Plant Distributions in the Southwestern United States: A Scenario Assessment of the Modern-Day and Future Distribution Ranges of 166 Species

By Kathryn A. Thomas, Patricia P. Guertin, and Leila Gass

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Abstract

The authors developed spatial models of the predicted modern-day suitable habitat (SH) of 166 dominant and indicator plant species of the southwestern United States (herein referred to as the Southwest) and then conducted a coarse assessment of potential future changes in the distribution of their suitable habitat under three climate-change scenarios for two time periods. We used Maxent-based spatial modeling to predict the modern-day and future scenarios of SH for each species in an over 342-million-acre area encompassing all or parts of six states in the Southwest—Arizona, California, Colorado, Nevada, New Mexico, and Utah. Modern-day SH models were predicted by our using 26 annual and monthly average temperature and precipitation variables, averaged for the years 1971–2000. Future SH models were predicted for each species by our using six climate models based on application of the average of 16 General Circulation Models to Intergovernmental Panel on Climate Change emission scenarios B1, A1B, and A2 for two time periods, 2040 to 2069 and 2070 and 2100, referred to respectively as the 2050 and 2100 time periods.

The assessment examined each species' vulnerability to loss of modern-day SH under future climate scenarios, potential to gain SH under future climate scenarios, and each species' estimated risk as a function of both vulnerability and potential gains. All 166 species were predicted to lose modern-day SH in the future climate change scenarios. In the 2050 time period, nearly 30 percent of the species lost 75 percent or more of their modern-day suitable habitat, 21 species gained more new SH than their modern-day SH, and 30 species gained less new SH than 25 percent of their modern-day SH. In the 2100 time period, nearly half of the species lost 75 percent or more of their modern-day SH, 28 species gained more new SH than their modern-day SH, and 34 gained less new SH than 25 percent of their modern-day SH. Using nine risk categories we found only two species were in the least risk category, while 20 species were in the highest risk category. The assessment showed that species respond independently to predicted climate change, suggesting that current plant assemblages may disassemble under predicted climate change scenarios.

This report presents the results for each species in tables (Appendix A) and maps (14 for each species) in Appendix B.

Introduction

Purpose and Scope of Study

Rapidly changing climate predicted for the 21st century may profoundly affect population sizes and distribution of biota (Solomon and others, 2007). Species may respond differentially to new climate patterns depending upon their individual response to changes in temperature and precipitation, among other factors. Concerned policymakers, resource managers, and the public are interested in having the best possible understanding of the sorts of ecological and biogeographical changes that may result. As a response to that need, the author's assessed potential changes in the geographic location of suitable habitat of dominant and indicator plant species in the arid and semi-arid Southwest, resulting from climate change.

This study is unique, because it evaluates plant response using three different climate change scenarios, presenting a range of potential climate windows under which a plant's habitat may be defined. The report documents the methods used to develop spatial models of SH for 166 plant species, both for modern-day and predicted future climate, and conducts an assessment of each species' vulnerability to loss of SH, potential to gain SH, and overall risk under different climate change scenarios. While overall results are discussed in the report body the appendices provide summary results for each plant, both in table and map format. These data provide resources for researchers and resource managers in the Southwest to examine how SH for plants may change in their area of concern or responsibility and to take account of uncertainty in future climate predictions. The data also provide a basis for predicting how entire ecosystems may respond to future climate change. The approach taken here can be applied to other geographic areas with the use of plant occurrence, modern-day climate data, and future climate predictions appropriate to that area.

Background Information

The general prediction for climate change in the Southwest is for warmer temperatures and a more arid climate (Seager and others, 2007: Overpeck and Udall, 2010). The Southwest supports a high proportion of public lands that are managed, in part or fully, for their biological diversity (Ernst and others, 2007), highlighting the need for information about the potential response of species in order to inform future conservation management decisions. Studies on potential shifts in distribution ranges of suitable habitat for plants in the Southwest have been limited. Shafer and others (2001) modeled the future simulated distribution of plant species in western North America, including some species in the Southwest, and predicted areas with no change, contraction, or extension of the species distribution. Cole and others (2007, 2011) focused on the predicted response of single species, *Pinus edulis* and *Yucca brevifolia,* and incorporated analysis of their potential to migrate to new suitable habitat.

Predictive modeling is one tool to assess the potential geographic response of species to future climate change. One regional approach is to examine how the distribution of modern-day SH of a species compares to predictions of the species' SH under future climate scenarios. Spatial redistribution of a species' SH in the future, due to changing climate, provides an estimate of the geographic "footprint" of habitat potentially available to the species for new occupation, without consideration of other edaphic, dispersal, or biological factors that may influence the species' actual occupancy. Comparing modern-day with predicted future SH provides a view of potential new habitats (increased SH), modern-day habitats that may become less suitable for the species (decreased SH), and modern-day habitats that may remain suitable (maintained SH). In addition, predictions of SH by our using different future climate scenarios illustrate the range of potential distribution shifts for a species regardless of which climate scenario actually develops.

We developed a spatial model of each species' modern-day SH based on annual and monthly average temperature and precipitation from 1971 to 2000. These models represent the climatic envelope of SH habitat within which individuals of a species may occur where soil, microclimate, and biotic interactions are favorable. Individuals of a species will not occur at every location within the SH. We developed spatial models of the potential future locations of the modern-day SH for three different climate change models over two time periods. The climate models represented the average of 16

General Circulation Models applied to the 2007 Intergovernmental Panel on Climate Change (AR4) emission scenarios B1, A1B, and A2 (Solomon and others, 2007). The time periods were 2040 to 2069 and 2070 and 2100, referred to respectively as the 2050 and 2100 time periods. We chose these climate models, because they were freely available and represent breadth of possible climate change currently predicted for the Southwest. Rather than attempting to choose one scenario that might be more applicable to the Southwest, we assess the potential range of SH predictions that might occur using different climate change predictions. We examined the certainty of model results by evaluating the area as maintained, decreasing, or increasing SH by one, two, or all three models for each time period.

We assessed the regional vulnerability of each of the 166 plants to potential future loss of SH by determining the proportion of predicted modern-day SH that becomes unsuitable under future climate change projections. We assessed the possibility of the species to adapt to changing climate by expanding into new SH by determining the proportional area of new SH that might become available for occupation compared to the area of the species' modern-day SH. Finally we examined the relative risk to the species over the 2050 time period using nine risk categories to classify the relations of the species' vulnerability to loss of SH and potential to gain SH. For all three assessments, we averaged the three climate-change-model results for each time period.

The Study Area

The study area consisted of all or parts of six southwestern states. We used the ecoregion units originally defined by Bailey (1995) and modified by The Nature Conservancy (unpub. data, 2005) to select areas within the six states that are part of major Southwest ecoregions (fig.1). The total study area for development of models was 342,098,664 acres (138,442,418 ha) and included all of Arizona and Utah, the majority of Nevada and New Mexico, the western part of Colorado, and the far eastern areas of California. Fourteen ecoregions are represented in all or part within the study area. Of these, six have 90 percent or more of their area within the study area—Arizona-New Mexico Mountains, Colorado Plateau, Great Basin, Mojave Desert, Southern Rocky Mountains, and Utah High Plateaus.

Methods

Modeling Environment

We used ESRI ArcGIS 9.2 and 9.3 to prepare data for model input and to process model output data. The study area was represented by a raster grid comprised of 1,945,672 standardized cells and with Albers NAD83 projection. We refer to this grid in this report as the standard grid as it was used to standardize all input data to the same extent, cell size (843.5 m^2), and projection.

Model Input Data Sources and Initial Processing

Plant Species and their Occurrence Locations

We compiled a list of dominant and/or indicator native tree, shrub, and grass species and their presence locations from 30 field studies, each consisting of multiple observation sites, conducted throughout the study area (table 1). The studies selected met the following criteria: (1) each plant or site location was georeferenced and had an accuracy of at least +/- 100 m; (2) the study was no older than 1990; and (3) the study listed, at the minimum, all dominant and associate perennial plants at each site. Nonnative species were not included as they are not normally considered dominant and/or indicator species in Southwest vegetation and the field studies did not systematically sample nonnative species.

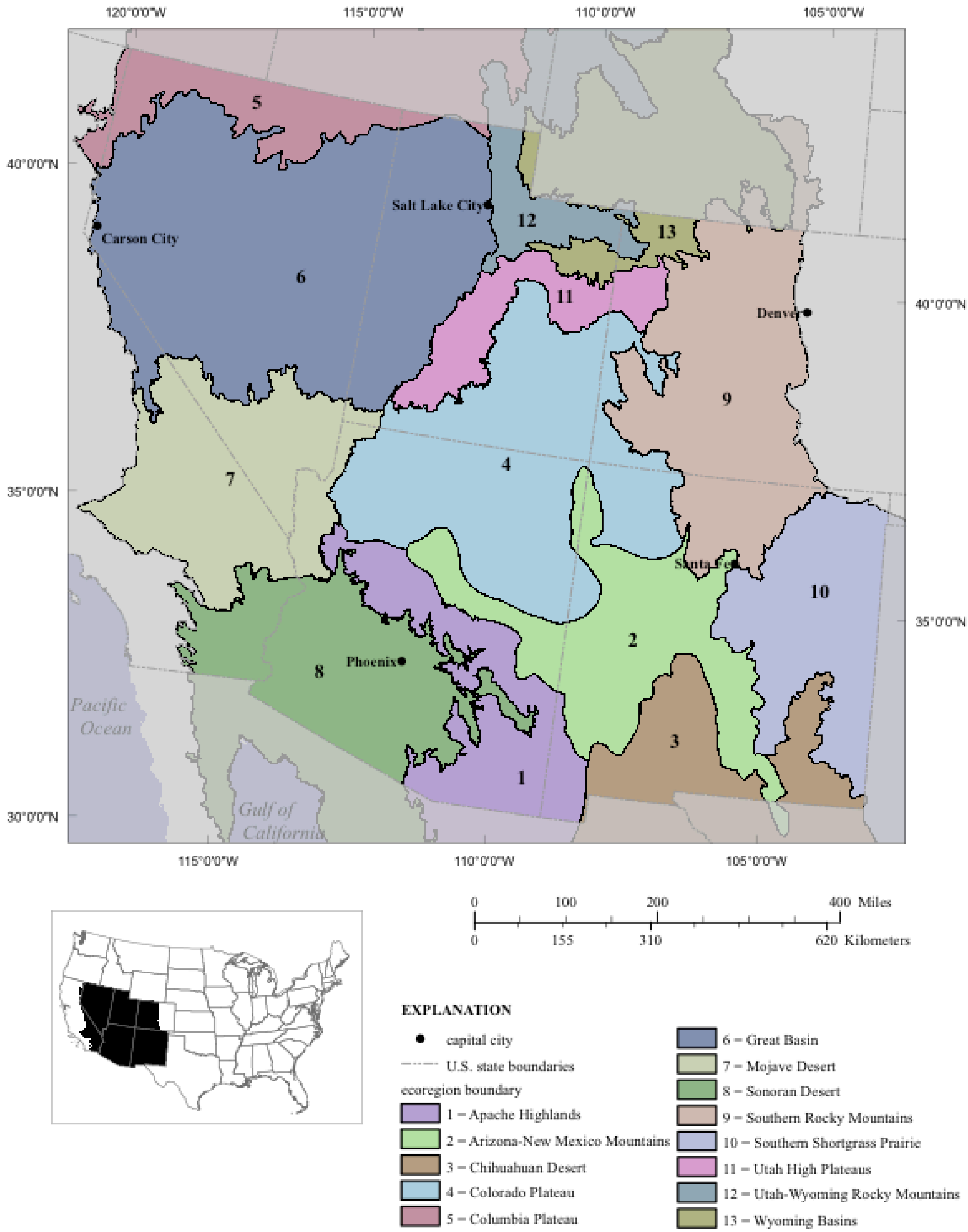

Figure 1. Map showing Southwest study area and ecoregions.

Collectively the occurrence data documented on the sites in these studies represented the breadth of the study area and, although not designed to sample all environments within the study area, the studies included many remote environments. However, the sites did not appear to adequately represent wetland and riparian habitats, so dominant and indicator species for these habitats were not included as part of the target species.

Table 1. Field studies supplying species' location data.

State	Study Name
Arizona	USGS, Arizona Gap Analysis (First Generation)
Arizona	USGS, Babbitt Ranches, Arizona - Benchmark Assessment
Arizona	USGS, Field Studies Petrified Forest National Park, Arizona
Arizona	NAU, Juniper Dataset, Arizona
Arizona	USGS, SWReGAP - Arizona Field Observations
Arizona	USGS/NPN Park Mapping, Sunset Crater National Monument
Arizona	USGS/NPN Park Mapping, Tuzigoot National Monument
Arizona	USGS/NPN Park Mapping, Walnut Canyon National Monument
Arizona	USGS/NPN Park Mapping, Wupatki National Monument
Arizona	USGS/NPS Park Mapping Canyon de Chelly National Monument, Arizona
Arizona	USGS/NPS Park Mapping Petrified Forest National Park, Arizona
California	29 Palms - California, Field Survey
California	29 Palms, California - Range Survey
California	CA Natural Heritage Vegetation Study, California
California	USGS, Coaxil Cable Study, California
California	Death Valley Tortoise Habitat Survey, California
California	Field Survey (Watts) – California
California	USGS, Field transects, California
California	Ft. Irwin Vegetation Survey, California
California	USGS, Mojave Desert Ecosystem Study, California
California	USGS, Mojave Pipeline Study, California
California	USGS, Owlshead Vegetation Study, California
Colorado	SWReGAP - Colorado Field Observations
Colorado	USGS/NPS Park Mapping Mesa Verde National Park, Colorado
Nevada	Nevada Test Site Studies (Oestler), Nevada
Nevada	SWReGAP - Nevada Field Observations
Nevada	Yucca Mtn. Vegetation Study, Nevada
New Mexico	SWReGAP - New Mexico Field Observations
Utah	SWReGAP - Utah Field Observations
Utah	USGS/NPN Park Mapping Program, Zion National Park

We used NatureServe Explorer (http://www.natureserve.org/explorer/) to define which species were dominant or an indicator for Southwest ecological systems. We used the Integrated Taxonomic Information System (ITIS, http://www.itis.gov/) as the taxonomic authority for plant nomenclature. The final species list was comprised of 36 tree, 97 shrub, and 33 grass species.

We compared the occurrence records for each species to the standard grid and chose the centroid of each grid cell in which the species occurred to represent the location of that record. Where multiple occurrence records for a species occurred in a single standard grid cell, they were all represented by the same centroid. Any species with less than 50 centroids was not included in the analysis. The number of species' centroids for each species ranged from 51 (*Rhus ovata*) to 10,139 (*Artemisia tridentata*); see appendix A, table 1 for the number of centroids available for each species and the common name of each species. We used 128,619 species by location centroids overall.

Modern-day Climate Data

The available spatially interpolated climate data consisted of average precipitation and temperature (minimum and maximum), both monthly and annually, for the years 1971–2000. We obtained these data from the online Parameter-elevation Regressions on Independent Slopes Model (PRISM) datasets (Prism Climate Group 2004). The PRISM data represent temperature in Celsius and precipitation in millimeters, each multiplied by 100. The native cell resolution of the PRISM data was maintained (843.5 m^2) and was used to define the cell resolution of the standard grid. We obtained PRISM data in ASCII format for the entire continental United States and used the standard grid as an input mask to extract PRISM data for the study area.

Development of future SH models required input of the same type of climate variables as used to develop the modern-day SH models. As the downscaled data available for future SH models (see below) expressed average precipitation and temperature on a monthly and annual basis, we averaged the minimum and maximum PRISM data to convert these to an average value. The processed PRISM data contained 26 modern-day climate variables comprised as average precipitation (12 monthly and 1 annual) and average temperature (12 monthly and 1 annual).

Future Climate Scenarios

Future SH models were based on climate models of future temperature and precipitation developed by the Climate Wizard collaboration (*http://www.climatewizard.org/*) of The Nature Conservancy, The University of Washington, and The University of Southern Mississippi. We ran six future climate scenarios that were based on three AR4 emission scenarios (table 2) for the years 2040–2069 (the 2050 time period) and the years 2070–2099 (the 2100 time period). The emission scenarios represented low (B1), medium (A1B), and high (A2) projected future global temperature increases as described by the 2007 IPPC report (Solomon and others, 2007). Each emission scenario describes a potential "story-line" based on assumptions of how economic, technological, and population growth might develop in the future. Each Climate Wizard model consisted of an ensemble of the nonparametric quantile-rank average of the median values of all 16 general circulation models (GCM, table 3) applied to each of the three emission scenarios. The scenario data for monthly and annual temperature and precipitation had been statistically downscaled at 12 km resolution and were available for the entire USA in ASCII format. Temperature was represented in degrees Fahrenheit and precipitation in inches.

