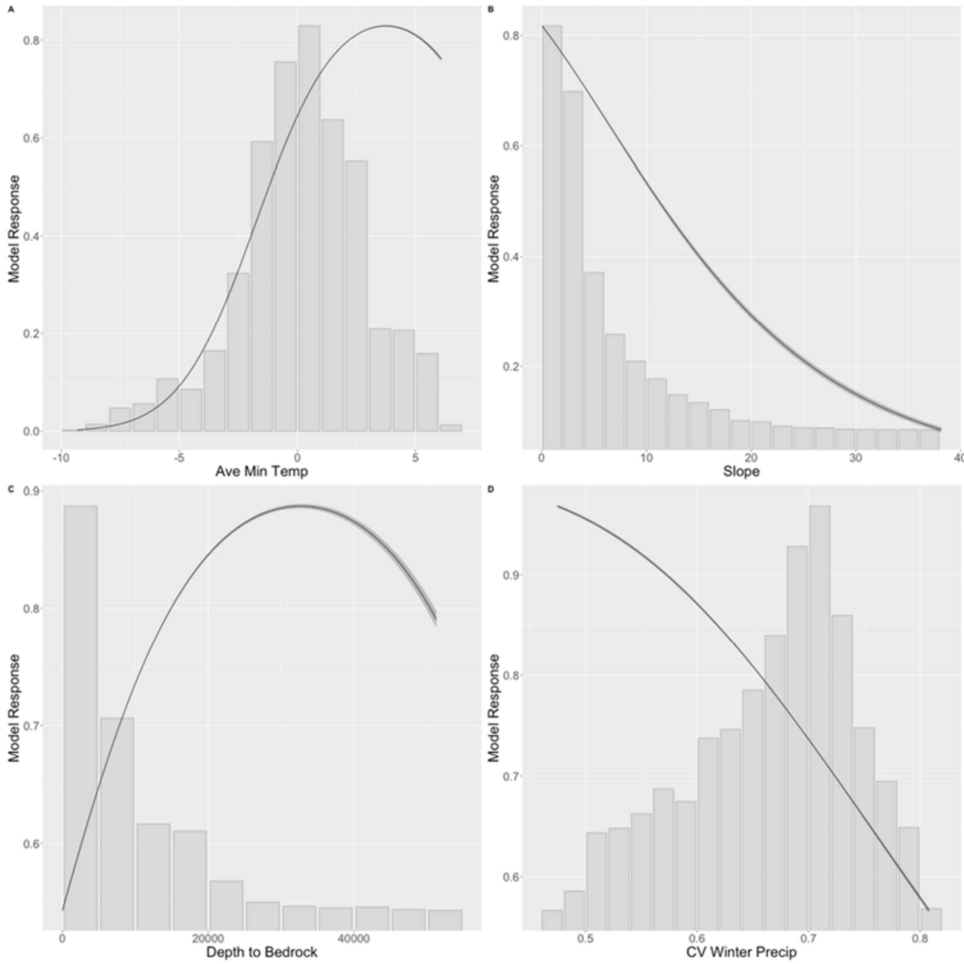
This model was largely influenced by Average Spring Maximum temperatures, which comprised 27% of the explained variance in the model (GOAG Table 2), and had a bimodal peaked response at temperatures lower than the study area average, and then following the average (GOAG Figure 4). Soil Sand Content was 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 (GOAG Figure 4). The fourth most influential variable was Average Minimum temperatures (7%) where habitat peaked with environmental values, remaining high above that level (GOAG Figure 4).



GOAG Figure 4. GAM partial response curves for the top four variables in the *Gopherus agassizii* 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.

MaxEnt Model

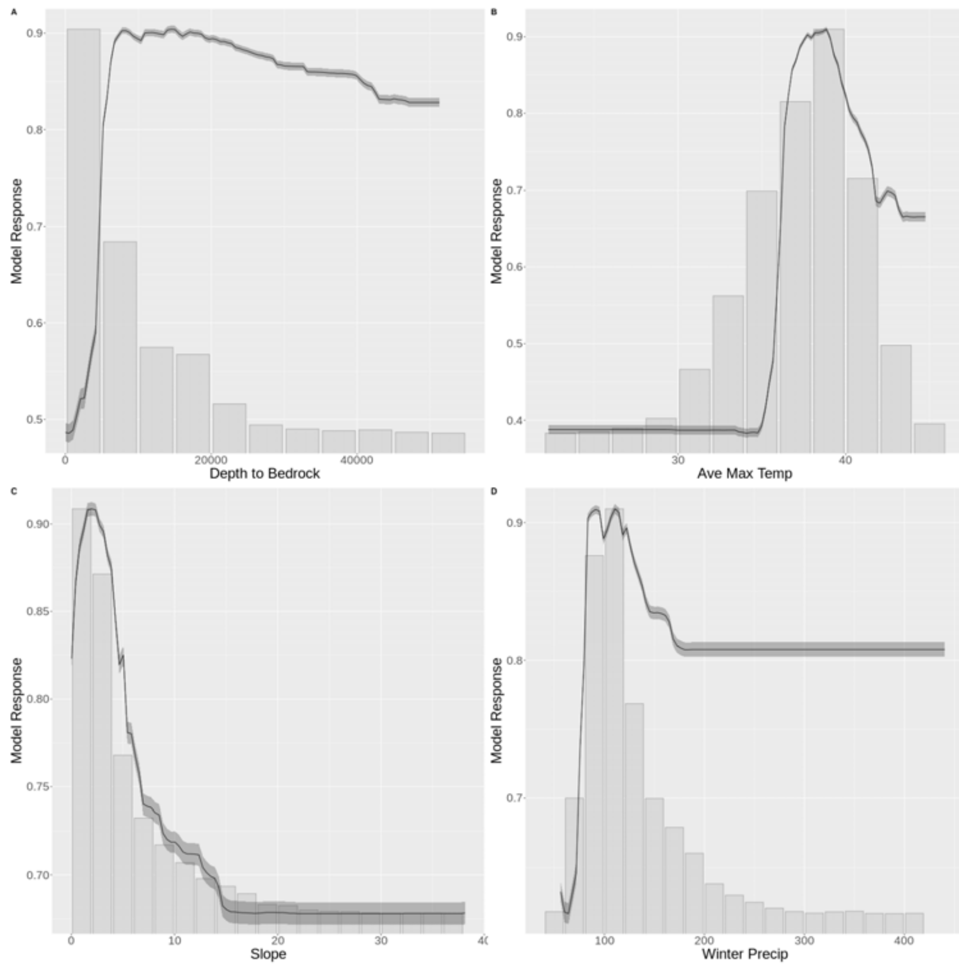
The top four influencing variables in the MaxEnt models were Average Minimum temperature, Depth to Bedrock, Slope, and the CV of Winter Precipitation (GOAG Table 2). Average Minimum temperature, and Depth to Bedrock each had positive responses, peaking above average values in the study area (GOAG Figure 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 (GOAG Table 2).



GOAG Figure 5. Response surfaces for the top four environmental variables included in the MaxEnt Ensemble model for *Gopherus agassizii.* 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.

Random Forest Model

The top four variables in the Random Forest models were Average Maximum temperature, Depth to Bedrock, Slope, and Winter Precipitation (GOAG Table 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 (GOAG Figure 6). Depth to Bedrock indicated higher habitat values in deeper soils, as was the case for the MaxEnt model (GOAG Figure 5). Slope generally followed habitat prevalence, and habitat tended to be higher in areas at and above the area average (GOAG Figure 6).



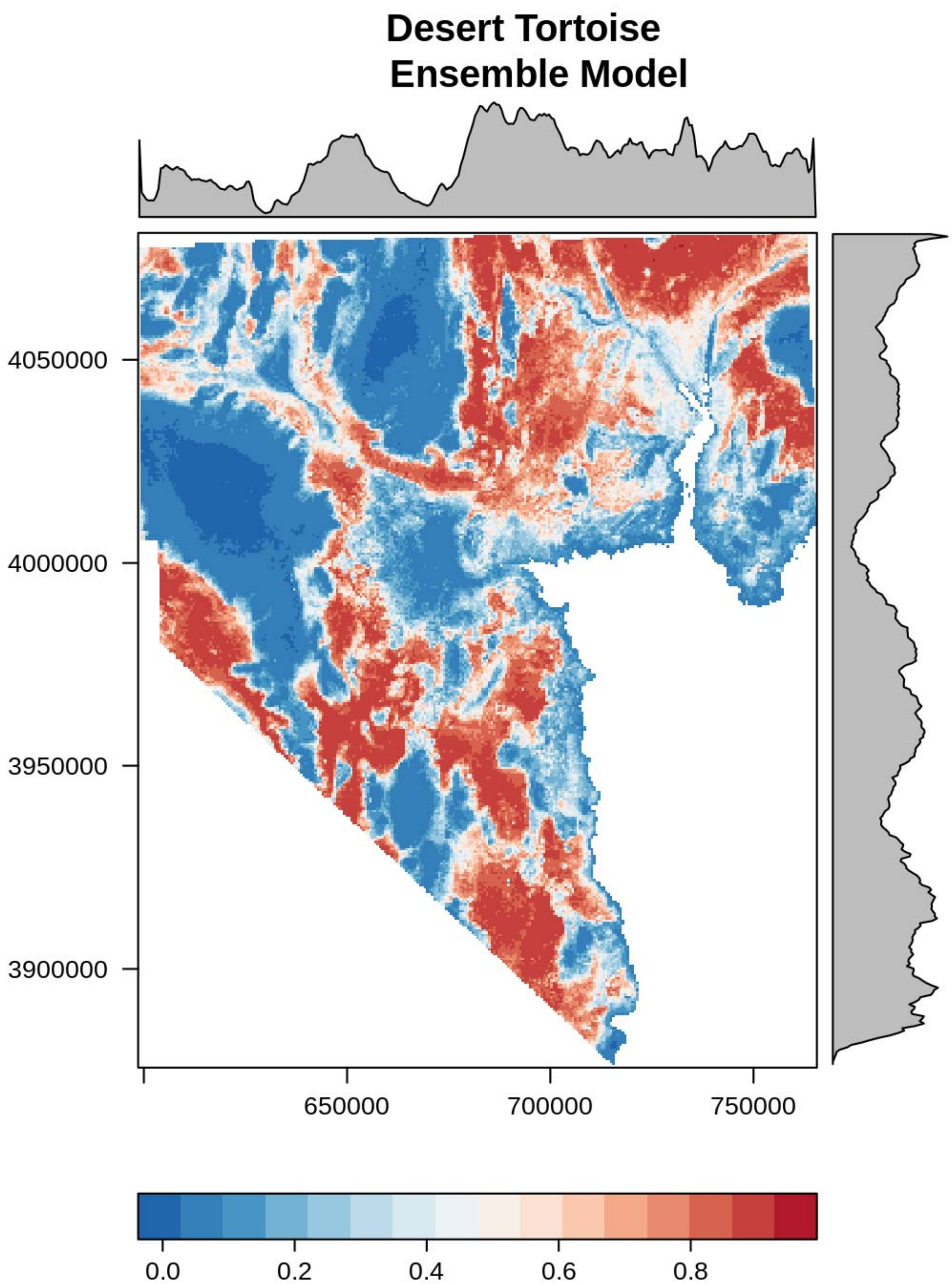
GOAG Figure 6. Partial response surfaces for the top four environmental variables included in the Random Forest Ensemble model for *Gopherus agassizii.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are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

Model Discussion

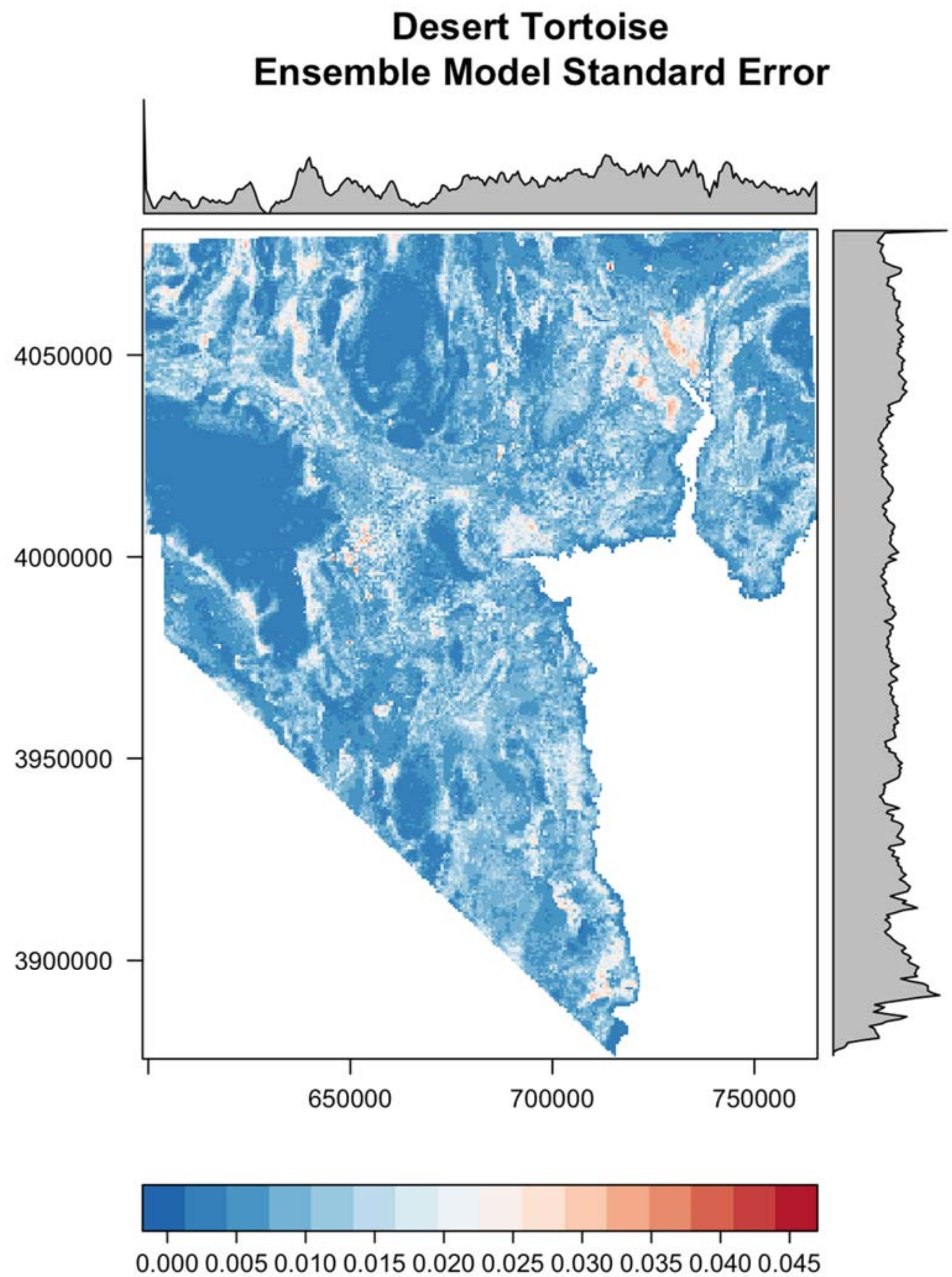
Gopherus agassizii habitat predictions for this model follow the localities for the species well, throughout the county, with similar habitat areas to that predicted by Nussear et al. (2009). Areas of lower habitat within the county are the mountainous areas in the Spring and Sheep ranges, Lucy Grey Mountains, Virgin Mountains, and southern Gold Butte. Habitat also becomes sparse in the northwestern extent of the county (GOAG Figure 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.

Standard Error

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



GOAG Figure 7. SDM map for *Gopherus agassizii* Ensemble model for Clark County, NV.



GOAG Figure 8. Standard Error map for the *Gopherus agassizii* Ensemble model for Clark County, NV.

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 (GOAG Table 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).

GOAG Table 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).

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.

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.

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.

<u>Mountain slopes and passes</u> - 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.

<u>Life history and ecology</u> – 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).

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.

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.

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).

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.

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 *G. agassizii* (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).

Summary of Direct Impacts

Modeled habitat for Mojave Desert Tortoise occurs throughout the plan area. Approximately 5459 km^2 of high and moderate category habitat for this species exists within the county (GOAG Table 3). Of this 3987 $km^2$are located within conserved habitats (ACEC's, National and State Parks, etc.). Areas already disturbed include ~ 439 km^2 of high and moderate category habitat (GOAG Table 3), although it should be noted that the Las Vegas Valley was likely once habitat, but no longer predicts as such. An additional 709 km^2 of high, and 3324 km^2 of moderate habitat will be potentially lost to development under the plan (GOAG Table 3).

GOAG Table 3. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	70901	298374	20490	389765
Med	32414	100307	23407	156128
Low	23095	114364	76417	213876

Existing Conservation Areas/Management Actions

The 1994 Mojave Desert Tortoise (Mojave Population) Recovery Plan describes a strategy for recovering the Mojave population of the Mojave Desert Tortoise. The recovery plan includes the identification of six recovery units, recommendations for a system of Desert Wildlife Management Areas (DWMAs) within the recovery units, and development and implementation of specific recovery actions, especially within DWMAs. Establishment of recovery units and DWMAs was intended, in part, to facilitate an ecosystem approach to land management and Mojave Desert Tortoise recovery, as stipulated by section 2(b) of the Endangered Species Act (USFWS 1994). Critical habitat is legally defined under the ESA as areas that are essential for the conservation of the Mojave Desert Tortoise, that support physical and biological features essential for Mojave Desert Tortoise survival, and that may require special management considerations or protection. Critical habitat for the Mojave Desert Tortoise was designated in 1994, largely based on proposed DWMAs in the draft Recovery Plan.

The BLM formalized the DWMAs from the 1994 Recovery Plan through its planning process and administers them as Areas of Critical Environmental Concern (ACEC). The BLM designates ACECs where special management is needed to protect and prevent irreparable damage to important historical, cultural, scenic values, fish and wildlife, and natural resources (in this case, the Mojave Desert Tortoise) or to protect life and safety from natural hazards. In Nevada, the BLM Las Vegas, Ely, and Battle Mountain field offices manage more than 940,000 acres of Mojave Desert Tortoise habitat designated as ACECs by the Las Vegas and Ely field offices (Bureau of Land Management 2009).

The Mojave Desert Tortoise Management Oversight Group was established in 1988 to coordinate agency planning and management activities affecting the Mojave Desert Tortoise and to implement the management actions in the BLM's Mojave Desert Tortoise Range-wide Plan. Charter members of the Management Oversight Group included the four BLM State Directors from Arizona, California, Nevada, and Utah; the four State Fish and Game Directors from these States; the three Fish and Wildlife Service Regional Directors that share tortoise management responsibilities; and, a BLM Washington Office representative. Membership was subsequently expanded to include representatives of the National Park Service, the US Geological Survey, and officials of the four branches of the military (Army, Air Force, Navy, and Marine Corps) that administers portions of Mojave tortoise habitat (USFWS 2008). County governments within the range of the Mojave Desert Tortoise were also included in 2007. Subsequent to the listing of the Mojave population as Threatened and following the publication of the recovery plan in 1994, the Mojave Desert Tortoise Management Oversight Group assumed a leadership role in coordinating agency activities directed toward recovery plan implementation.

The Mojave Desert Tortoise Recovery Office (DTRO) was established by the USFWS in 2004. The DTRO's staff focuses solely on the Mojave Desert Tortoise and its recovery. The DTRO coordinates recovery planning and implementation, research, monitoring, and recovery permitting, while working closely with those Service biologists focusing on regulatory issues. The DTRO assists in the coordination among land managers, research scientists, the interagency Mojave Desert Tortoise Management Oversight Group, the Desert Managers Group (DMG), and other local, state, or regional working groups. To complement the DTRO, the USFWS assembled a Mojave Desert Tortoise Science Advisory Committee (SAC) in 2005. This committee is presently composed of five scientists from diverse and experienced backgrounds charged with providing recommendations relative to Mojave Desert Tortoise recovery implementation and approach and ensuring rigorous scientific standards are met (USFWS 2008).

In Nevada, the Mojave Desert Tortoise is protected under the Nevada Administrative Code 503.080, wherein the species is listed as a state protected reptile further classified as Threatened, and collection is controlled under section 503.093. An appropriate license, permit, or authorization must be obtained from NDOW to possess an individual animal. The Mojave Desert Tortoise is also considered a Species of Conservation Priority under the Nevada Wildlife Action Plan (NWAP), which is implemented by NDOW (Wildlife Action Plan Team 2012).

The Mojave Desert Tortoise is also considered a Species of Conservation Priority under the Nevada Wildlife Action Plan (NWAP), which is implemented by NDOW (Wildlife Action Plan Team 2012). Recommended conservation actions particular to this species and its suitable habitat are included in the NWAP. The NWAP recommended approach is to protect large tracts of suitable tortoise habitat, well dispersed throughout their range. Furthermore, the recommended conservation strategies to conserve this habitat that this species occurs in 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 Nevada Department of Transportation (NDOT), and Clark County, Nevada have taken action to protect Mojave Desert Tortoise on Nevada highways by installing exclusion fencing along many roadways that traverse Mojave Desert Tortoise habitat. Fencing impedes tortoise access to roadways, thus minimizing or avoiding tortoise injury and mortality from collisions with vehicles. Annual road mortality of Mojave Desert Tortoises has decreased by 75 percent or greater since NDOT began installing exclusion fencing (Mojave Desert Tortoise Recovery Office 2009).

In Clark County, the Mojave population of Mojave Desert Tortoise is also covered under the Lower Colorado River Multi-Species Conservation Program and the Coyote Springs Investment Multiple-Species Habitat Conservation Plan. The intended goals of each are to conserve habitat of federally listed species and minimize the potential for federal listing of additional species; to accommodate covered activities; and to provide incidental take authorizations (Lower Colorado River Multi-Species Conservation Program 2004, Coyote Springs Investment Multiple-Species Habitat Conservation Plan 2008).

In southern Nevada, the Mojave population of Mojave Desert Tortoise is addressed in the Southeastern Lincoln County HCP, which was issued in May 5, 2010. The focus of this plan is to permit growth and development in portions of tortoise habitat north of Mesquite and urban expansion in the Alamo area in Lincoln County (Southeastern Lincoln County Habitat Conservation Plan 2008).

LALU - 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.

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

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).

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).

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 (LALU Figure 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 (LALU Table 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 (LALU Figure 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 (LALU Table 2).

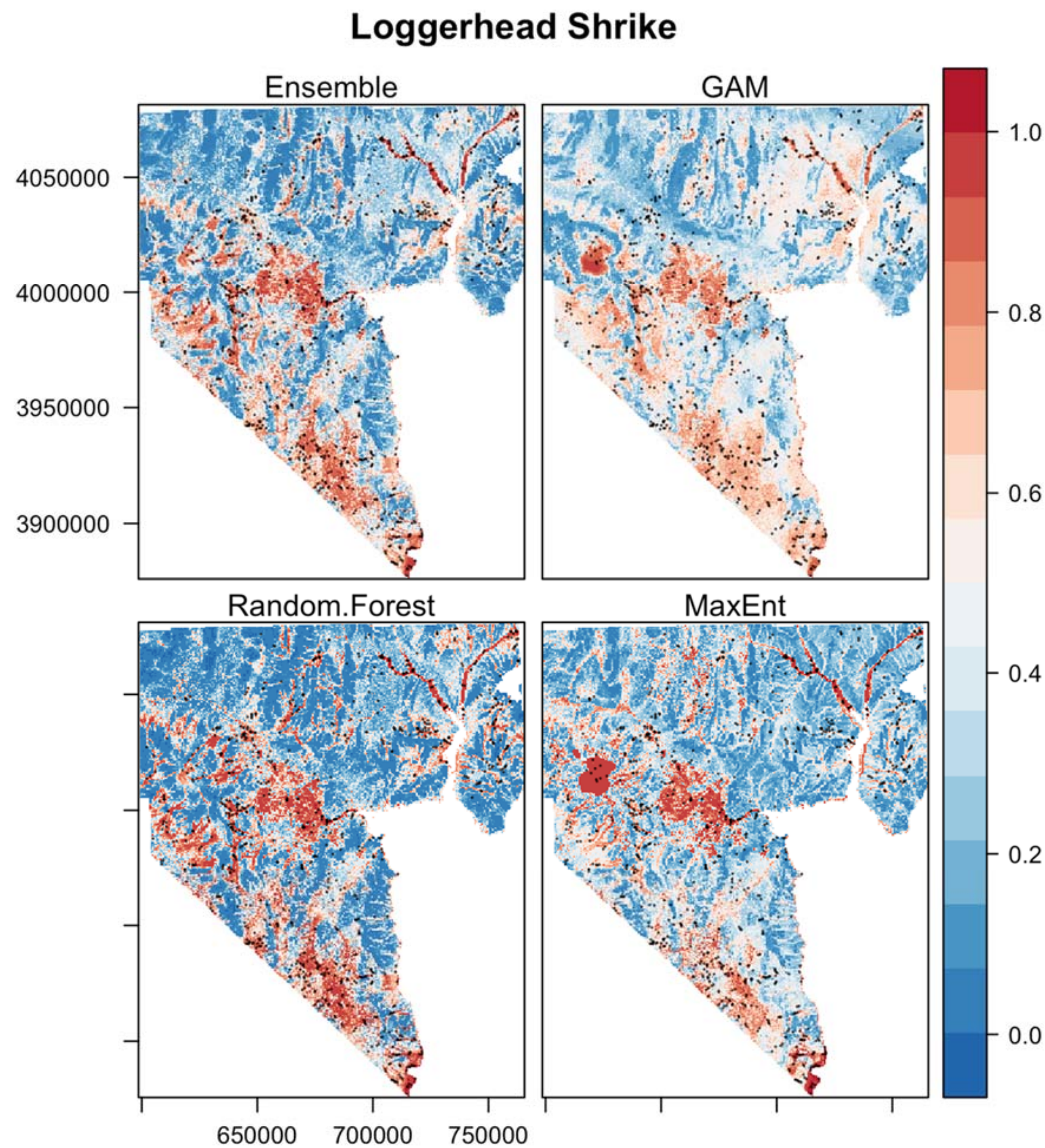
The Standard error maps for all algorithms very low, with the GAM having the lowest SE across the county, and the others with only low to moderate error rates for the most part (LALU Figure 4). The Continuous Boyce curves indicated good model performance, however the MaxEnt had a much more gradual curve, likely due to its reduced accuracy (LALU Figure 3).

LALU Table 1. Model performance values for *L. ludovicianus* 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.

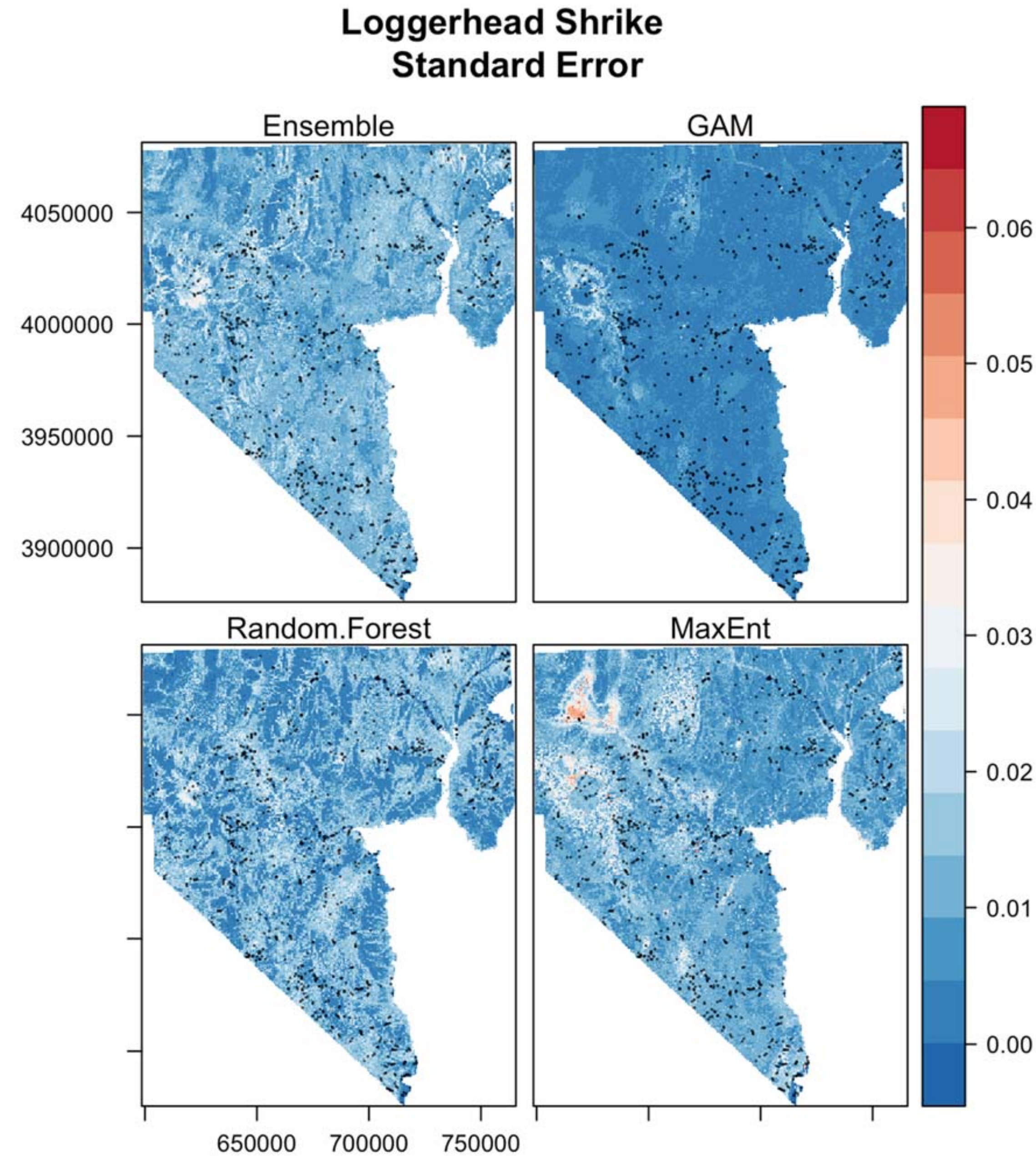
Model	AUC	BI	TSS	PRBE
Ensemble	0.78	0.97	0.42	0.47
GAM	0.7	0.94	0.31	
Random Forest	0.78	0.94	0.43	
MaxEnt	0.69	0.92	0.26	

LALU Table 2. Percent contributions for input variables for *L. ludovicianus* 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.