We used the standard grid as an input mask to extract the downloaded temperature and precipitation data for each scenario for the study area. A nearest neighbor algorithm was used during the extraction to resample the 12-km native grid cell size to the standard grid cell size of 843 m^2; note, this step did not increase the resolution of the downscaled climate scenarios. The temperature grids were converted from degrees Fahrenheit to degrees Celsius and the precipitation grids were converted from inches to millimeters. All values were multiplied by 100 so that they were in equivalent units to the PRISM data.

Table 2. 2007 Intergovernmental Panel on Climate Change scenarios represented by Climate Wizard climate grids and used to predict future suitable habitat.

Emission Scenario	Description
B1	Low population growth, service/information economy, clean and efficient technologies, global temperature change estimated to be 2.4ºC (1.4–3.8ºC range)
A1B	Low population growth, rapid economic growth, new and efficient technologies, global temperature change estimated to be 2.8ºC (1.7–4.4ºC range)
A2	High population growth, regional economic development, technologies changing slowly, global temperature change estimated to be 3.4ºC (2–5.4ºC range)

Model Development

We used the freely available maximum-entropy-based algorithm Maxent version 3.3.1 (Phillips and others, 2006; Elith and others, 2011) to create modern-day SH models and project future SH models. Maxent has been shown to be a high-performing approach to species distribution modeling (Phillips and others, 2009; Elith and others, 2006) and is designed to deal with “presence-only” occurrence datasets. Each “run” of Maxent requires input sample files, environmental layers files, and projection layer files. We used a “samples with data” or SWD input format because the environmental input layers and projection layer files were large. The default logistic output was maintained, which results in each unit (grid cell) of the predictive output files to consist of scores in a continuous range between 0 and 1. These scores represent the relative probability of presence of the species in that unit.

Sample files: A sample file was created for each species consisting of the geographic coordinates for the species’ centroids and the values of the modern-day climate data at each centroid. We used an ArcGIS shapefile of each species’ centroid to extract the modern-day climate data for the centroids from the processed PRISM data. The table of species’ centroid locations and corresponding climate data for each species was converted to comma delimited (.csv) format for input into Maxent.

“Background” Data: SWD requires a single input file of “background” locations and their respective modern-day climate values. We selected 10,000 random background centroids from the standard grid and added the geographic coordinates to each. We then extracted the modern-day climate data for each background centroid from the processed PRISM data and converted the resulting tables of background points and their respective climate variables to ASCII format for input in Maxent.

Projection Layers Files: Seven sets of projection layers files were developed, the modern-day climate conditions and the six future climate scenarios (table 4). We extracted the data for each standardized grid cell for the 26 climate variables for each modern-day or future scenario into tables and converted the values to ASCII format. Each projection layer set thus consisted of 26 ASCII files representing monthly average temperature (12 files), monthly average precipitation (12 files), yearly average temperature (1 file), and yearly average precipitation (1 file).

Table 3. General circulation models incorporated into Climate Wizard climate grids used to predict future suitable habitat.

Acronym	**Origin**
BCCR-BCM2.0	Bjerknes Centre for Climate Research, University of Bergen, Norway
CGCM3.1(T47)	Canadian Centre for Climate Modelling & Analysis, Climate Research Branch, Environment Canada
CNRM-CM3	Centre National de Recherches Mététrologigues, Météo France, France
CSIRO-Mk3.0	CSIRO Atmospheric Research, Australia
GFDL-CM2.0	National Oceanic and Atmospheric Administration/Geophysical Fluid Dynamics Laboratory, United States
GFDL-CM2.1	National Oceanic and Atmospheric Administration/Geophysical Fluid Dynamics Laboratory, United States
GISS-ER	US National Aeronautics and Space Administration/ Goddard Institute for Space Studies, United States
INM-CM3.0	Institute for Numerical Mathematics, Russian Academy of Science, Russia
IPSL-CM4	Institut Pierre Simon Laplace, Center for Climate System Research, France
MIROC3.2	Center for Climate System Research, University of Tokyo; National Institute for Environmental Studies; and Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology
ECHO-G	Meteorological Institute of the University of Bonn, Germany; Meteorological Research Institute of KMA, Korea; and Model and Data Group
ECHAM5/MPI-OM	Max Planck Institute for Meteorology, Germany
MRI-CGCM2.3.2	Meteorological Research Institute, Japan Meteorological Agency, Japan
CCSM3	National Center for Atmospheric Research, United States
PCM	National Center for Atmospheric Research, United States
UKMO-HadCM3	Hadley Centre for Climate Prediction and Research/ Met Office, United Kingdom

Model Runs: We used the sample layer file for each species, the background layer file, and each of the projection layer files (table 4) as input to Maxent to develop the modern-day and future SH models for each of the 166 species. Modern-day SH models were tested in two ways within Maxent. Maxent automatically calculates a performance measure, the receiver operating characteristic (ROC) area under curve (AUC) metric, for the input sample data. An AUC value of 1 indicates perfect model performance, 0.5 a random prediction, and lower than 0.5 is worse than random (Elith and others, 2006). For the first model run, we used settings on Maxent to randomly divide the sample data into a test data set (20 percent) and a training dataset (80 percent) to obtain two AUC scores (test and training). For the second run, we incorporated all sample data for calculation of only a training AUC score.

Table 4. Climate scenarios used to predict suitable habitat for modern-day and future conditions. Two runs were made for modern-day—one (test) with 20 percent of the data withheld from the training dataset for a test of model performance and the second with all data included in the training data set.

Run Number	Scenario
1	Modern-day - test
2	Modern-day – main run
3	B1 2050
4	A1B 2050
5	A2 2050
6	B1 2100
7	A1B 2100
8	A2 2100

Each species had eight SH model runs (table 4): the modern-day with 20 percent test data withheld, the modern-day with no test data withheld, one for each of the three scenarios for the 2050 time period, and one for each of the three scenarios for the 2100 time period. We used the modern-day SH model with no sample data withheld as input for each of the future SH projections; the modern-day SH model with 20 percent test data was used only to test the model performance. The initial raw ASCII output for each prediction was converted to a raster grid with Albers Nad83 projection. The raster grids expressed SH with cell values ranging continuously from 0 to 1 (continuous models), with 0 indicating the lowest predictive certainty.

A breakpoint of 0.5 was applied to the raster model output to convert the continuous output values to binary representing unsuitable and suitable habitat. This 0.5 breakpoint is known as the default or conventional threshold (Franklin, 2009). A number of threshold approaches have been proposed. For example, Franklin (2009) lists 12 approaches in addition to the default approach. While Liu and others (2005) in a study comparing the performance of different approaches to determining the threshold breakpoint did not recommend the default method, Freeman and Moisen (2008) found the default method produces equally useful results when model performance is high and prevalence is not low. Prevalence is the proportion of sampled sites where a species is present (Santika, 2011).

To apply the threshold, we reclassified the predicted cell values to <0.5 = 0, 0.5 – 1.0 =1, where 0 indicated unsuitable habitat and 1 indicated suitable habitat. We conducted a second performance evaluation after applying the threshold by calculating for each model the number of centroids correctly identified as SH for the species. This check was used to estimate prevalence where all sample locations for the species were taken as the known occurrences and the number predicted correctly was used to determine the prevalence proportion, and where:

Overall threshold accuracy = no. species' centroids correctly predicted as suitable/ no. all species' centroids

We used the same threshold levels to convert the continuous grid output to binary for the future SH models output, but we assigned a different reclassification value in preparation for the SH change assessment. We reclassified the predicted cell values for future SH models as <0.5 = 10 and 0.5 – 1.0 = 20, where 10 indicated unsuitable habitat and 20 indicated SH. Whereas modern-day SH model output had a continuous (0 to 1 cell values, relative probability) and a binary (0 or 1 cell values, unsuitable or suitable) representation, the future SH models had only binary representation of unsuitable or suitable (10 or 20 cell values).

Suitable Habitats: Modern-day and Future scenarios

The modern-day binary-SH models for each species were added to each of the future binary-SH models for that species (using map algebra in ArcGIS's Spatial Analyst) to create six change grids, one for each of the future climate scenarios. A unique cell value of 10, 11, 20, or 21 was assigned to each cell depending on the values of its constituent modern-day suitability and future suitability cell values (table 5).

A count of cells for each category was extracted for each species and was used to calculate four metrics for each species for each scenario:

1) Percent SH modern-day = no. cells suitable SH/ no. cells study area
2) Percent Maintained SH future = no. cells maintained SH/no. cells SH modern-day
3) Percent Increased SH future = no. cells increased SH /no. cells SH modern-day
4) Percent Decreased SH future = no. cells decreased suitability SH /no. cells SH modern-day

Table 5. Future suitable habitat (SH) suitability classes and their relations to modern-day and future model suitability predictions. Each suitability class represents the relation of SH in the future predictions compared to the SH in the modern-day prediction. The suitability classes were applied numerically to each standard grid cell.

Future SH suitability class	Modern-Day binary-SH model cell value	Future binary-SH model cell value	Future SH model cell value
maintained unsuitability	0 (unsuitable)	10 (unsuitable)	10
decreased suitability	1 (suitable)	10 (unsuitable)	11
increased suitability	0 (unsuitable)	20 (suitable)	20
maintained suitability	1 (suitable)	20 (suitable)	21

Model Agreement for Suitability Classes

To determine the certainty of each future SH model, we deconstructed each change grid into three grids representing each of the suitability classes in the change grid. For each component grid the suitability class represented—maintained, increased, or decreased—was reclassified to 1 and otherwise 0. Next all grids for a suitability class, regardless of scenario, were combined for each time period. For each species, the scenario model agreement score was calculated as the number of cells in a suitability grid with 0, 1, 2, or 3 grids predicting that suitability class. The raw count for each total was converted to a percent of all cells predicted for that suitability class in the grid. For the results where all three models agreed, we calculated the average percent and standard deviation for all trees, shrubs and grasses respectively

Species' Vulnerability, Potential, and Risk Categories

We developed a metric to represent each species' vulnerability to decreases in modern-day SH under changing climate that was based on the proportion of modern-day SH that is predicted to decrease for each time period. Decreases in SH were averaged for all three scenarios per time period:

Vulnerability to loss = Average area SH decreased/Modern-day area SH

We also developed a metric for the species' potential for adaptation under changing climate for each time period due to gain in SH, using the average area for all three scenarios predicted as increased SH:

Potential for gain = Average area SH increased suitability/Modern-day area SH

To examine the relative risk to each species we divided the vulnerability scores into three levels representing low, moderate to high, or very high predicted loss of modern-day SH. The thresholds for the three vulnerability level were assigned using the following breaks in the vulnerability scores:

Low loss: 0 to 0.25
Moderate to high: > 0.25 to ≤ 0.75
Very high :> 0.75 to 1.00

We also divided the potential scores into three levels to represent predicted gain in SH in the future. The two potential levels were assigned with the following breaks in the potential scores:

Very high: ≥ 0.75
Moderate to high: > 0.25 and < 0.75
Low: 0-0.25

A very high potential score indicates that predicted future gains in SH are greater in area than the area of modern-day SH. On the other hand, a low potential score indicates that predicted future gains in SH are less than 25 percent in the area of modern-day SH. The combination of the levels of the vulnerability and potential categories created nine risk categories (table 6). This risk analysis was conducted only for the 2050 time period predictions.

Results

The data summaries (tables) and maps of model output described below appear for all 166 species in the two appendices to this report. Below, we report on the results considering all 166 species in aggregate. We also present representative results for five species from appendix A and one figure from appendix B to illustrate the results for each species available in the appendices.

Model Performance Metrics

Maxent generates an AUC performance score during each model run. Three AUC scores were obtained for the prediction of modern-day SH for each species: (1) AUC for 20 percent test data withheld, (2) AUC for the 80 percent remaining training data, and (3) AUC with no withheld data. AUC scores were consistently high for model performance: (1) 20 percent test, range of 0.828–0.998, (2) 80 percent training, range of 0.837–0.973, and (3) no withheld training, range of 0.836–0.999. Based on guidelines described by Swets (1988), AUC values above 0.9 are highly accurate and between 0.7 and 0.9 are useful. Of the 166 species models with no withheld training points, 154 had AUC scores above 0.9. The other 12 species had AUC scores above 0.828. The individual scores for each species are listed in appendix A, table 1, and illustrated on table 7.

Table 6. Species were assigned to one of nine risk categories that represented three levels of vulnerability to loss of modern-day habitat and three levels of potential to gain of new habitat.

Vulnerability score	Potential score: Very high (>1.00)	Potential score: Moderate to High (>0.25 and ≤0.75)	Potential score: Low (0-0.25)
Low (0-.25)	Species will maintain 75 percent or more of modern-day SH and will gain double or more SH in the future.	Species will maintain 75 percent or more of modern-day SH and will gain 25 to 75 percent new SH in the future.	Species will maintain 75 percent or more of modern-day SH and will gain 0 to 25 percent new SH in the future.
Moderate to high (>0.25 to ≤0.75)	Species will maintain 25 to 75 percent of modern-day SH and will gain double or more SH in the future.	Species will maintain 25 to 75 percent of modern-day SH and will gain 25 to 75 percent new SH in the future.	Species will maintain 25 to 75 percent of modern-day SH and will gain 0 to 25 percent new SH in the future.
Very high (>0.75 to 1.00)	Species will maintain less than 25 percent of modern-day SH and will gain double or more SH in the future.	Species will maintain less than 25 percent of modern-day SH and will gain 25 to 75 percent new SH in the future.	Species will maintain less than 25 percent of modern-day SH and will gain 0 to 25 percent new SH in the future.

A performance metric was calculated for the overall accuracy of using a threshold of 0.50 to convert the continuous model output to binary. The choice of this threshold was successful in capturing 72.7 to 97.1 percent of the species' centroids used for each species (appendix A, table 1). This test was used as an estimate of prevalence and supported the use of the threshold using the criteria of Freeman and Moisen (2008).

Suitable Habitats—Modern-day and Future Scenarios

The proportion of the study area predicted as modern-day SH ranged from 0.3 to 31.5 percent among the species (appendix A, table 2; illustrated table 8). Species with the greatest proportion of the study area of predicted SH were *Artemisia tridentata* (31.5 percent), *Gutierrezia sarothrae* (28.3 percent), *Juniperus osteosperma* (22.2 percent), *Achnatherum hymenoides* (21.6 percent), and *Bouteloua gracilis* (20.4 percent). An additional 18 species have predicted modern-day SH proportion between 10 and 20 percent. Forty-eight species had greater than 5 percent but less than 10 percent predicted modern-day SH proportion of the study area. Only three species had predicted modern-day SH of less than 1 percent: *Tetradymia spinosa* (0.9 percent), *Lupinus argenteus* (0.7 percent), and *Pinus strobiformis* (0.3 percent).

The geographic location of predicted modern-day SH for each of the 166 species is represented by a map of the continuous values (appendix B, insert map A; illustrated on fig. 2, insert map A) and the binary representation (Appendix B, insert map B; illustrated on fig. 2, insert map B).

Table 7. An illustrative subsection of summary data presented in appendix A, table 1. For each species the table lists its scientific and USDA PLANTS code, number of locations for each species used to develop predicted modern-day and future climate models, and model performance metrics. AUC indicates the receiver operator curve area under curve statistic. The standardized centroids for each species were randomly divided into a test data set containing 20 percent of the data (AUC20) and a training dataset with the remaining 80 percent (AUC20 training). All standardized centroids were incorporated in the second model run (AUC all training). The overall threshold accuracy score indicates the number of species' centroids correctly predicted as suitable using the 50 percent threshold criterion divided by the total number of centroids for the species.

Species	common_name	USDA PLANTS code	no. of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Trees							
Pinus flexilis	limber pine	PIFL2	255	0.957	0.986	0.985	0.894
Yucca brevifolia	Joshua tree	YUBR	470	0.977	0.989	0.988	0.913
Shrubs							
Artemisia tridentata	big sagebrush	ARTR2	10139	0.834	0.843	0.839	0.874
Grasses							
Bouteloua gracilis	blue grama	BOGR2	4538	0.899	0.902	0.901	0.838

All species experienced a reduction of modern-day SH under the future scenarios. For scenario B1, the proportion of modern-day SH maintained in the future ranged from 0.5 to 90.8 percent for 2050 time period, and from 0 to74.5 percent for the 2100 time period. For scenario A1B, the range was 0 to78.0 percent for the 2050 period and 0 to 84.3 percent for the 2100 period. For scenario A2, the range was 0.6 to 90.4 percent and 0 to 74.2 percent for the respective time periods. Each species' predicted future SH is illustrated in appendix B for the 2050 period scenarios (B1, insert map C; A1B, insert map D; A2, insert map E) and for the 2100 period scenarios (B1, insert map F; A1B, insert map G; A2, insert map H; illustrated fig. 2, insert maps C–H).

Model Agreement for Suitability Classes

Areas with all three models agreeing for a suitability class have the most certainty. The average percent agreement was highest for areas predicted to decrease in suitability, with the scores slightly higher for the 2100 time period (69.0–70.8 percent) than the 2050 time period (63.5–66.6 percent), table 9. Average percentages were noticeably lower for the areas predicted to maintain or increase suitability. The lowest agreement was for the areas predicted to increase in suitability in the 2100 time period (19.6–30.7 percent). Overall, scores for trees were higher than scores for grasses; and scores for both trees and grasses were higher than scores for shrubs. The standard deviation was high for all averaged percentages indicating species predicted response was highly variable with respect to the climate change model used.

Table 8. An illustrative subsection of summary data presented in appendix A, table 2. For each species, the table shows its predicted modern-day proportion of the study area (S) and the percent of the modern-day suitable habitat (SH) predicted to be decreasing suitability (DS), increasing suitability (IS), and maintained suitability (MS). The future scenarios were B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

			Predicted future SH (percent of modern-day SH area) by scenario and time period					
	Suitability Class	Predicted modern-day SH (percent of study area)	B1 (Low)		A1B (Medium)		A2 (High)	
Species			2050	2100	2050	2100	2050	2100
Trees								
Pinus flexilis	S	4.1						
	DS		86.4	95.8	94.5	95.7	95.9	98.7
	IS		20.4	8.8	11.1	19.2	5.1	6.5
	MS		13.6	4.2	5.5	4.3	4.1	1.3
Yucca brevifolia	S	3.9						
	DS		72.3	88.6	75	84.8	60.1	94.9
	IS		46.3	31.1	99.3	139.9	108.1	53.4
	MS		27.7	11.4	25	15.2	39.9	5.1
Shrubs								
Artemisia tridentata	S	3.1						
	DS		47.5	52.6	52.4	61.1	45.9	63.1
	IS		7.6	6.3	9.9	6.4	11	7.3
	MS		52.5	47.4	47.6	38.9	54.1	36.9
Grasses								
Pleuraphis mutica	S	5.0						
	DS		80.4	88.9	85.5	96.6	85.5	98.3
	IS		87.1	92.1	120.7	71.1	92.7	106.2
	MS		19.6	11.1	14.5	3.4	14.5	1.7

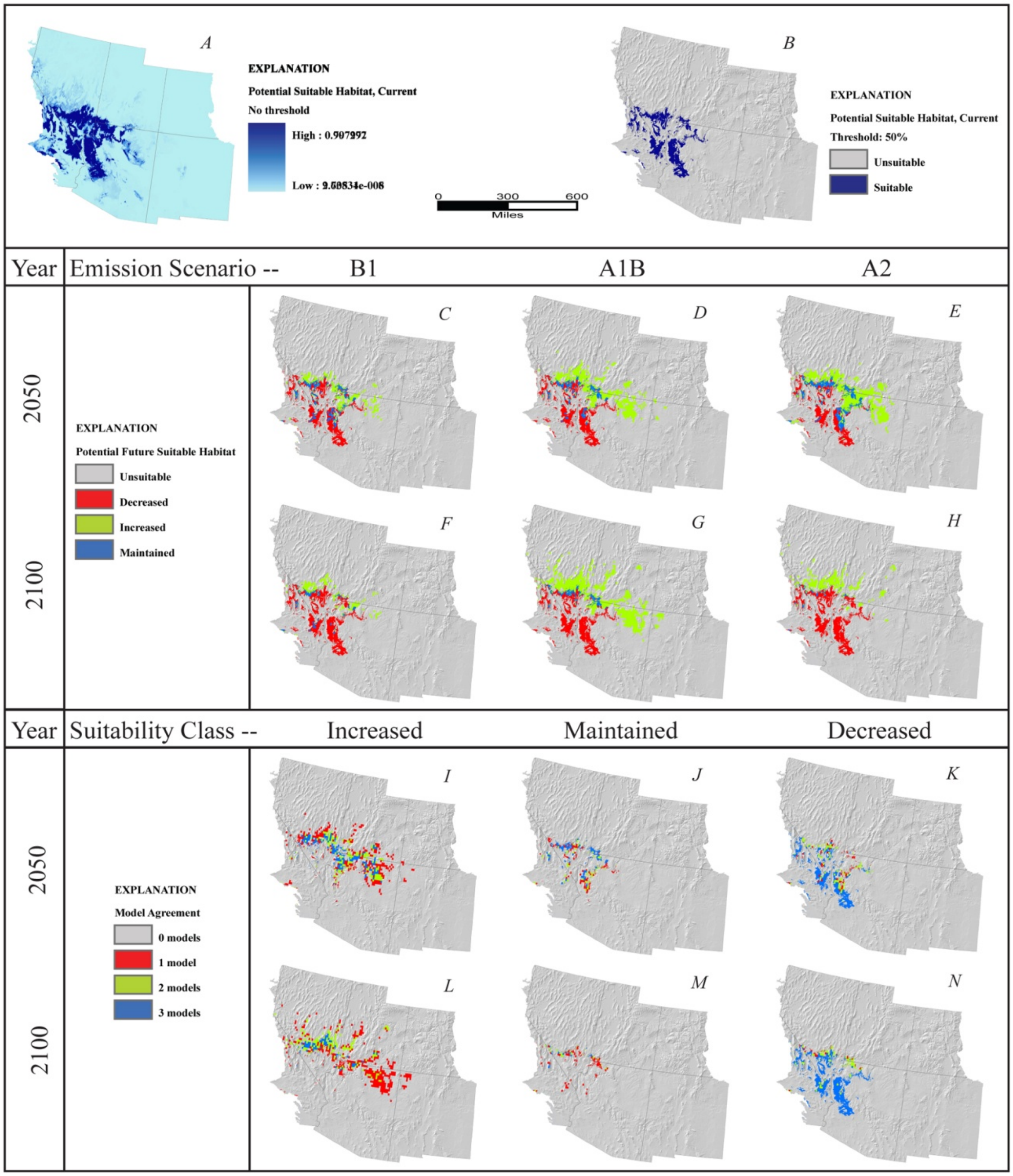

Figure 36. *Yucca brevifolia*. A, Potential suitable habitat for species based on average annual and monthly precipitation and temperature from 1971 to 2000, continuous model output with no threshold. B, Potential suitable habitat, binary output using .5 threshold. C-E, Potential suitable habitat predicted by year 2050 under emission scenario (C), B1, (D), A1B, (E), A2. F-H, Potential suitable habitat predicted by year 2100 under emission scenario (F), B1, (G), A1B, (H), A2. I-K, Number of 2050 emission scenario models predicting each suitability class, (I), increased suitability, (J), maintained suitability, (K), decreased suitability. L-N, Number of 2100 emission scenario models predicting each suitability class, (L), increased suitability, (M), maintained suitability, and (N), decreased suitability.

Figure 2. Example of map results reported for each species in appendix B.

Table 9. The average percentage and standard deviation for tree, shrub, and grass species of the total area predicted for each suitability class by all three model results concurrently to the total areas predicted by all three combined. The three classes are (1) DS, decreased suitability; (2) IS, increased suitability; and (3) MS, maintained suitability.

	Average percent +/- standard error					
	2050			2100		
	DS	IS	MS	DS	IS	MS
Trees	63.5 +/- 19.7	35.0 +/- 17.9	47.2 +/- 21.2	69.3 +/- 18.6	30.7 +/- 17.5	39.4 +/- 21.1
Shrubs	66.6 +/- 16.4	26.9 +/- 13.8	40.4 +/- 19.7	69.0 +/- 17.0	19.6 +/- 14.0	24.1 +/- 18.8
Grasses	64.5 +/- 14.5	28.1 +/- 9.2	43.1 +/- 13.4	70.8 +/- 15.2	22.3 +/- 11.6	30.2 +/- 18.2

The spatial distributions of model agreement for each species-scenario are illustrated in appendix B (insert maps I–N) and the corresponding area metrics listed in appendix A, table 3. These results are also illustrated with figure 2, insert maps I–N, and table 10.

Species' Vulnerability, Potential, and Risk Categories

Species Vulnerability to Loss of Modern-day Suitable Habitat

Overall, vulnerability scores ranged from 0.215 (the least vulnerable) to 0.995 (the most vulnerable) in the 2050 time period and from 0.248 to 0.999 in the 2100 time period (appendix A, table 4; illustrated on table 11). By our using the vulnerability classes applied to the risk analysis, only two species had low vulnerability scores (0–.25), indicating 75 percent or more of their modern-day SH was predicted to be SH in the future under the average of the scenarios. Only one tree had low vulnerability, *Prosopis velutina*, with low scores occurring in both the 2050 and 2100 time period. The shrub, *Shepherdia canadensis*, had low vulnerability in the 2050 time period but no shrubs had low vulnerability in the 2100 time period. None of the grasses had low vulnerability in either time period. Many species had vulnerability scores in the moderate to high range (>0.25 to ≤0.75) indicating 25 to 75 percent of their modern-day SH would become unsuitable in the future. Twenty-seven of the tree species (75.0 percent of the trees considered) were in this range in the 2050 time period and 21 (58.3 percent) in the 2100 time period. Sixty-five (67.0 percent) of the shrubs were in this category in the 2050 time period and 40 (41.2 percent) in the 2100 time period. The grass species had 25 (75.8 percent) in this category in the 2050 time period and 18 (54.5 percent) in the 2100 time period.

The species most vulnerable to loss of modern-day SH were identified as those with vulnerability scores of 0.75 or greater, indicating that 25 percent or less of their modern-day SH would be maintained in future climates. Eight trees (22.2 percent) were identified in this category for the 2050 time period: *Fraxinus velutina, Juglans major, Quercus arizonica, Quercus grisea, Pinus aristata, Pinus flexilis, Pinus monophylla,* and *Pinus strobiformis.* These trees and *Abies concolor, Picea pungens, Pinus ponderosa, Populus angustifolia, Quercus emoryi, Quercus grisea,* and *Yucca brevifolia* were identified as most vulnerable for the 2100 time period, a total of 15 or 41.7 percent of the tree species. Of the shrubs 33 (34.0 percent) were identified as highly vulnerable in the 2050 time period and 57 (57.6 percent) in the 2100 time period. These species are not listed here for space considerations, but are identified in appendix A, table 4. Eight grass species (24.2 percent) were very highly vulnerable in the 2050 time period: *Achnatherum speciosum Achnatherum thurberianum, Festuca arizonica, Pleuraphis mutica, Pleuraphis rigida, Schizachyrium scoparium, Sporobolus cryptandrus,* and

Sporobolus flexuosus. These grass species with the addition of *Bouteloua curtipendula, Bouteloua eriopoda, Elymus elymoides, Festuca brachyphylla, Leymus cinereus, Muhlenbergia montana, and Poa fendleriana* comprise the 15 (45.5 percent) most vulnerable grasses in the 2100 time period.

Table 10. An illustrative subsection of summary data presented in appendix A, table 3. For each species, the number of future suitable habitat (SH) models predicting one of three classes is shown as a percent of the total area predicted for that class by the three climate models combined for each time period. The three classes are (1) DS, decreased suitability; (2) IS, increased suitability; and (3) MS, maintained suitability. The total area predicted for each class was the spatial area predicted concurrently for that class for each species using the 2007 IPPC scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

Species	**no. of models agreeing**	**Model agreement for each suitable habitat class (percent of total area predicted for that suitability class) for two time periods**					
		2050			**2100**		
		DS	**IS**	**MS**	**DS**	**IS**	**MS**
Trees							
Pinus flexilis	1	3.3	54.5	56.1	1.4	60.1	78.3
	2	8.2	26.9	22.9	6.1	34.7	17.7
	3	88.5	18.6	21.1	92.5	5.2	4
Yucca brevifolia	1	13	47.4	36.8	4	60.5	68.5
	2	20.5	26.6	23.3	15.4	28.3	17.9
	3	66.5	26	39.9	80.6	11.3	13.6
Shrubs		0	0	0	0	0	0
Artemisia tridentata	1	17.6	32.2	15.5	21	35.7	35.4
	2	16.2	22.8	16.8	28	19.8	26.5
	3	66.2	45	67.6	51	44.5	38
Grasses		0	0	0	0	0	0
Pleuraphis mutica	1	5.9	42.7	39.3	3.2	52.5	65.6
	2	10.6	24.5	22.1	7.6	35.8	27.8
	3	83.5	32.8	38.6	89.2	11.7	6.6

When vulnerability for the species with the most area predicted SH under modern-day conditions—*Artemisia tridentata*, *Gutierrezia sarothrae*, *Juniperus osteosperma*, *Achnatherum hymenoides*, and *Bouteloua gracilis*—we see that these species are predicted to lose 44 to 54 percent of their modern-day SH in the 2050 time period and 54 to 67percent by the 2100 time period. The three species with predicted modern-day SH of less than 1 percent—*Tetradymia spinosa*, *Lupinus argenteus*, and *Pinus strobiformis*—are predicted the lose 58 to 77 percent of their modern-day SH in the 2050 time period and 89 to 93 percent of their modern-day SH in the 2100 time period.

Table 11. An illustrative subsection of summary data presented in appendix A, table 4 for the suitable habitat (SH) vulnerability and potential scores for a species. The vulnerability score represents the suitable habitat (SH) area, averaged over three climate scenarios, predicted to decrease in the future, divided by area predicted as SH for the species in modern-day. The higher the score, the more SH predicted to be lost and the higher the species' predicted vulnerability. The potential score is the SH, averaged over three climate scenarios, predicted to be gained in the future divided by the area predicted as SH for the species in modern-day. The higher the potential score, the more SH is predicted to be gained during the future time period. A score greater than 1 indicates the species is predicted to have more SH in the future than was predicted for the modern day. PRISM climate data was used to predict modern-day SH and future climate scenarios were represented by IPPC scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

	Vulnerability scores		**Opportunity scores**	
time period	**2050**	**2100**	**2050**	**2100**
Trees				
Pinus flexilis	-0.922	-0.967	0.122	0.115
Yucca brevifolia	-0.691	-0.894	0.846	0.748
Shrubs				
Artemisia tridentata	-0.486	-0.59	0.095	0.067
Grasses				
Pleuraphis rigida	-0.837	-0.969	0.644	0.406

Species Potential to Gain Suitable Habitat

Species' potential scores ranged from 0.044 (least gain of suitable habitat) to 2.333 (most gain of suitable habitat) in the 2050 time period and from 0.006 to 4.019 in the 2100 time period (appendix A, table 4; illustrated table 11). Scores larger than 1.0 indicate that the species' gain of future SH area was predicted to be greater than the area of its predicted modern-day SH. For the 2050 time period, six tree species had scores greater than 1.0: *Parkinsonia florida*, *Acer glabrum*, *Acer negundo Juniperus coahuilensis*, *Prosopis velutina*, and *Quercus havardii*. In the 2100 time period, all of these trees, except *Quercus havardii* and with the addition of *Prosopis glandulosa*, had scores greater than 1.0. Ten shrub species were predicted to gain more SH than their modern-day SH for the 2050 time period: *Simmondsia chinensis*, *Atriplex obovata*, *Ziziphus obtusifolia*, *Atriplex filifolia*, *Ephedra torreyana*, *Ephedra trifurca*, *Fouquieria splendens*, *Lycium andersonii*, *Parthenium incanum*, *Shepherdia canadensis*, and *Suaeda moquinii*. For the 2100 time period, all of the 2050 listed shrubs and *Baccharis sarothroides*, *Eriogonum wrightii*, *Flourensia cernua*, *Larrea tridentata*, and *Paxistima myrsinites* had potential scores greater than one. The grass species with the most predicted potential to gain SH for the 2050 time period were *Dasyochloa pulchella*, *Muhlenbergia porteri*, *Elymus glaucus*, and *Pleauraphis mutica*. For the 2100 time period, five grass species had predicted potential scores greater than 1.0: *Boutleoua eriopoda*, *Dasyochloa pluchella*, *Hilaria belangeri*, *Koeleria macrantha*, and *Muhlenbergia porteri*.

The lowest potential scores (0.25 and less) indicated those species that will gain no more than 25 percent of their modern-day SH in the future. For the trees this includes *Abies concolor, Juniperus deppeana, Juniperus osteosperma, Picea engelmannii, Pinus flexilis, Pinus monophylla, Pinus* *ponderosa,* and *Pinus strobiformis* for the 2050 time period. In the 2100 time period, the potential scores for *Abies concolor, Juniperus deppeana*, and *Juniperus osetesperma* were higher than 0.25; the other species remained in the low category with the addition of *Abies lasiocarpa, Pinus contorta,* and *Populus tremuloides.* Twenty-one shrubs had low potential scores in the 2050 time period; four of these had higher potential scores in the 2100 time period but, with the addition of other species with lower scores, there was a total of twenty-seven plant species in the low category in this time period. Eight grass species had low potential scores in both the 2050 and 2100 time periods: *Achnatherum hymenoides, Achnatherum speciosum, Achnatherum thurberianum, Bouteloua gracilis, Elymus elymoides, Leymus cinereus, Poa secunda*, and *Schizachyrium scoparium,*

Relative Risk

The risk analysis (tables 12, 13, and 14) illustrates a complex interaction within the species between predicted vulnerability to loss of SH and potential to gain SH. Except for the two opposing ends of the categories—low vulnerability/high to very high potential of gain and very high vulnerability to loss SH/ low potential for gain SH where plant "winners" and plant "losers" can be predicted—the regional response of species can only be generally categorized by its relative potential to gain new SH and lose modern-day SH.