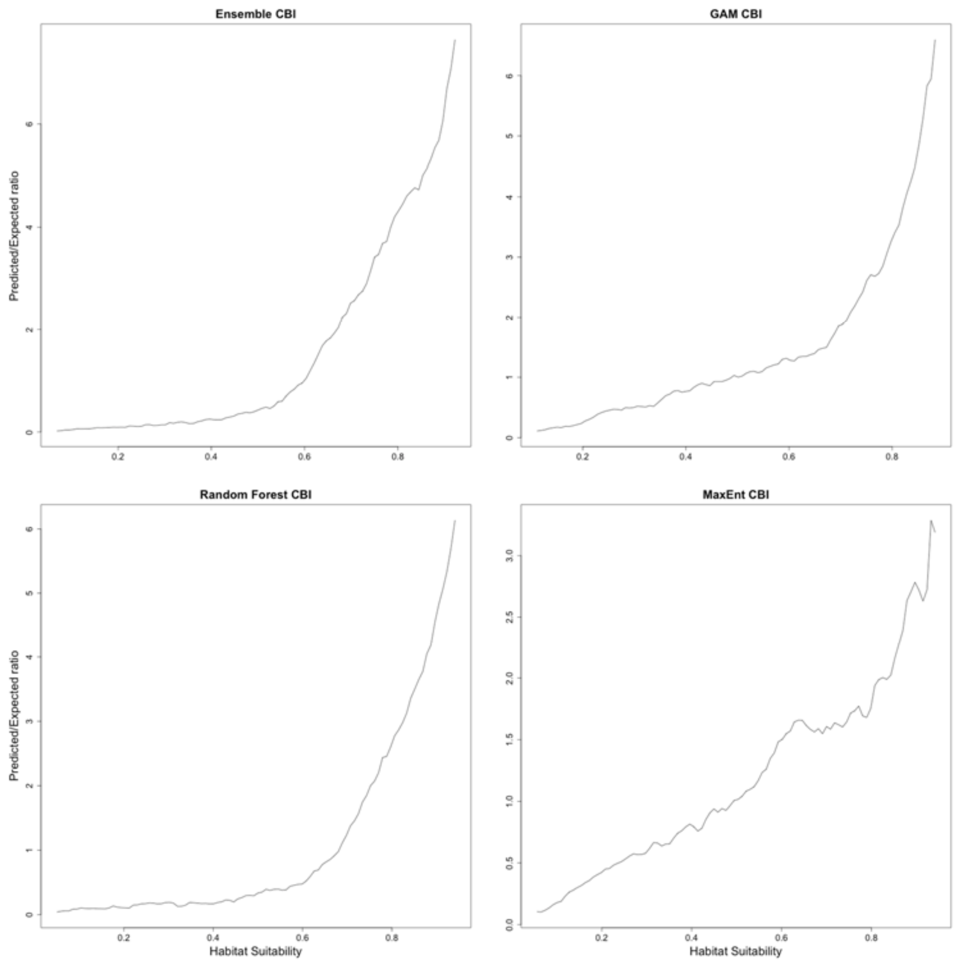
Variable	GAM	RF	MaxEnt
Dist to cliffs	0.1	1.5	0.8
NDVI Amplitude	8.4	3.1	3.2
NDVI Length of Season	0.8	1.7	1.7
NDVI Max	15.6	7	13.7
Winter Precip	10.5	10.5	7.1
CV Winter Precip	9.4	12.1	11.8
Average Spring Max Temp	23.5	2.8	9.7
CV Average Spring Max Temp	13.6	2.6	5.4
Slope	10.7	9.3	7.4
NDVI Start of Season	6.9	17.8	15.3
Flow Accum	0.3	31.7	23.8



LALU Figure 1. SDM maps for *Lanius ludovicianus* 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.



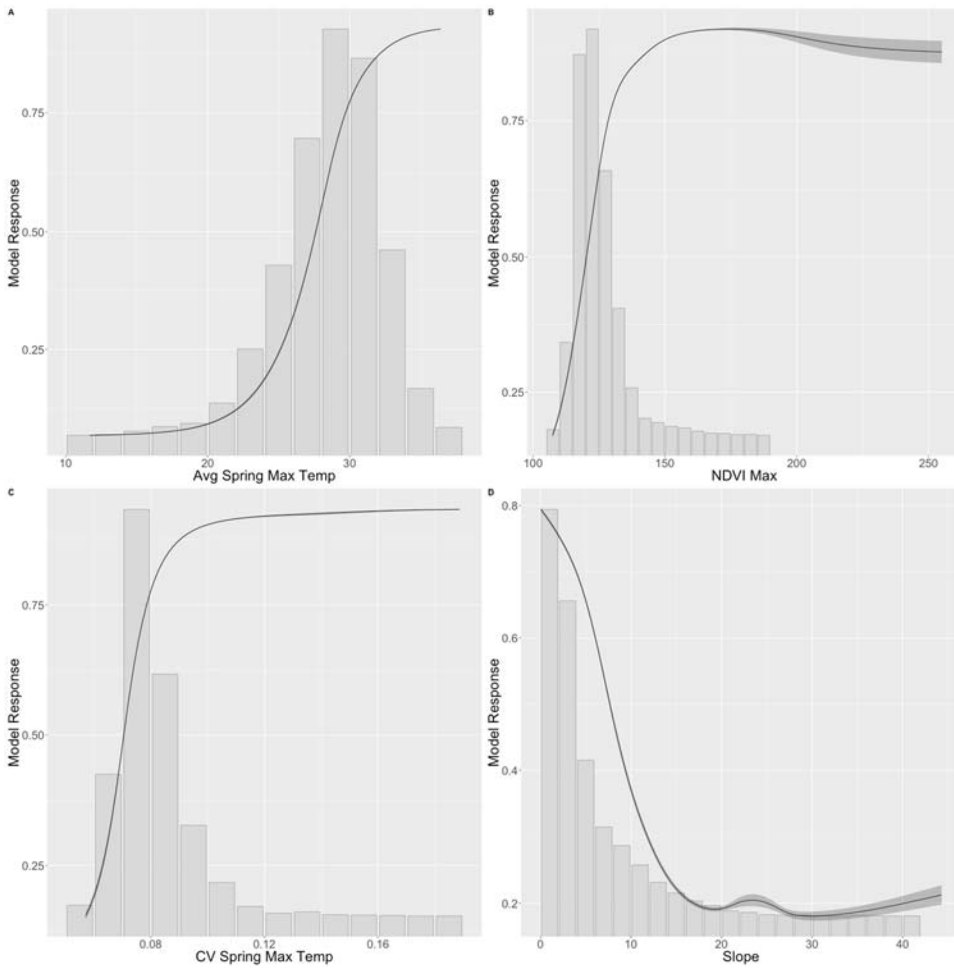
LALU Figure 2. Standard error maps for *Lanius ludovicianus* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



LALU Figure 3. Graphs of Continuous Boyce Indices [CBI] for *L. ludovicianus* 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).

General Additive Model

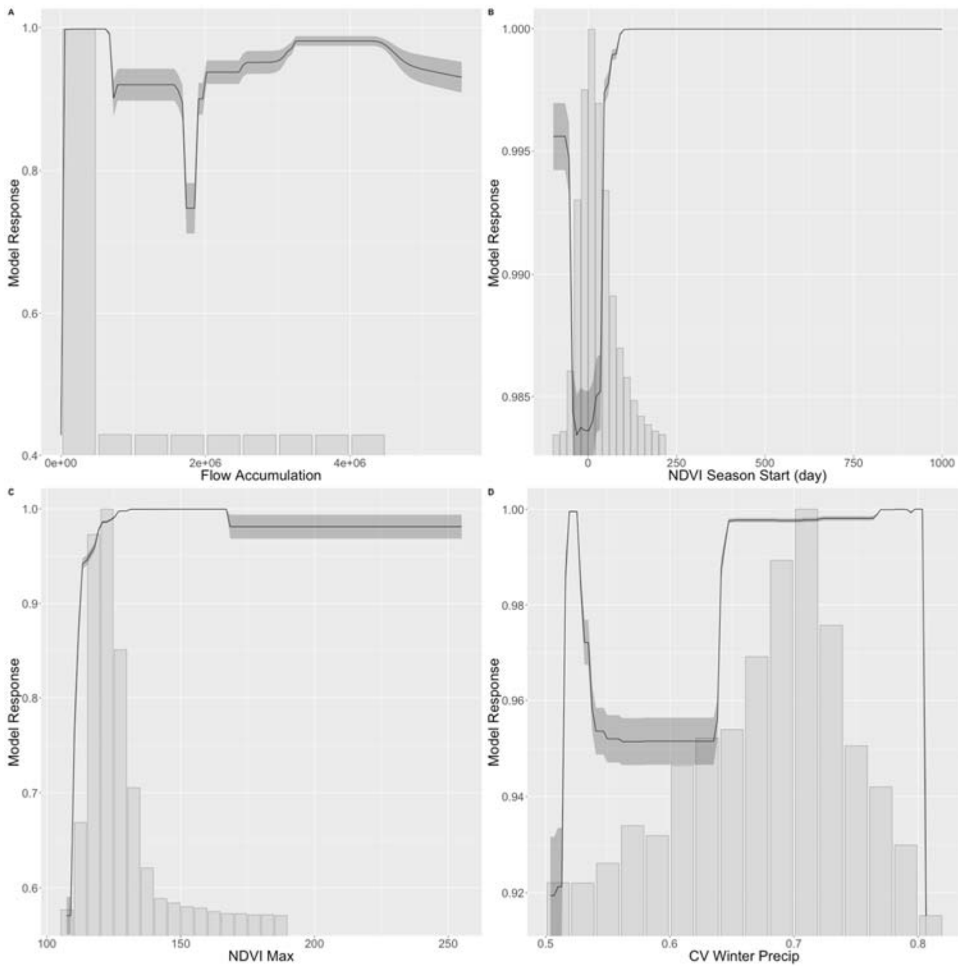
The top four contributing environmental layers for the GAM model were Average Spring Maximum temperature and its CV, the Maximum NDVI value, and Slope. Average Winter Precipitation also contributed nearly as highly (LALU Table 2). Habitat for the shrike was predicted to be highest in areas with higher and more variable Maximum Spring temperatures, and high NDVI max values (LALU Figure 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 (LALU Figure 4).



LALU Figure 4. GAM partial response curves for the top four variables in the *Lanius ludovicianus* 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.

MaxEnt Model

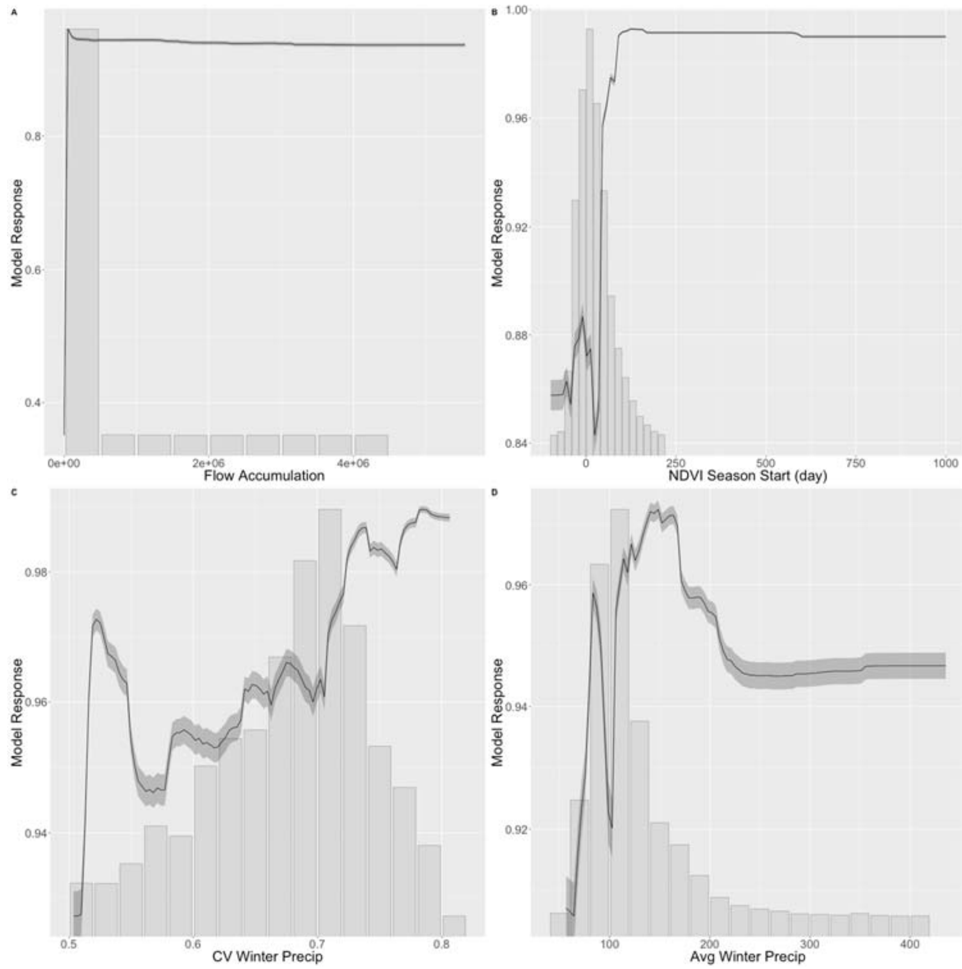
The top four influencing variables in the MaxEnt models were Flow Accumulation, NDVI indication of the Start of Season, the Maximum NDVI value, and the CV of Winter Precipitation (LALU Table 2). The response curves for maxent indicated threshold type responses for most of these, with higher habitat predicted at the highest values for each of the environmental variables (LALU Figure 5). The irregular curve shapes in areas with 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 (LALU Table 1).



LALU Figure 5. Response surfaces for the top four environmental variables included in the MaxEnt Ensemble model for *Lanius ludovicianus.* 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.

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 (LALU Figure 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 (LALU Figure 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 (LALU Figure 6). Standard Error rates for this, as well as the other models were relatively low throughout the county (LALU Figure 3).



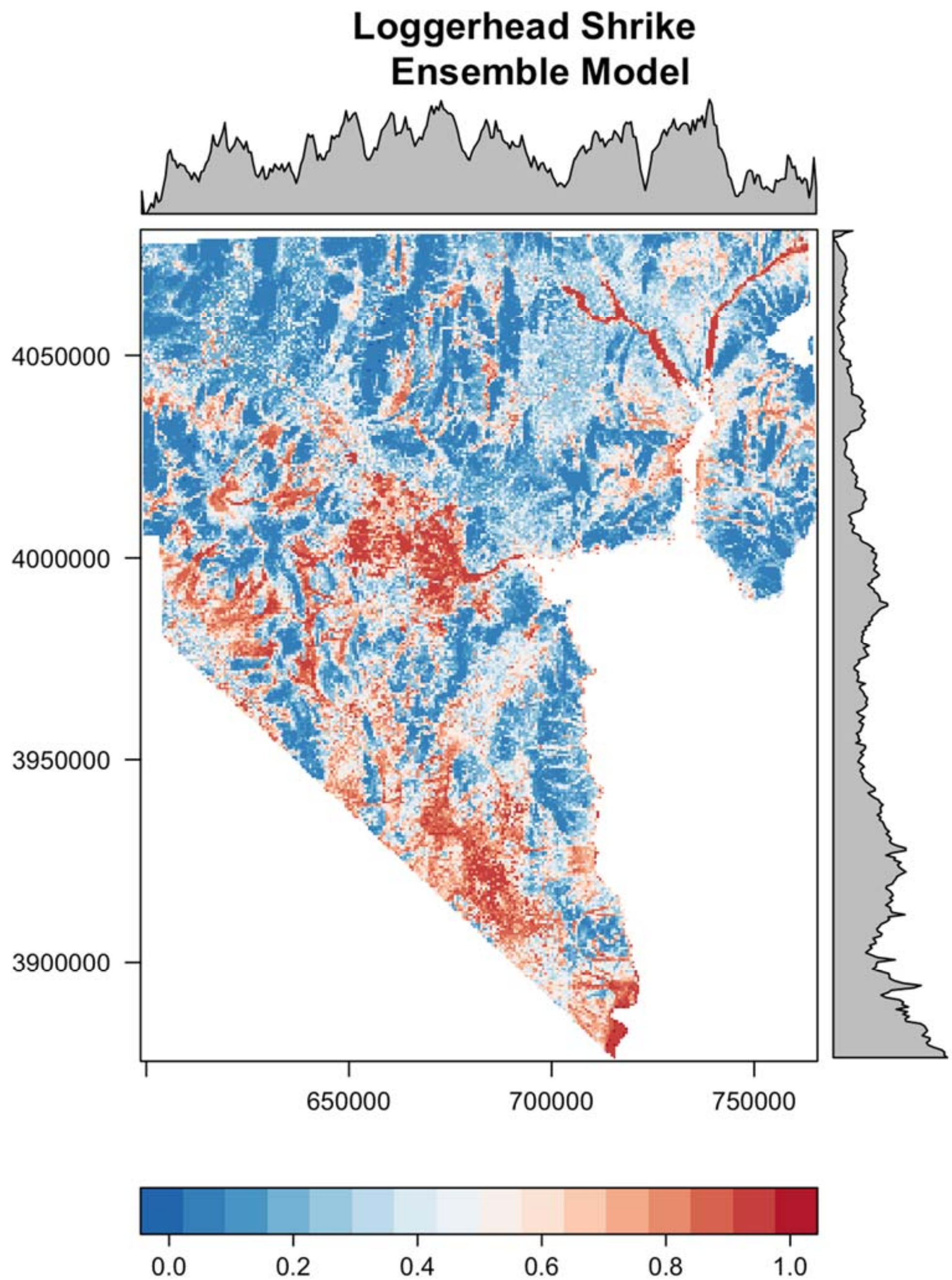
LALU Figure 6. Partial response surfaces for the top four environmental variables included in the Random Forest Ensemble model for *Lanius ludovicianus.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are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

Model Discussion

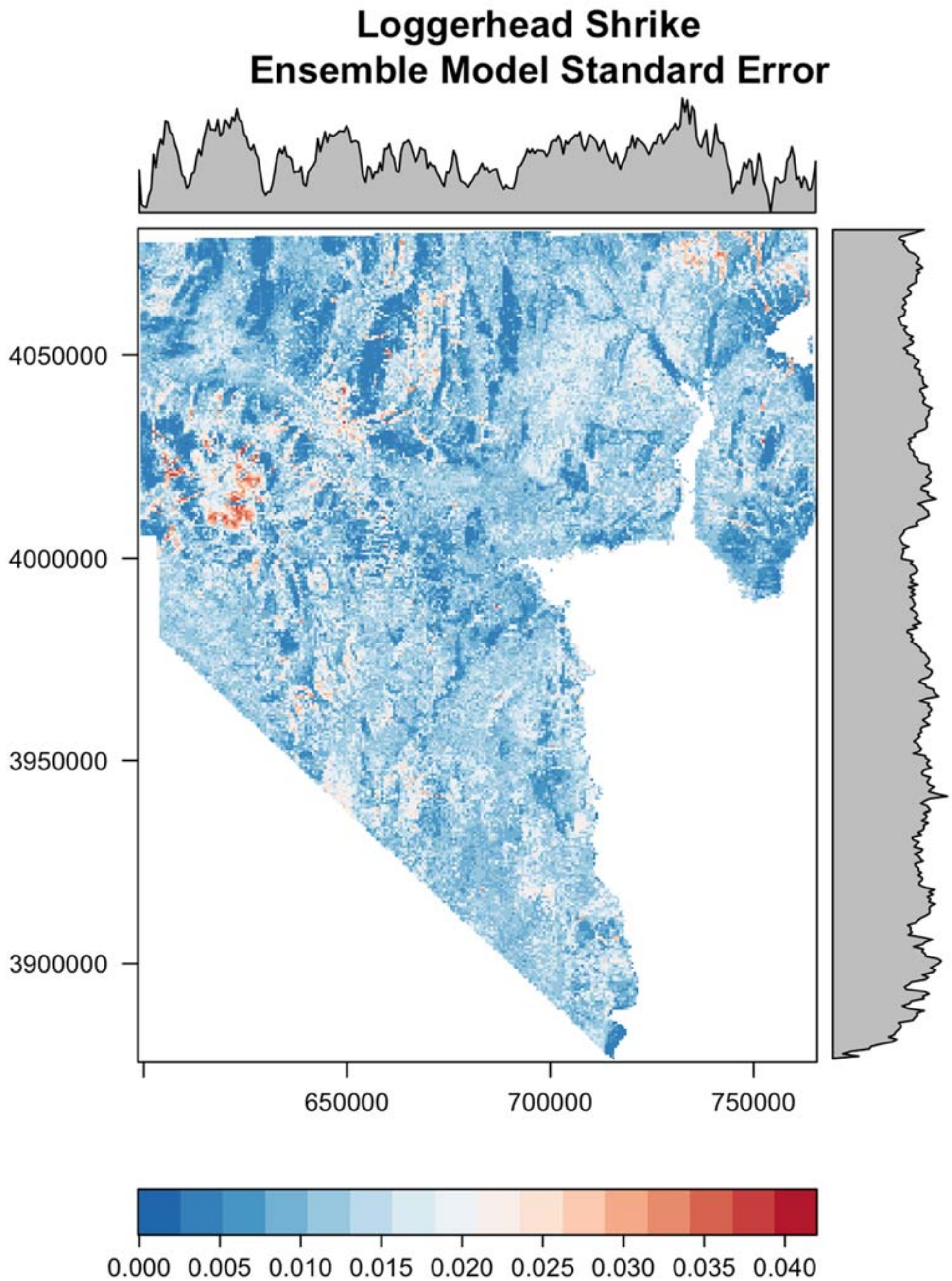
Lanius ludovicianus habitat is predicted to be prevalent throughout much of the lowland habitats in the southern 2/3 of Clark County (LALU Figure 7). Range maps for this species indicate widespread occurrence through much of the western United States. The Ensemble model had relatively high performance values (LALU Table 1), and discriminatory ability (LALU Figure 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.

Standard Error

The Ensemble model had low error rates (SE 0.01 – 0.02) among models across most of the study area (LALU Figure 8). Areas of moderate error were in small portions near Amargosa Valley.



LALU Figure 7. SDM map for *Lanius ludovicianus* Ensemble model for Clark County, NV.



LALU Figure 8. Standard Error map for the *Lanius ludovicianus* Ensemble model for Clark County, NV.

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 (LALU Table 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).

LALU Table 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

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 (LALU Table 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).

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.

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).

Summary of Direct Impacts

High suitability Loggerhead Shrike habitat is modeled to encompass 2498 km^2 of habitat, of which 1358 km^2 (54%) are expected to be in conserved areas (LALU Table 4). Lower areas of high suitability habitat are located in disturbed (31%) or areas to be impacted (14%) by this amendment. The area of moderate suitability habitat is similarly predicted throughout the county and 33% combined may be disturbed or impacted, and 67% is expected to lie within conservation areas (LALU Table 4).

LALU Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	36254	135844	77761	249859
Med	53446	179183	32867	265496
Low	36579	187753	9689	234021

PEAL - White-margined Beardtongue (Penstemon albomarginatus)

White-margined Beardtongue 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 *Anthidium paroselae, Ashmeadiealla gillettei, A. holtii, A. xenomastax,* and *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).

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

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).

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).

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 (PEAL Figure 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 (PEAL Figure 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 (PEAL Table 1).

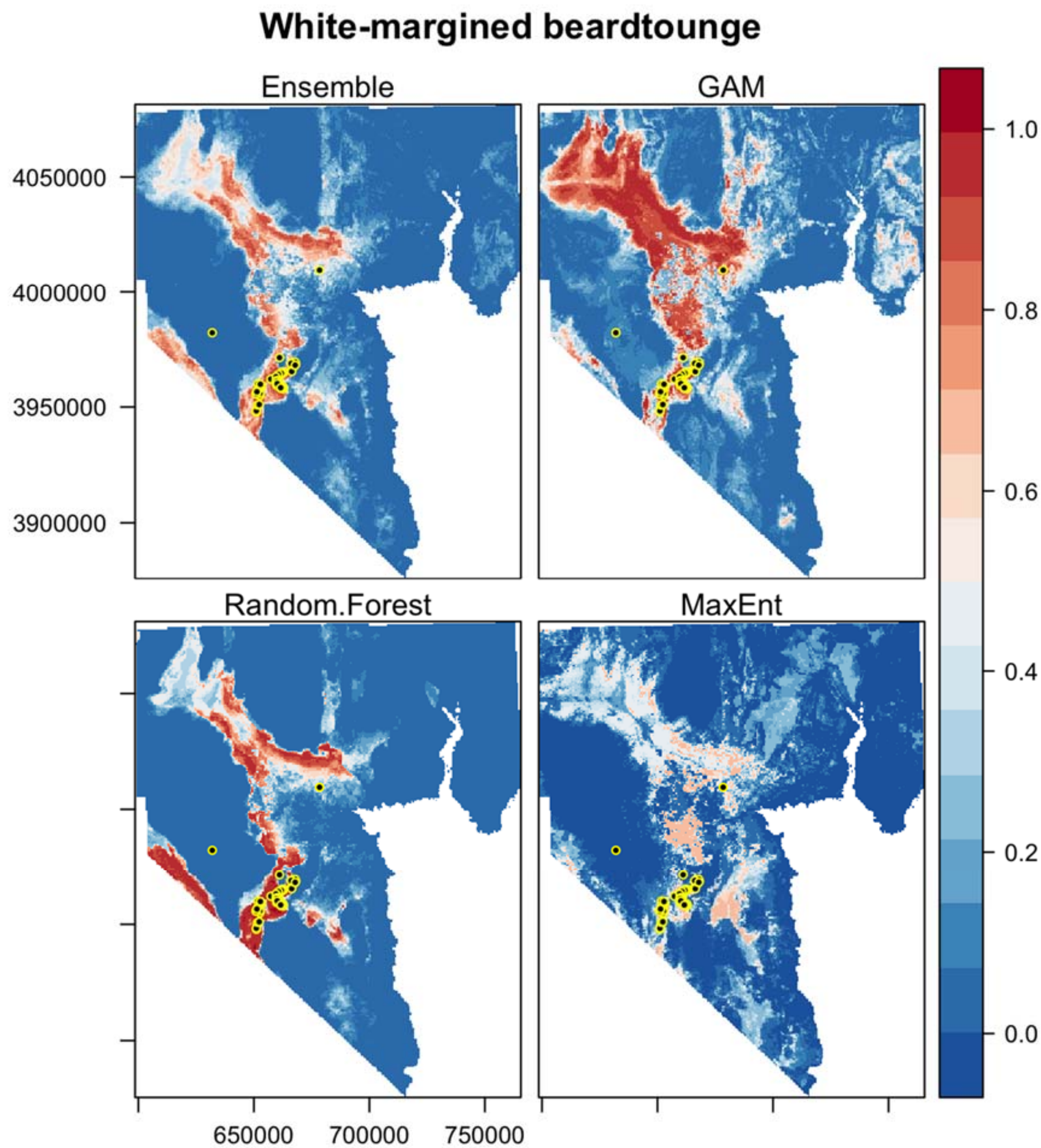
All three models shared Winter Precipitation content as one of the top four most influential variables. The GAM and RF, models shared two additional variables of the top four influential environmental variables, where the CV Winter Precipitation, and the CV Spring Maximum temperature were among the largest contributors (PEAL Table 2). The RF and MaxEnt model shared Depth to Bedrock as a top influential variable (PEAL Table 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 (PEAL Figure 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 (PEAL Figure 3, PEAL Figure 1).

PEAL Table 1. Model performance values for *Penstemon albomarginatus* 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.

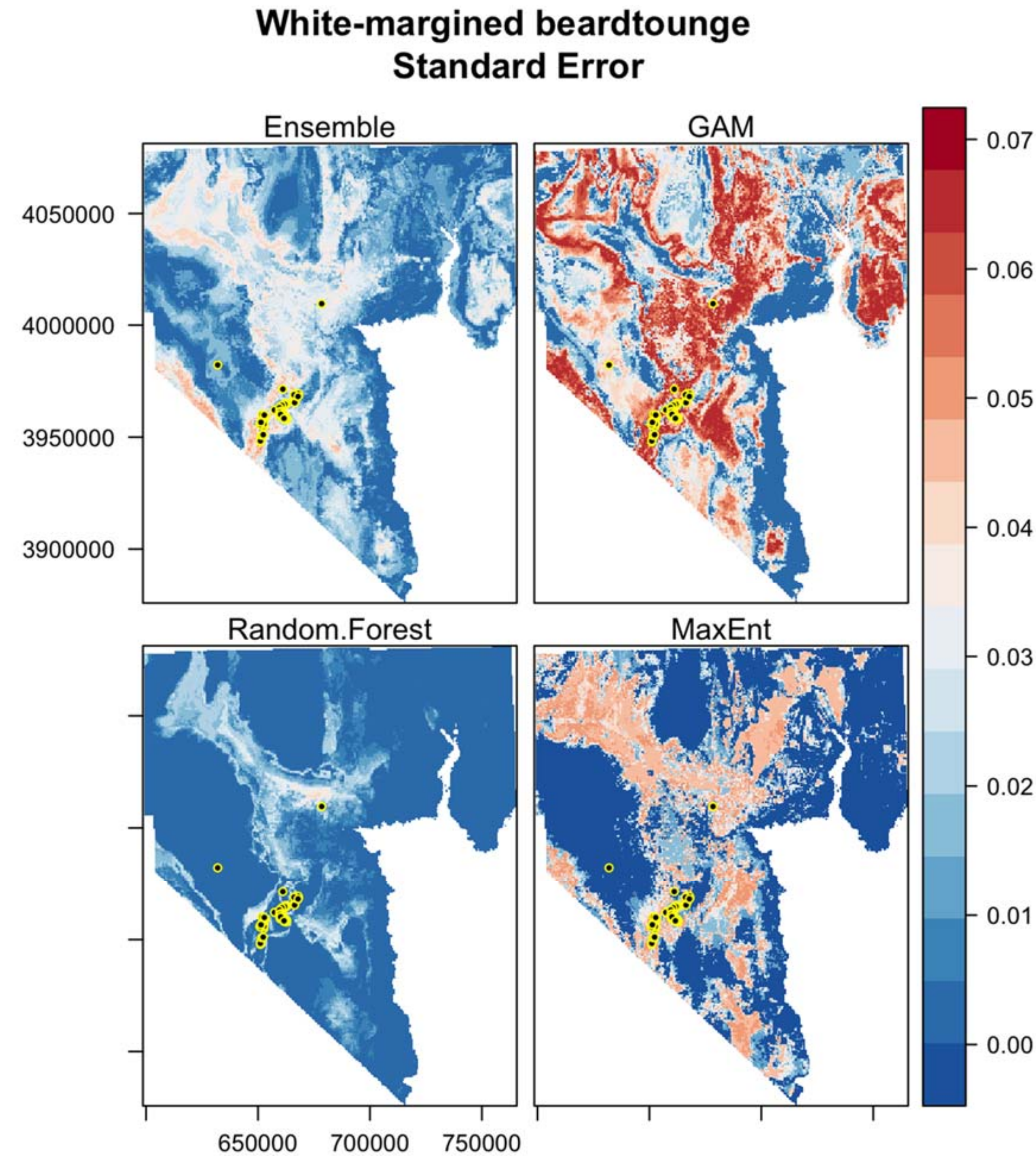
Model	AUC	BI	TSS	PRBE
Ensemble	0.96	0.98	0.82	0.44
GAM	0.9	0.89	0.76	
Random Forest	0.93	0.68	0.88	
MaxEnt	0.94	0.7	0.76	

PEAL Table 2. Percent contributions for input variables for *Penstemon albomarginatus* 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.

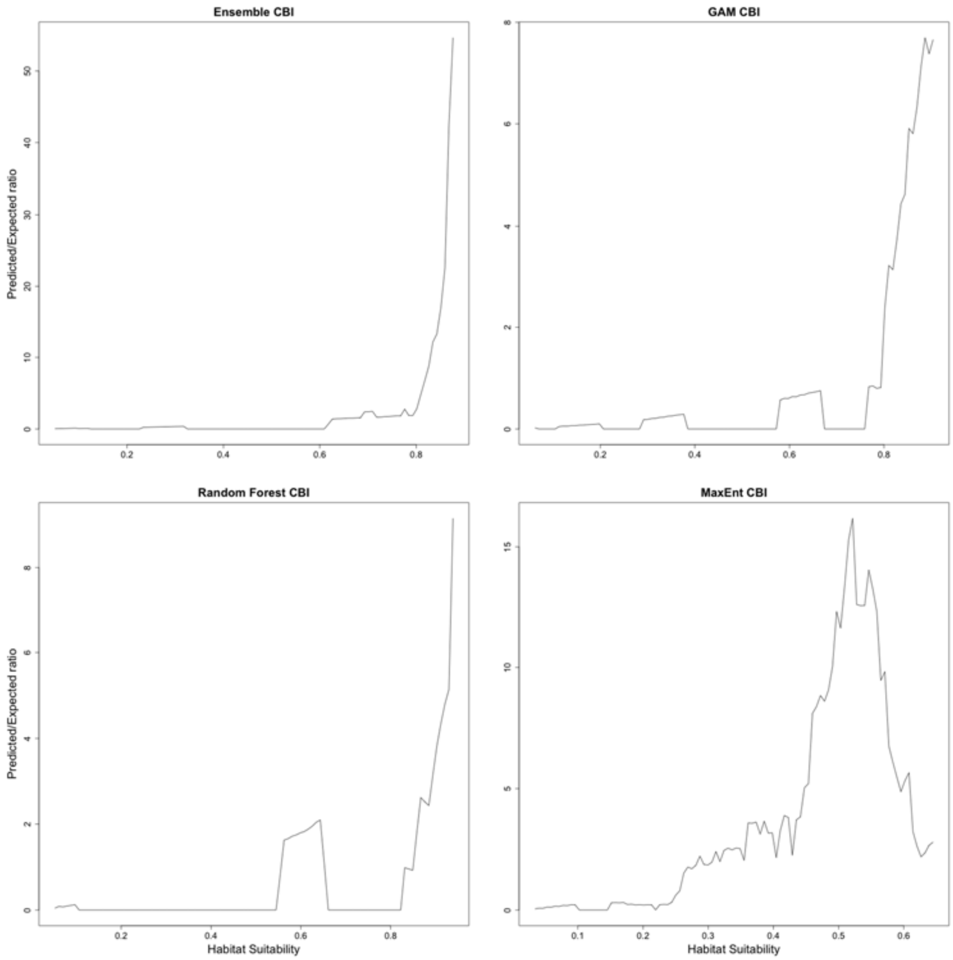
Variable	GAM	RF	MaxEnt
Average Spring Max Temp	15.1	1.3	13.1
Depth to bedrock	4.9	9.2	13.8
Clay	2.4	2.1	8.6
CV Average Spring Max Temp	19.7	13.8	1.5
CV Max Temp	9.8	5.5	6.3
Extreme Min Temp	8.6	2.7	10.3
NDVI Max	9.7	2.4	18
Slope	4.3	0.5	6.5
Winter Precip	12.5	33.3	11.9
CV Winter Precip	13	29.2	9.9



PEAL Figure 1. SDM maps for *Penstemon albomarginatus* 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.



PEAL Figure 2. Standard error maps for *Penstemon albomarginatus* 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).

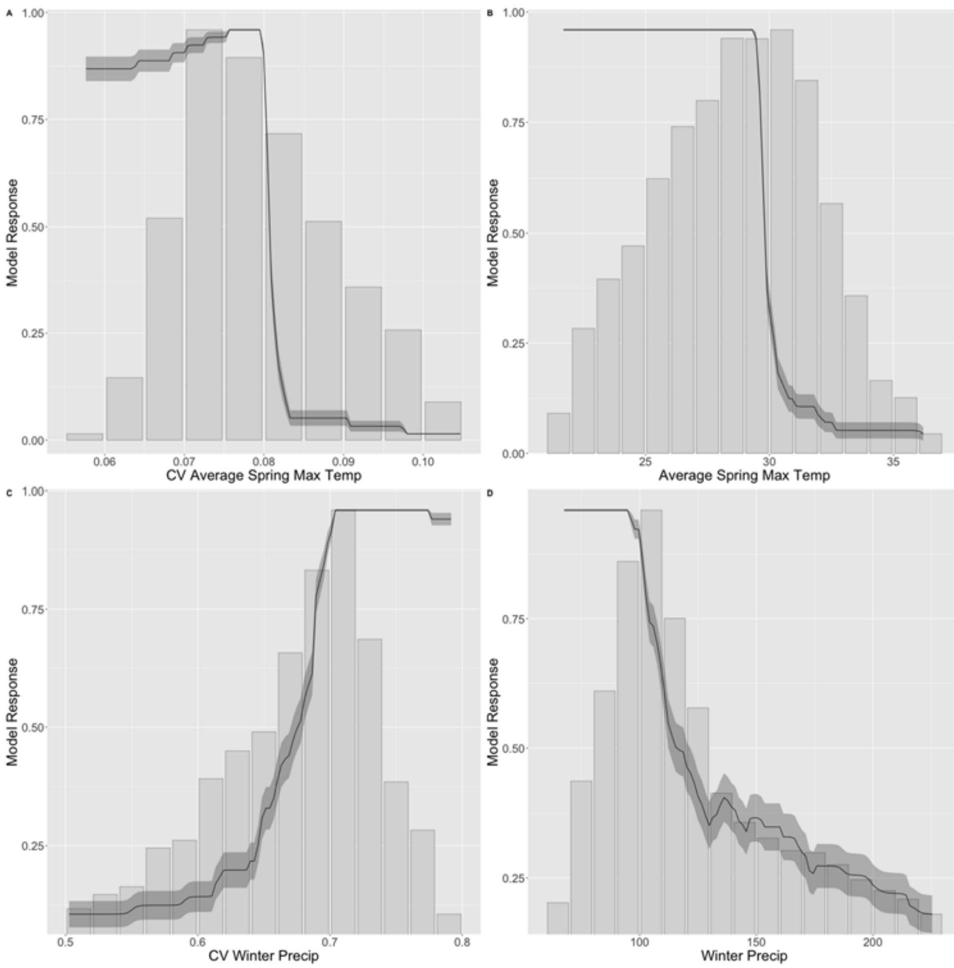


PEAL Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Penstemon albomarginatus* models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

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 (PEAL Table 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 (PEAL Figure 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 (PEAL Figure 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.

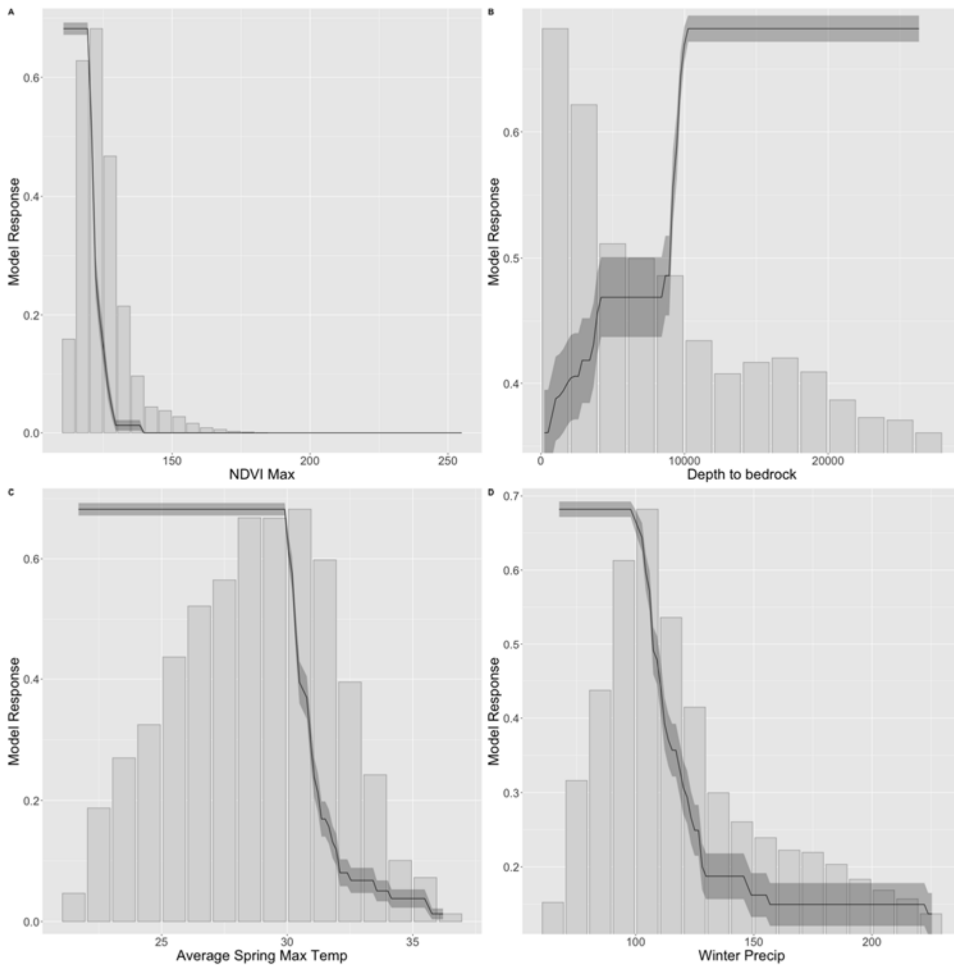
The GAM algorithm had higher standard error values, indicating some dissimilar predictions among the 50 model cross-validation runs (PEAL Figure 3).



PEAL Figure 4. GAM partial response curves for the top four variables in the *Penstemon albomarginatus* 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.

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 (PEAL Table 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 (PEAL Figure 4, PEAL Figure 5, PEAL Figure 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 (PEAL Figure 5, PEAL Figure 6). The similarity of these response curves in different algorithms indicates relatively robust model selection (PEAL Figure 4, PEAL Figure 5, PEAL Figure 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 (PEAL Figure 6).

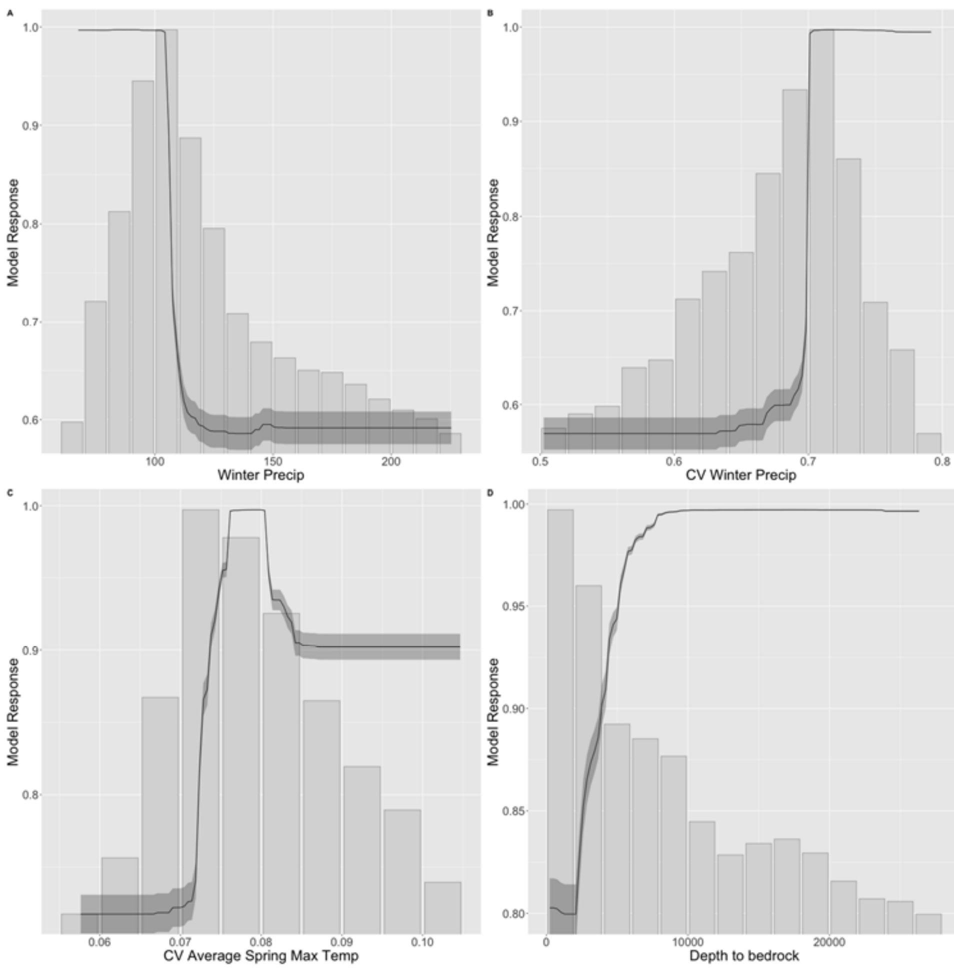


PEAL Figure 5. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for *Penstemon albomarginatus.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the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

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 (PEAL Table 2). The collective model influence of these four variables was 85.5%, where very little additional influence was proved by several other input variables (PEAL Table 2). Winter Precipitation indicated higher habitat suitability in areas with lower Winter Precipitation (PEAL Figure 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

(PEAL Figure 4, PEAL Figure 6). The RF models are also concordant with the MaxEnt models with respect to the Depth to Bedrock variable (PEAL Figure 5, PEAL Figure 6). In both cases, constant high habitat values are indicated when Depth to Bedrock exceeds 10000 mm.



PEAL Figure 6. Partial response curves for the top four environmental variables included in the Random Forest Ensemble model for *Penstemon albomarginatus.* 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.

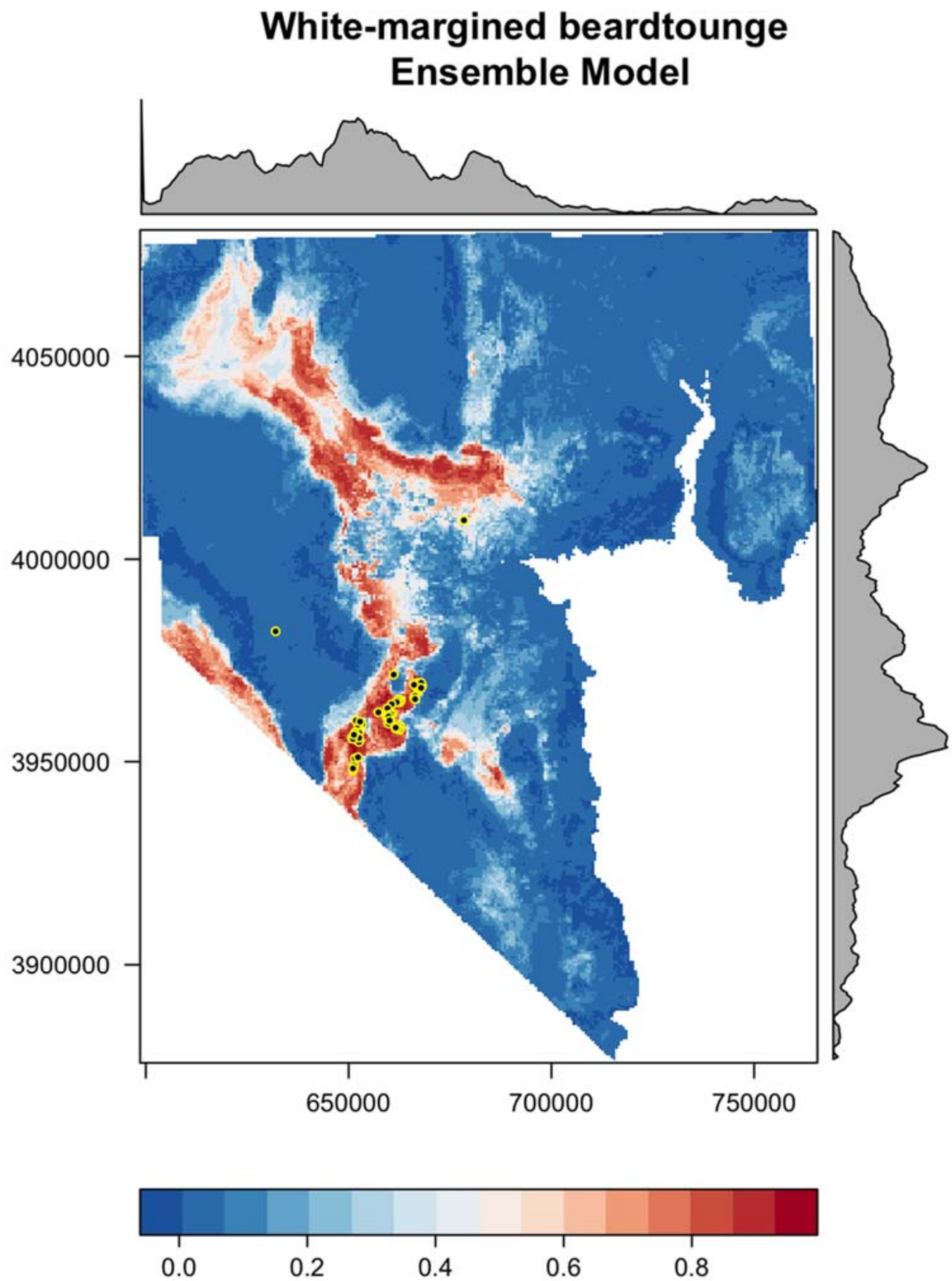
Model Discussion

Higher predicted habitat suitability for *Penstemon albomarginatus* 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.

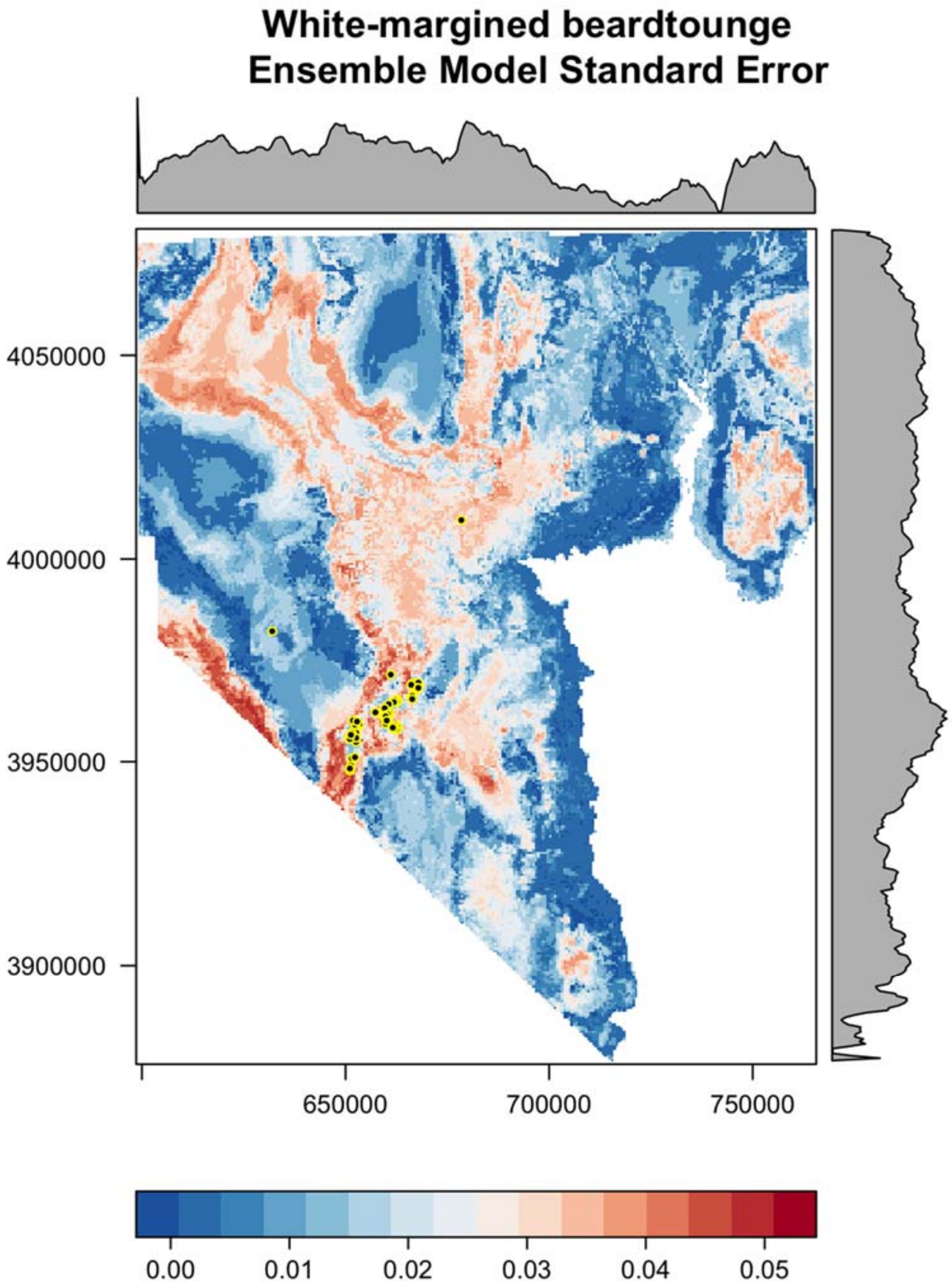
The locality data for this species consisted of 15,915 records within the buffered modeling area, which had an *extremely* high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to only 85 records. Observations spread across a broader area,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

Standard Error

The standard error map for the Ensemble model indicated relatively low error (< 0.05) throughout much of the study area (PEAL Figure 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.



PEAL Figure 7. SDM map for *Penstemon albomarginatus* Ensemble model for Clark County, NV.



PEAL Figure 8. Standard Error map for the *Penstemon albomarginatus* Ensemble model for Clark County, NV.

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 (PEAL Table 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 *Larrea tridentata*, *Ambrosia dumosa*, and *Hilaria rigida* associations. While the beardtongue may be found beneath *A. dumosa* and *H. rigida*, it is never found within the dripline of *Larrea* (Etyemezian et al. 2010). Soil types possessing these characteristics in this region include Bluepoint and Arizo soil series (Etyemezian et al. 2010).

PEAL Table 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

Ecosystem Level Threats

White-margined Beardtongue habitat occurs primarily in Mojave Desert Scrub and Salt Desert Scrub Ecosystems within Clark County, Nevada (PEAL Table 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)

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.

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).

Summary of Direct Impacts

Habitat for this species totals an estimated 1861 km^2 of combined high and moderate modeled habitat, 47% of which (combined) is likely to be impacted by the proposed MSHCP Amendment, while 25% is located within Conserved areas. Twenty Five percent of high and moderate habitat is considered to be already disturbed (PEAL Table 4).

PEAL Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	71565	23153	18077	112795
Med	16192	23815	33378	73385
Low	39060	466544	68868	574472

PHPA – Parish's phacelia (Phacelia parishii)

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

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

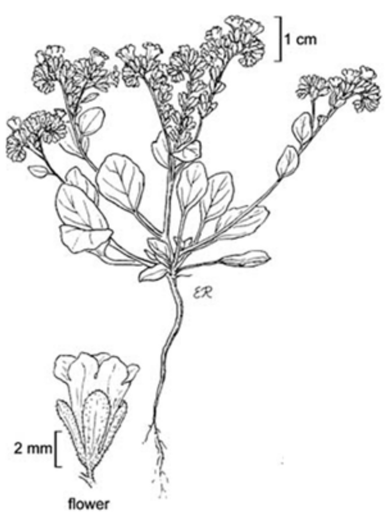
"**Habit:** Annual 5--15 cm, aromatic. **Stem:** ascending to erect, branched at base, short-stiff-hairy, minutely glandular. **Leaf:** +- basal, 8--30 mm; blade > petiole, +- widely elliptic to obovate, entire to +- toothed. **Flower:** calyx lobes 3--5 mm, 6--8 mm in fruit, not alike, especially in 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 (Genevive et al. 2013; Moorefield 2001).

Figure 1. Parish's phacelia



Species Status

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).

Legal / Conservation status:

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

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).

Population trends

Phacelia parishii 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 CA 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.

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 (PHPA Figure 1). 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 (PHPA Figure 1). 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 (PHPA Figure 1). 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 (PHPA Figure 1). 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 (PHPA Table 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 (PHPA Table 1). Overall AUC performance was very high, with all models performing above 0.94, while BI scores were relatively high.

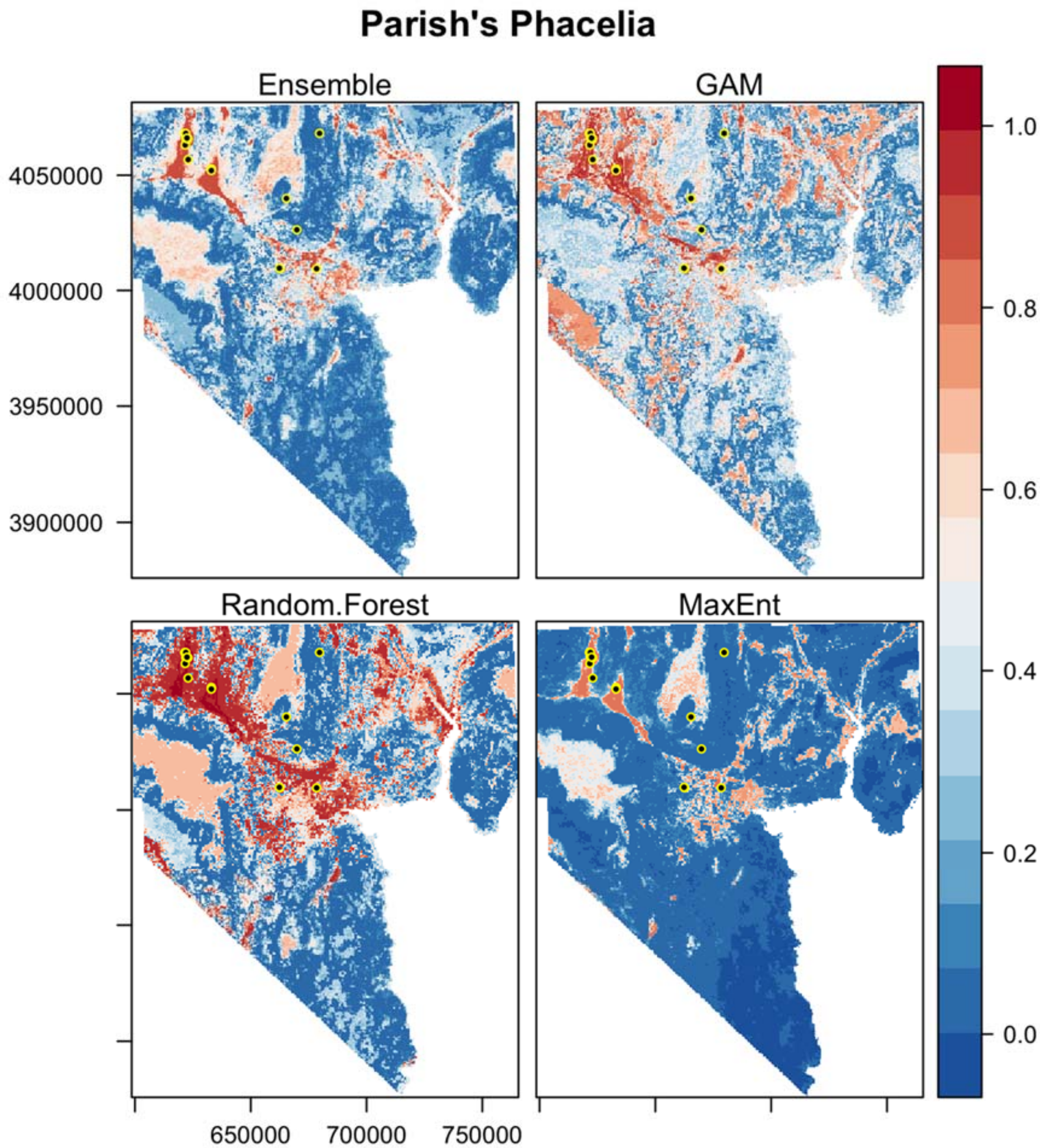
Due to a paucity of localities with which to model (43) we reduced the number of environmental variables considered to five, as many of the modeling algorithms were unable to produce models that converged. All three models shared Clay Content, and NDVI Maximum as the largest contributors (PHPA Table 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 (PHPA Table 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 (PHPA Table 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 (PHPA Figure 2). All other models had standard errors that were very low (PHPA Figure 2). The Continuous Boyce Indices showed fair model performance in all algorithms (PHPA Figure 3). 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 (PHPA Figure 3), 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.

PHPA Table 1. Model performance values for *Phacelia parishii* 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.

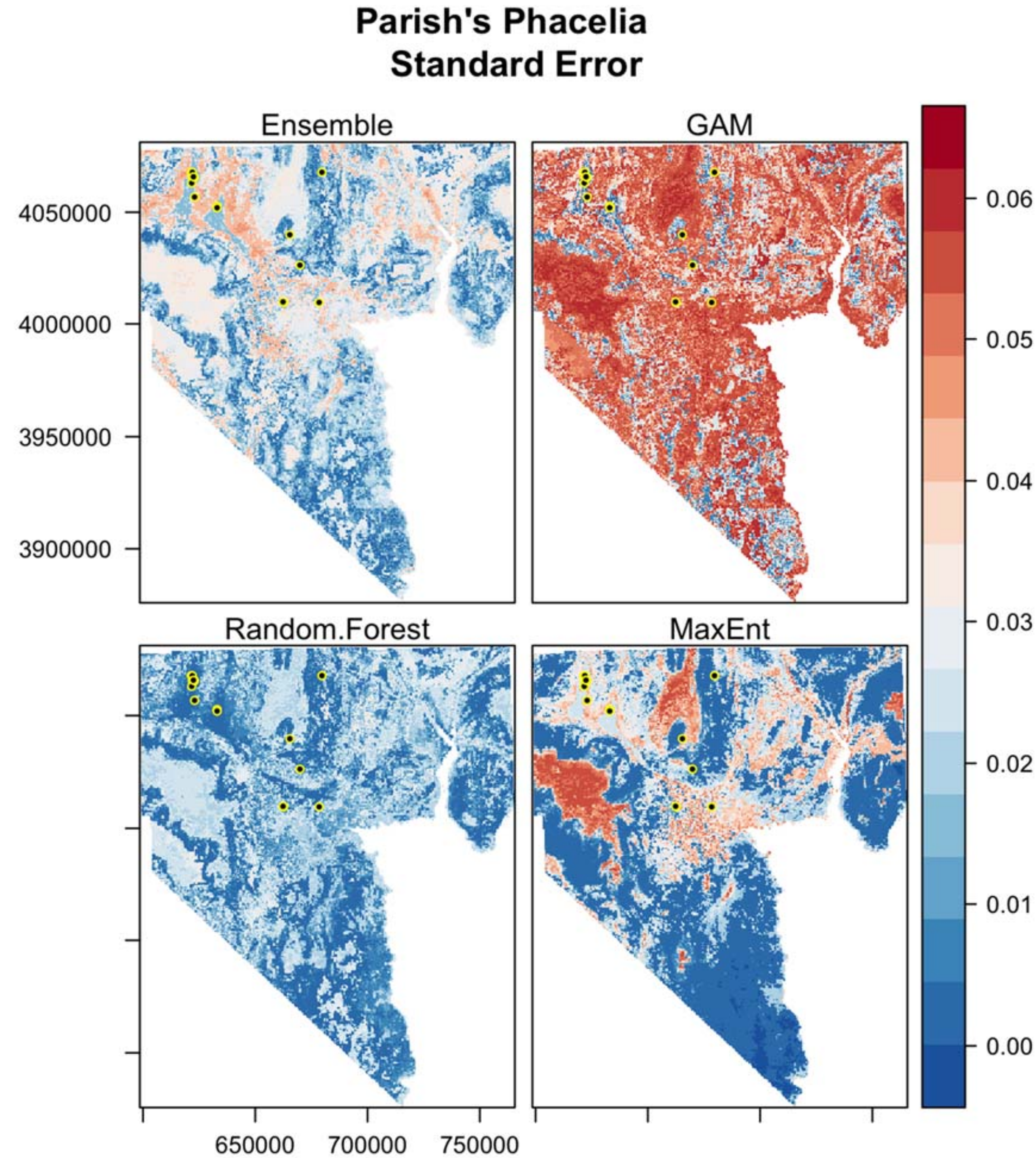
Model	AUC	BI	TSS	PRBE
Ensemble	0.94	0.94	0.78	0.34
GAM	0.9	0.72	0.67	
Random Forest	0.85	0.58	0.67	
MaxEnt	0.96	0.57	0.78	

PHPA Table 2. Percent contributions for input variables for *Phacelia parishii* 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.