Table 12. Assignment of tree species to risk categories. Risk categories consist of categorical rankings of a species' vulnerability and potential scores combined. Vulnerability is defined as the proportion of the area of suitable habitat (SH) predicted to decrease in the 2050 time period averaged over three future climate change scenarios divided by the area predicted for the species as SH for modern-day climate conditions. Species that have are predicted to have 5 percent or more SH regionally in the modern day are indicated. Future climate scenarios were represented by IPPC scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

Vulnerability	Potential: High to very high	Potential: Moderate	Potential: Low
Low	***Prosopis velutina***		
Moderate to high	***Acer glabrum*** ***Acer grandidentatum*** ***Acer negundo*** ***Juniperus coahuilensis*** ***Olneya tesota*** ***Parkinsonia florida*** ***Picea pungens*** ***Prosopis glandulosa*** ***Quercus havardii*** ***Yucca brevifolia***	***Abies lasiocarpa*** ***Carnegia gigantea*** ***Juniperus monosperma ***** ***Juniperus scopulorum*** ***Parkinsonia microphylla*** ***Pinus contorta*** ***Pinus edulis ***** ***Populus angustifolia*** ***Populus tremuloides*** ***Pseudotsuga menziesii*** ***Quercus emoryi*** ***Quercus gambelii ***** ***Quercus emoryi***	***Abies concolor*** ***Juniperus deppeana*** ***Juniperus osteosperma **** ***Picea engelmannii*** ***Pinus ponderosa***
Very high		***Fraxinus velutina*** ***Juglans major*** ***Pinus aristata*** ***Quercus arizonica*** ***Quercus grisea***	***Pinus flexilis*** ***Pinus monophylla ***** ***Pinus strobiformis***

* Species is predicted to have SH in 20 percent of more of the study area under modern-day climate conditions

** Species is predicted to have SH in more than 10 percent and less than 20 percent of the study area under modern-day climate conditions

Table 13. Assignment of shrub species to risk categories. Risk categories consist of categorical rankings of a species' vulnerability and potential scores combined. Vulnerability is defined as the proportion of the area of suitable habitat predicted to decrease in the 2050 time period averaged over three future climate change scenarios divided by the area predicted for the species as suitable habitat for modern-day climate conditions. Future climate scenarios were represented by IPPC scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

		Potential		
		High to very high	Moderate	Low
Vulnerability	Low	Shepherdia canadensis		
	Moderate to high	Arctostaphylos uva-ursi Artemisia filifolia Atriplex obovata Coleogyne ramosissima Ephedra torreyana Ephedra trifurca Fouquieria splendens Larrea tridentata ** Parthenium incanum Salix geyeriana Simmondsia chinensis Suaeda moquinii Symphoricarpos rotundifolius Yucca elata Ziziphus obtusifolia	Acacia constricta Acacia gregii Ambrosia dumosa Amelanchier alnifolia Amelanchier utahensis Arctostaphylos pungens Artemisia bigelovii Artemisia frigida Artemisia nova ** Atriplex canescens ** Atriplex confertifolia ** Artemisia tridentata * Atriplex gardneri Atriplex polycarpa Baccharis sarothroides Cercocarpus montanus Ephedra nevadensis Encelia viridis ** Eriogonum wrightii Fallugia paradoxa Grayia spinosa Gutierrezia microcephala Gutierrezia sarothrae * Juniperus communis Krascheninnikovia lanata ** Lupinus argenteus Mahonia repens Mimosa aculeaticarpa Opuntia engelmannii Paxistima myrsinites Prunus virginiana Purshia mexicana	Chrysothamnus viscidiflorus ** Robinia neomexicana Symphoricarpos oreophilus Yucca baccata Yucca glauca

	Potential		
	High to very high	Moderate	Low
Very high		Purshia tridentata ** Quercus turbinella Rhus trilobata Ribes cereum Ribes montigenum Sarcobatus vermiculatus ** Symphoricarpos albus Tetradymia spinosa Vaccinium myrtillus Vaccinium scoparium Yucca angustissima Yucca baccata Yucca elata	
	Lycium andersonii	Ambrosia deltoidea Arctostaphylos patula Arctostaphylos pringlei Atriplex corrugata Canotia holacantha Chrysothamnus depressus Chrysothamnus greenei Ericameria linearifolia Flourensia cernua Garrya wrightii Hymenoclea salsola Menodora spinescens Opuntia basilaris Purshia stansburiana Rhus microphylla Rosa woodsii Salazaria mexicana Tetradymia glabrata	Artemisia arbuscula Atriplex hymenelytra Ceanothus greggii Cercocarpus intricatus Cercocarpus ledifolius Encelia farinosa Ericameria nauseosa Eriogonum fasciculatum Garrya flavescens Lycium pallidum Picrothamnus desertorum Prunus fasciculata Rhus ovata Yucca schidigera

* Species is predicted to have SH in 20 percent of more of the study area under modern-day climate conditions

** Species is predicted to have SH in more than 10 percent and less than 20 percent of the study area under modern-day climate conditions

Table 14. Assignment of grass species to risk categories. Risk categories consist of categorical rankings of a species' vulnerability and potential scores combined. Vulnerability is defined as the proportion of the area of suitable habitat (SH) predicted to decrease in the 2050 time period averaged over three future climate change scenarios divided by the area predicted for the species as SH for modern-day climate conditions. Future climate scenarios were represented by IPPC scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100).

Vulnerability	Potential: High to very high	Potential: Moderate	Potential: Low
Low			
Moderate to high	***Dasyochloa pulchella*** ***Elymus glaucus*** ***Muhlenbergia porteri*** ***Hordeum jubatum***	***Bouteloua curtipendula*** ***Bouteloua hirsuta*** ***Festuca brachyphylla*** ***Festuca idahoensis*** ***Festua thurberi*** ***Hesperostipa comata ***** ***Muhlenbergia emersleyi*** ***Pascopyrum smithii*** ***Pleuraphis jamesii ***** ***Muhlenbergia montana*** ***Poa fendleriana***	***Achnatherum hymenoides **** ***Bouteloua eriopoda*** ***Bouteloua gracilis **** ***Elymus elymoides ***** ***Hilaria belangeri*** ***Koeleria macrantha*** ***Leymus cinereus*** ***Poa secunda ***** ***Sporobolus airoides***
Very high	***Pleuraphis mutica*** ***Sporobolus flexuosus***	***Festuca arizonica*** ***Pleuraphis rigida*** ***Sporobolus cryptandrus ***** ***Elymus trachycaulus***	***Achnatherum speciosum*** ***Achnatherum thurberianum*** ***Schizachyrium scoparium***

* Species is predicted to have SH in 20 percent of more of the study area under modern-day climate conditions

** Species is predicted to have SH in more than 10 percent and less than 20 percent of the study area under modern-day climate conditions

Summary and Discussion

This study examines the potential response of 166 plant species to predicted climate change from the perspective of two time periods and three different potential emission scenarios. Predicted future habitat predictions were classified as decreasing, maintaining, or increasing suitability. Using these categories, we evaluated the concurrence among the different model results and calculated metrics indicating potential vulnerability, potential, and risk for each species using the average of the three emission scenarios for each time period.

Concurrence among the models showed that predictions for areas of decreasing suitability were much higher than predictions for maintained or decreased suitability. This indicates that the predictions of maintenance of suitable habitat or potential new suitable habitats are highly dependent upon the actual climate change trajectory that is used for predictions.

Suitable habitat is an indicator of the amount of actual habitat that is available for a plant species, but it does not reflect the actual occupancy of the species within that suitable habitat. In this study SH does not take into account the myriad biotic and abiotic interactions and conditions that influence the realized niche-space of a species within the SH. As an indicator, it is useful for determining a broad picture assessment of species occurrence and the potential impacts that could occur as a result of climate variation. The study makes no claims about the species' ability to adapt in situ to loss of SH or the species' ability to occupy potential SH.

In the first part of the study, vulnerability was defined as the proportion of modern-day SH that would be lost in each time period averaged over the three climate models. All 166 species were predicted to lose modern-day SH in the future climate change scenarios. In the 2050 time period, only two species were predicted to lose less than 25 percent of their modern-day SH and 49, or nearly 30 percent of the 166 species, were predicted to lose 75 percent or more of their modern-day suitable habitat. For the 2100 time period, only one species was predicted to lose less than 25 percent of its modern-day SH and nearly half, 88 of 166 species, were predicted to lose 75 percent or more of their modern-day SH.

The second part of the study examined the potential for a species to adapt as measured by the amount of new SH that might be gained in each time period averaged over the three climate models. The model results indicated that some species will have potential to occupy double or more of their modern-day habitat in the future; this includes 21 species in the 2050 time period and 28 in the 2100 time period. Other species will have very little potential to occupy new SH in the future; based on a threshold of 25 percent or less of potential SH, this includes 30 species in the 2050 time period and 34 species in the 2100 time period.

The third part of the study was a relative risk assessment, done only for the 2050 time period averaged over the three climate models. In this assessment, nine risk categories were used to classify the proportion of a species' vulnerability score to its potential score. The risk analysis showed that there are plants that are likely to be overall winners, others overall losers, and others for which losses and gains might be distributed across the region. Overall winners were predicted to be *Prosopis velutina* and *Shepherdia canadensis.* Overall losers included three tree species (*Pinus flexilis, P. monophylla,* and *P. strobiformis)*, 14 shrub species (*Artemisia arbuscula, Atriplex hymenelytra, Ceanothus greggii, Cercocarpus intricatus, Cercocarpus ledifolius, Encelia farinosa, Ericameria nauseosa, Eriogonum fasciculatum, Garry flavescnes, Lycium pallidum, Picrothamnus desertorum, Prunus faciculata, Rhus ovata,* and *Yucca schidigera*),and three grass species (*Achnatherum speciosum Achnatherum thurberianum, Schizachyrium scoparium*).

Factors in Interpreting Results

A model is only an approximation of expected conditions. The map output and derived metrics presented in this study indicate possible trends in the future. Their interpretation and use should be done with mindfulness of the various limitations inherently involved in developing the models and the other factors that ultimately influence a species' distribution. While we found our model output to be consistent, based on the high AUC metrics obtained, there are other points of consideration.

The initial model output is influenced by the quality of input data and the decisions made in calibrating the model runs. In this study the key input factors are the occurrence data and the climate data, both current and future climate change models. Corrections for bias in sample data (occurrence data) have been a topic of recent discussion within the Maxent modeling community (Phillips and others, 2009). Newer versions of Maxent than the one used in this study provide some correction approaches for occurrence data that were collected in a non-systematic manner. Although these approaches were not applied to the occurrence data in this study, typically these concerns are related to the non-systematic sampling bias associated with occurrence data derived from herbaria and museum records (Phillips and others, 2009). In this study, the collective set of studies and their associated sites constitute a broad representation of the study area and its associated environments. Additional filters were applied to eliminate species that may have been underrepresented due to the nature of the field studies used. Although a threshold of 50 or more occurrence records was used as an additional filter, some of the species with low numbers of occurrence records may be underrepresented. For example, *Rhus ovata*, with only 50 locations, often occurs in narrowly defined locations and the available location data may cause underestimation of its SH range.

There are a number of climate models available for future climate modeling. Virtually all of these derive from models reported in AR4. There is no definitive model of future climate change, because the science of climate modeling is constantly being refined and the drivers of climate change are dynamic and not stable, particularly with respect to human contribution to greenhouse gasses. The ongoing 5th IPPC plans to produce a new set of climate models in their 2014 reporting. Rather than choose one climate model thought to be best fitting to previous Southwest regional climate, for this project we chose to look at potential response framed by climate models representing lower projected climate change and models representing higher projected climate change. Users of these data should benefit by having the predictions of the responses of Southwest plant species to climate change based on different views of how climate might change in the future. This approach facilitates comparison and evaluation of the convergence or non-convergence of predicted species response across a range of possible climate change trajectories. Owing to the fact that climate change is not fully predictable, this view provides more information than that based on a single trajectory.

One feature of the ClimateWizard climate models to note is that these climate models have been statistically downscaled to 12-km resolution from global climate models that were developed at 2.5- to 3.5-degree resolution. Temperature and precipitation are generally considered to be good proxies to topography in most cases; however, at the resolution of 12 km, the user should remember that topographic variation is averaged and microsite variation is not captured within each grid cell of model results. This means that there may be micro-scale sites of SH suitability or unsuitability that were not captured with each grid cell of model results. The current distribution models were run at the standard grid cell size of 843.5 m^2, which corresponded to the available modern-day climate data. The future projections, although displayed at the standard grid cell size, have less resolution because of the 12-km resolution of the future climate models. For this reason decision-making should not be based on single grid cell results.

Maxent may be conservative in its interpolation and predict more tightly to the species' occurrence input locations than other modeling approaches. The choice of threshold breakpoint becomes important in how any conservative bias is expressed in the SH predictions. A different threshold approach would have set the breakpoint lower in order to capture all possible suitable habitats, even if occupation frequency were very low.

The choice of threshold is a good indicator of the type of error that may occur in the model results. For the modern-day and future suitable habitat results, the chosen threshold reduces the probability of false positive predictions. In other words, there is less chance of a prediction of SH in areas not actually SH. However, for the potential SH, the opposite situation occurs where there is more chance of false negatives where potential SH exists but was not predicted. As noted by Freeman and Moisen (2008) and Franklin (2009), the continuous model output provides the unconstrained prediction and this output can be used to develop different views of predicted SH.

It is important to note that a number of ecological and physiological factors are not included in this first-order assessment but that ultimately influence how a species responds to climate change. Within modern predicted SH, the actual distribution of a species will depend on factors such as edaphic and micro-topographic factors, biological interactions including mutualisms and predation, and various disturbance factors. These factors will also be of importance in the species' future occupation of any SH. In addition a species' ability to physiologically adapt to changing conditions, such as through changing phenology, can mitigate changes in habitat suitability. The ability of a species to occupy potential habitat is very dependent upon a species' ability to migrate to the new areas. Migration is a function of the species' dispersal characteristics, the establishment environment in the new habitat, and landscape features such as fragmentation and transport corridors. The authors acknowledge the importance of these factors and, for this reason, have labeled potential new SH as only potential.

Next Steps

A major goal of this study was to develop model outputs that could be used to support more focused study of how climate change may affect plant species and vegetation distribution in the Southwest. The approach can be applied in other broad biomes with the use of an appropriate subset of modern-day PRISM data, ClimateWizard climate scenarios, and plant species presence data. Also, the approach can be applied iteratively to the Southwest as finer resolution and/or more refined climate scenarios are developed.

The purpose of this report was to present the methods, model outputs, and a first-order assessment for these 166 plant species. This report provides information that natural resource managers can use as input to more comprehensive climate change action planning, such as contemporary large-area planning documents (for example Bureau of Land Management Resource Management Plans) that could help prioritize actions for a future environment. There are a number of follow-on studies that can be pursued within the region using these data and results:

- Assessment of individual species vulnerability using a broader set of criteria,
- Evaluation of model results against long-term plot data existing within the region,
- Assessment of predicted species change within ecoregions, by major vegetation types and/or by administrative unit, or
- Identification of landscapes at risk due to loss of species and landscapes of interest due to potential for gain of species.

The products and findings of this report provide one perspective that might inform management decisions to be considered and focused studies to be conducted in the face of rapidly changing climate. Ultimately, these predictions can serve as the basis for specific hypotheses of species, vegetation, and landscape change. The report also presents an analytic approach toward assessing species response to changing climate that might be duplicated and refined in other regions in the nation.

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References Cited

Bailey, Robert G., 1995, Description of the ecoregions of the United States (2d ed., revised and expanded): U.S. Department of Agriculture, Forest Service Miscellaneous Publication 1391, 108 p., available at http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html.

Climate Wizard, 2009, Future Climate Model: accessed during 2009, at http://www.climatewizard.org/.

Cole, K.L., Ironside, K.E., Arundel, S.T., Duffy, P.B., and Shaw, John, 2007, Modeling future plant distributions on the Colorado Plateau—An example using *Pinus edulis*, *in* van Riper III, Charles, and Sogge, M.K., eds., The Colorado Plateau III—Integrating research and resources management for effective conservation: Tucson, The University of Arizona Press, p. 319–330.

Cole, K.L., Ironside, K.E., Eischeid, Jon, Garfin, Greg, Duffy, P.B., and Toney, Chris, 2011, Past and ongoing shifts in Joshua tree distribution support future modeled range contraction: Ecological Applications, v. 21, no. 1, p. 137–149.

Elith, Jane, Graham, C.H., Anderson, R.P., and 24 others, 2006, Novel methods improve prediction of species' distributions from occurrence data: Ecography, v. 29, no. 2, p. 129–151.

Elith, Jane, Phillips, S.J., Hastie, Trevor, Dudik, Miroslav, Chee, Y.E., and Yates, C.J., 2011, A statistical explanation of MaxEnt for ecologists: Diversity and Distributions, v. 17, no. 1, p. 43–57.

Ernst, A.E., Schrader, Scott, Lopez, Veronica, and 8 others, 2007, Land Stewardship. Chapter 4. *in* Prior-Magee, J.S., Boykin, K.G., Bradford, D.F., and 5 others, eds., Southwest Regional Gap Analysis Project final report: U.S. Geological Survey, Gap Analysis Program, Moscow, ID., available at http://fws-nmcfwru.nmsu.edu/swregap/report/SWReGAP%20Final%20Report.pdf.

Franklin, Janet, 2009, Mapping species distributions—Spatial inference and prediction: Cambridge, U.K., Cambridge University Press, 320 p.

Freeman, E.A., and Moisen, G.C., 2008, A comparison of the performance of threshold criteria for binary classification in terms of predicted prevalence: Ecological Modeling, v. 217, p. 48–58.

Integrated Taxonomic Information System, accessed 2010 at http://www.itis.gov/.

Liu, C.R., Berry, P.M., Dawson, T.P., and Pearson, R.G., 2005, Selecting thresholds of occurrence in the prediction of species distributions: Ecography, v. 28, p. 385–393.

NatureServe Explorer, 2010, Ecological communities and Systems: database accessed 2010 at http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol.

Overpeck, Jonathan, and Udall, Bradley, 2010, Dry times ahead: Science, v. 328, no. 5986, p. 1642–1643.

PRISM Climate Group, 2004, Oregon State University, 30-arcsec (800m) Normals, accessed 2009 at http://www.prismclimate.org.

Phillips, S.J., Anderson, R.P., and Schapire, R.E., 2006, Maximum entropy modeling of species' geographic distribution: Ecological Modeling, v. 190, no. 3–4, p. 231–259.

Phillips, S.J., Dudik, Miroslav, Elith, Jane, and 4 others, 2009, Sample selection bias and presence-only distribution models—Implications for background and pseudo-absence data: Ecological Applications, v. 19, no. 1, p. 181–197.

Santika, Truly, 2011, Assessing the effect of prevalence on the predictive performance of species distribution models using simulated data: Global Ecology and Biogeography, v. 20, no. 1, p. 181–192.

Seager, Richard, Ting, Mingfang, Held, Isaac, and 10 others, 2007, Model projections of an imminent transition to a more arid climate in Southwestern North America: Science, v. 316, no. 5828, p. 1181–1184.

Shafer, S.L., Bartlein, P.J., and Thompson, R.S., 2001, Potential changes in the distributions of western North America tree and shrub taxa under future climate scenarios: Ecosystems, v. 4, no. 3, p. 200–215.

Solomon, Susan, Qin, Dahe, Manning, Martin, and 5 others, eds., 2007, Climate change 2007—The physical science basis—Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge, U.K., Cambridge University Press, 996 p.

Swets, John A., 1988, Measuring the accuracy of diagnostic systems: Science, v. 240, no. 4857, p. 1285–1293.

Contents of the Appendixes

Appendix A Assessment results for the 166 plant species: Summary tables

Appendix B Assessment results for the 166 plant species: Spatial models

Link to Appendix B, *Assessment Results for the 166 Plant Species: Spatial Models Figures 1 to 166*. The data are presented as a single large PDF; as one PDF each for trees, shrubs, and grasses; and as a set of 166 single-page PDFs—one for each of the species (2.6 GB total).

Trees

Abies concolor
Abies lasiocarpa
Acer glabrum
Acer grandidentatum
Acer negundo
Carnegiea gigantea
Fraxinus velutina
Juglans major
Juniperus coahuilensis
Juniperus deppeana
Juniperus monosperma
Juniperus osteosperma
Juniperus scopulorum
Olneya tesota
Parkinsonia florida
Parkinsonia microphylla
Picea engelmannii
Picea pungens
Pinus aristata

Pinus contorta
Pinus edulis
Pinus flexilis
Pinus monophylla
Pinus ponderosa
Pinus strobiformis
Populus angustifolia
Populus tremuloides
Prosopis glandulosa
Prosopis velutina
Pseudotsuga menziesii
Quercus arizonica
Quercus emoryi
Quercus gambelii
Quercus grisea
Quercus havardii
Yucca brevifolia

Shrubs

Acacia constricta
Acacia greggii
Ambrosia deltoidea
Ambrosia dumosa
Amelanchier alnifolia
Amelanchier utahensis
Arctostaphylos patula
Arctostaphylos pringlei
Arctostaphylos pungens
Arctostaphylos uva-ursi
Artemisia arbuscula
Artemisia bigelovii
Artemisia filifolia
Artemisia frigida
Artemisia nova
Artemisia tridentata
Atriplex canescens
Atriplex confertifolia
Atriplex corrugata
Atriplex gardneri
Atriplex hymenelytra
Atriplex obovata
Atriplex polycarpa
Baccharis sarothroides
Canotia holacantha
Ceanothus greggii
Cercocarpus intricatus
Cercocarpus ledifolius

Cercocarpus montanus
Chrysothamnus depressus
Chrysothamnus greenei
Chrysothamnus viscidiflorus
Coleogyne ramosissima
Encelia farinosa
Ephedra nevadensis
Ephedra torreyana
Ephedra trifurca
Ephedra viridis
Ericameria linearifolia
Ericameria nauseosa
Eriogonum fasciculatum
Eriogonum wrightii
Fallugia paradoxa
Flourensia cernua
Fouquieria splendens
Garrya flavescens
Garrya wrightii
Grayia spinosa
Gutierrezia microcephala
Gutierrezia sarothrae
Hymenoclea salsola
Juniperus communis
Krascheninnikovia lanata
Larrea tridentata
Lupinus argenteus
Lycium andersonii
Lycium pallidum
Mahonia repens
Menodora spinescens
Mimosa aculeaticarpa
Opuntia basilaris
Opuntia engelmannii
Parthenium incanum
Paxistima myrsinites
Picrothamnus desertorum
Prunus fasciculata
Prunus virginiana
Purshia mexicana
Purshia stansburiana
Purshia tridentata
Quercus turbinella
Rhus microphylla
Rhus ovata
Rhus trilobata

Ribes cereum
Ribes montigenum
Robinia neomexicana
Rosa woodsii
Salazaria mexicana
Salix geyeriana
Sarcobatus vermiculatus
Shepherdia canadensis
Simmondsia chinensis
Suaeda moquinii
Symphoricarpos albus
Symphoricarpos oreophilus
Symphoricarpos rotundifolius
Tetradymia glabrata
Tetradymia spinosa
Vaccinium myrtillus
Vaccinium scoparium
Yucca angustissima
Yucca baccata
Yucca elata
Yucca glauca
Yucca schidigera
Ziziphus obtusifolia

Grasses

Achnatherum hymenoides
Achnatherum speciosum
Achnatherum thurberianum
Bouteloua curtipendula
Bouteloua eriopoda
Bouteloua gracilis
Bouteloua hirsuta
Dasyochloa pulchella
Elymus elymoides
Elymus glaucus
Elymus trachycaulus
Festuca arizonica
Festuca brachyphylla
Festuca idahoensis
Festuca thurberi
Hesperostipa comata
Hilaria belangeri
Hordeum jubatum
Koeleria macrantha
Leymus cinereus
Muhlenbergia emersleyi
Muhlenbergia montana

Muhlenbergia porteri
Pascopyrum smithii
Pleuraphis jamesii
Pleuraphis mutica
Pleuraphis rigida
Poa fendleriana
Poa secunda
Schizachyrium scoparium
Sporobolus airoides
Sporobolus cryptandrus
Sporobolus flexuosus

Appendix A Assessment Results for the 166 Plant Species: Summary Tables

Table 1. Plant species (n=166) included in this study, number of locations for each species used to develop predicted modern-day and future climate change scenario models, and model performance metrics. AUC indicates the receiver operator curve area under curve statistic. The sample data was randomly divided into a test data set containing 20 percent of the data (AUC20) and a training dataset with the remaining 80 percent (AUC20 training). All sample data was incorporated in the second model run (AUC all training). The overall threshold accuracy score indicates the number of species' standard locations correctly predicted as suitable using the 50 percent threshold criterion divided by the total number of standard locations for the species.

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Trees							
Abies concolor	white fir	ABCO	632	0.972	0.979	0.978	0.877
Abies lasiocarpa	subalpine fir	ABLA	731	0.981	0.984	0.984	0.88
Acer glabrum	Rocky Mountain maple	ACGL	55	0.97	0.972	0.976	0.764
Acer grandidentatum	Bigtooth maple	ACGR3	123	0.989	0.995	0.995	0.911
Acer negundo	boxelder	ACNE2	122	0.944	0.99	0.987	0.902
Carnegiea gigantea	saguaro	CAGI10	539	0.987	0.99	0.99	0.911
Fraxinus velutina	velvet ash	FRVE2	59	0.949	0.989	0.987	0.814
Juglans major	New Mexico walnut	JUMA	105	0.971	0.993	0.993	0.867
Juniperus coahuilensis	redberry juniper	JUCO1 1	137	0.994	0.998	0.998	0.942
Juniperus deppeana	alligator juniper	JUDE2	1259	0.98	0.984	0.984	0.902
Juniperus monosperma	oneseed juniper	JUMO	1560	0.907	0.923	0.922	0.82
Juniperus osteosperma	Utah juniper	JUOS	5550	0.886	0.888	0.887	0.84
Juniperus scopulorum	Rocky mountain juniper	JUSC2	759	0.926	0.956	0.954	0.837
Olneya tesota	ironwood	OLTE	317	0.994	0.995	0.995	0.921
Parkinsonia florida	blue paloverde	PAFL6	175	0.987	0.992	0.992	0.931
Parkinsonia microphylla	littleleaf palo verde	PAMI5	639	0.986	0.99	0.99	0.911
Picea engelmannii	Engelmann spruce	PIEN	959	0.975	0.981	0.98	0.882
Picea pungens	blue spruce	PIPU	235	0.976	0.988	0.988	0.868
Pinus aristata	bristlecone pine	PIAR	64	0.988	0.997	0.997	0.906
Pinus contorta	lodgepole pine	PICO	344	0.98	0.992	0.991	0.927
Pinus edulis	Colorado pinyon	PIED	3827	0.91	0.919	0.917	0.852
Pinus flexilis	limber pine	PIFL2	255	0.957	0.986	0.985	0.894
Pinus monophylla	single-leaf juniper	PIMO	1765	0.948	0.96	0.959	0.901
Pinus ponderosa	ponderosa pine	PIPO	3920	0.966	0.968	0.968	0.916
Pinus strobiformis	southwestern white pine	PIST3	139	0.998	0.999	0.999	0.971
Populus angustifolia	narrowleaf cottonwood	POAN3	210	0.864	0.949	0.939	0.79
Populus tremuloides	quaking aspen	POTR5	2020	0.96	0.96	0.96	0.868

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Prosopis glandulosa	honey mesquite	PRGL2	1180	0.956	0.962	0.961	0.88
Prosopis velutina	velvet mesquite	PRVE	621	0.972	0.98	0.979	0.876
Pseudotsuga menziesii	douglas fir	PSME	1522	0.959	0.964	0.964	0.855
Quercus arizonica	Arizona white oak	QUAR	133	0.995	0.998	0.997	0.917
Quercus emoryi	emory oak	QUEM	289	0.993	0.995	0.995	0.952
Quercus gambelii	Gambel's oak	QUGA	2948	0.949	0.956	0.956	0.88
Quercus grisea	gray oak	QUGR3	301	0.982	0.992	0.991	0.877
Quercus havardii	shinnery oak (Havard)	QUHA3	86	0.982	0.986	0.995	0.965
Yucca brevifolia	Joshua tree	YUBR	470	0.977	0.989	0.988	0.913
Shrubs							
Acacia constricta	twinthorn acacia (white)	ACCO2	247	0.975	0.986	0.985	0.87
Acacia greggii	catclaw acacia	ACGR	684	0.968	0.981	0.979	0.858
Ambrosia deltoidea	triangle bursage	AMDE4	244	0.989	0.995	0.995	0.914
Ambrosia dumosa	white bursage	AMDU2	1970	0.974	0.976	0.976	0.916
Amelanchier alnifolia	Saskatoon serviceberry	AMAL2	499	0.966	0.978	0.977	0.852
Amelanchier utahensis	Utah serviceberry	AMUT	679	0.949	0.972	0.972	0.882
Arctostaphylos patula	greenleaf manzanita	ARPA6	142	0.968	0.991	0.99	0.887
Arctostaphylos pringlei	Pringle manzanita	ARPR	82	0.963	0.993	0.995	0.902
Arctostaphylos pungens	pointleaf manzanita	ARPU5	445	0.986	0.991	0.991	0.903
Arctostaphylos uva-ursi	bearberry manzanita	ARUV	67	0.963	0.975	0.977	0.821
Artemisia arbuscula	low sagebrush	ARAR8	670	0.932	0.955	0.954	0.818
Artemisia bigelovii	Bigelow's sagebrush	ARBI3	411	0.972	0.987	0.987	0.912
Artemisia filifolia	sand sagebrush	ARFI2	555	0.942	0.971	0.968	0.874
Artemisia frigida	fringed sagewort	ARFR4	363	0.949	0.973	0.971	0.835
Artemisia nova	black sagebrush	ARNO4	2036	0.931	0.943	0.942	0.855
Artemisia tridentata (shrub)	big sagebrush	ARTR2	10139	0.834	0.843	0.839	0.874
Atriplex canescens	fourwing saltbush	ATCA2	2253	0.894	0.909	0.908	0.807

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Atriplex confertifolia	shadscale saltbush	ATCO	3515	0.909	0.92	0.918	0.871
Atriplex corrugata	mat saltbush	ATCO4	175	0.98	0.993	0.994	0.954
Atriplex gardneri	Gardner's saltbush	ATGA	169	0.979	0.99	0.99	0.911
Atriplex hymenelytra	Yuma desert holly	ATHY	183	0.992	0.996	0.996	0.934
Atriplex obovata	mound saltbush	ATOB	325	0.991	0.996	0.996	0.954
Atriplex polycarpa	desert saltbush	ATPO	144	0.939	0.977	0.977	0.854
Baccharis sarothroides	desert broom	BASA2	69	0.92	0.968	0.963	0.739
Canotia holacantha	canotia	CAHO3	290	0.99	0.996	0.996	0.941
Ceanothus greggii	desert ceanothus	CEGR	322	0.989	0.992	0.992	0.898
Cercocarpus intricatus	littleleaf mountain mahogany	CEIN7	76	0.947	0.965	0.964	0.803
Cercocarpus ledifolius	curlleaf mountain mahogany	CELE3	422	0.966	0.979	0.978	0.858
Cercocarpus montanus	true mountain mahogany	CEMO2	1001	0.942	0.958	0.957	0.822
Chrysothamnus depressus	dwarf rabbitbrush	CHDE2	57	0.968	0.961	0.968	0.754
Chrysothamnus greenei	Greene rabbitbrush	CHGR6	1059	0.96	0.969	0.969	0.894
Chrysothamnus viscidiflorus	Douglas' rabbitbrush	CHVI8	2534	0.905	0.919	0.918	0.824
Coleogyne ramosissima	blackbrush	CORA	1529	0.973	0.975	0.975	0.915
Encelia farinosa	white brittlebush	ENFA	468	0.958	0.974	0.973	0.84
Ephedra nevadensis	Nevada mormon tea	EPNE	2078	0.958	0.969	0.968	0.892
Ephedra torreyana	Torrey mormon tea	EPTO	514	0.974	0.988	0.987	0.912
Ephedra trifurca	longleaf mormon tea	EPTR	164	0.932	0.99	0.986	0.915
Ephedra viridis	mormon-tea	EPVI	1816	0.921	0.937	0.935	0.845
Ericameria linearifolia	slimleaf goldenbush	ERLI6	70	0.992	0.996	0.995	0.886
Ericameria nauseosa	rubber rabbitbrush	CHNA2	267	0.945	0.977	0.974	0.843
Eriogonum fasciculatum	yellow buckwheat	ERFA2	560	0.982	0.983	0.983	0.886
Eriogonum wrightii	shrubby buckwheat	ERWR	93	0.968	0.978	0.992	0.925