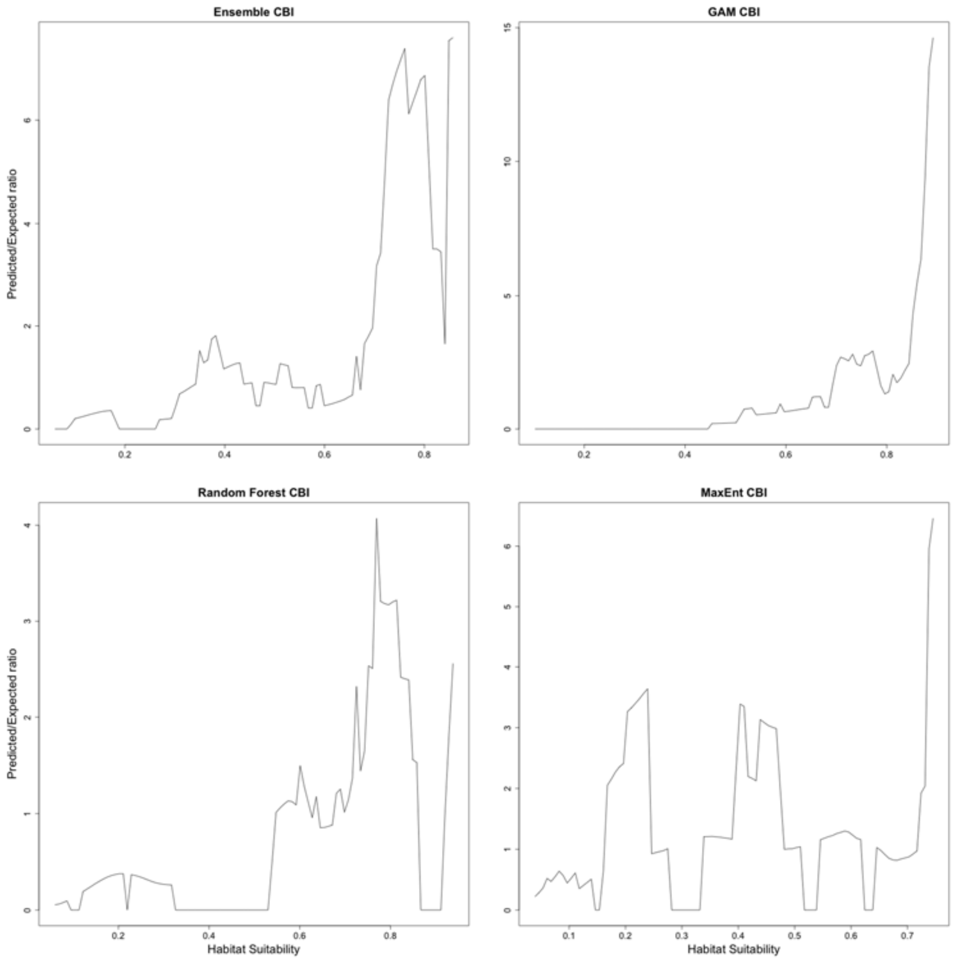
Variable	GAM	RF	MaxEnt
Clay	31.4	41.1	35.5
Extreme Min Temp	11.6	4	27.8
Soil gypsum	8.5	5.9	19.8
NDVI Amplitude	16.3	15.8	7.8
NDVI Max	32.2	33.2	9.1



PHPA Figure 1. SDM maps for *Phacelia parishii* 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.



PHPA Figure 2. Standard error maps for *Phacelia parishii* 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).

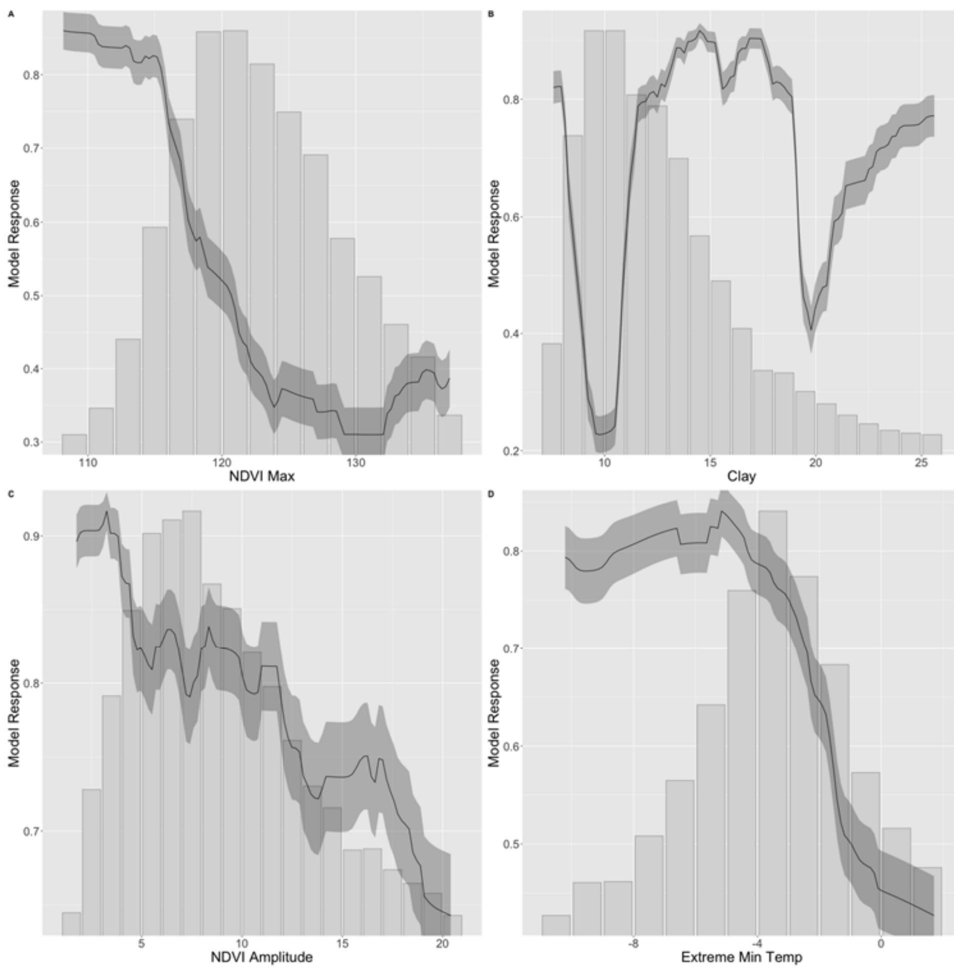


PHPA Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Phacelia parishii* models for the Ensemble model prediction (upper left) and for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, and MaxEnt - lower right).

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 (PHPA Table 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% (PHPA Figure 4, PHPA Figure 5, PHPA Figure 6). 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 (PHPA Figure 4). 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 (PHPA Figure 4, PHPA Figure 5, PHPA Figure 6). 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 (PHPA Figure 4, PHPA Figure 6). 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 (PHPA Figure 4, PHPA Figure 6).

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 (PHPA Figure 3).



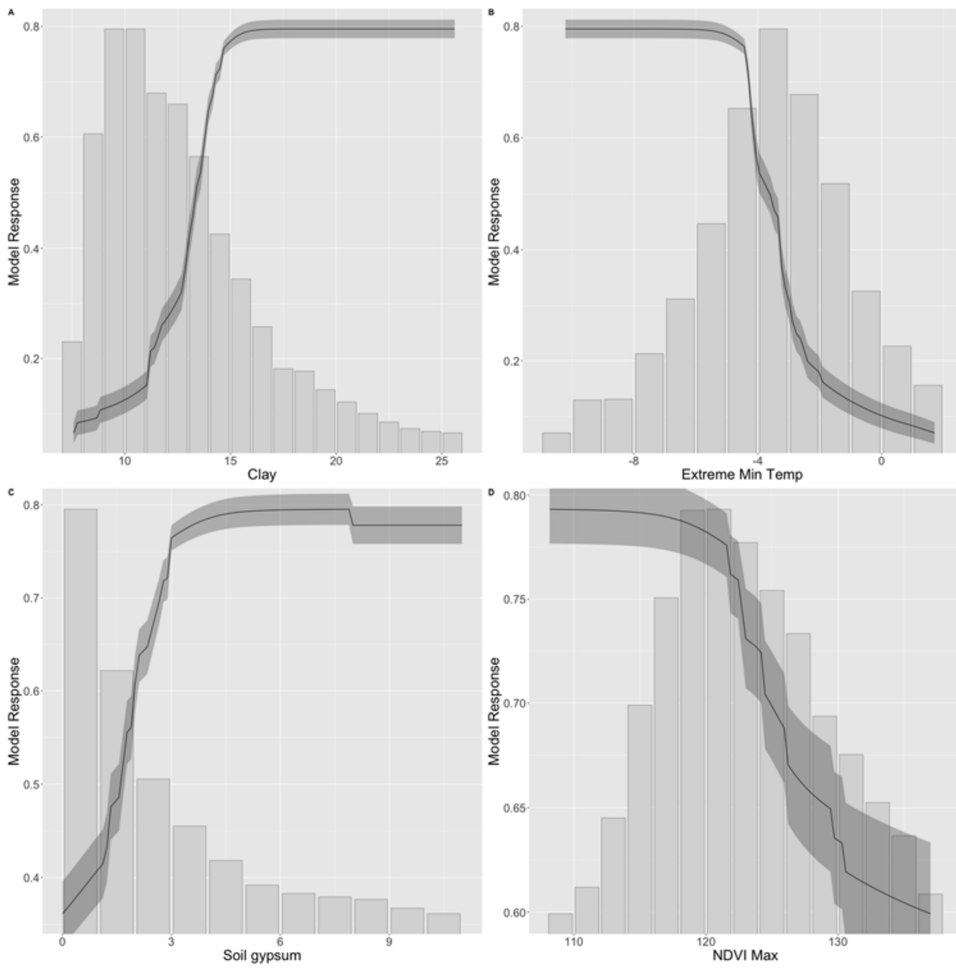
PHPA Figure 4. GAM partial response curves for the top four variables in the *Phacelia parishii* model overlaid over distribution of environmental variable inputs in the study area. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat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

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 (PHPA Table 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 (PHPA Figure 4, PHPA Figure 5, PHPA Figure 6). 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% (PHPA Figure 4, PHPA Figure 5). Habitat values are high in all models, until NDVI Maximum exceeds ca. 115, at which point habitat values decrease rapidly and remain low (PHPA Figure 4, PHPA Figure 5, PHPA Figure 6). The variable Gypsum Content of the soil was shared as a top variable with the RF model (PHPA Table 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% (PHPA Figure 5, PHPA Figure 6). Similarly, the MaxEnt and GAM models shared Extreme Minimum temperature as an important variable (PHPA Table 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 (PHPA Figure 4, PHPA Figure 6).

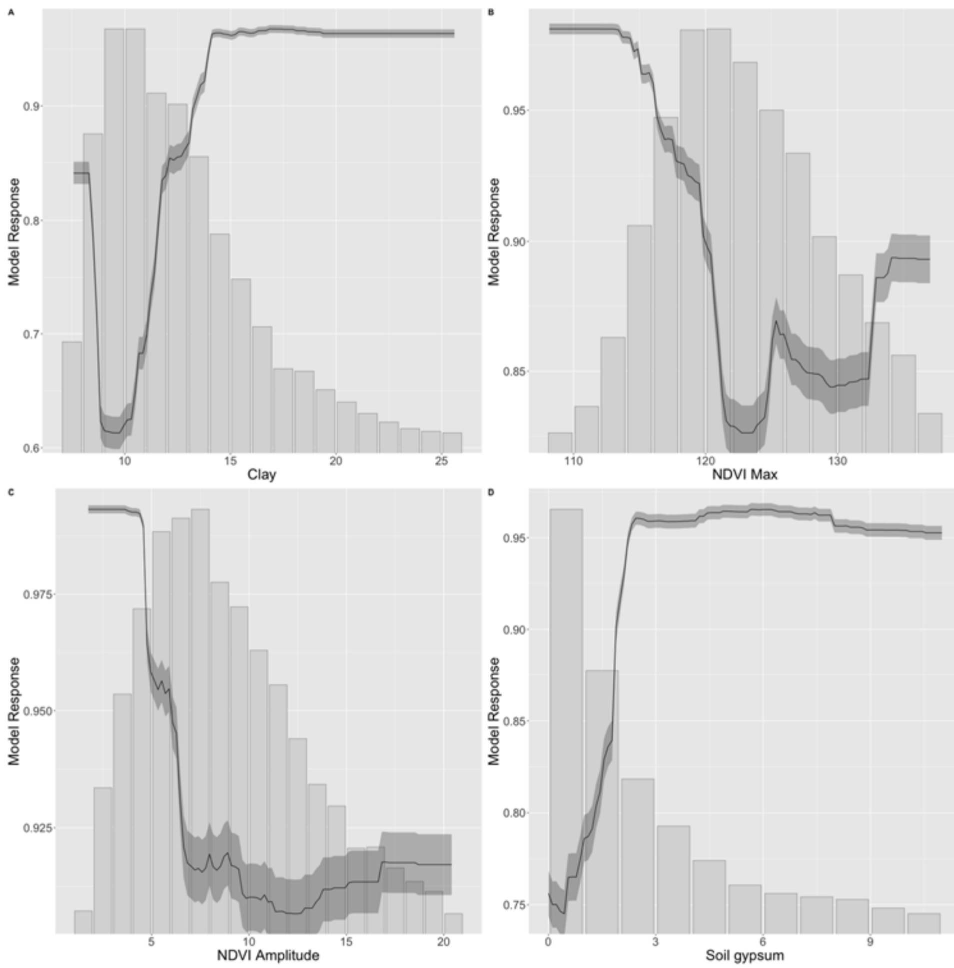
This model had relatively low standard errors, indicating general agreement in the predictions among the 50 model cross-validation runs (PHPA Figure 3).



PHPA Figure 5. Partial response curves for the top environmental variables included in the MaxEnt Ensemble model for *Phacelia parishii.* 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.

Random Forest Model

The Random Forest model was driven by Clay Content of soil, Gypsum Content of soil, NDVI Amplitude, and NDVI Maximum (PHPA Table 2). The collective model influence of these four variables was 96% (PHPA Table 2). All four variables are also important variables in either one or both of the other models (PHPA Table 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 (PHPA Figure 6). Habitat values are high when NDVI Amplitude is low, and rapidly decrease when NDVI Amplitude exceeds 5 (PHPA Figure 6).



PHPA Figure 6. Partial response curves for the environmental variables included in the Random Forest Ensemble model for *Phacelia parishii.* 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.

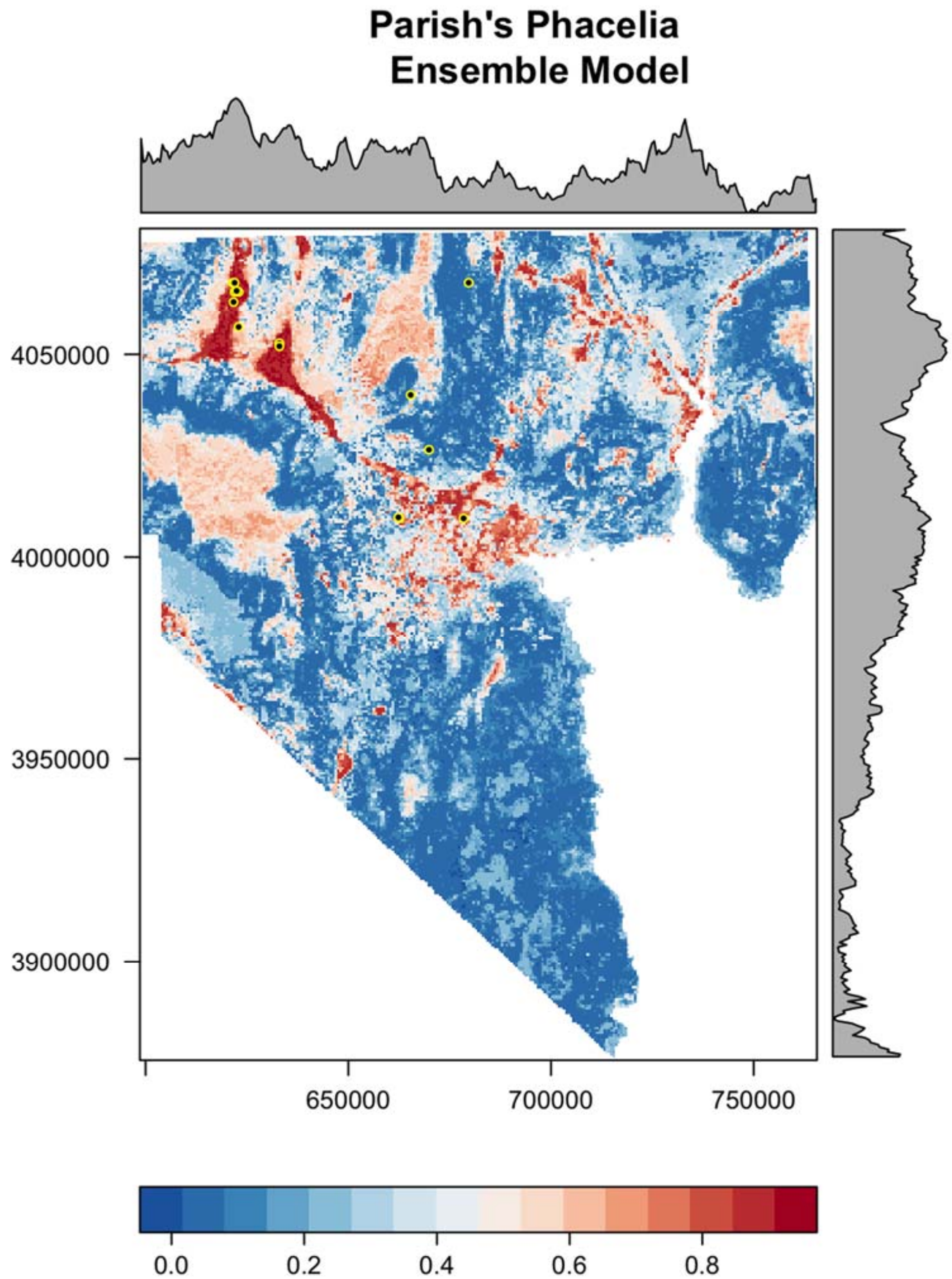
Model Discussion

Phacelia parishii 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.

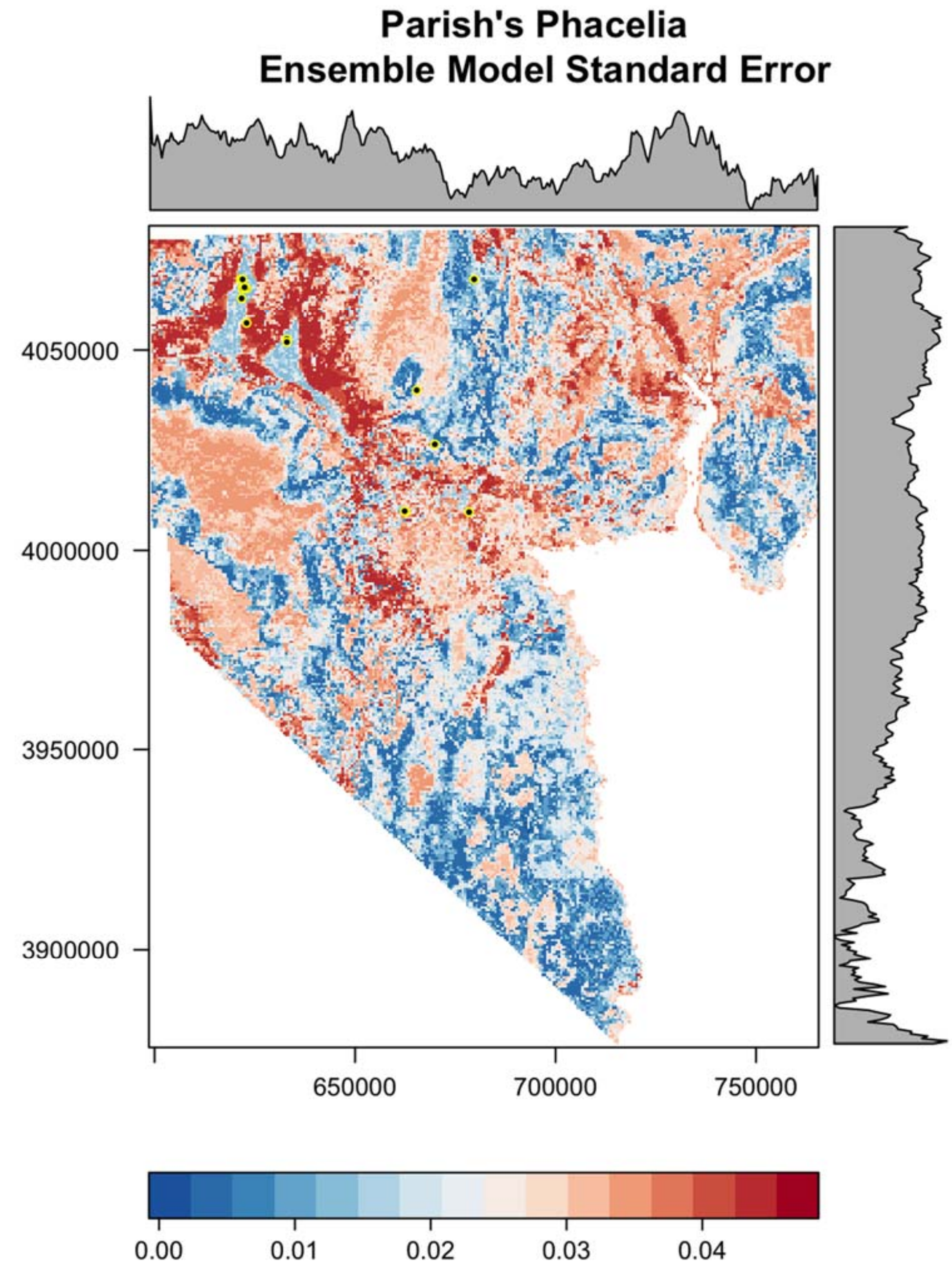
The locality data for this species consisted of 64 records within the buffered modeling area, which had a very high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 43 records.

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 (PHPA Figure 8), 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.



PHPA Figure 7. SDM map for *Phacelia parishii* Ensemble model for Clark County, NV.



PHPA Figure 8. Standard Error map for the *Phacelia parishii* Ensemble model for Clark County, NV.

Distribution and habitat use within Clark County

In Clark County, the species is found *Phacelia parishii* 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; Figure 2). 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 (Figure 2). A portion of the center of Eldorado Valley (in and around the dry lake) is also predicted to have high habitat suitably (Figure 2).

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.

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 (PHPA Table 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).

PHPA Table 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

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).

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).

Summary of Direct Impacts

Of the 1088 km^2 of predicted high suitability habitat within the county, 19% is in proposed conserved areas, while 22% is considered already disturbed, and 59% is likely to be impacted by planned development activities (PHPA Table 4). Moderate habitat is 43% in conserved areas, with 35% already disturbed and 23% potentially impacted.

PHPA Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	64629	20243	24004	108876
Med	41504	74771	61556	177831
Low	20545	418068	34645	473258

RAOB - 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.

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

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.

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).

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 (RAOB Table 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 (RAOB Figure 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 (RAOB Figure 1, RAOB Table 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 (RAOB Figure 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 (RAOB Figure 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 RAOB Figure 1.

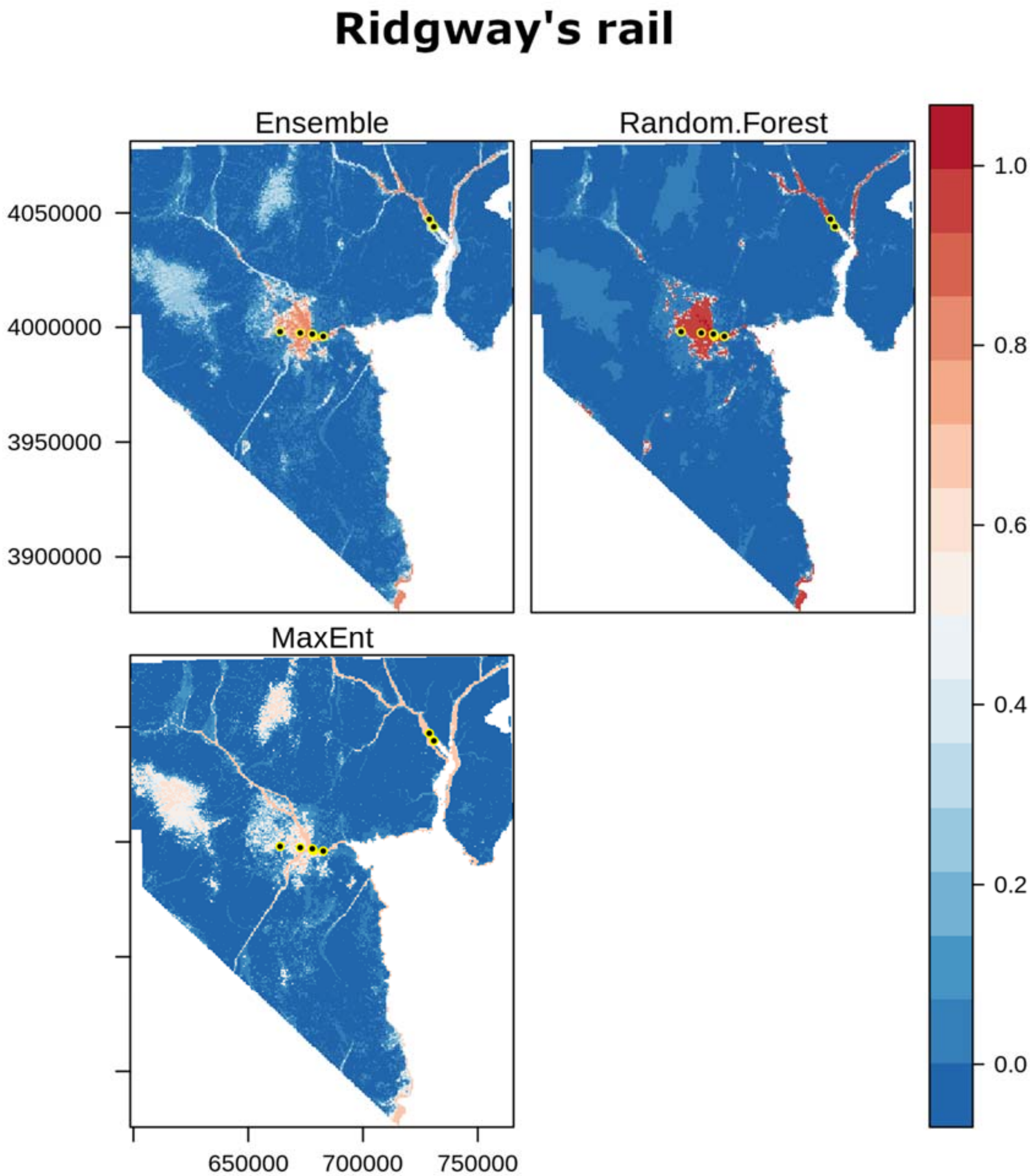
The top four influential variables were different between the two modeling approaches, sharing only the soil Sand component. The top four influential variables for the Random Forest models were rounded out by Clay Content and Extreme Minimum and Average Maximum temperatures, while the Random Forest models highlighted Flow Accumulation, and NDVI metrics for Start of the Spring Season, and NDVI Amplitude values (RAOB Table 2).

RAOB Table 1. Model performance values for *R. obsoletus* 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.

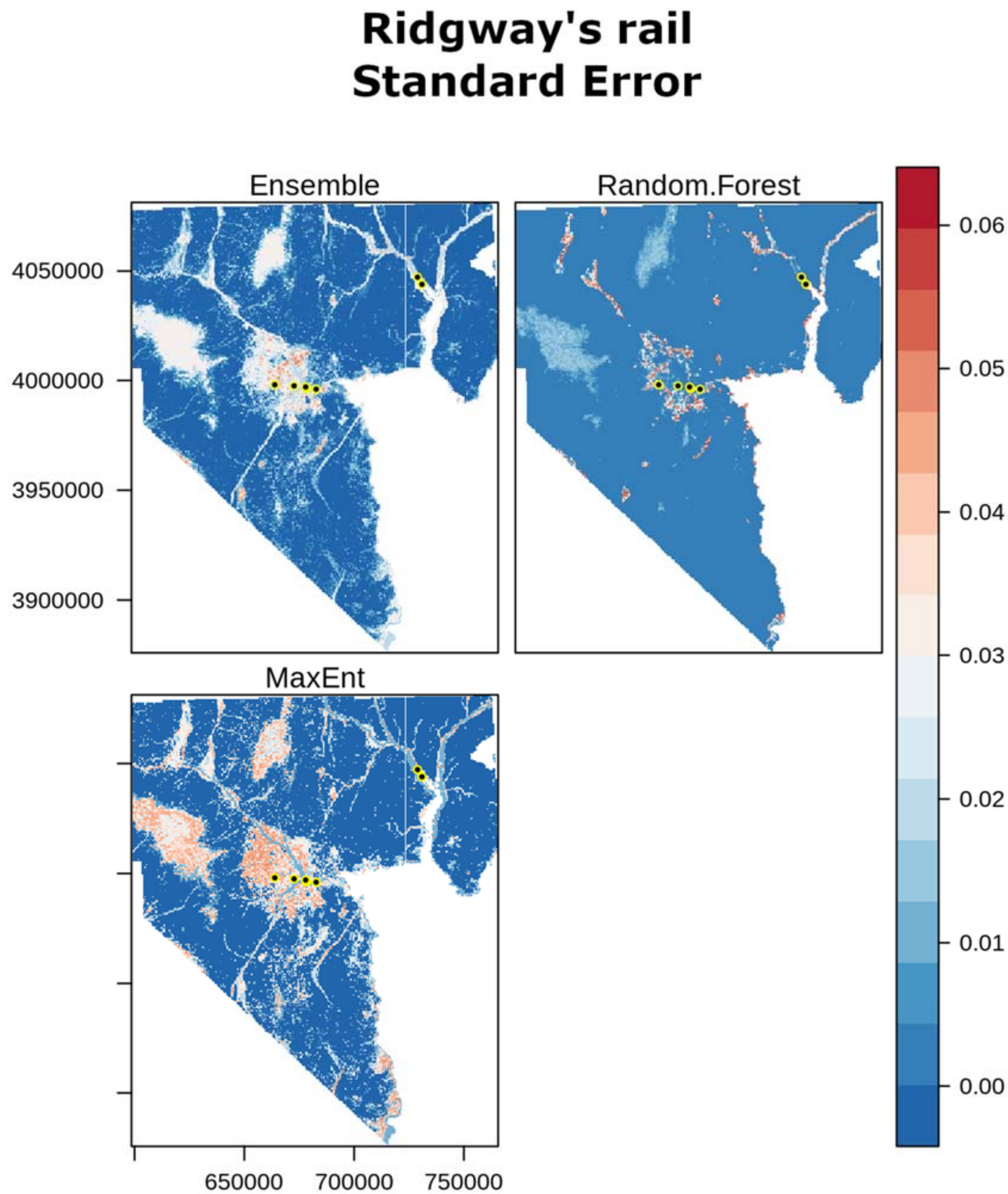
Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.98	0.96	0.86	0.64
GAM	-	-	-	
Random Forest	0.98	0.5	0.88	
MaxEnt	0.92	0.99	0.86	

RAOB Table 2. Percent contributions for the top 10 input variables for *R. obsoletus* 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.