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Fallugia paradoxa	Apache plume	FAPA	219	0.939	0.979	0.978	0.863
Flourensia cernua	American tarwort	FLCE	128	0.99	0.995	0.995	0.891
Fouquieria splendens	ocotillo	FOSP2	481	0.967	0.981	0.981	0.842
Garrya flavescens	yellowleaf silktassel	GAFL2	64	0.993	0.994	0.994	0.906
Garrya wrightii	Wright's silktassel	GAWR3	130	0.964	0.997	0.995	0.923
Grayia spinosa	spiny hopsage	GRSP	1268	0.946	0.959	0.958	0.834
Gutierrezia microcephala	threadleaf snakeweed	GUMI	334	0.948	0.968	0.968	0.859
Gutierrezia sarothrae	broom snakeweed	GUSA2	5052	0.828	0.837	0.836	0.782
Hymenoclea salsola	white burrobrush	HYSA	1232	0.957	0.972	0.97	0.878
Juniperus communis	common juniper	JUCO6	501	0.976	0.981	0.98	0.892
Krascheninnikovia lanata	winterfat	KRLA2	1919	0.899	0.918	0.917	0.818
Larrea tridentata	creosote bush	LATR2	2978	0.946	0.951	0.949	0.876
Lupinus argenteus	silvery lupine	LUAR3	146	0.998	0.998	0.998	0.966
Lycium andersonii	Anderson's wolfberry	LYAN	125	0.966	0.987	0.989	0.92
Lycium pallidum	pale wolfberry	LYPA	172	0.918	0.977	0.971	0.855
Mahonia repens	creeping barberry	MARE1 1	416	0.948	0.977	0.976	0.861
Menodora spinescens	spiny menodora	MESP2	220	0.978	0.994	0.993	0.918
Mimosa aculeaticarpa	mimosa	MIAC3	189	0.956	0.991	0.988	0.889
Opuntia basilaris	beavertail pricklypear	OPBA2	293	0.977	0.988	0.986	0.877
Opuntia engelmannii	cactus apple	OPEN3	205	0.966	0.99	0.99	0.917
Parthenium incanum	mariola	PAIN2	58	0.978	0.987	0.986	0.828
Paxistima myrsinites	Oregon boxleaf	PAMY	112	0.964	0.991	0.99	0.866
Picrothamnus desertorum	bud sagebrush	PIDE4	963	0.961	0.971	0.971	0.874
Prunus fasciculata	desert almond	PRFA	70	0.981	0.982	0.986	0.857
Prunus virginiana	chokecherry	PRVI	326	0.956	973	0.973	0.813
Purshia mexicana	Mexican cliffrose	PUME	391	0.98	0.983	0.983	0.88
Purshia stansburiana	stansbury cliffrose	PUST	469	0.939	0.971	0.967	0.866
Purshia tridentata	antelope bitterbrush	PUTR2	927	0.909	0.943	0.94	0.834

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Quercus turbinella	turbinella oak	QUTU2	1074	0.972	0.983	0.982	0.91
Rhus microphylla	littleleaf sumac	RHMI3	71	0.964	0.985	0.982	0.789
Rhus ovata	sugar sumac	RHOV	51	0.996	0.994	0.995	0.824
Rhus trilobata	skunkbush sumac	RHTR	582	0.924	0.955	0.951	0.816
Ribes cereum	wax currant	RICE	179	0.938	0.986	0.982	0.877
Ribes montigenum	gooseberry current	RIMO2	132	0.954	0.991	0.99	0.856
Robinia neomexicana	New Mexico locust	RONE	209	0.988	0.993	0.993	0.88
Rosa woodsii	Wood's rose	ROWO	489	0.938	0.947	0.949	0.796
Salazaria mexicana	Mexican bladdersage	SAME	348	0.986	0.99	0.989	0.879
Salix geyeriana	geyer willow	SAGE2	67	0.96	0.974	0.975	0.731
Sarcobatus vermiculatus	black greasewood	SAVE4	2131	0.92	0.932	0.93	0.841
Shepherdia canadensis	russet buffaloberry	SHCA	66	0.972	0.984	0.983	0.758
Simmondsia chinensis	jojoba	SICH	139	0.991	0.997	0.996	0.95
Suaeda moquinii	Torrey seepweed	SUMO	214	0.962	0.991	0.99	0.907
Symphoricarpos albus	common snowberry	SYAL	283	0.976	0.986	0.986	0.88
Symphoricarpos oreophilus	mountain snowberry	SYOR2	1218	0.964	0.971	0.97	0.876
Symphoricarpos rotundifolius	roundleaf snowberry	SYRO	207	0.993	0.993	0.993	0.908
Tetradymia glabrata	littleleaf horsebrush	TEGL	365	0.957	0.971	0.971	0.83
Tetradymia spinosa	shortspine horsebrush	TESP2	113	0.991	0.995	0.996	0.912
Vaccinium myrtillus	myrtle blueberry	VAMY2	125	0.989	0.989	0.99	0.872
Vaccinium scoparium	grouse whortleberry	VASC	101	0.992	0.996	0.997	0.941
Yucca angustissima	narrowleaf yucca	YUAN2	696	0.978	0.984	0.984	0.908
Yucca baccata	banana yucca	YUBA	1065	0.937	0.958	0.957	0.843
Yucca elata	soaptree yucca	YUEL	385	0.958	0.972	0.971	0.818
Yucca glauca	small soapweed	YUGL	356	0.943	0.966	0.964	0.787
Yucca schidigera	mojave yucca	YUSC2	223	0.988	0.993	0.993	0.901
Ziziphus obtusifolia	graythorn	ZIOB	69	0.977	0.993	0.991	0.812
Grasses							

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Achnatherum hymenoides	Indian ricegrass	ACHY	3384	0.87	0.884	0.881	0.796
Achnatherum speciosum	desert needlegrass	ACSP12	61	0.923	0.981	0.982	0.836
Achnatherum thurberianum	Thurber's needlegrass	ACTH7	66	0.988	0.975	0.978	0.727
Bouteloua curtipendula	sideoats grama	BOCU	844	0.944	0.95	0.95	0.78
Bouteloua eriopoda	black grama	BOER4	523	0.938	0.955	0.955	0.849
Bouteloua gracilis	blue grama	BOGR2	4538	0.899	0.902	0.901	0.838
Bouteloua hirsuta	hairy grama	BOHI2	187	0.963	0.976	0.976	0.834
Dasyochloa pulchella	fluffgrass	DAPU7	133	0.956	0.987	0.987	0.895
Elymus elymoides	bottlebrush squirreltail	ELEL5	1592	0.879	0.904	0.902	0.788
Elymus glaucus	blue wildrye	ELGL	143	0.996	0.993	0.994	0.895
Elymus trachycaulus	slender wild rye	ELTR7	234	0.855	0.946	0.942	0.799
Festuca arizonica	Arizona fescue	FEAR2	604	0.983	0.991	0.99	0.925
Festuca brachyphylla	alpine fescue	FEBR	130	0.992	0.994	0.995	0.938
Festuca idahoensis	Idaho fescue	FEID	130	0.965	0.989	0.989	0.892
Festuca thurberi	Thurber's fescue	FETH	80	0.966	0.989	0.995	0.9
Hesperostipa comata	hesperostipa	HECO26	1074	0.882	0.917	0.914	0.811
Hilaria belangeri	curley mesquite	HIBE	70	0.992	0.994	0.994	0.871
Hordeum jubatum	foxtail barley	HOJU	217	0.919	0.966	0.963	0.82
Koeleria macrantha	prairie junegrass	KOMA	491	0.972	0.98	0.981	0.884
Leymus cinereus	basin wildrye	LECI4	386	0.924	0.957	0.955	0.803
Muhlenbergia emersleyi	bullgrass	MUEM	58	0.988	0.992	0.992	0.828
Muhlenbergia montana	mountain muhly	MUMO	447	0.967	0.989	0.986	0.864
Muhlenbergia porteri	bush muhly	MUPO2	195	0.939	0.984	0.98	0.862
Pascopyrum smithii	western wheatgrass	PASM	602	0.923	0.941	0.941	0.787
Pleuraphis jamesii	galleta	PLJA	3165	0.909	0.918	0.917	0.841
Pleuraphis mutica	tobosa	PLMU3	436	0.961	0.977	0.976	0.826
Pleuraphis rigida	big galleta	PLRI3	307	0.965	0.981	0.981	0.86
Poa fendleriana	muttongrass	POFE	1370	0.974	0.984	0.983	0.924
Poa secunda	big bluegrass	POSE	1757	0.924	0.938	0.937	0.837
Schizachyrium scoparium	little bluestem	SCSC	70	0.95	0.946	0.954	0.743

Species	common_name	USDA PLANTS code	# of occurrence points	AUC 20% test	AUC 20% training	AUC all training	Overall threshold accuracy
Sporobolus airoides	alkali sacaton	SPAI	798	0.958	0.975	0.975	0.876
Sporobolus cryptandrus	sand dropseed	SPCR	641	0.861	0.927	0.921	0.799
Sporobolus flexuosus	mesa dropseed	SPFL2	104	0.981	0.985	0.99	0.904

Table 2. Suitable habitat predictions for the study plant species (n=166) showing the predicted modern-day proportion of the study area (S) and the percent of the modern-day suitable habitat (SH) predicted in the future to be decreasing suitability (DS), increasing suitability (IS), and maintained suitability (MS). The future SH predictions were based on climate models based on 2007 IPPC emission scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100) as compiled by the Climate Wizard collaboration.

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Trees								
Abies concolor	SH	5.2						
	DS		69.5	78.3	74.3	68	69.9	82.1
	IS		20.7	19.5	27	38.6	21.9	31.1
	MS		30.5	21.7	25.7	32	30.1	17.9
Abies lasiocarpa	SH	3.9						
	DS		49.5	53.9	48.3	51.7	44	59.1
	IS		30	24.3	27.8	25.9	37.2	21.6
	MS		50.5	46.1	51.7	48.3	56	40.9
Acer glabrum	SH	2.2						
	DS		34.8	37.5	40.7	45.9	33.1	45.7
	IS		137.5	169.9	157.9	168.4	168.9	222.8
	MS		65.2	62.5	59.3	54.1	66.9	54.3
Acer grandidentatum	SH	1.3						
	DS		53.2	51	50.2	49.7	50.7	55.4
	IS		83.4	100.1	100.4	140.3	99.7	170.9
	MS		46.8	49	49.8	50.3	49.3	44.6
Acer negundo	SH	3.1						
	DS		64.5	77.7	73.7	71.5	70.1	70.1
	IS		109	109.7	117.8	176.7	147.2	215.5
	MS		35.5	22.3	26.3	28.5	29.9	29.9
Carnegiea gigantea	SH	2.5						
	DS		67.2	74.9	77.1	40.2	21.6	76.4
	IS		23.2	49.9	33.5	70.2	116.5	32.9
	MS		32.8	25.1	22.9	59.8	78.4	23.6
Fraxinus velutina	SH	1.7						
	DS		80.8	91	98.1	90.3	79	89.2
	IS		32.1	28.1	19.8	67.4	62.9	60.1
	MS		19.2	9	1.9	9.7	21	10.8
Juglans major	SH	2.3						
	DS		84.7	93.3	92.1	90.7	83.1	78.9
	IS		32.4	19.9	14.9	53.9	29.3	95.4
	MS		15.3	6.7	7.9	9.3	16.9	21.1
Juniperus coahuilensis	SH	1						
	DS		78.1	78.1	77	67.1	36.2	65.5
	IS		36.8	50.1	72	121.7	197.2	342.6
	MS		21.9	21.9	23	32.9	63.8	34.5

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Juniperus deppeana	SH	4						
	DS		48.7	63.4	64.5	66	56.1	71.2
	IS		21.8	17	20.3	30.4	22	29
	MS		51.3	36.6	35.5	34	43.9	28.8
Juniperus monosperma	SH	15.1						
	DS		39.8	63.5	65.9	65.7	63.4	84
	IS		27	27.7	29	29.8	20.4	30.7
	MS		60.2	36.5	34.1	34.3	36.6	16
Juniperus osteosperma	SH	22.2						
	DS		52.3	53.9	52.7	45.9	50.2	63.1
	IS		19	19.5	27.1	34.3	20.4	26.9
	MS		47.7	46.1	47.3	54.1	49.8	36.9
Juniperus scopulorum	SH	9.9						
	DS		57.8	65.3	74.9	73.4	73.9	82.3
	IS		39.4	45	31.2	45.9	29	38.8
	MS		42.2	34.7	25.1	26.6	26.1	17.7
Olneya tesota	SH	1.7						
	DS		55.9	41.4	44.4	45.3	34.3	38.9
	IS		43.9	89.4	86	71.3	122.9	113.5
	MS		44.1	58.6	55.6	54.7	65.7	61.1
Parkinsonia florida	SH	2.8						
	DS		69	62.3	77.4	74	33.7	81.9
	IS		124.8	256.6	163.4	131.2	204.5	167.7
	MS		31	37.7	22.6	26	66.3	18.1
Parkinsonia microphylla	SH	2.7						
	DS		43.3	50.2	49.6	35.4	24.9	49.5
	IS		30.5	50.7	49.7	97.6	102.7	79
	MS		56.7	49.8	50.4	64.6	75.1	50.5
Picea engelmannii	SH	5.1						
	DS		46.9	53.7	54.3	60.2	48.3	67.7
	IS		18.7	14.5	13.7	12.7	17.2	10.4
	MS		53.1	46.3	45.7	39.8	51.7	32.3
Picea pungens	SH	2.9						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	DS		60.2	72.3	70.8	76.2	64.1	79.9
	IS		95.4	78.5	77.8	70.1	94.3	87.5
	MS		39.8	27.7	29.2	23.8	35.9	20.1
Pinus aristata	SH	1						
	DS		55	80	87	84.3	87.7	98
	IS		73.1	51.5	29	59.6	15.9	12.5
	MS		45	20	13	15.7	12.3	2
Pinus contorta	SH	2.5						
	DS		44.9	52.4	53.5	79.3	42.7	88.1
	IS		44.2	38.3	41.3	20.4	53.6	13.8
	MS		55.1	47.6	46.5	20.7	57.3	11.9
Pinus edulis	SH	17.1						
	DS		47.1	58.9	59.8	63.7	63.5	78.2
	IS		26.3	37.2	30.2	45.2	22.9	39.7
	MS		52.9	41.1	40.2	36.3	36.5	21.8
Pinus flexilis	SH	4.1						
	DS		86.4	95.8	94.5	95.7	95.9	98.7
	IS		20.4	8.8	11.1	19.2	5.1	6.5
	MS		13.6	4.2	5.5	4.3	4.1	1.3
Pinus monophylla	SH	10						
	DS		78.4	87.9	79	87.9	78.9	97.1
	IS		7.8	4.4	13.7	13.1	15.1	5.4
	MS		21.6	12.1	21	12.1	21.1	2.9
Pinus ponderosa	SH	9.7						
	DS		60.7	76	79.4	82.5	71.5	88.4
	IS		15.5	21.5	16.4	26.7	15.1	25.7
	MS		39.3	24	20.6	17.5	28.5	11.6
Pinus strobiformis	SH	0.3						
	DS		68.6	80	94.1	94.7	67.3	90.7
	IS		19.6	7.6	17.3	2.6	18.7	14.5
	MS		31.4	20	5.9	5.3	32.7	9.3
Populus angustifolia	SH	9.8						
	DS		59.9	69.9	76.8	84.2	75	90.5
	IS		43.9	44.8	34.3	35	35.5	38.2
	MS		40.1	30.1	23.2	15.8	25	9.5
Populus tremuloides	SH	8.7						
	DS		45	57.9	57	66.2	51.7	73.7

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	IS		30.5	24.7	26.4	25.3	30.1	24.3
	MS		55	42.1	43	33.8	48.3	26.3
Prosopis glandulosa	SH	8.8						
	DS		9.2	25.5	35.4	49.6	37.8	66.2
	IS		100.8	137.7	103.6	126.6	59.3	172.3
	MS		90.8	74.5	64.6	50.4	62.2	33.8
Prosopis velutina	SH	4.7						
	DS		23.3	33	33.8	15.7	9.6	25.8
	IS		94.2	93.6	98.3	140.4	127.5	158.9
	MS		76.7	67	66.2	84.3	90.4	74.2
Pseudotsuga menziesii	SH	8.6						
	DS		46.8	57.8	60	62.3	57	69.6
	IS		30	30.3	29.9	35.9	31.3	39.7
	MS		53.2	42.2	40	37.7	43	30.4
Quercus arizonica	SH	1						
	DS		86	84.4	92.1	81.7	79.5	85.5
	IS		52.6	64.4	31.6	91	80.1	77.9
	MS		14	15.6	7.9	18.3	20.5	14.5
Quercus emoryi	SH	2.1						
	DS		69.6	80.1	69.3	75.6	63.1	78.4
	IS		29.4	33.6	59.4	79.1	58.3	69.4
	MS		30.4	19.9	30.7	24.4	36.9	21.6
Quercus gambelii	SH	10.5						
	DS		45.2	57.7	61.8	67.9	56.5	73.7
	IS		43.1	47.5	43.8	52.6	42.2	54.4
	MS		54.8	42.3	38.2	32.1	43.5	26.3
Quercus grisea	SH	2.4						
	DS		65.3	93.4	94.5	90.9	87	85.9
	IS		54	26.2	18.1	23.3	36.5	45.1
	MS		34.7	6.6	5.5	9.1	13	14.1
Quercus havardii	SH	1.8						
	DS		67.1	67.8	74.2	97.4	80.4	94.5
	IS		154.2	185.1	110.2	23.2	67.7	55.2
	MS		32.9	32.2	25.8	2.6	19.6	5.5
Yucca brevifolia	SH	3.9						
	DS		72.3	88.6	75	84.8	60.1	94.9
	IS		46.3	31.1	99.3	139.9	108.1	53.4

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		27.7	11.4	25	15.2	39.9	5.1
Shrubs								
Acacia constricta	SH	3.4						
	DS		65.2	76.4	74.2	80.1	61	94
	IS		50.6	54.8	83.5	81.7	73.5	88.5
	MS		34.8	23.6	25.8	19.9	39	6
Acacia greggii	SH	4.4						
	DS		49.4	68.2	57.2	80.1	45.5	86.3
	IS		91.3	95.4	119	119.9	116.5	100
	MS		50.6	31.8	42.8	19.9	54.5	13.7
Ambrosia deltoidea	SH	1.9						
	DS		75.6	83.7	89.8	64.8	88.3	96.5
	IS		42.6	48.9	28.4	26.5	12.2	9.2
	MS		24.4	16.3	10.2	35.2	11.7	3.5
Ambrosia dumosa	SH	7.3						
	DS		73.2	62.8	50.5	64.5	54.1	79.8
	IS		17.5	26.6	45.2	68.8	49.3	22
	MS		26.8	37.2	49.5	35.5	45.9	20.2
Amelanchier alnifolia	SH	4.6						
	DS		34.4	33.3	49.1	54.1	43.3	51.7
	IS		58.7	75	49.6	65	61.8	91.9
	MS		65.6	66.7	50.9	45.9	56.7	48
Amelanchier utahensis	SH	7.8						
	DS		58.7	56.9	59.6	58.3	59.4	64
	IS		36	45	45.6	51.4	42.9	52.8
	MS		41.3	43.1	40.4	41.7	40.6	36
Arctostaphylos patula	SH	2.6						
	DS		82.3	88.1	71.1	61.5	75.5	76.1
	IS		14.9	11.3	60.6	123.8	32.4	61.5
	MS		17.7	11.9	28.9	38.5	24.5	23.9
Arctostaphylos pringlei	SH	1.2						
	DS		73.1	94.7	89.5	81.4	91.2	99.9
	IS		32.2	18.7	30.2	85.5	17.5	9.5
	MS		26.9	5.3	10.5	18.6	8.8	0.1

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Arctostaphylos pungens	SH	2.8						
	DS		58.6	85.9	65.4	64.8	71.7	94.7
	IS		28.9	17.1	62	69.3	22.1	16.6
	MS		41.4	14.1	34.6	35.2	28.3	5.3
Arctostaphylos uva-ursi	SH	3						
	DS		54.4	70.3	74	72.6	77.4	87.7
	IS		110.2	87.4	78.2	68.2	68.5	32
	MS		45.6	29.7	26	27.4	22.6	12.3
Artemisia arbuscula	SH	8.3						
	DS		76.2	83.5	85	94.7	86.3	97.8
	IS		11.5	4.6	6.9	1	6.4	0.1
	MS		23.8	16.5	15	5.3	13.7	2.2
Artemisia bigelovii	SH	4.5						
	DS		52	68.5	70.7	84.4	59.4	85.7
	IS		67.4	58	43.9	54.2	46.5	41
	MS		48	31.5	29.3	15.6	40.6	14.3
Artemisia filifolia	SH	7.6	0	0	0	0	0	0
	DS		39.8	55.1	67.6	82.9	57.3	85.9
	IS		134.1	143.5	116.7	133.8	101.7	146.3
	MS		60.2	44.9	32.4	17.1	42.7	14.1
Artemisia frigida	SH	5.5						
	DS		49.5	56.3	62.9	56.9	65	74.7
	IS		48.5	39.3	33.1	57.1	28.9	32.6
	MS		50.5	43.7	37.1	43.1	35	25.3
Artemisia nova	SH	11.5						
	DS		59.6	71.8	60.6	72	55.6	80.2
	IS		19.7	15.7	26.4	26.1	34.8	25.9
	MS		40.4	28.2	39.4	28	44.4	19.8
Artemisia tridentata	SH	31.5						
	DS		47.5	52.6	52.4	61.1	45.9	63.1
	IS		7.6	6.3	9.9	6.4	11	7.3
	MS		52.5	47.4	47.6	38.9	54.1	36.9
Atriplex canescens	SH	17						
	DS		30	40.4	38.8	50.2	28.7	66.6
	IS		64.6	65	81.4	95.4	64.3	87.5

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		70	59.6	61.2	49.8	71.3	33.4
Atriplex confertifolia	SH	17.7						
	DS		39.2	49.8	52.7	61.1	50.6	70.9
	IS		36	31	26	18.3	29.8	20
	MS		60.8	50.2	47.3	38.9	49.4	29.1
Atriplex corrugata	SH	2.2						
	DS		79.6	78.4	83.8	83	83.3	87.9
	IS		30.3	27.6	26.1	16.5	29.8	12
	MS		20.4	21.6	16.2	17	16.7	12.1
Atriplex gardneri	SH	2.8						
	DS		70.5	75.4	74.8	76.1	74.2	77.7
	IS		25.3	20.2	31.7	25.1	17.7	17.9
	MS		29.5	24.6	25.2	23.9	25.8	22.3
Atriplex hymenelytra	SH	1.6						
	DS		66	73.9	86.6	91.1	82.2	97.8
	IS		24.7	58.4	14	47.5	13.3	23.7
	MS		34	26.1	13.4	8.9	17.8	2.2
Atriplex obovata	SH	2.5						
	DS		19.9	38.9	36.9	67.2	24.6	43.3
	IS		223.7	246.9	220	177.3	220.7	372.9
	MS		80.1	61.1	63.1	32.8	75.4	56.7
Atriplex polycarpa	SH	4.4						
	DS		68.5	63.3	65.2	68.8	69.6	83.2
	IS		26.6	47.3	60.3	75.1	34.6	34.5
	MS		31.5	36.7	34.8	31.2	30.4	16.8
Baccharis sarothroides	SH	3						
	DS		61.8	75.4	75.3	43.8	62.6	84.2
	IS		39.6	22.9	34.1	224.1	40.5	77.4
	MS		38.2	24.6	24.7	56.2	37.4	15.8
Canotia holacantha	SH	1.7						
	DS		77.8	98.9	89.9	99.1	77.9	99.7
	IS		30.1	13.6	49.9	68	56.3	56.5
	MS		22.2	1.1	10.1	0.9	22.1	0.3
Ceanothus greggii	SH	2.2						
	DS		91.7	98.6	95.3	96.4	94.6	99.7
	IS		13	3.6	9.7	18	13.7	4.4

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		8.3	1.4	4.7	3.6	5.4	0.3
Cercocarpus intricatus	SH	5.6						
	DS		89.6	84.1	98.3	94.1	97	98.9
	IS		12.2	22.1	6.9	27.5	4.5	5
	MS		10.4	15.9	1.6	5.9	3	1.1
Cercocarpus ledifolius	SH	4.1						
	DS		77.5	87.7	78.8	87.4	76.3	90
	IS		15.2	6.6	15.8	11.9	16.3	7.2
	MS		22.5	12.3	21.2	12.6	23.7	10
Cercocarpus montanus	SH	9.4						
	DS		52.5	64.1	72.7	71.6	75.6	77.3
	IS		74.1	69.6	60.1	85.6	51.5	75.9
	MS		47.5	35.9	27.3	28.4	24.4	22.7
Chrysothamnus depressus	SH	4.3						
	DS		94.4	97.1	85.7	75.7	91.9	92.8
	IS		18.9	23.2	43.5	51.2	20.5	32.1
	MS		5.6	2.9	14.3	24.3	8.1	7.2
Chrysothamnus greenei	SH	7.2						
	DS		75.7	86.3	79.3	92.8	77	95.7
	IS		42.2	50.4	55.9	56.7	28.9	32.8
	MS		24.3	13.7	20.7	7.2	23	4.3
Chrysothamnus viscidiflorus	SH	15.3						
	DS		68.8	84.2	73.9	94.6	73.3	99.1
	IS		9	4	6.9	2.2	7.8	1.4
	MS		31.2	15.8	26.1	5.4	26.7	0.9
Coleogyne ramosissima	SH	6.7						
	DS		57.6	73	76	89.1	64.2	98.4
	IS		71.6	81.8	92.6	94.9	77.5	59.2
	MS		42.4	27	24	10.9	35.8	1.6
Encelia farinosa	SH	5.6						
	DS		69.4	85.4	84.5	89.5	80.4	99
	IS		29.7	23.6	20.2	24.7	24.1	6.3

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		30.6	14.6	15.5	10.5	19.6	1
Ephedra nevadensis	SH	7.9						
	DS		63.9	83	66.7	55.5	46.2	72.7
	IS		39.9	31.9	84.5	99	71.7	80.8
	MS		36.1	17	33.3	44.5	53.8	27.3
Ephedra torreyana	SH	4						
	DS		24.7	34.6	37.6	68.5	36.3	45.7
	IS		99.6	150.9	114.1	114.7	106.6	134.8
	MS		75.3	65.4	62.4	31.5	63.7	54.3
Ephedra trifurca	SH	3.5						
	DS		39.7	32.5	49.6	68.3	26	71.3
	IS		64	101.3	90.2	73.2	148.5	189.4
	MS		60.3	67.5	50.4	31.7	74	28.7
Ephedra viridis	SH	13.3						
	DS		54.9	60.4	57.2	50.1	44.9	81
	IS		25.8	35.3	47.4	70.1	36.8	34.4
	MS		45.1	39.6	42.8	49.9	55.1	19
Ericameria linearifolia	SH	1.1						
	DS		90.2	96.5	91.3	99.8	89.3	100
	IS		36.7	26.5	57.8	4.2	57.7	3.8
	MS		9.8	3.5	8.7	0.2	10.7	0
Ericameria nauseosa	SH	5.1						
	DS		70.4	79.5	82.7	84.7	80.6	88.6
	IS		28	30.5	22.3	24.5	19.3	18.2
	MS		29.6	20.5	17.3	15.3	19.4	11.4
Eriogonum fasciculatum	SH	4.4						
	DS		96.1	97.7	97.3	94	81.6	99
	IS		5.2	4	7.6	47.2	53.5	8.1
	MS		3.9	2.3	2.7	6	18.4	1
Eriogonum wrightii	SH	2.6						
	DS		87.3	97.7	86.6	44.6	41.5	82.6
	IS		23.6	23.8	51.2	198	114.4	117.7
	MS		12.7	2.3	13.4	55.4	58.5	17.4
Fallugia paradoxa	SH	4						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	DS		43.7	59.9	53.9	63.5	63.4	83
	IS		90.5	73.8	100.8	99.1	27.1	66.9
	MS		56.3	40.1	46.1	36.5	36.6	17
Flourensia cernua	SH	1.8						
	DS		82.3	81.9	91.4	89.1	97.8	94.3
	IS		75.6	137.2	66.7	141.9	21.4	47.8
	MS		17.7	18.1	8.6	10.9	2.2	5.7
Fouquieria splendens	SH	4.3						
	DS		35.4	33.8	39.2	32.4	20.1	51.5
	IS		80.3	145.9	126.2	145.2	152.1	167.5
	MS		64.6	66.2	60.8	67.6	79.9	48.5
Garrya flavescens	SH	1.3						
	DS		98.4	97.4	87.2	69.7	86.7	97.7
	IS		4.8	7.1	22.8	92.9	15.1	16.1
	MS		1.6	2.6	12.8	30.3	13.3	2.3
Garrya wrightii	SH	1.4						
	DS		71.8	91.8	85.7	81.7	79.4	87.3
	IS		29.7	21.6	23.2	54	26.2	50.1
	MS		28.2	8.2	14.3	18.3	20.6	12.7
Grayia spinosa	SH	9						
	DS		78.4	86.2	72.9	61.2	66.1	80
	IS		20.8	16.4	52.1	71.8	58.3	24.7
	MS		21.6	13.8	27.1	38.8	33.9	20
Gutierrezia microcephala	SH	7.2						
	DS		71.8	79.1	77.4	75.7	70.6	84.3
	IS		28.4	44	29.6	70.6	38.7	81
	MS		28.2	20.9	22.6	24.3	29.4	15.7
Gutierrezia sarothrae	SH	28.3						
	DS		40	45.6	45.1	61	46.1	70.7
	IS		27.1	30.7	36.3	41.3	26.9	37.5
	MS		60	54.4	54.9	39	53.9	29.3
Hymenoclea salsola	SH	7.3						
	DS		86	90	84.4	78.2	76.4	94.8
	IS		17.3	13.4	34.7	87.5	50.3	46.1
	MS		14	10	15.6	21.8	23.6	5.2
Juniperus	SH	5.3						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
communis								
	DS		41.4	50.4	49.3	52.8	48	79.9
	IS		36.5	29.7	32.8	35.5	32.6	17.1
	MS		58.6	49.6	50.7	47.2	52	20.1
Krascheninnikovia lanata	SH	16.4						
	DS		73	82.9	67.4	62	65.1	81.4
	IS		29.6	15.3	35.9	40.3	34.8	20
	MS		27	17.1	32.6	38	34.9	18.6
Larrea tridentata	SH	12.9						
	DS		32.3	38.7	42.4	60.6	44.8	73.4
	IS		72.3	96.5	110.2	146.9	84.7	124.7
	MS		67.7	61.3	57.6	39.4	55.2	26.6
Lupinus argenteus	SH	0.7						
	DS		56.7	82.8	70.8	96.9	46.2	98.6
	IS		100.5	24.3	106.7	117.3	17.1	53.6
	MS		43.3	17.2	29.2	3.1	53.8	1.4
Lycium andersonii	SH	2.2						
	DS		73.7	75.1	80.3	72.7	83.4	73.1
	IS		161.5	181.3	190.2	159.8	92.9	179.1
	MS		26.3	24.9	19.7	27.3	16.6	26.9
Lycium pallidum	SH	5.6						
	DS		97.2	99.6	99.7	92.2	97.2	100
	IS		18.5	10.2	8.4	44.8	9.4	2.7
	MS		2.8	0.4	0.3	7.8	2.8	0
Mahonia repens	SH	6						
	DS		40	51.3	51.1	58.1	54.5	67.8
	IS		68.8	62.9	65.1	68.1	63.8	65.5
	MS		60	48.7	48.9	41.9	45.5	32.2
Menodora spinescens	SH	2.1						
	DS		98	97.7	97.1	97.8	99.1	99.1
	IS		59	46.9	56.1	47.7	44.1	27.7
	MS		2	2.3	2.9	2.2	0.9	0.9
Mimosa aculeaticarpa	SH	3.2						
	DS		63.2	81.2	81.1	80.5	64.9	89.9
	IS		35.7	33.3	27.8	55.9	55.8	50