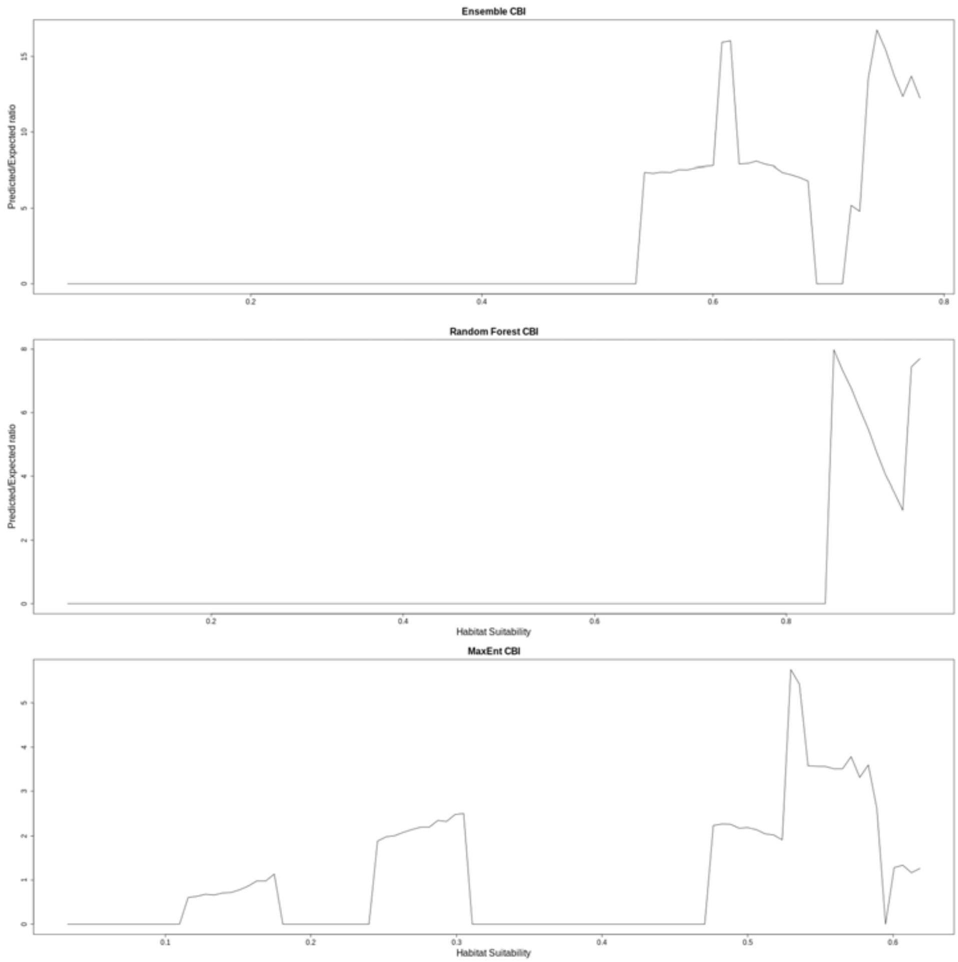
Variable	RF	MaxEnt
PPT Sand	25.7	8.3
Flow Accum	4.9	23.1
Start of Season (day)	2.6	19.6
NDVI Amplitude	4.2	11.7
PPT Clay	13.3	2.3
Ave Min Temp	5.1	7.9
NDVI Max	4.6	6.9
Extreme Min Temp	5.6	0.8
PPT Silt	5.4	4.7
Ave Max Temp	6.6	2.6



RAOB Figure 1. SDM maps for *R. obsoletus* 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.



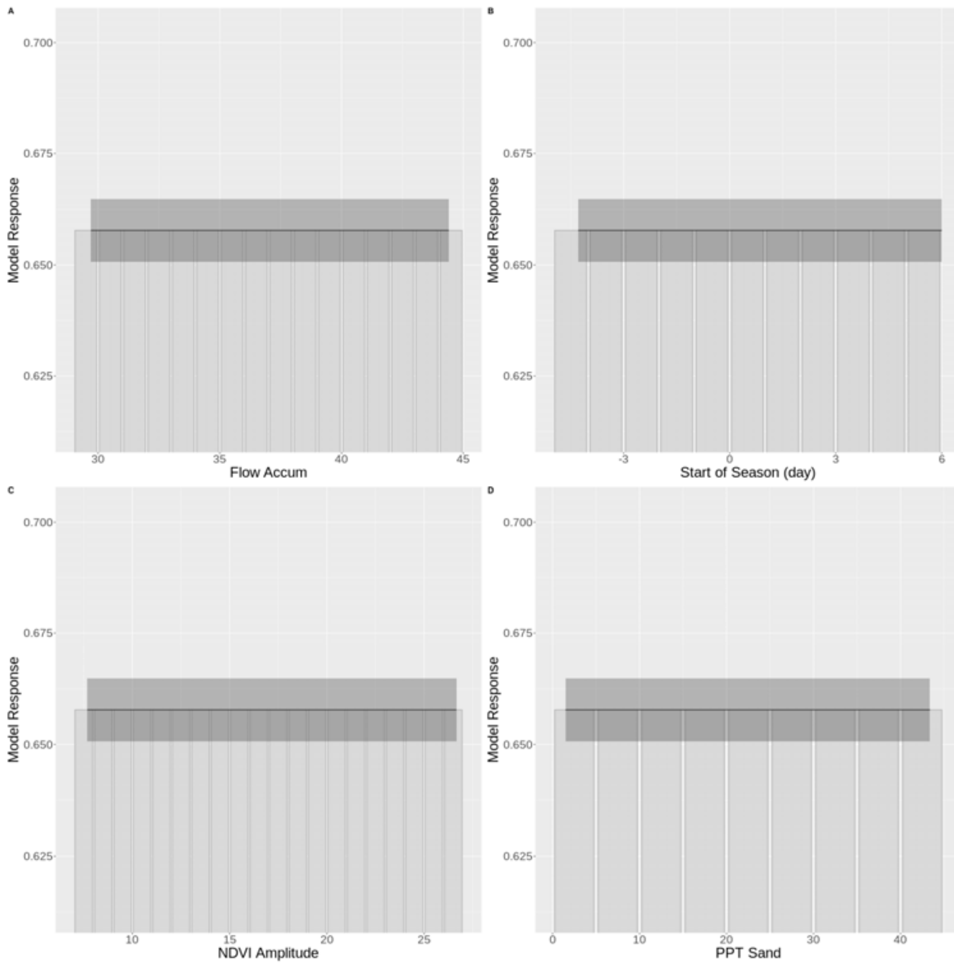
RAOB Figure 2. Standard error maps for *R. obsoletus* models for each of the modeling algorithms used (Ensemble - upper left, Random Forest - upper right, MaxEnt - lower left).



RAOB Figure 3. Graphs of Continuous Boyce Indices [CBI] for *R. obsoletus* models for the Ensemble model prediction (top and for each of the modeling algorithms used (Random Forest – center, and MaxEnt - bottom).

MaxEnt Model

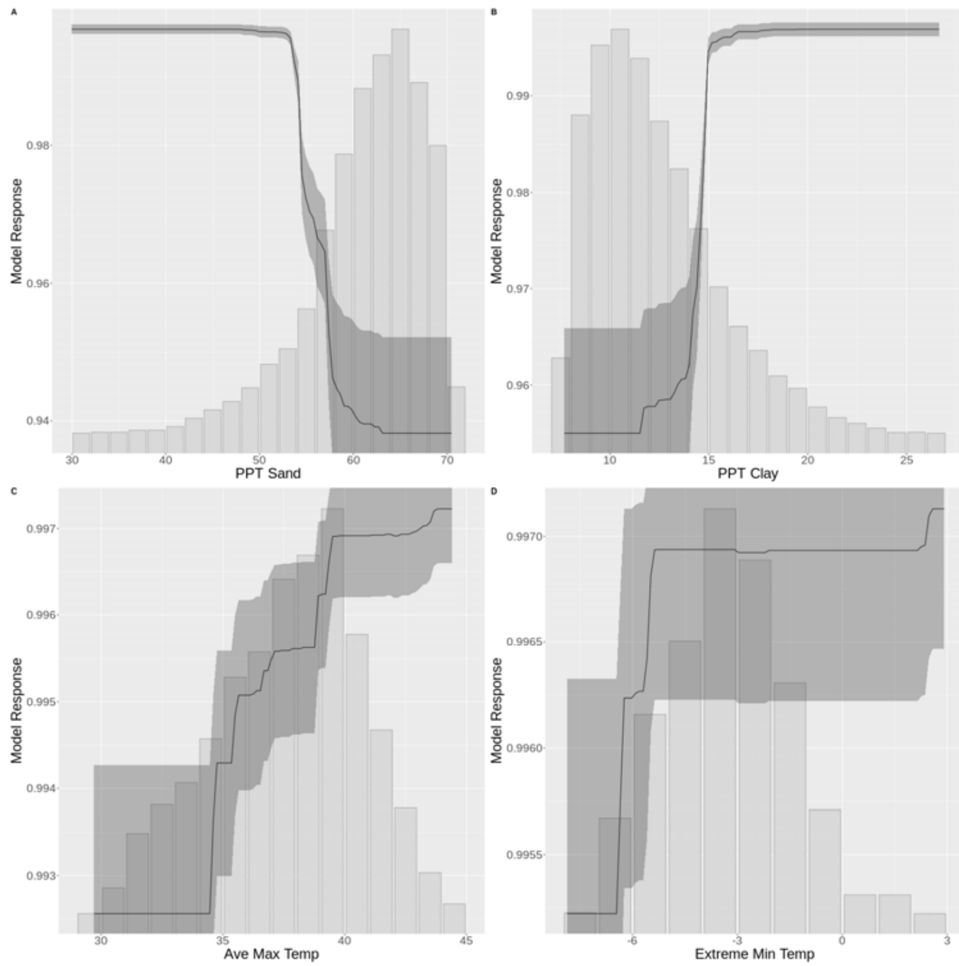
The MaxEnt models were most influenced by the terrain index describing the potential for Flow Accumulation, the Start of the Spring Season (as indicated by NDVI) and the Amplitude of NDVI signal at its peak value. Collectively these contributed to 63% of the model influence. Due to the lower sample sizes – 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 (RAOB Figure 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.



RAOB Figure 4. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *R. obsoletus.* 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.

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; RAOB Figure 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 (RAOB Figure 1).



RAOB Figure 5. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *R. obsoletus.* 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.

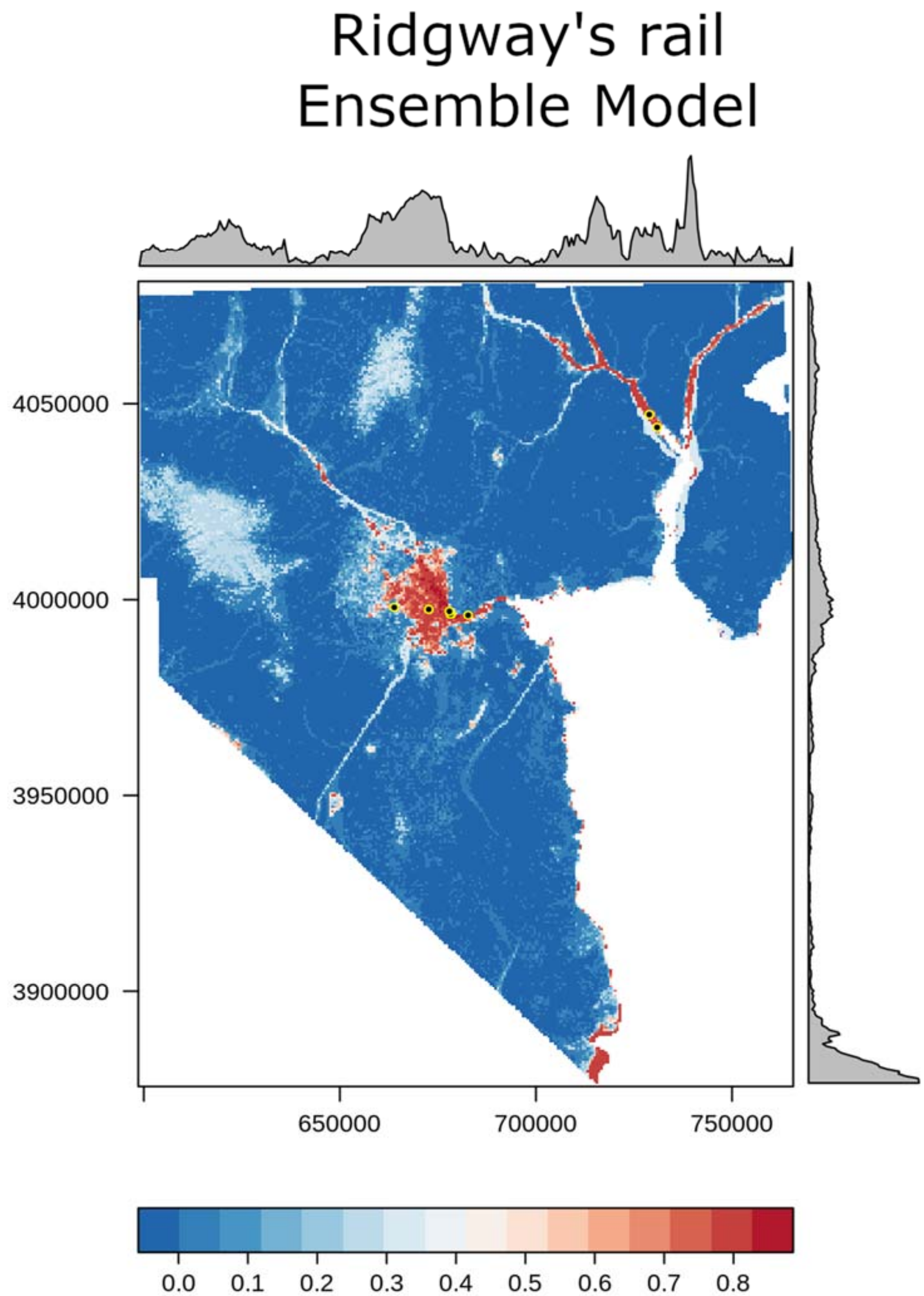
Model Discussion

In Clark County, *R. obsoletus* 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 (RAOB Figure 6).

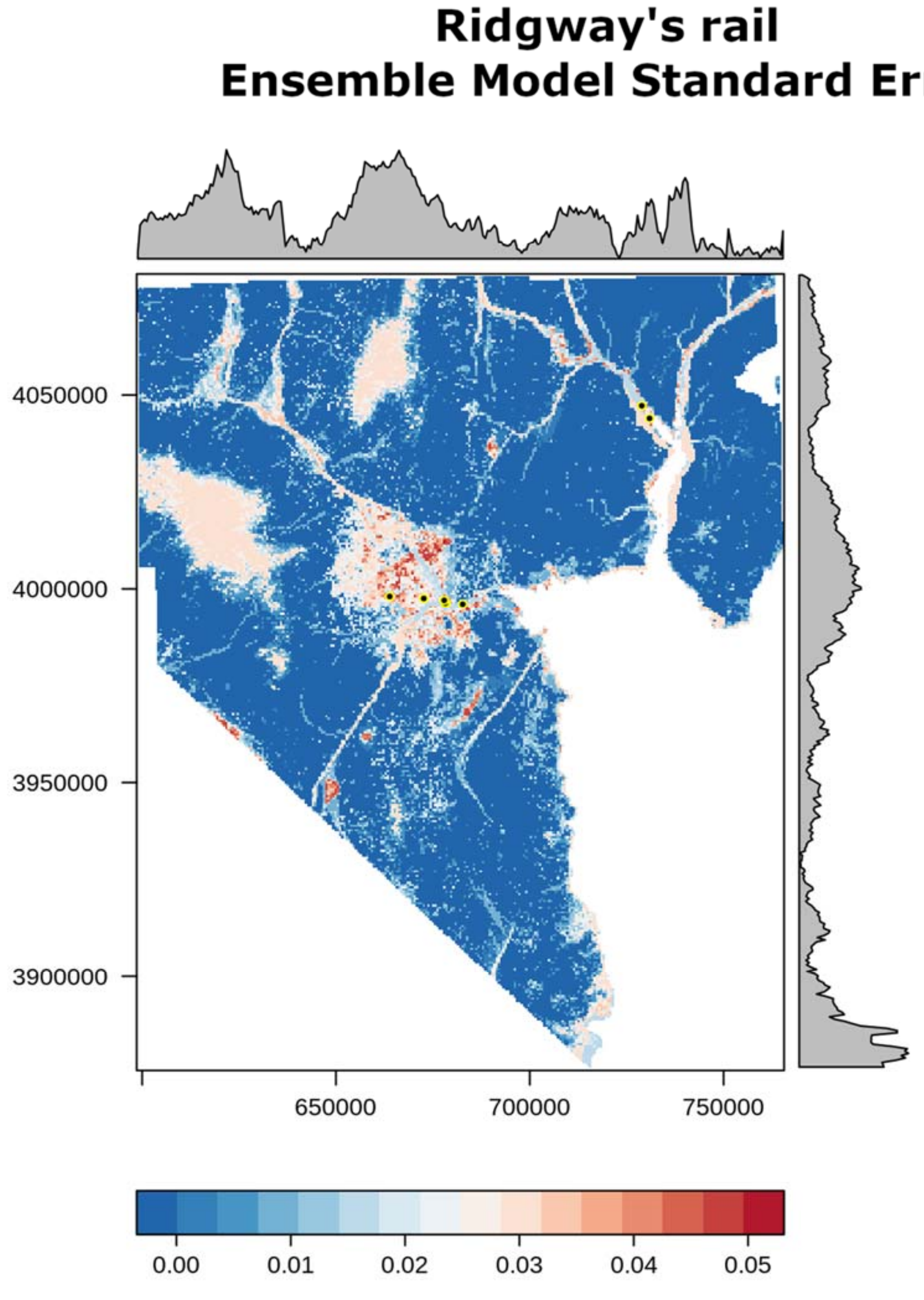
The locality data for this species consisted of 82 records within the buffered modeling area. Spatial thinning of the data and the removal of duplicated records (or multiple within a given pixel size) reduced the number of localities used for training and testing to 47 records. The rarity of this species within the county makes modeling difficult, and as with all rare species, models would benefit from increased observations.

Standard Error

Areas of elevated standard error rates (SE ~0.05) were largely located within the Las Vegas area and near Primm (RAOB Figure 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.



RAOB Figure 6. SDM map for *R. obsoletus* Ensemble model for Clark County, NV.



RAOB Figure 7. Standard Error map for the *R. obsoletus* Ensemble model for Clark County, NV.

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).

Ecosystem Level Threats

This subspecies occurs exclusively in the Mojave Desert Scrub, Desert Riparian and Mesquite Acacia habitats of Clark County, NV (ROAB Table 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)

RAOB Table 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

Ecosystem	Low	Medium	High
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

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.

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).

Summary of Direct Impacts

The Yuma Ridgway's Rail is a very rare breeding bird and summer resident in Clark County. Approximately 384 km^2 of modeled high suitability habitat exists within Clark County (ROAB Table 4), although the proportion of this that is suitable for Yuma Ridgway's Rail nesting (i.e., open marsh habitat) is estimated to be much less. This species rarely occurs in the plan area; however, due to the limited amount of potential habitat, covered activities have the potential to adversely affect this species within Clark County. It is estimated that approximately 79 percent of high suitability modeled habitat within Clark County is already disturbed, and an additional 16% could be impacted by activities covered under the Amendment. Just 5% of high suitability habitat is in conserved areas (ROAB Table 4).

RAOB Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	6185	1796	30504	38485
Med	7088	2840	14812	24740
Low	77822	189795	71841	339458

TOBE - 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.

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

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).

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, Le Conte’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).

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 (TOBE Figure 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 (TOBE Figure 1).

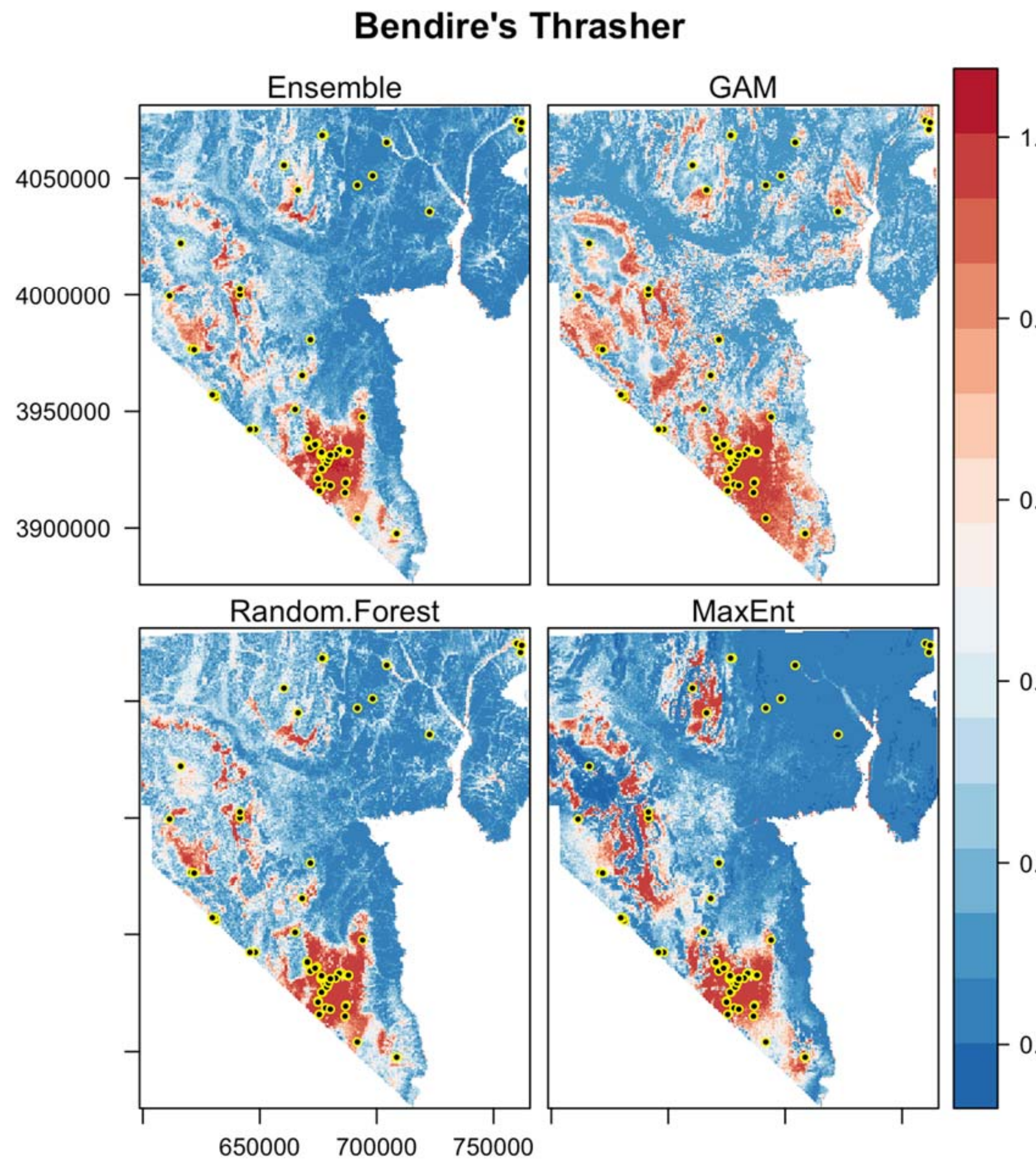
The Ensemble model had high performance relative to other models, scoring the highest on all of the performance metrics AUC and TSS when considering the testing, and all data combined. The GAM and Random Forest models were nest highest performing algorithms, but all models have relatively high, and similar performance metrics (TOBE Table 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 (TOBE Table 2). The MaxEnt Models had higher contribution due to Slope, and with the Average Spring Maximum temperature as the fifth most important variable (TOBE Table 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 (TOBE Figure 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 (TOBE Figure 3).

TOBE Table 1. Model performance values for *T. bendirei* 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.

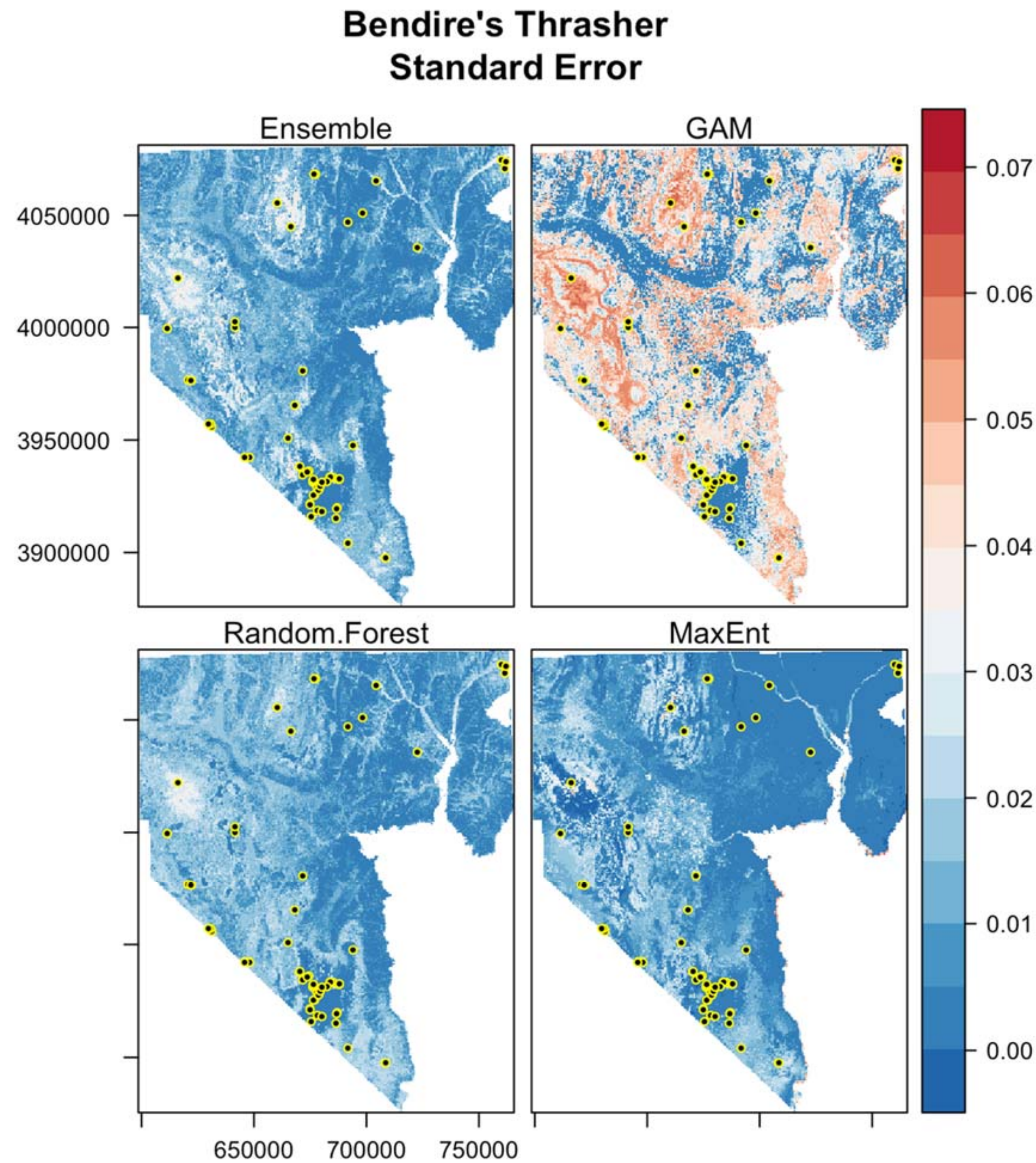
Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.89	0.94	0.68	0.73
GAM	0.87	0.85	0.66	
Random Forest	0.87	0.9	0.63	
MaxEnt	0.85	0.86	0.63	

TOBE Table 2. Percent contributions for input variables for *T. bendirei* 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.

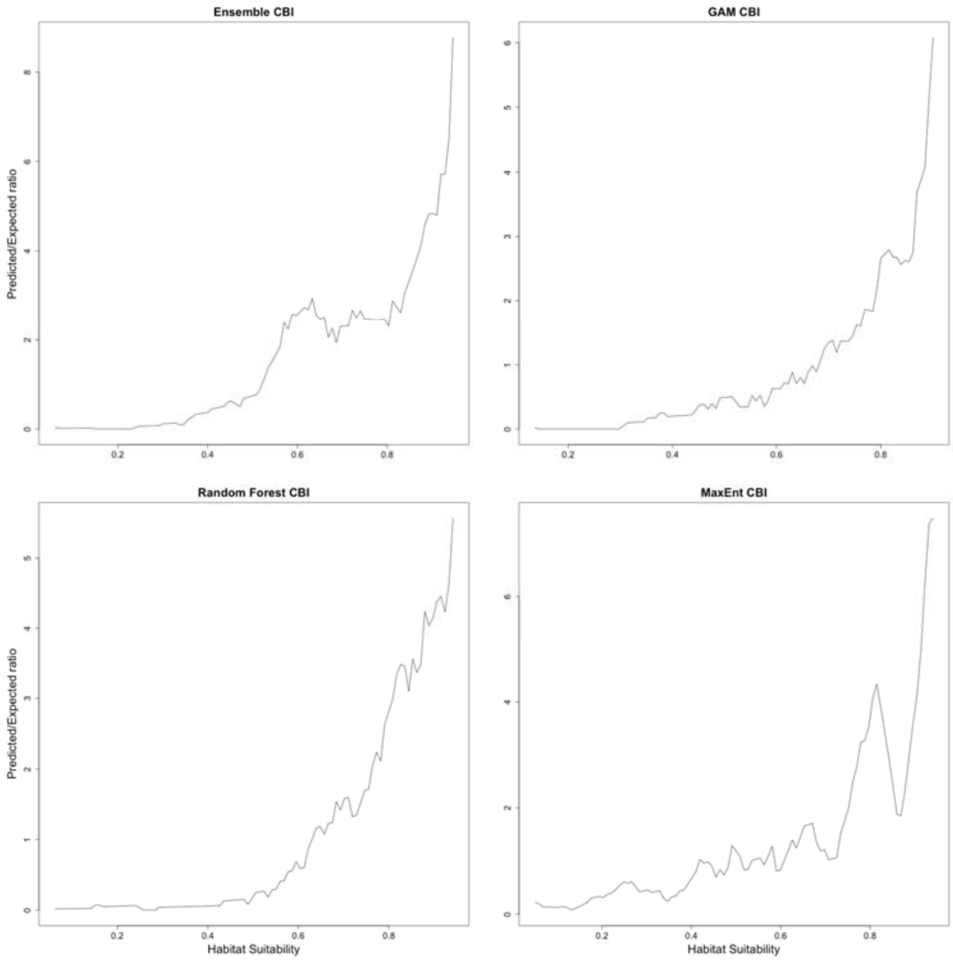
Variable	GAM	RF	MaxEnt
Dist to cliffs	2.8	1.1	0.9
NDVI Amplitude	6.3	1.8	0.5
NDVI Length of Season	2.9	1.2	0.6
NDVI Max	9.4	4.8	1.2
Winter Precip	13.8	12.6	11.4
CV Winter Precip	12.9	37.3	29.2
Average Spring Max Temp	13.5	11	3.9
CV Average Spring Max Temp	24.2	12.3	34
Slope	9.6	9.3	16
NDVI Start of Season	3.1	2.4	1.9
Flow Accum	1.6	6.2	0.3



TOBE Figure 1. SDM maps for *Toxostoma bendirei* 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.



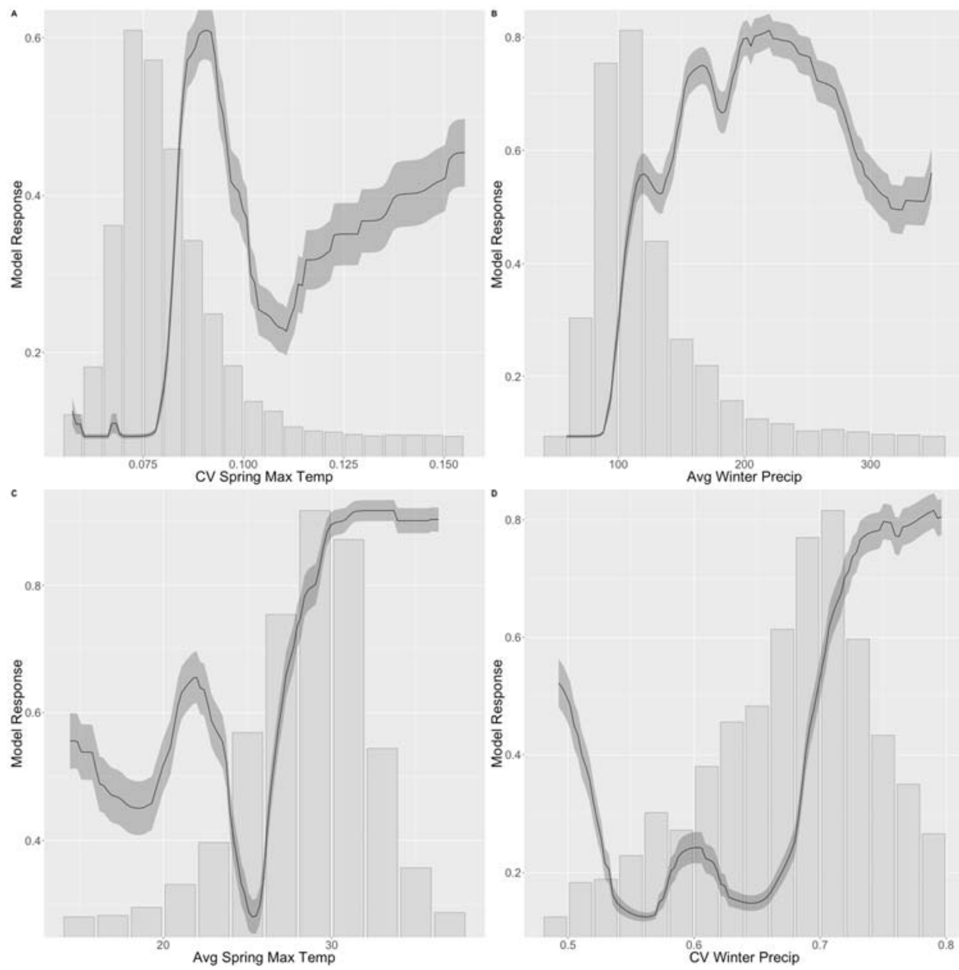
TOBE Figure 2. Standard error maps for *Toxostoma bendirei* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper right).



TOBE Figure 3. Graphs of Continuous Boyce Indices [CBI] for *T. bendirei* 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).

General Additive Model

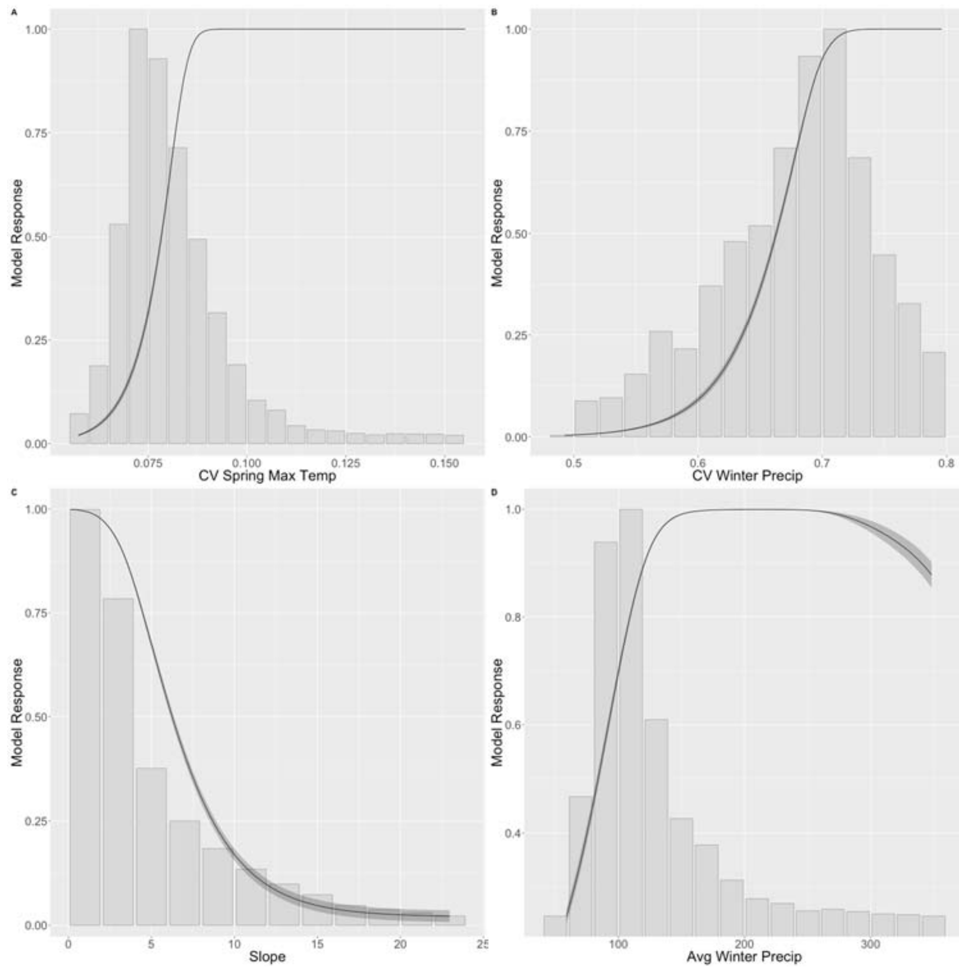
The top four contributing environmental layers were Average Winter Precipitation and its coefficient of variation, and the Average Spring Maximum temperature and its coefficient of variation (TOBE Table 2). Model scores were higher in areas with more Winter Precipitation than average, with a peak value slightly above the average for the study area, and falling off in areas with the highest amounts of rainfall (TOBE Figure 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 (TOBE Figure 4). Predicted habitat values peaked just above the mean CV for this metric, and were lower but trending higher in more variable areas (TOBE Figure 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 (TOBE Figure 3).



TOBE Figure 4. GAM partial response curves for the top four variables in the *Toxostoma bendirei* 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.

MaxEnt Model

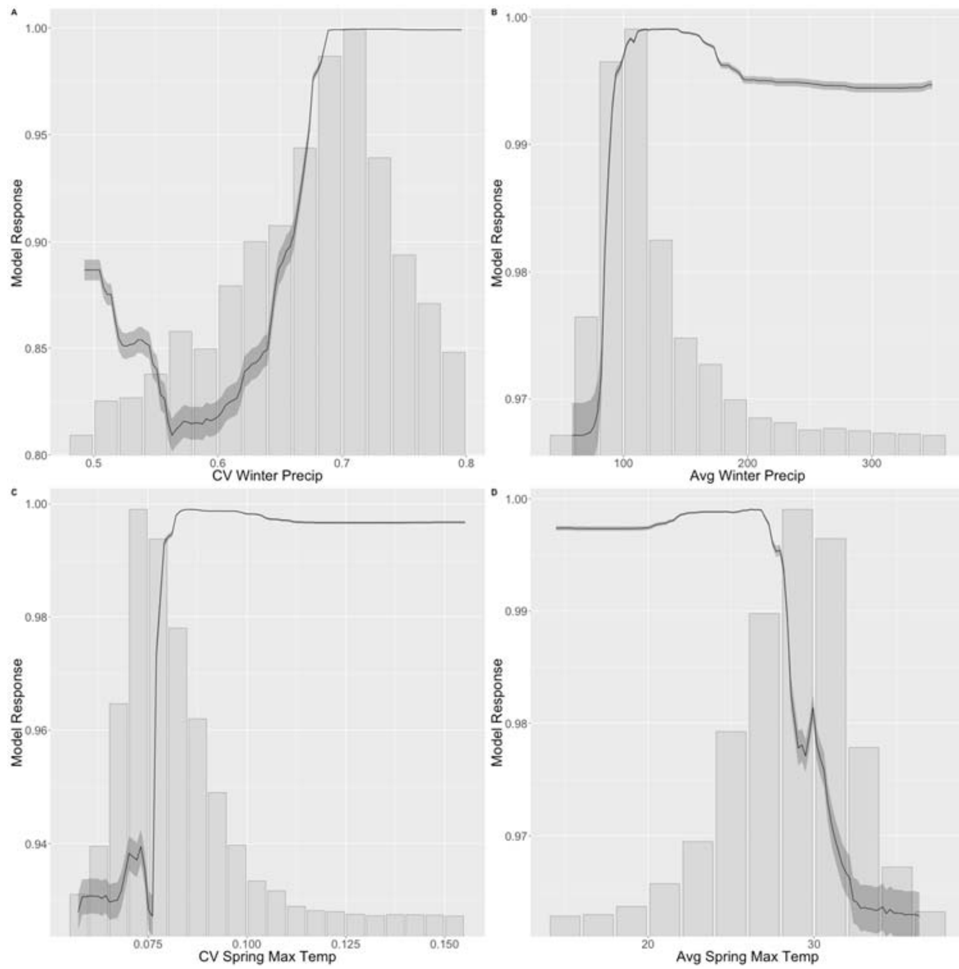
The MaxEnt models relied heavily on three of the four top variables as those in the GAM models, with the addition of Slope into the top four performing models contributing 16% (TOBE Table 2). This model also had similar response curves among algorithms indicating relatively robust model selection (TOBE Figure 4, TOBE Figure 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.



TOBE Figure 5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *Toxostoma bendirei.* 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.

Random Forest Model

The Random Forest model for this species had the same top four input variables as the GAM models (TOBE Table 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 (TOBE Table 1) as well as the Continuous Boyce plots indicated high model performance (TOBE Figure 3).



TOBE Figure 6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *Toxostoma bendirei.* 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.

Model Discussion

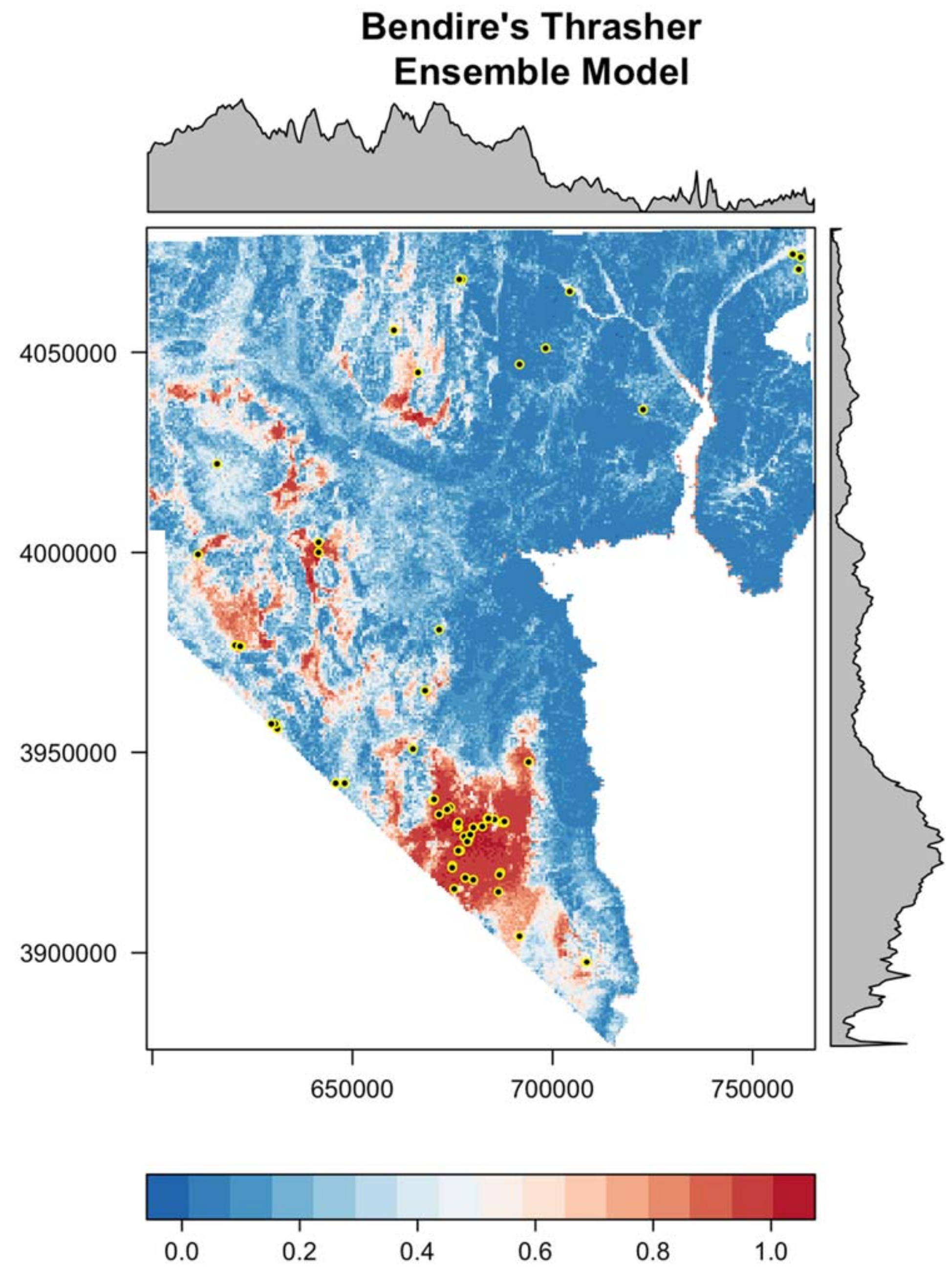
Toxostoma bendirei largely occupy the western half of the southern-most portions of Clark County, NV, with additional localities in lower predicted suitability areas in the lower slopes of the Sheep and Spring ranges. There are additional localities in in the northern and eastern extent of the county that did not correspond with high modeled habitat values (TOBE Figure 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.

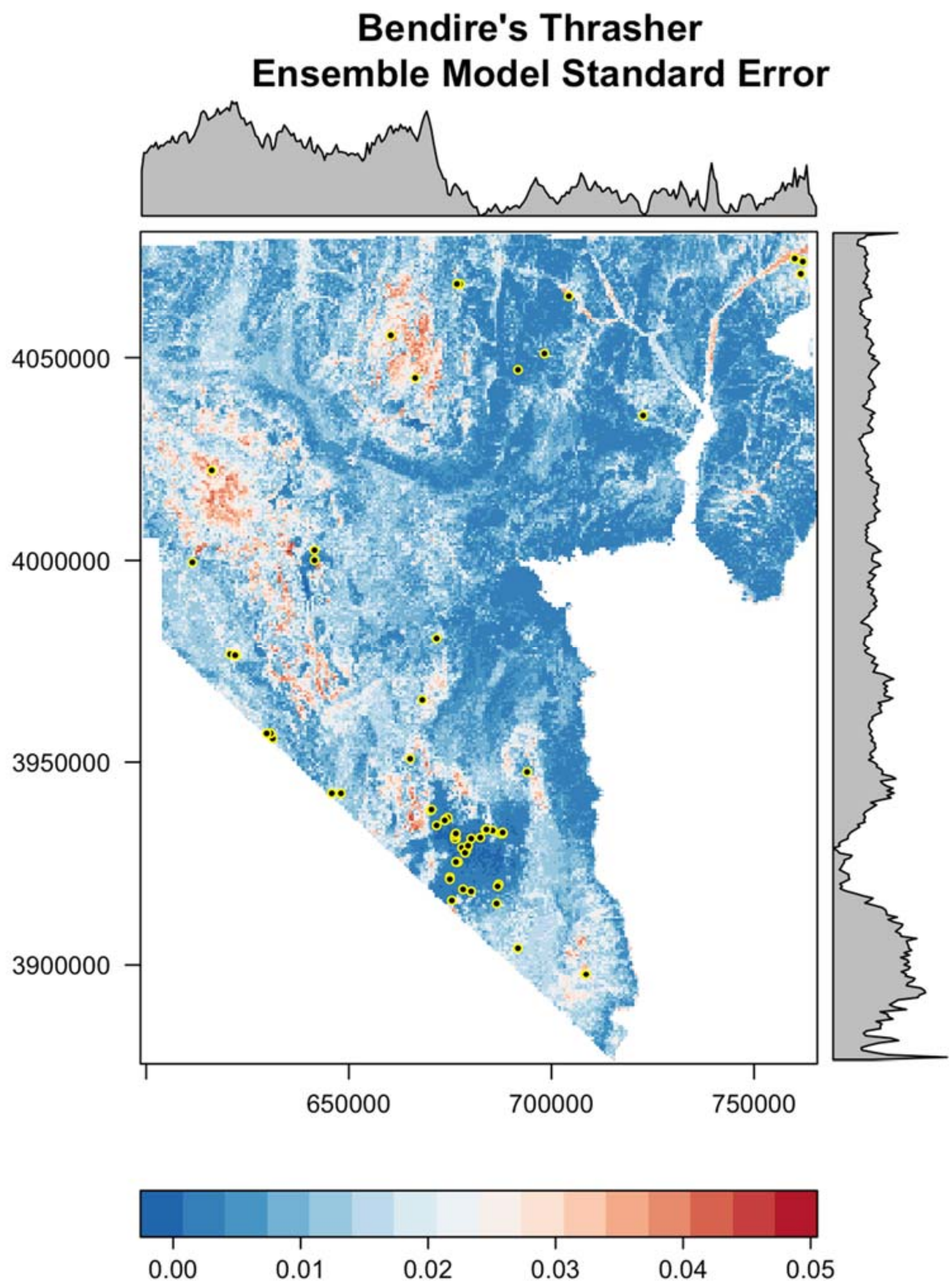
The locality data for this species consisted of 400 records within the buffered modeling area, which had a high degree of overlap. Spatial thinning of the data reduced the number of localities used for training and testing to 208 records.

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 (TOBE Figure 8). There is also an area higher error along the Virgin river.



TOBE Figure 7. SDM map for *Toxostoma bendirei* Ensemble model.



TOBE Figure 8. Standard Error map for the *Toxostoma bendirei* Ensemble model for Clark County, NV.

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 (TOBE Table 3). Moderate habitat was similarly distributed, and included large amounts of Salt Desert Scrub (TOBE Table 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).

TOBE Table 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

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.

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).

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).

Summary of Direct Impacts

Approximately 951 km^2 of high suitability and 1216 km^2 of moderate suitability are located within Clark county. Most of this habitat is located within conserved areas (91 and 61% respectively), and little is either disturbed (11% high and moderate combined) or likely to be impacted (14% high and moderate combined, TOBE Table 4).

TOBE Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	6054	87358	1778	95190
Med	24494	74045	23073	121612
Low	95676	325564	95354	516594

TOLE - Le Conte's Thrasher (Toxostoma lecontei)

Le Conte'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. Le Conte'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 Le Conte'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, Le Conte's Thrashers nest in *Opuntia ramosissima*, *O. echinocarpa*, and *Atriplex polycarpa* (Dawson 1923, Jongsomjit et al. 2012). In Rock Valley, NV, Le Conte'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). Le Conte's Thrashers are shy birds that prefer running away from intruders to flying (Fisher 1893).

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

Range

Le Conte'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, Le Conte'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).

Population Trends

Le Conte'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) – Le Conte'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 Le Conte'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.

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 (TOLE Figure 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 (TOLE Table 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 (TOLE Table 2).

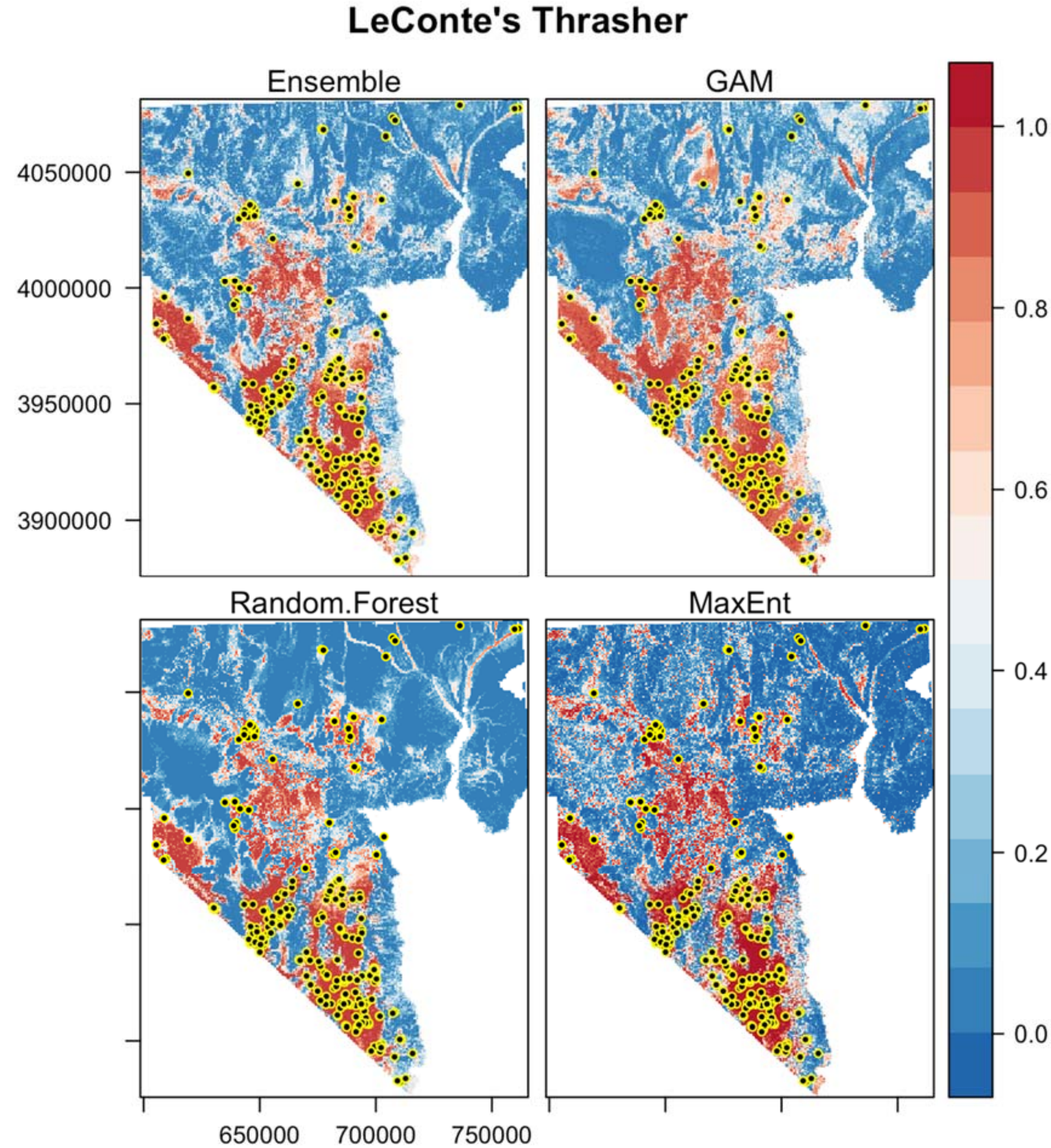
The Standard error maps indicated higher standard error among the MaxEnt models than the others, with widespread SE's of approximately 0.05. The GAM model had a larger area of elevated SE in the North Central portion of the County near the NNTS. Error rates for the other Random Forest and the Ensemble Model were relatively low throughout the county (TOLE Figure 2). The Continuous Boyce curves indicated good model performance across all algorithms (TOLE Figure 3).

TOLE Table 1. Model performance values for *T. lecontei* 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.

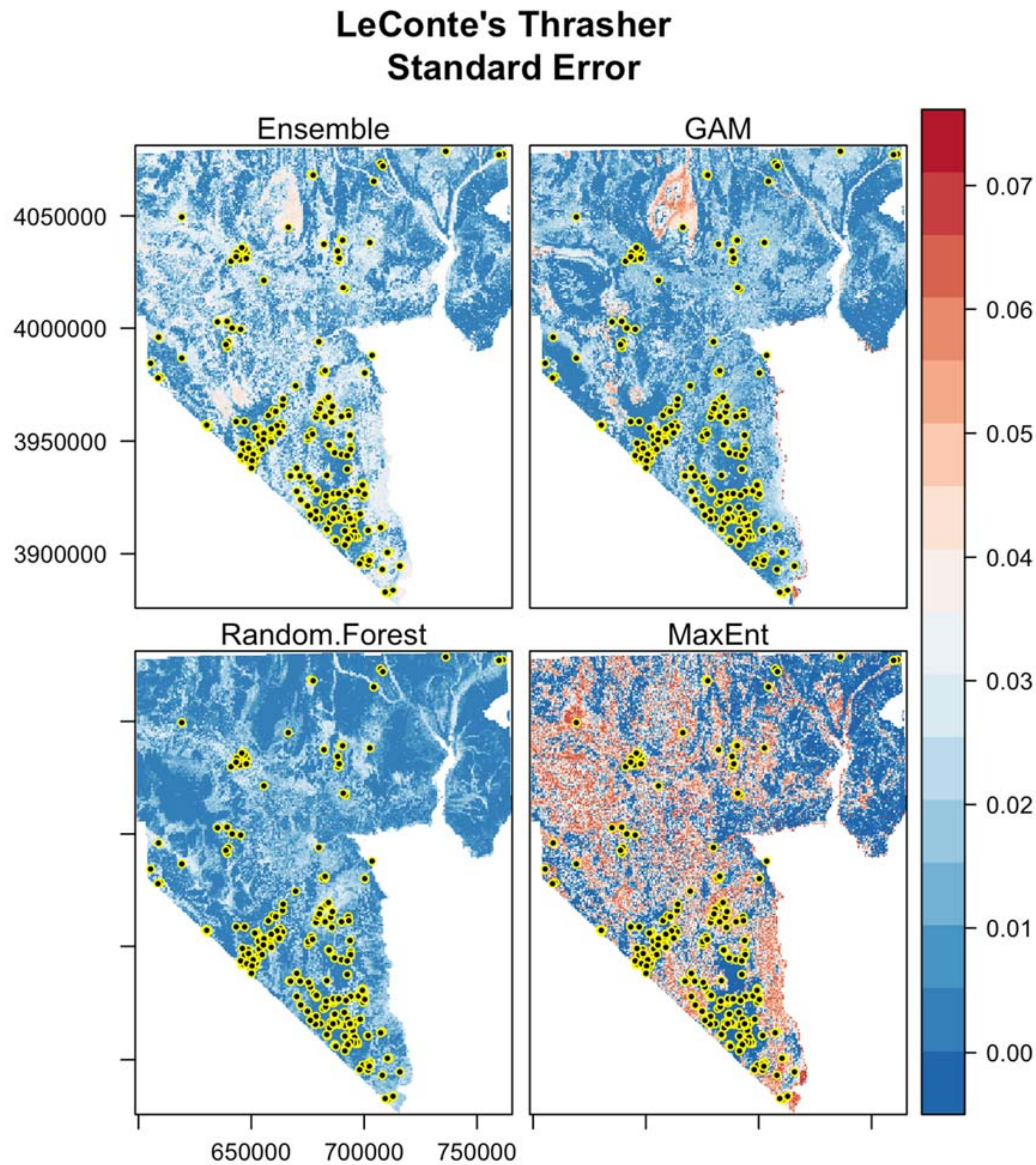
Model	**AUC**	**BI**	**TSS**	**PRBE**
Ensemble	0.85	0.83	0.6	0.46
GAM	0.78	0.77	0.45	
Random Forest	0.85	0.78	0.62	
MaxEnt	0.79	0.95	0.5	

TOLE Table 2. Percent contributions for input variables for *T. lecontei* 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.

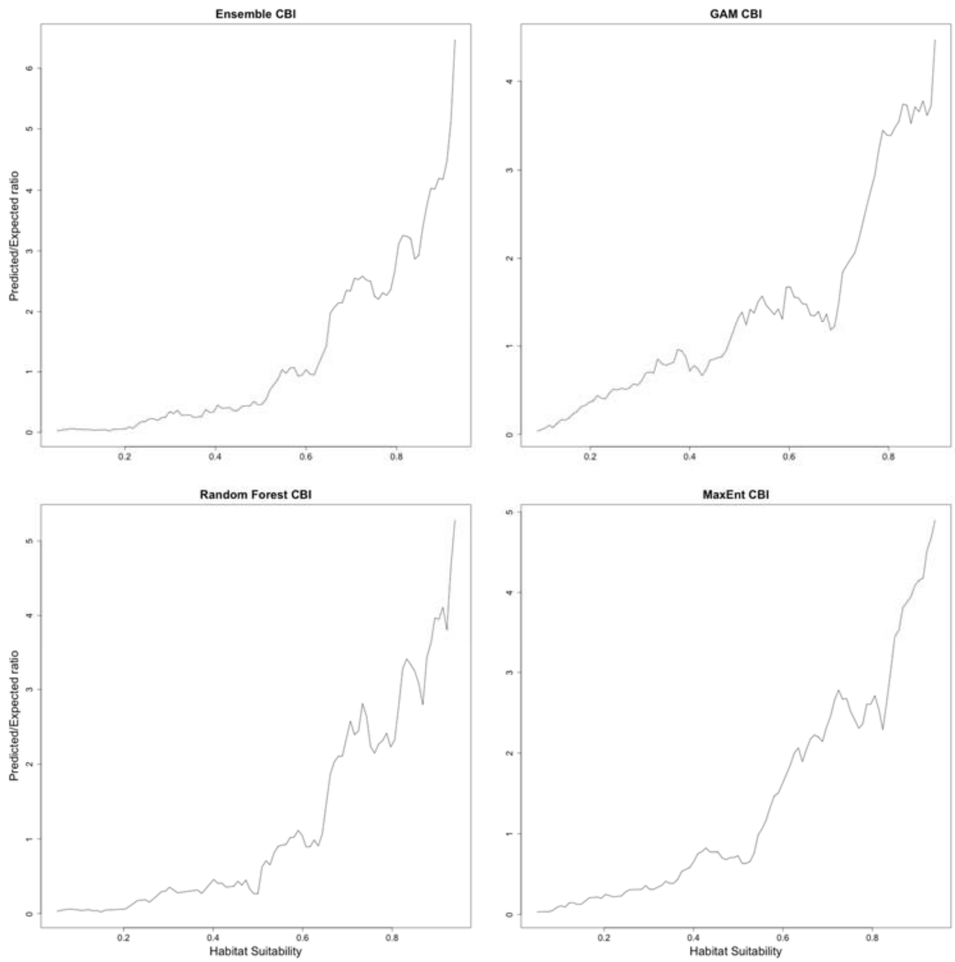
Variable	GAM	RF	MaxEnt
Dist to cliffs	0.1	1	0.1
NDVI Amplitude	9.5	1.4	1.1
NDVI Length of Season	0.2	0.9	1
NDVI Max	7.2	1.4	1.6
Winter Precip	13.1	10.6	3.3
CV Winter Precip	19.1	40.5	23.2
Average Spring Max Temp	17.5	11.4	16.4
CV Average Spring Max Temp	21.1	4.1	23.9
Slope	10.3	11.3	26.1
NDVI Start of Season	1.2	5.6	3.1
Winter Precip	0.6	11.8	0.2



TOLE Figure 1. SDM maps for *Toxostoma lecontei* 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.



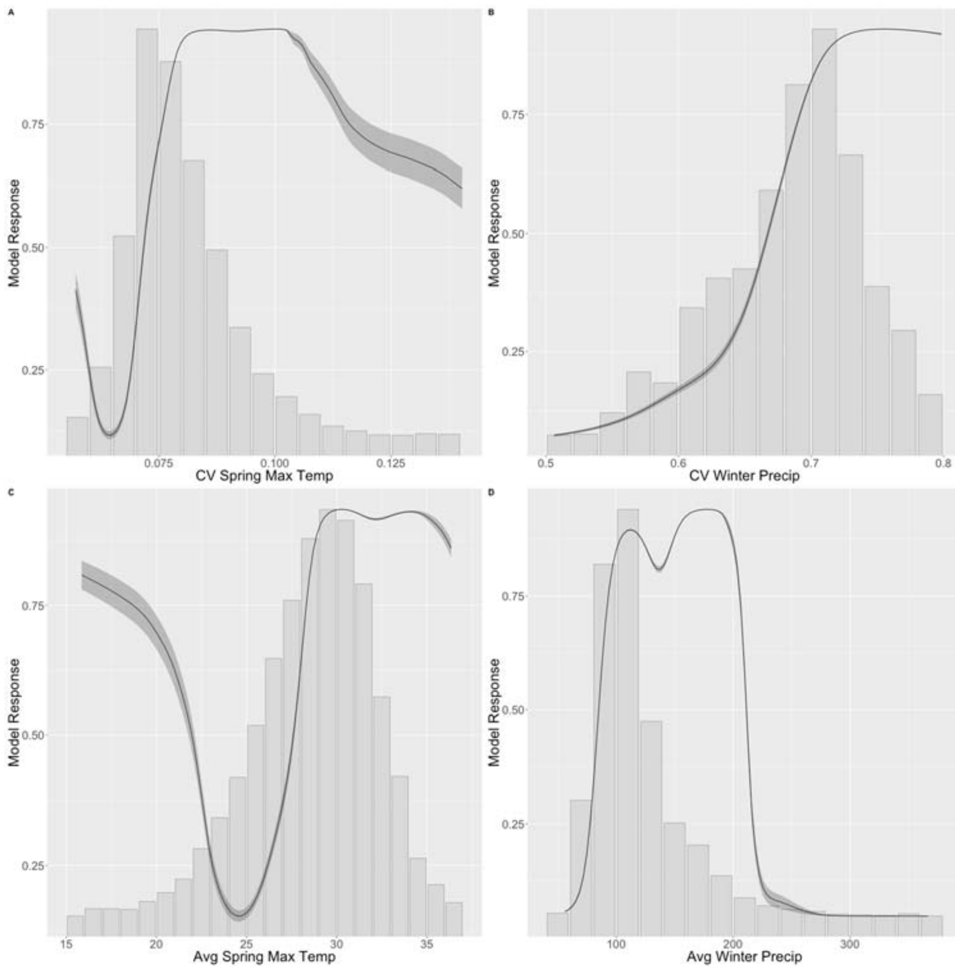
TOLE Figure 2. Standard error maps for *Toxostoma lecontei* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



TOLE Figure 3. Graphs of Continuous Boyce Indices [CBI] for *T. lecontei* 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).

General Additive Model

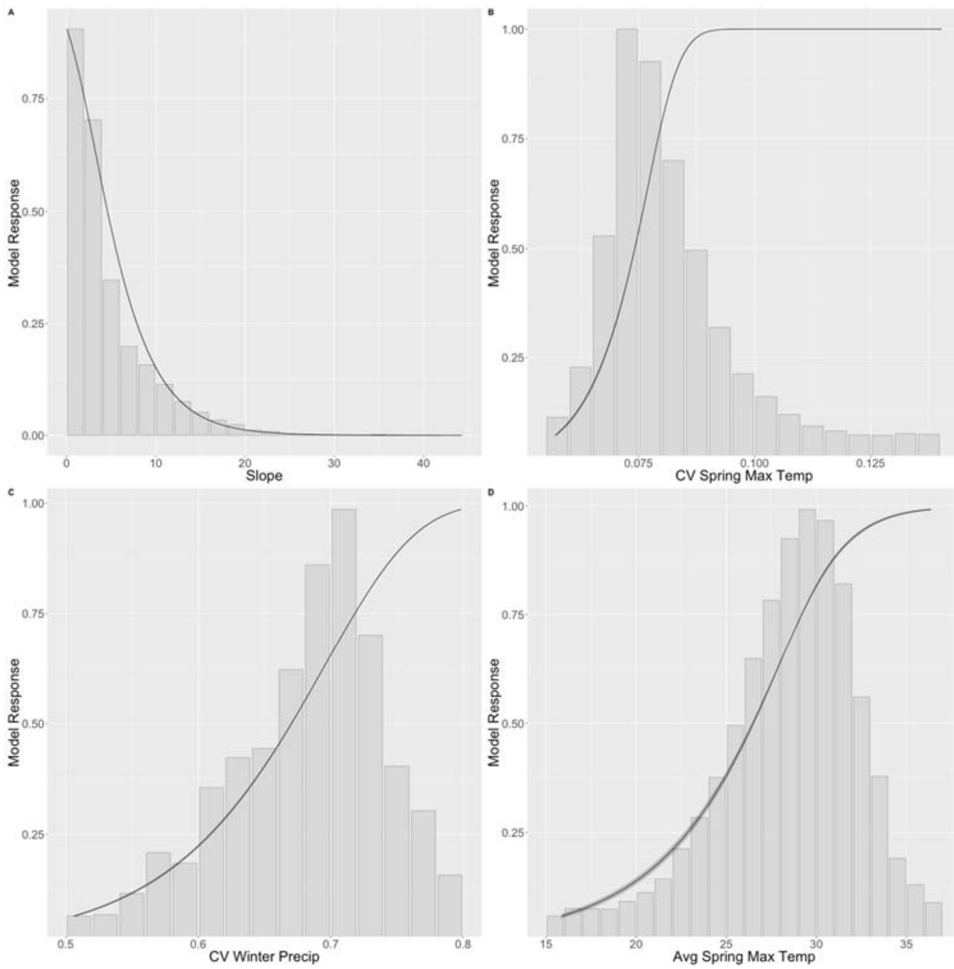
The top four contributing environmental layers were Average Winter Precipitation and its Coefficient of Variation, and the Average Spring Maximum temperature and its Coefficient of Variation (TOLE Table 2). Model scores were higher in areas with more variation in Winter Precipitation than average, but with suitability associated with precipitation values themselves peaking just above the average for the study area (TOLE Figure 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 (TOLE Figure 4). The Coefficient of Variation for Spring Maximum temperatures peaked in areas where the temperature was just above the average for the study area (TOLE Figure 4).



TOLE Figure 4. GAM partial response curves for the top four variables in the *Toxostoma lecontei* 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.

MaxEnt Model

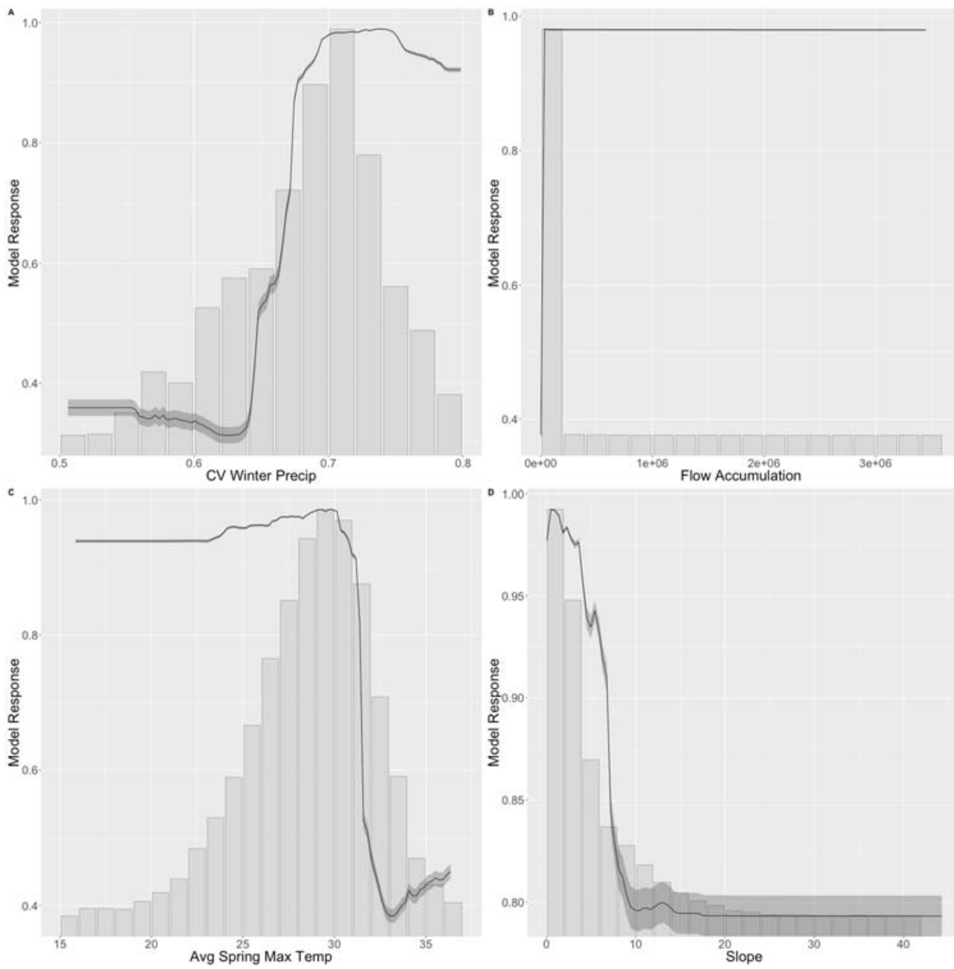
The top four influencing variables in the MaxEnt models were the same as three out of the four top variables as those in the GAM models, with the addition of Slope (TOLE Table 2). This model also had similar response curves among algorithms indicating relatively robust model selection (TOLE Figure 4, TOLE Figure 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 (TOLE Figure 5).



TOLE Figure 5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *Toxostoma lecontei*. 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.

Random Forest Model

The Random Forest model performance curves for Slope and the CV of Winter Precipitation were similar to the other two algorithms (TOLE Figure 6, Figures 4 and 5), however, Average Spring Maximum temperature had a different relationship, instead predicting higher habitat scores at lower temperatures while the other variables remained constant (TOLE Figure 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 (TOLE Figure 3).



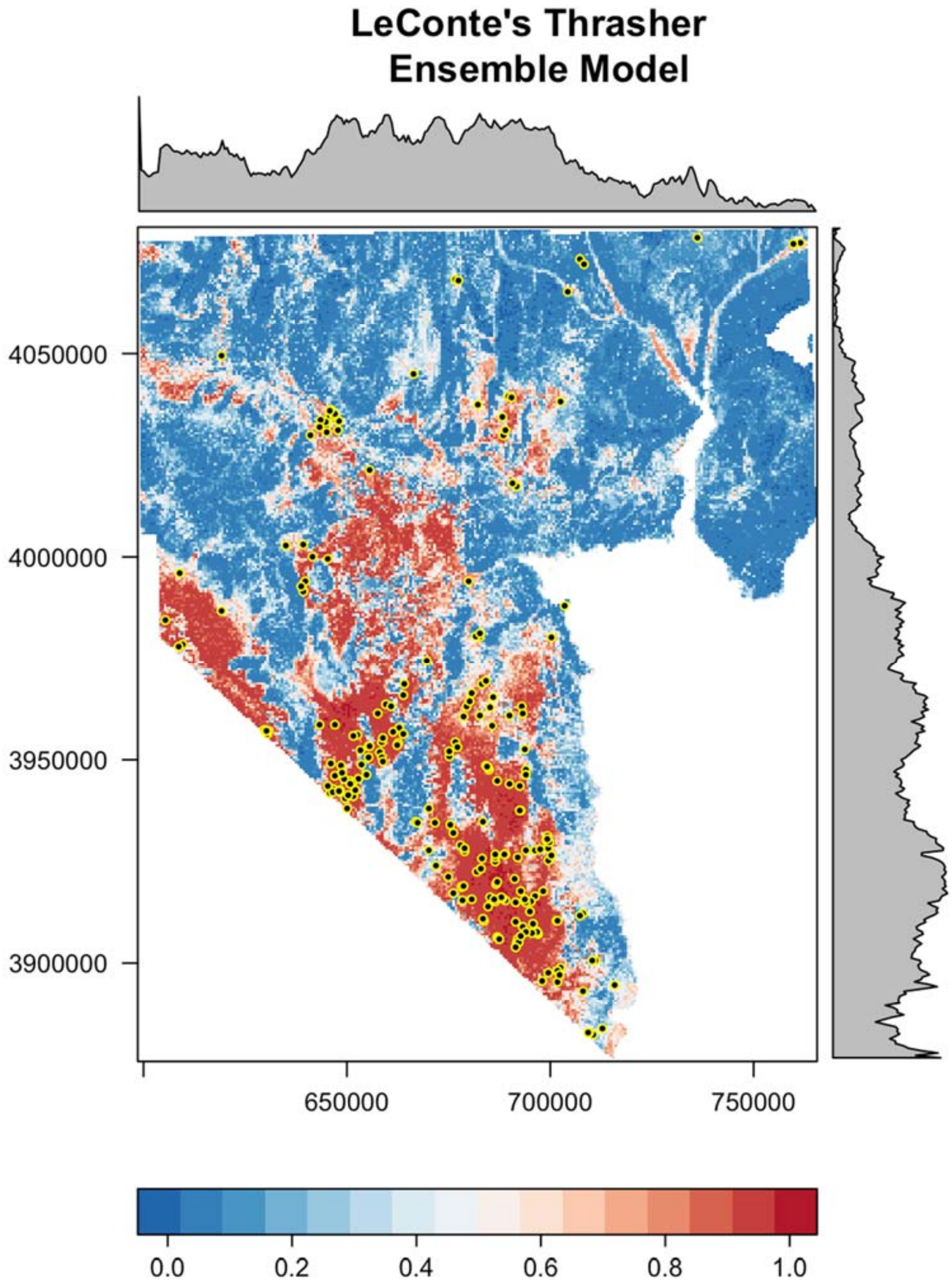
TOLE Figure 6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *Toxostoma lecontei*. Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

Model Discussion

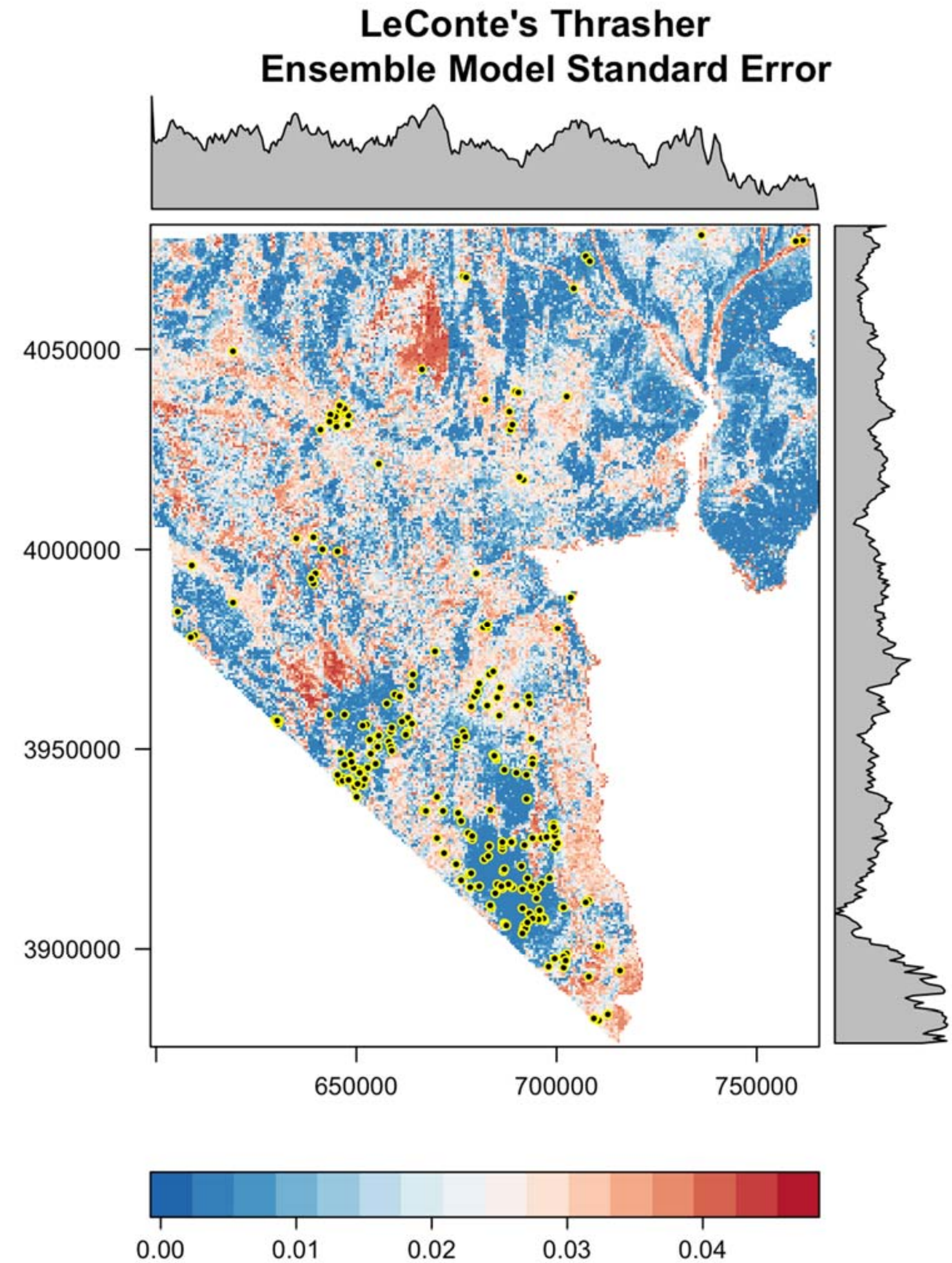
Toxostoma lecontei habitat is predicted to be widespread in the southern and western lowland areas throughout the county. The model discrimination indicated that models were correctly capturing predictions for most of the locality locations (TOLE Figure 3), and where localities were less common, there were predictions of only isolated patches of habitat (TOLE Figure 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).

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 (TOLE Figure 8).



TOLE Figure 7. SDM map for *Toxostoma lecontei* Ensemble model in Clark County, NV.



TOLE Figure 8. Standard Error map for the *Toxostoma lecontei* Ensemble model for Clark County, NV.

Distribution and Habitat Use within Clark County

Le Conte'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). Le Conte'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 Le Conte'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 (TOLE Table 3)

Valleys throughout Clark County were surveyed at 432 random sites for presence of Le Conte'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 Le Conte'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 (TOLE Figure 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 Le Conte's Thrashers, and only the Riparian areas in the northeast quarter of the county are predicted in our model (TOLE Figure 7).

TOLE Table 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

Ecosystem Level Threats

The Le Conte'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 (TOLE Table 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 Le Conte's Thrashers (Germano et al. 2001).

Threats to Species

The greatest current threats to Le Conte'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.

Le Conte's Thrasher habitats are particularly vulnerable to solar energy farms because the Thrashers and the farms both require the flattest landscape available. Therefore, Le Conte's the highest quality Thrasher habitat and the most sought after solar development areas overlap nearly 100%.

Existing Conservation Areas/Management Actions

Most of the modeled habitat of high habitat suitability does not occur within protected areas. The Le Conte’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.

Le Conte’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 Le Conte’s Thrashers.

Le Conte’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) Le Conte’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).

Summary of Direct Impacts

The direct impacts to Le Conte’s Thrashers and their habitats are any activity or process that reduces the availability of vegetation providing cover, foraging areas, and nesting substrate. Such activities include construction activities (especially urbanization, highways, and solar energy capture and distribution infrastructure), military training and infrastructure, and off-highway vehicle activities. The introduction of invasive species and fire also can be detrimental to the habitat of Le Conte’s Thrashers. Habitat models resulted in an estimated 4019 km^2 of high and moderate level habitat combined (TOLE Table 4) most of which (55%) is in conserved areas outside of the areas considered in this planning effort. Higher suitability habitat disturbed to date consists of 736 km^2. An additional 493 km^2 will be potentially impacted by this project, while 1693 km^2 of higher suitability habitat is located within conservation areas (TOLE Table 4).

TOLE Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

Habitat Level	Impact	Conserved	Disturbed	Area (Hectares)
High	49286	169314	73567	292167
Med	30019	52252	27465	109736
Low	47118	281961	19302	348381

VIBE - 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 is recognized as endangered under the Federal Endangered Species Act, as well as the California Endangered Species Act. The *V. arizonae* subspecies occurs in desert riparian areas along the Colorado River drainage and is known to use various types of desert riparian vegetation.

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 (*Vireo bellii pusillus*) 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 (*Vireo bellii arizonae*) 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 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.

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. *V. b. arizonae* 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).

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).

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 (VIBE Figure 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 (VIBE Table 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 (VIBE Figure 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 (VIBE Figure 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 (VIBE Figure 2).

The Continuous Boyce Index curves all indicated good performance and discrimination among all models (VIBE Figure 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 (VIBE Figure 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 (VIBE Table 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 (VIBE Table 2).

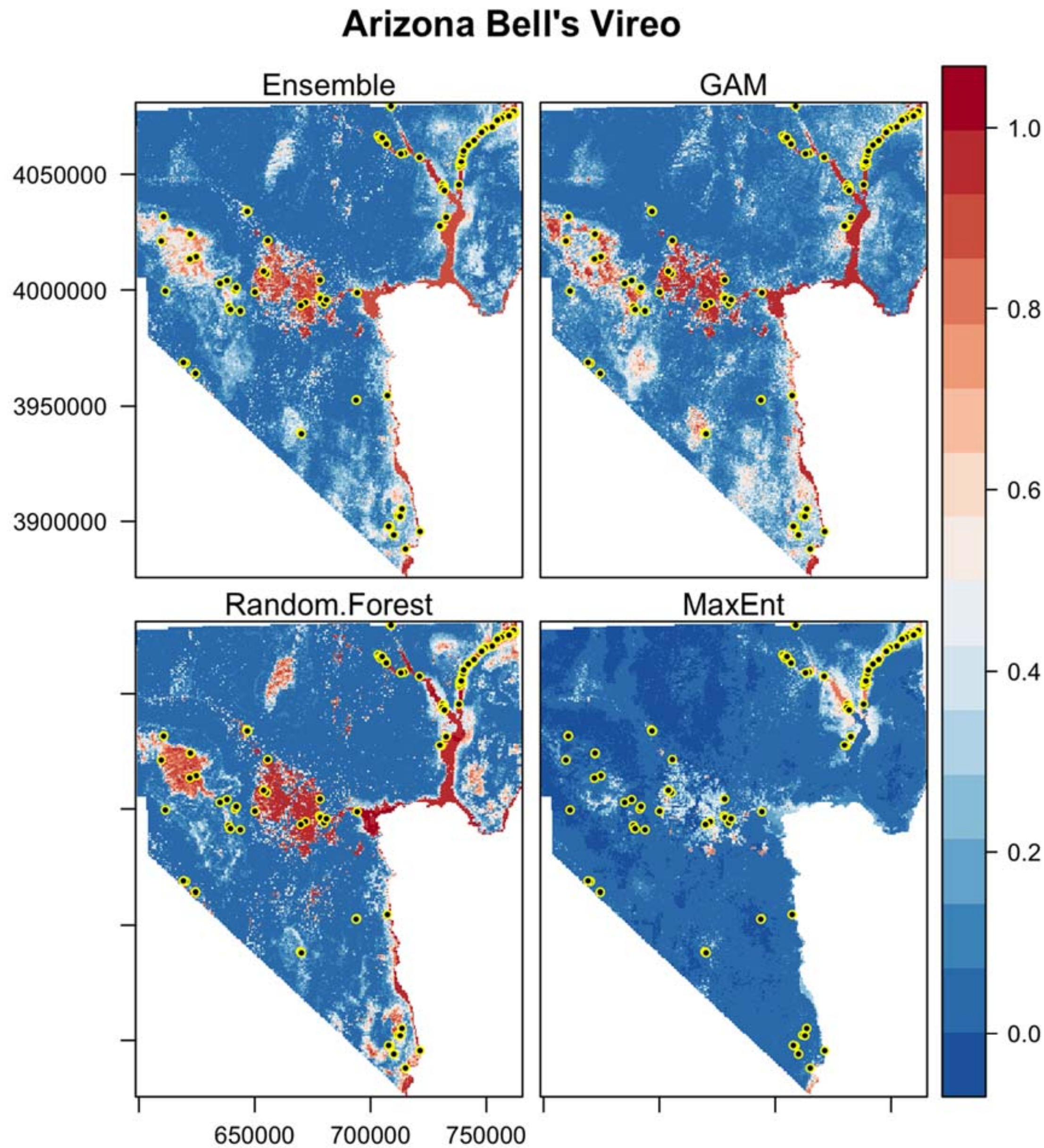
VIBE Table 1. Model performance values for *Vireo bellii arizonae* models giving Area under the Receiver Operator Curve (AUC), Boyce Index (BI), and True Skill Statistic (TSS) for the Ensemble model, and the individual algorithms for the testing data sets. PRBE cutoff for the Ensemble Model is given 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	

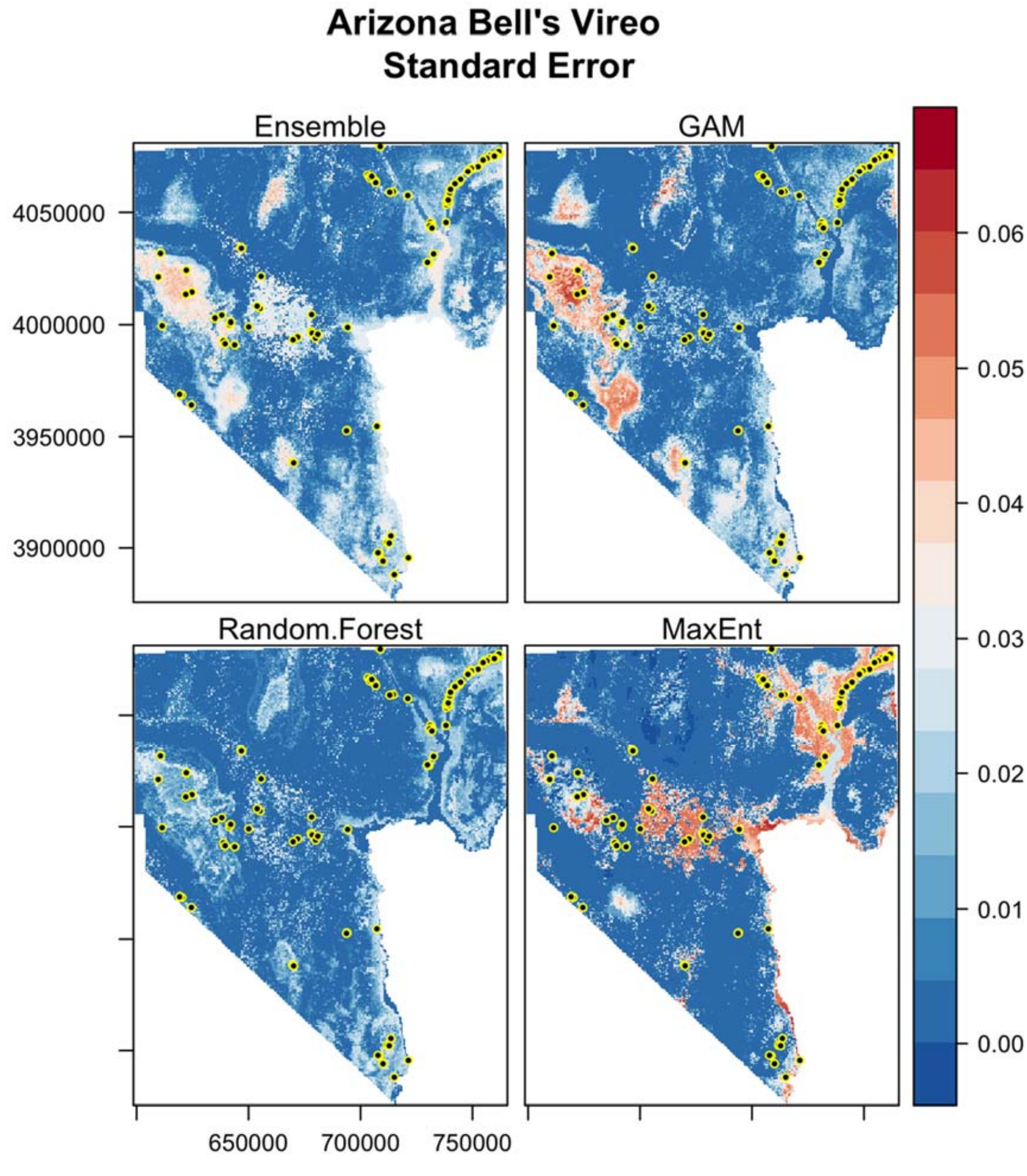
VIBE Table 2. Percent contributions for the top 10 input variables for *Vireo bellii arizonae* for Ensemble models using GAM, MaxEnt and Random Forest algorithms. The top four contributing variables are highlighted, and response curves for these variables within each algorithm are given in the corresponding 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

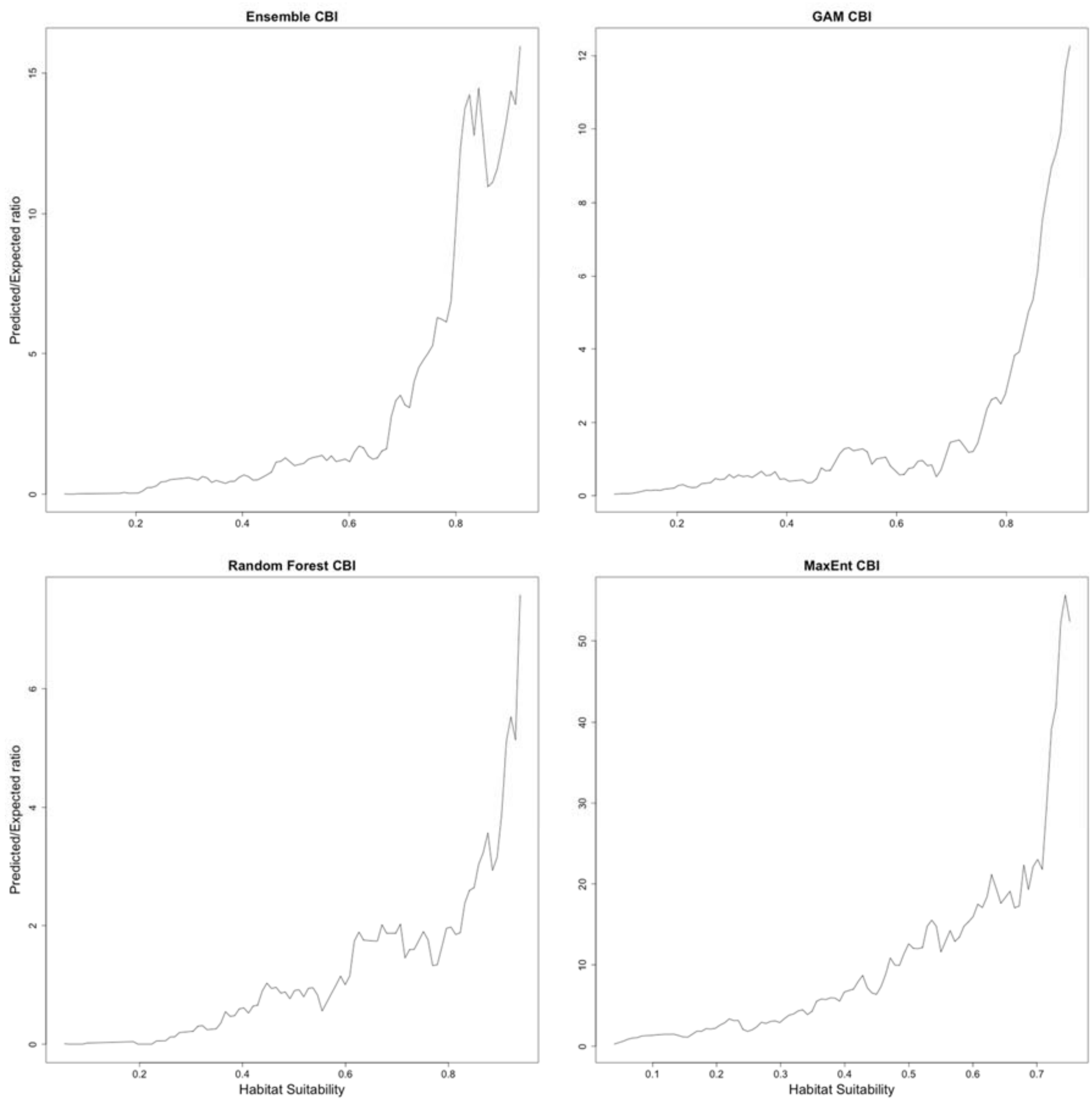
Extreme Max Temp	7.4	5.6	4.2
Extreme Min Temp	7	1.4	16.6
NDVI Amplitude	4.9	2.4	10.7
NDVI Max	21.1	35.5	22.6
Start of Season (day)	7.2	38.6	7.7
Winter Precip	4.5	6	2.3



VIBE Figure 1. SDM maps for *Vireo bellii arizonae* 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.



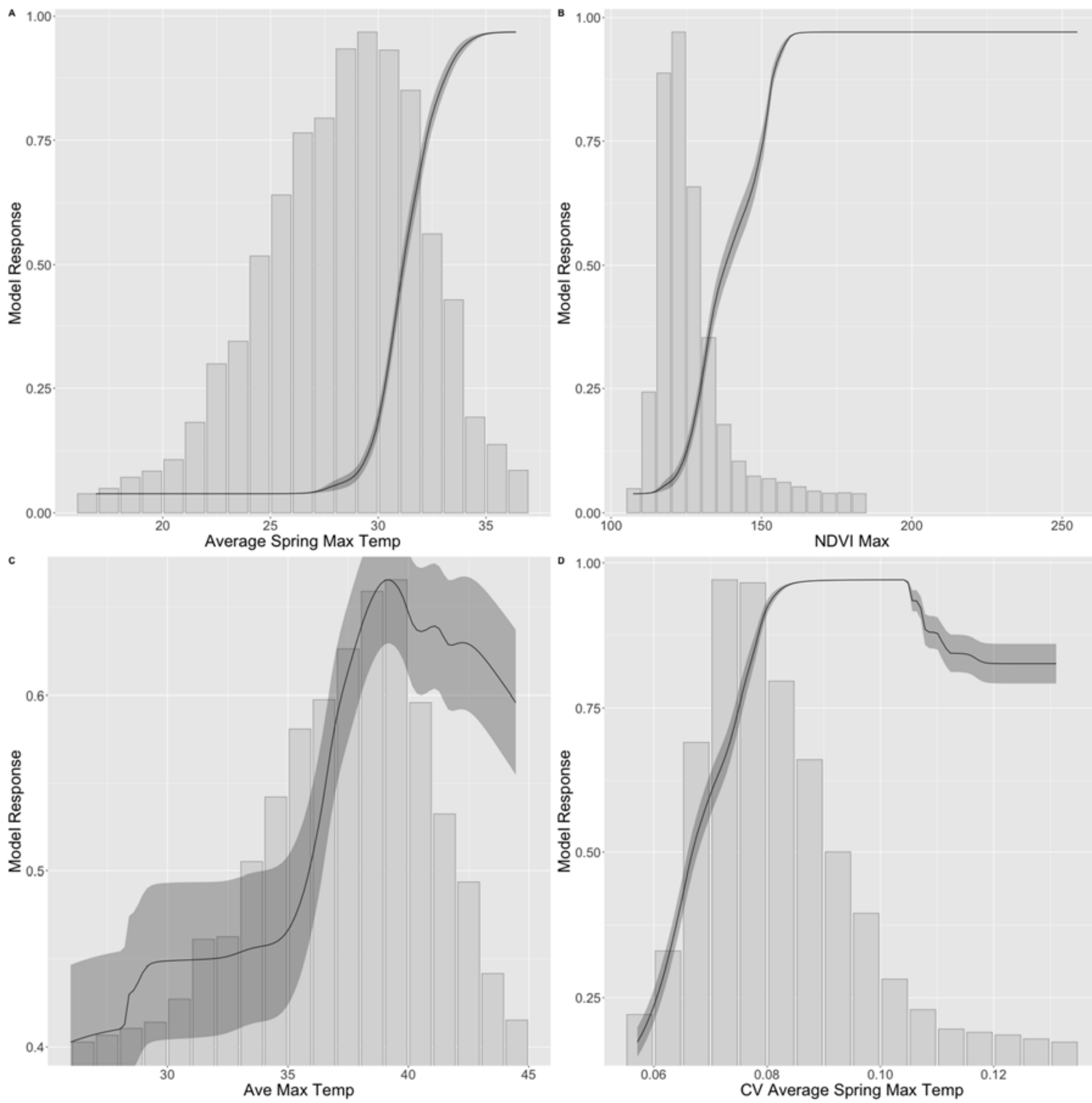
VIBE Figure 2. Standard error maps for *Vireo bellii arizonae* models for each of three modeling algorithms used (GAM - upper right, Random Forest – lower left, MaxEnt - lower right), and an Ensemble model averaging the three (upper left).



VIBE Figure 3. Graphs of Continuous Boyce Indices [CBI] for *Vireo bellii arizonae* 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).

General Additive Model

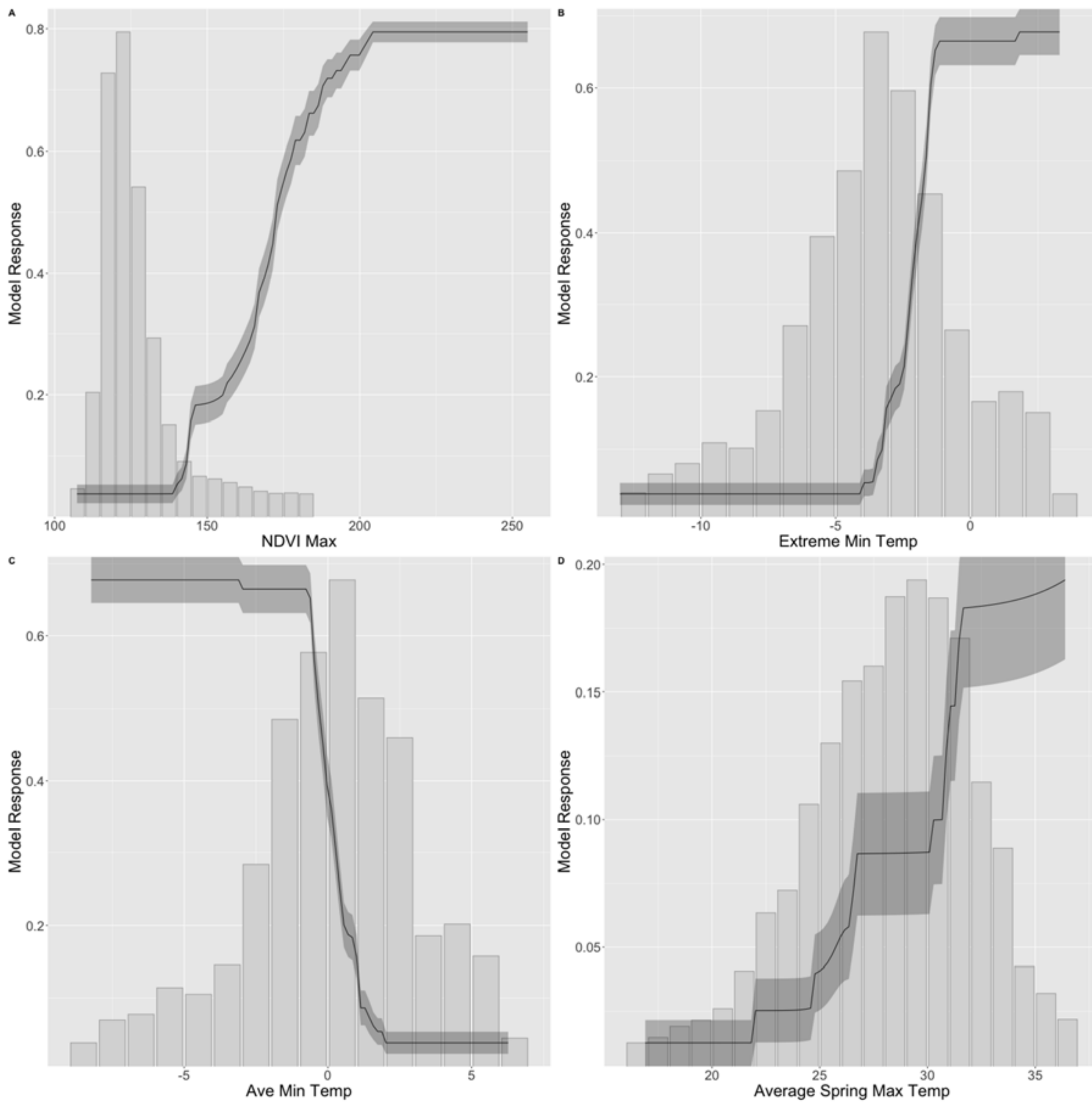
The top four contributing environmental layers were Average Maximum temperature, Average Maximum Spring temperature, CV of Average Maximum Spring temperature, and NDVI Maximum (VIBE Table 2). Model scores were higher in areas with higher Average Maximum Spring temperature, peaking and remaining high at the mean values for the county (VIBE Figure 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; VIBE Figure 4), a response also shown in the MaxEnt and RF models. Standard errors were elevated (SE ~ 0.05) around the base of the indicating disagreement among the multiple runs of this model in those areas, while the rest of the county had relatively lower error values throughout (VIBE Figure 2). Habitat predictions indicated strong habitat predictions throughout the riverine systems along the county's eastern border, but with substantial inland habitat predicted along



VIBE Figure 4. GAM partial response curves for the top four variables in the *Vireo bellii arizonae* 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.

MaxEnt Model

The MaxEnt models was most influenced by the timing of the Maximum value for NDVI (VIBE Table 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 (VIBE Table 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 (VIBE Figure 5) – which was a similar response to that seen in the GAM and RF models (VIBE Figure 4; VIBE Figure 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 (VIBE Figure 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 (VIBE Figure 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).

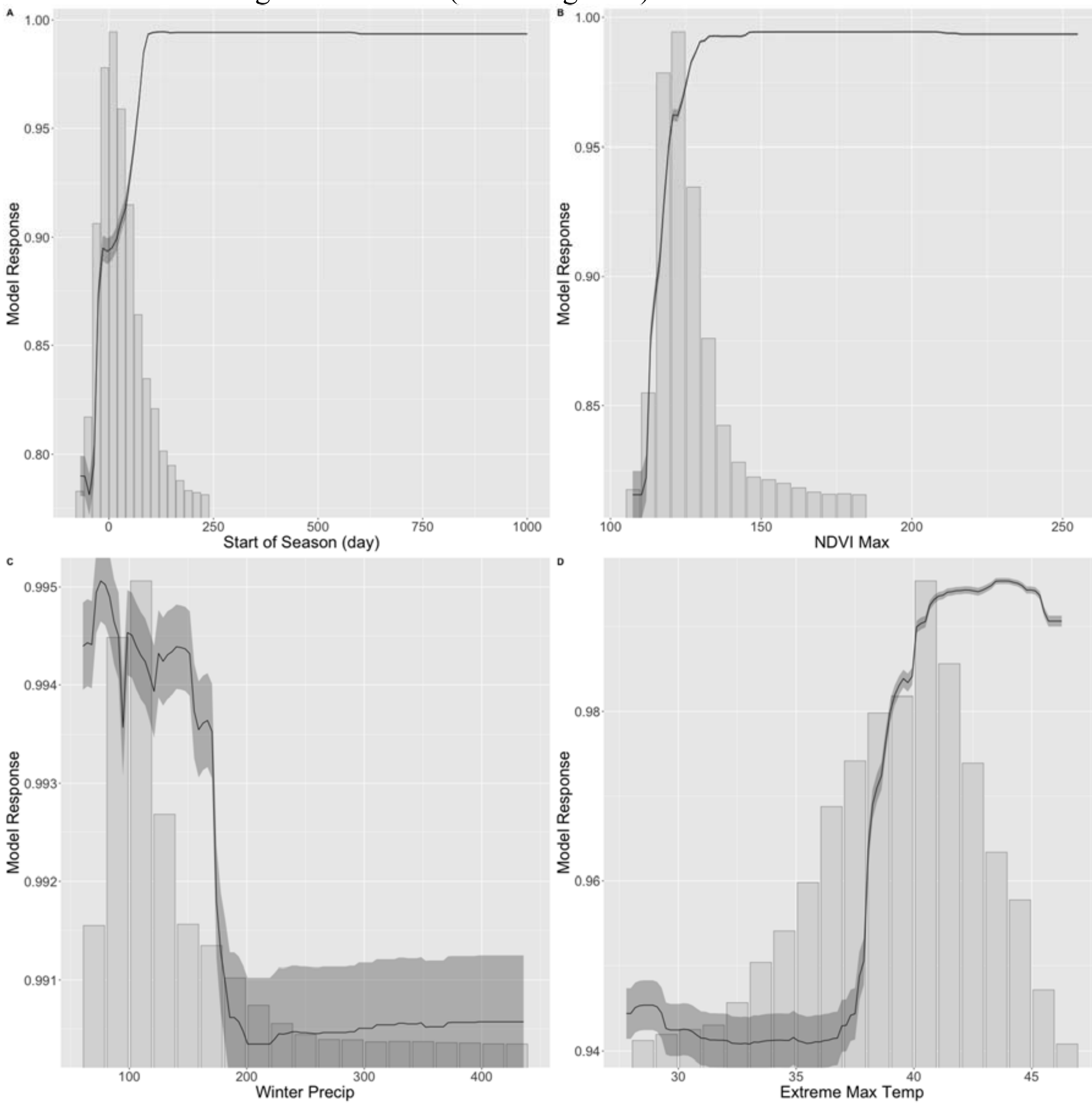


VIBE Figure 5. Response surfaces for the top environmental variables included in the MaxEnt Ensemble model for *Vireo bellii arizonae.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

Random Forest Model

The Random Forest predicted similar habitat areas as that seen in the GAM model (VIBE Figure 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 (VIBE Figure 4; VIBE Figure 5; VIBE Figure 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 (VIBE Figure 6). Winter Precipitation showed lower habitat values with increasing Winter Precipitation.

This pattern was similar to that which was available in the environment (VIBE Figure 6). Performance metrics indicated strong model predictive performance (VIBE Table 1), and discrimination among habitat levels (VIBE Figure 3).



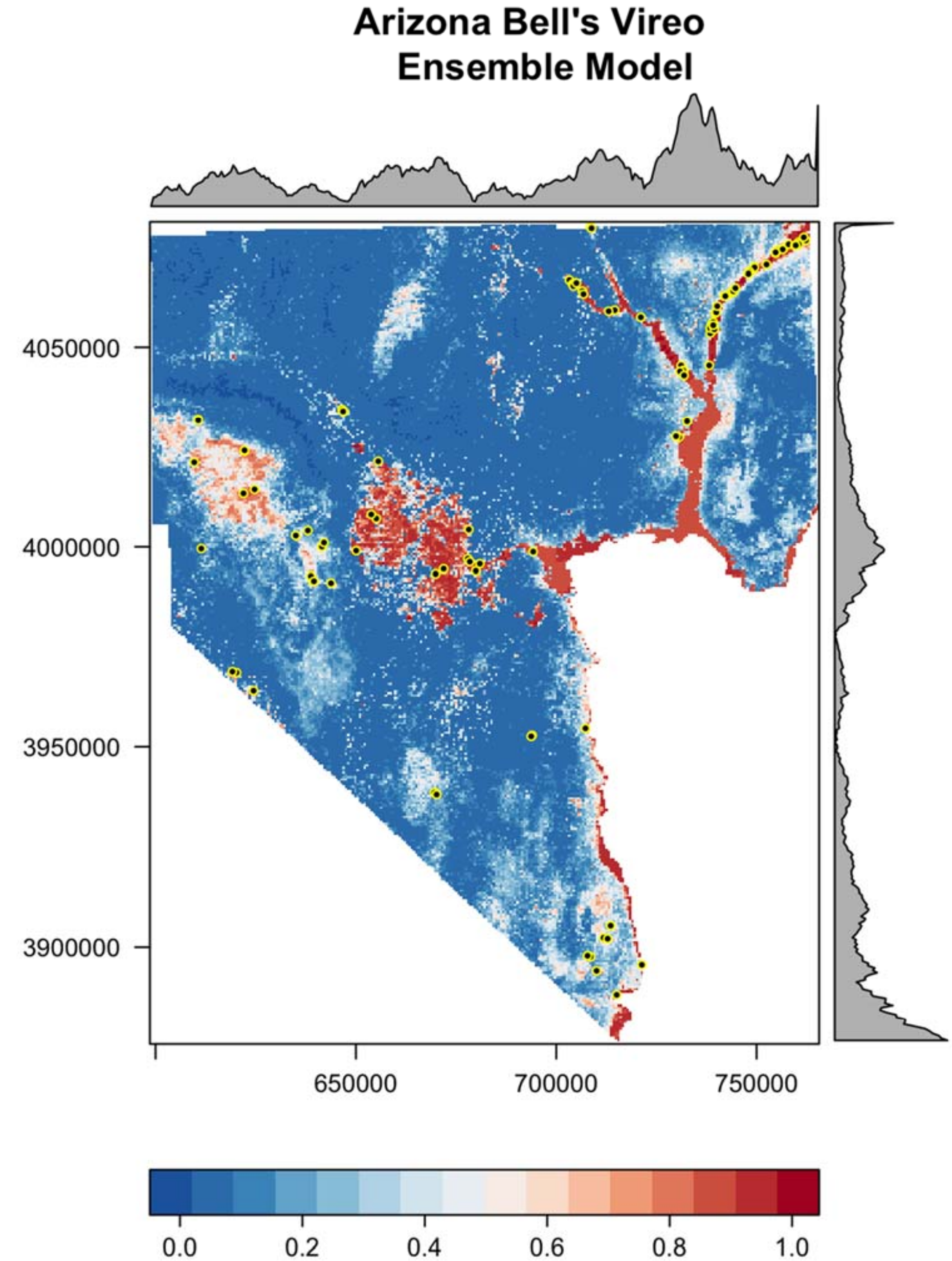
VIBE Figure 6. Partial response surfaces for the environmental variables included in the Random Forest Ensemble model for *Vireo bellii arizonae.* Histograms represent the range of each environmental variable across the x-axis, and predicted dependence relative to habitat suitability values are on the y-axis.

Model Discussion

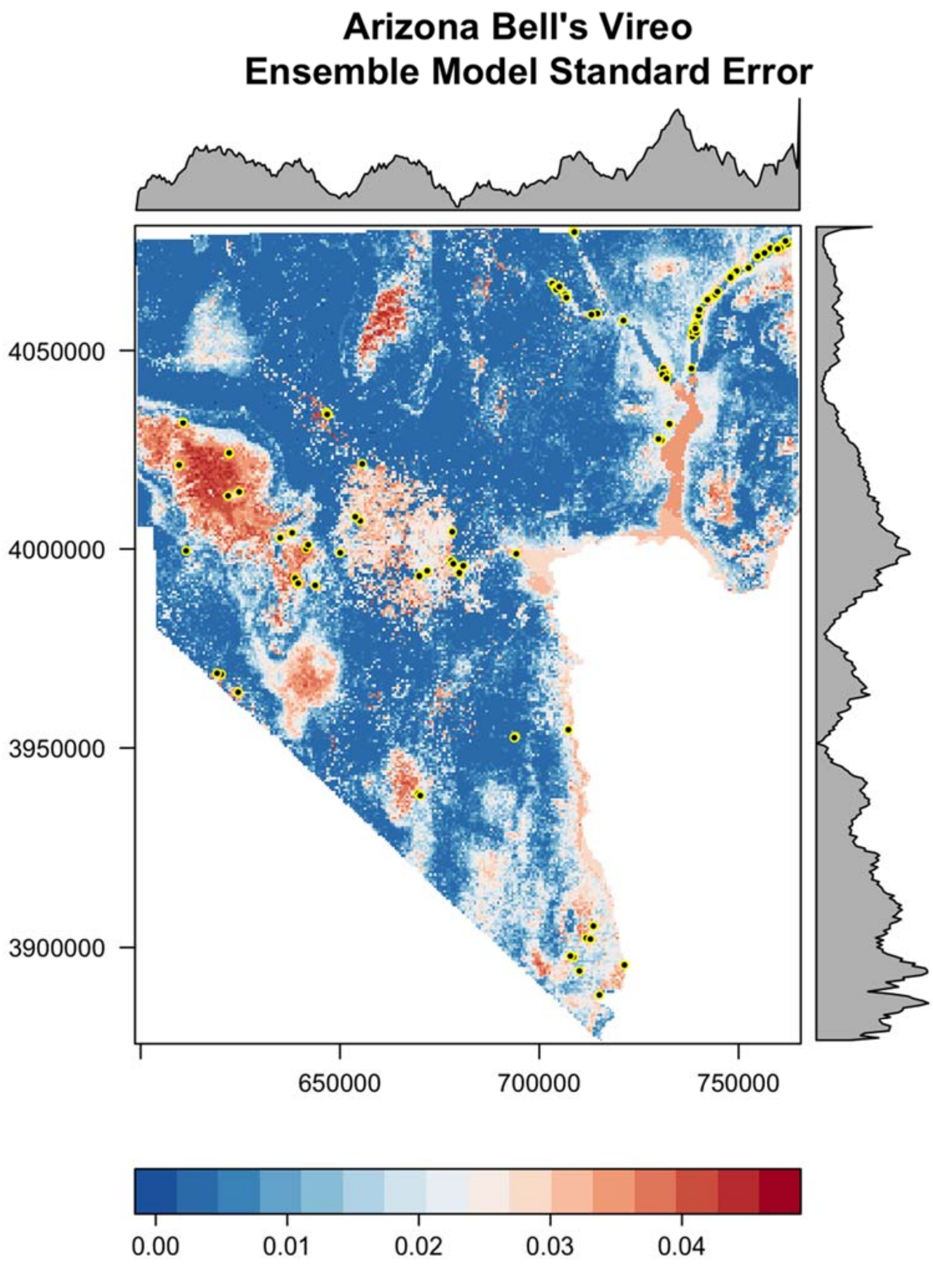
Vireo bellii arizonae are predicted to occupy the riverine and larger drainage systems located along the Muddy and Virgin rivers, the immediate shorelines of Lake Mead, down the Colorado river extending to Avi at the southern end of the county (VIBE Figure 7). A large expanse of predicted habitat also occurs along the Las Vegas wash, the general metropolitan area, and, to a lesser extent, the foothills of the Spring range (VIBE Figure 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 (VIBE Figure 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.

Standard Error



VIBE Figure 7. SDM map for *Vireo bellii arizonae* Ensemble model in Clark County, NV.



VIBE Figure 8. Standard Error map for the *Vireo bellii arizonae* Ensemble model for Clark County, NV.

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 (VIBE Table 3).

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

Alpine	16	107	0
Bristlecone Pine	108	4785	2646
Mesquite Acacia	12610	3517	4083
Mojave Desert Scrub	1115726	154836	94251
Sagebrush	3447	1207	44

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).

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).

Existing Conservation Areas/Management Actions

The 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 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).

Summary of Direct Impacts

Bell's Vireo is a locally common breeding bird and summer resident in Clark County. Approximately 1527 km^2 acres of modeled habitat (high and moderate categories combined) exists in Clark County (VIBE Table 4) although the proportion of this habitat that meets the criteria for nest suitability is estimated to be much less. This species is locally common in the plan area; and covered activities have the potential to affect modeled habitat for the species. The total disturbed High and Moderate habitat for this species is 811 km^2, and an additional 240 km^2 is likely to be impacted by development under this amendment (16% of total). Conservation areas will contain 476 km^2 of high and moderate habitat (31% of total; VIBE Table 4).

VIBE Table 4. Categorized modeled habitat values (High, Medium, and Low) and the average area (Hectares) predicted in the potential impact areas, conservation areas, already disturbed areas, and overall area.

High	9001	4373	61387	74761
Low	102552	465810	39272	607634

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Responses to Comments

Below are comments and responses for four species that NDOW personnel commented on

Arizona Bell's Vireo

Comment: While not quite as alarming as with SWFL, we question the accuracy of the observations used to produce these models for AZ Bell's Vireo. The points in the Spring Mts. and across Las Vegas seem questionable, and Gray and Plumbeous vireos seem more likely for many of the mountainous locations. The more restrictive MaxEnt model appears more likely, but even that appears to be developed using questionable data points that could be quite misleading.

Response: We agree and eliminated some questionable records and re-ran the analyses. The resultant models are somewhat more restricted.

Comment: Again, what is the source and expected ID accuracy of the points used to generate these models? The Spring Mountain and LV points appear questionable, and would likely heavily impact modeling if inaccurate species ID points were included.

Response: For this analysis, the data were provided by IFC, GBBO, with added data from the GBIF, eBird, BISON and VertNet databases.

While areas along the Virgin and Muddy Rivers, Las Vegas Wash, and Colorado River south of Lake Mohave are to be expected, the modeled predicted areas within the LV metropolitan area and Spring/Sheep ranges isn't very reasonable.

Ridgway's Rail

Comment: While areas along the Virgin and Muddy Rivers, Las Vegas Wash, and Colorado River south of Lake Mohave are to be expected, the modeled predicted areas within the LV metropolitan area and Spring/Sheep ranges isn't very reasonable.

Response: Agreed, many of these are historical records that contribute to the model. However, one thing that the County is interested in is how much potential habitat has been impacted vs. conserved. Therefore, our models include these historical data. We were explicitly asked not to mask habitat given urbanized boundaries. It is likely that these can be applied in subsequent analyses of these models

Comment: [re: the MaxEnt model] Not very reasonable for this species.

Response: Agreed, and this is why we offer an ensemble model for each species that reduces the influence of any give algorithm and is based only on higher performing models within each one.

Southwestern Willow Flycatcher

Comment: Given what we know about the habitat requirements and limited distribution of SWFLs in southern NV, the MaxEnt model makes a lot more sense. The other models appear much more predictive well-beyond what is a reasonable expectation.

Response: See general comments about the models presented.

Comment: Where did these observation points come from? While many points in the Las Vegas, Spring Mtns, Sheep Range area may very well be Willow Flycatchers migrating through (or other Empidonax spp.), it doesn't seem likely they could be confirmed as SW Willow Flycatchers. Obviously the Las Vegas Wash points are quite reasonable though – as are those along the Colorado, Virgin, and Muddy Rivers, and Meadow Valley Wash. Including points not confirmed to be SWFLs would presumably go a long way toward producing over-inclusive models. As in the SWFL survey protocol (Sogge et al. 2010), plumage and color differences can't be relied on to differentiate subspecies, so the fitz-bew during breeding is necessary.
… and similarly …
Comment: Many of these points within Las Vegas, the Spring Mountains, and Sheep Range seem highly suspect. They easily could be Willow Flycatchers (E. traillii) moving through, but we question strongly whether they could be confirmed as SW Willow Flycachers (E. traillii extimus).

Response: We agree that there is potential for mis-identification in any of the datasets, but that is beyond our control. We were provided with data for the subspecies from NNHP, NDOW, IFC, Entrix and NPS. We also used databases for museum records, and research grade observations, and other records, as requested by the County. It is also important to note that some records of observations could possibly include animals migrating between habitat patches, or otherwise outside of their normal habitat. The models should be most affected by the majority of data within the habitat and not by a few outliers, as with most other analyses. We have restricted the most recent version of the model to the sub species.

Yellow Billed Cuckoo

Comment: Given that suitable breeding habitat patches for YBCU is often considered at least 15-20 hectares (possibly overly large, especially in irruptive years like 2019), and they generally are restricted to habitat patches at least 100 m wide, these models appear to over estimate predictive habitat for this species. It's unclear if these models are attempting to model breeding habitat (vs. migratory or transitory habitat), but the Random Forest model appears to greatly overestimate suitable habitat even if including nonbreeding habitat.

Response: As noted, we include all records asked for by the County. In most cases, there is no designation as to whether the animals are transitioning between habitat patches, or are resident/breeding. However, from a conservation perspective, both areas important for the species. Should a nesting, vs. foraging, vs. transition type model be desired then data with those attributes are necessary, and those are not given in any of the datasets we have seen to date.