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		36.8	18.8	18.9	19.5	35.1	10.1
Opuntia basilaris	SH	3.7						
	DS		87.9	86.9	93.1	93.3	94.7	99.5
	IS		14	8.1	10.5	10.4	19.5	3.1
	MS		12.1	13.1	6.9	6.7	5.3	0.5
Opuntia engelmannii	SH	2.9						
	DS		69.5	80.9	74.7	85.5	63.6	84.6
	IS		15.8	13.7	32.6	24.8	51	72.7
	MS		30.5	19.1	25.3	14.5	36.4	15.4
Parthenium incanum	SH	2.7						
	DS		29.4	65.4	70.7	74.7	80.6	97.7
	IS		195.3	224.6	176.2	170.5	76	38.5
	MS		70.6	34.6	29.3	25.3	19.4	2.3
Paxistima myrsinites	SH	2.6						
	DS		51.9	48.8	56.8	44.9	53.7	34.6
	IS		66.1	84.5	60.2	103.7	78.4	153.6
	MS		48.1	51.2	43.2	55.1	46.3	65.4
Picrothamnus desertorum	SH	6.8						
	DS		78.8	96.1	90.5	98.4	96	100
	IS		25.8	7.6	21.8	1	7.7	0
	MS		21.2	3.9	9.5	1.6	4	0
Prunus fasciculata	SH	2						
	DS		85.1	94.7	85.2	91.2	77.2	100
	IS		11.9	3.5	12.4	109.2	29.1	52.8
	MS		14.9	5.3	14.8	8.8	22.8	0
Prunus virginiana	SH	4.7						
	DS		40.8	48.2	54.3	60.9	43.2	61.6
	IS		63.6	63.8	56.7	63.6	64.4	67
	MS		59.2	51.8	45.7	39.1	56.8	38.4
Purshia mexicana	SH	4.4						
	DS		54.3	74.6	51.8	46.3	66.1	86.5
	IS		37.9	35.8	96.9	129.5	28	53.6
	MS		45.7	25.4	48.2	53.7	33.9	13.5
Purshia stansburiana	SH	7.8						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	DS		76.3	74	87.3	66.7	76.2	80.8
	IS		37.1	48.4	45.7	87.5	35.7	72.9
	MS		23.7	26	12.7	33.3	23.8	19.2
Purshia tridentata	SH	11.2						
	DS		52.9	67.3	57.7	76.6	56.6	84.3
	IS		42.7	34.6	48.8	41.7	45.7	36.7
	MS		47.1	32.7	42.3	23.4	43.4	15.7
Quercus turbinella	SH	5.3						
	DS		52.8	79.1	88.7	79.2	71.5	92.6
	IS		41.2	34.5	23.9	43.6	36.1	35.6
	MS		47.2	20.9	11.3	20.8	28.5	7.4
Rhus microphylla	SH	2.6						
	DS		55.4	63.2	82.3	72.8	91.3	96.6
	IS		82.3	78.9	50.9	82.7	23.6	28.5
	MS		44.6	36.8	17.7	27.2	8.7	3.4
Rhus ovata	SH	1						
	DS		99.2	99.4	100	100	99.4	100
	IS		6.1	1.6	0.1	0.1	7	0.1
	MS		0.8	0.6	0	0	0.6	0
Rhus trilobata	SH	8.4						
	DS		53.1	76.7	83.4	64.4	73.3	80
	IS		33	25.2	25.1	52.3	26.4	37
	MS		46.9	23.3	16.6	35.6	26.7	20
Ribes cereum	SH	5.1						
	DS		54.7	66.5	67.6	62.7	73.4	77.9
	IS		58.5	46.7	48.4	65.3	30.9	54
	MS		45.3	33.5	32.4	37.3	26.6	22.1
Ribes montigenum	SH	2.3						
	DS		78.2	83.4	72.7	89.7	58.1	90.5
	IS		22	13.3	25.5	10.3	46.6	7.8
	MS		21.8	16.6	27.3	10.3	41.9	9.5
Robinia neomexicana	SH	1.9						
	DS		71.1	93.8	72	59.7	70.4	96.1
	IS		13.8	10.6	21.8	43.1	23.1	24.6
	MS		28.9	6.2	28	40.3	29.6	3.9
Rosa woodsii	SH	9.6						
	DS		72.4	81.2	81.2	85.2	89.6	92.7

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	IS		37.4	27.7	29.9	26.8	15.7	17.2
	MS		27.6	18.8	18.8	14.8	10.4	7.3
Salazaria mexicana	SH	2.8						
	DS		92.5	92.7	91.8	92	80.3	96
	IS		11.1	11.9	20	40.9	84.5	13.6
	MS		7.5	7.3	8.2	8	19.7	4
Salix geyeriana	SH	2.5						
	DS		44.3	46.1	84	98.2	89.9	99.2
	IS		106.3	72.6	70.5	30.3	61.3	38.2
	MS		55.7	53.9	16	1.8	10.1	0.8
Sarcobatus vermiculatus	SH	14.2						
	DS		41.9	68.7	71.1	75.9	67.7	85.3
	IS		50.2	26.8	24.2	22.5	22.3	17.2
	MS		58.1	31.3	28.9	24.1	32.3	14.7
Shepherdia canadensis	SH	2.2						
	DS		16.6	25.7	22	34.1	25.9	43.6
	IS		156.1	121.1	137.4	100.6	142.6	92.6
	MS		83.4	74.3	78	65.9	74.1	56.4
Simmondsia chinensis	SH	1.3						
	DS		46.6	42.8	25.7	52	18.3	59.8
	IS		87.2	266.5	202.5	233.2	410.3	193.5
	MS		53.4	57.2	74.3	48	81.7	40.2
Suaeda moquinii	SH	2.1						
	DS		34.8	38.7	40.7	52.6	39.4	63.2
	IS		176.5	164.6	114.3	102.5	153.6	111.9
	MS		65.2	61.3	59.3	47.4	60.6	36.8
Symphoricarpos albus	SH	3						
	DS		55.3	62.4	76.9	86.5	80.9	91.3
	IS		84.6	74.1	52.7	67.5	43.5	50.1
	MS		44.7	37.6	23.1	13.5	19.1	8.7
Symphoricarpos oreophilus	SH	6.6						
	DS		59	66.6	66	80.9	67.2	84.7
	IS		23.2	14.5	27.1	23.1	21.6	20.5

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	MS		41	33.4	34	19.1	32.8	15.3
Symphoricarpos rotundifolius	SH	2.1						
	DS		71.6	54.6	71.9	84.2	62	77.7
	IS		58.9	109.5	76.3	67.7	102.8	103.2
	MS		28.4	45.4	28.1	15.8	38	22.3
Tetradymia glabrata	SH	5.9						
	DS		85.6	93.2	93.7	98.1	93.8	99.9
	IS		40.4	53.9	52.5	33.2	39.2	3
	MS		14.4	6.8	6.3	1.9	6.2	0.1
Tetradymia spinosa	SH	0.9						
	DS		74.3	86.2	86.8	87.6	51.4	98.5
	IS		10.8	12.1	19.8	10	57.5	8.2
	MS		25.7	13.8	13.2	12.4	48.6	1.5
Vaccinium myrtillus	SH	1.9						
	DS		55.7	62.9	74.6	81.6	63.4	90.7
	IS		59.7	48.7	36.4	34.8	56.6	17.1
	MS		44.3	37.1	25.4	18.4	36.6	9.3
Vaccinium scoparium	SH	1.1						
	DS		58.5	57.5	67.2	88.8	62	88.5
	IS		39	60.6	33.5	6.9	53.5	6.6
	MS		41.5	42.5	32.8	11.2	38	11.5
Yucca angustissima	SH	5						
	DS		45.2	65	71.2	85.4	83	94.3
	IS		64.9	76.1	43.3	41	12.4	17.9
	MS		54.8	35	28.8	14.6	17	5.7
Yucca baccata	SH	9.4						
	DS		46.5	53.7	54.6	65.3	48.7	74
	IS		35.1	46.4	58.2	88.1	42.8	80.6
	MS		53.5	46.3	45.4	34.7	51.3	26
Yucca elata	SH	6						
	DS		54.9	57.3	59.6	87.6	48.2	67.4
	IS		27	38	58	79.1	100.4	146.9
	MS		45.1	42.7	40.4	12.4	51.8	32.6
Yucca glauca	SH	6.2						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	DS		63.7	81.7	61.7	78.7	54.3	57.8
	IS		12.9	12.7	19.9	13.5	30.8	23.8
	MS		36.3	18.3	38.3	21.3	45.7	42.2
Yucca schidigera	SH	2						
	DS		99.5	100	98.9	99.6	96	100
	IS		0.1	1.7	6.2	8.8	32.8	10.3
	MS		0.5	0	1.1	0.4	4	0
Ziziphus obtusifolia	SH	1.4						
	DS		54.8	75.6	73.9	64.5	17.1	64.3
	IS		83.6	89.9	117.8	492.8	329.7	623
	MS		45.2	24.4	26.1	35.5	82.9	35.7
Grasses								
Achnatherum hymenoides	SH	21.6						
	DS		50.8	59.6	54.4	60	45.7	72
	IS		16.2	16.9	21.7	27.8	18.3	20.6
	MS		49.2	40.4	45.6	40	54.3	28
Achnatherum speciosum	SH	3.3						
	DS		80.8	83.1	81.8	89.4	92.3	97.1
	IS		14.3	13.4	18.3	2.8	7.6	2
	MS		19.2	16.9	18.2	10.6	7.7	2.9
Achnatherum thurberianum	SH	2.7						
	DS		71.3	92.1	88.8	100	85.1	100
	IS		15.9	6.9	12.6	3.2	7	0
	MS		28.7	7.9	11.2	0	14.9	0
Bouteloua curtipendula	SH	8.3						
	DS		62.7	73.4	71	74	69.1	82
	IS		29.3	31	29.9	54.5	24	49.4
	MS		37.3	26.6	29	26	30.9	18
Bouteloua eriopoda	SH	9.8						
	DS		60.1	70.4	73.6	80.2	77	93.6
	IS		82.8	116	110.9	118.9	72.2	76.8
	MS		39.9	29.6	26.4	19.8	23	6.4
Bouteloua gracilis	SH	20.4						
	DS		42	56.4	61.5	65.4	59.3	78.5

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	**B1 (Low)**		**A1B (Medium)**		**A2 (High)**	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	IS		14.9	17.4	19.1	20.2	9.8	13.5
	MS		58	43.6	38.5	34.6	40.7	21.5
Bouteloua hirsuta	SH	4						
	DS		69.1	70.4	77	66.1	57.8	75.2
	IS		35.5	41.3	37	62.7	61.6	125.8
	MS		30.9	29.6	23	33.9	42.2	24.8
Dasyochloa pulchella	SH	4.8						
	DS		46	58.5	59	54.8	61.6	76.5
	IS		179.8	242.4	279.1	284.9	172.3	178.8
	MS		54	41.5	41	45.2	38.4	23.5
Elymus elymoides	SH	18						
	DS		69.6	70.3	77.8	80.5	76.9	91.2
	IS		20.3	22.6	20.2	25.9	12.7	18.5
	MS		30.4	29.7	22.2	19.5	23.1	8.8
Elymus glaucus	SH	1.3						
	DS		50.8	49.4	45.9	47.6	37.6	47.3
	IS		61.5	40.1	115.8	80.9	153.1	85.6
	MS		49.2	50.6	54.1	52.4	62.4	52.7
Elymus trachycaulus	SH	9.6						
	DS		43.9	52.4	46.4	57	49.9	64.5
	IS		71.7	58.4	74.4	43.7	69.8	29.9
	MS		56.1	47.6	53.6	43	50.1	35.5
Festuca arizonica	SH	2						
	DS		63.3	87.8	87.5	91.4	91.3	94.2
	IS		78.1	50.7	77.7	108.1	50.9	78.5
	MS		36.7	12.2	12.5	8.6	8.7	5.8
Festuca brachyphylla	SH	2.1						
	DS		57.5	68.4	71.3	96	87.1	98.5
	IS		85.9	70.9	62.7	35.1	22.1	22.9
	MS		42.5	31.6	28.7	4	12.9	1.5
Festuca idahoensis	SH	2.6						
	DS		61.7	62.2	74.9	82.3	67.1	75.2
	IS		62.3	48.1	40.4	11.4	47	20.2
	MS		38.3	37.8	25.1	17.7	32.9	24.8
Festuca thurberi	SH	2.3						
	DS		50.1	55.9	53.9	64.9	65.1	82.9

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	**B1 (Low)**		**A1B (Medium)**		**A2 (High)**	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
	IS		80.2	64.2	61.7	54.4	55.8	28.5
	MS		49.9	44.1	46.1	35.1	34.9	17.1
Hesperostipa comata	SH	14.8						
	DS		62.5	66.8	69.1	69.9	64.5	80.3
	IS		26.6	37.2	35.7	46.9	25.1	28
	MS		37.5	33.2	30.9	30.1	35.5	19.7
Hilaria belangeri	SH	1.1						
	DS		56.6	50.6	59.3	46	24.2	69.6
	IS		53.1	81.2	97.9	158	143.1	230.8
	MS		43.4	49.4	40.7	54	75.8	30.4
Hordeum jubatum	SH	4.9						
	DS		59.5	72.2	65.7	72	61.6	79.5
	IS		67.7	57.2	76.8	79.9	90.3	55.2
	MS		40.5	27.8	34.3	28	38.4	20.5
Koeleria macrantha	SH	4.4						
	DS		56.3	64.1	68	74.1	62.4	73.7
	IS		89	102.1	86.2	103.7	82	115.3
	MS		43.7	35.9	32	25.9	37.6	26.3
Leymus cinereus	SH	8.1						
	DS		53.2	74.3	69.7	94.2	76.9	98.2
	IS		19.1	5.2	8.1	0.9	5.8	0.7
	MS		46.8	25.7	30.3	5.8	23.1	1.8
Muhlenbergia emersleyi	SH	1.4						
	DS		72.1	71.9	83.4	60.1	50	69
	IS		48	46.1	26.6	78.3	83	73.7
	MS		27.9	28.1	16.6	39.9	50	31
Muhlenbergia montana	SH	2.6						
	DS		69.5	82.7	82.2	86.4	83	92.2
	IS		63.4	64.6	65.6	74	54.4	80.5
	MS		30.5	17.3	17.8	13.6	17	7.8
Muhlenbergia porteri	SH	5.2						
	DS		34.1	32.1	54.5	32.3	40.4	60.9
	IS		119.4	134.8	137.3	177.8	102.2	230
	MS		65.9	67.9	45.5	67.7	59.6	39.1
Pascopyrum	SH	9.2						

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
smithii								
	DS		57.1	63.3	64.9	73.6	57.7	79.9
	IS		52.8	64.3	57.6	57.5	58.3	46.2
	MS		42.9	36.7	35.1	26.4	42.3	20.1
Pleuraphis jamesii	SH	16.9						
	DS		42.7	60.9	65.9	74.8	58.5	88
	IS		29.5	35.5	36.5	40.1	27.4	23.8
	MS		57.3	39.1	34.1	25.2	41.5	12
Pleuraphis mutica	SH	5						
	DS		80.4	88.9	85.5	96.6	85.5	98.3
	IS		87.1	92.1	120.7	71.1	92.7	106.2
	MS		19.6	11.1	14.5	3.4	14.5	1.7
Pleuraphis rigida	SH	4.1						
	DS		88.2	98	80.6	94.5	82.4	98.1
	IS		39.9	19.8	78.5	68.6	74.9	33.5
	MS		11.8	2	19.4	5.5	17.6	1.9
Poa fendleriana	SH	6.2	0	0	0	0	0	0
	DS		68.2	74.6	77	73.3	75.8	80.4
	IS		52.9	75.7	70.5	110.3	49	97.1
	MS		31.8	25.4	23	26.7	24.2	19.6
Poa secunda	SH	10.6	0	0	0	0	0	0
	DS		26.3	34.6	35.6	56.1	47.5	71.7
	IS		19	9.8	9.5	7.1	8.4	3.1
	MS		73.7	65.4	64.4	43.9	52.5	28.3
Schizachyrium scoparium	SH	6.5						
	DS		74.6	86.8	85.2	87.3	72.1	80.7
	IS		23.4	15.1	13.4	17.4	26.6	27.4
	MS		25.4	13.2	14.8	12.7	27.9	19.3
Sporobolus airoides	SH	6.8						
	DS		32.1	46.7	49.2	73.3	43	83.2
	IS		65.1	80.1	93	67.2	73.3	65.7
	MS		67.9	53.3	50.8	26.7	57	16.8
Sporobolus cryptandrus	SH	15.1						
	DS		69.8	82.2	87.6	95.1	76.6	97.4
	IS		46.8	51.1	53.6	46.7	53.7	50.8
	MS		30.2	17.8	12.4	4.9	23.4	2.6

	Suitability Class	Predicted modern-day SH (% of study area)	Predicted future SH (% of modern-day SH area) by scenario and time-period					
		Modern-day	B1 (Low)		A1B (Medium)		A2 (High)	
Species			**2050**	**2100**	**2050**	**2100**	**2050**	**2100**
Sporobolus flexuosus	SH	2.9						
	DS		81.4	88.2	94.4	97.6	90.2	99.2
	IS		98.2	111.3	70.3	40.8	119.1	34.2
	MS		18.6	11.8	5.6	2.4	9.8	0.8

Table 3. Model agreement for future suitable habitat (SH) predictions for the study plant species (n=166). For each future time period, model agreement was calculated for three suitability classes for SH models based on three future climate models. The area of agreement for where a suitability class was predicted by one, two, or three concurring SH models was expressed as a proportion of area for each to the total area predicted for the suitability class by all three SH models. The three suitability classes were (1) DS, decreased suitability; (2) IS, increased suitability; and (3) MS, maintained suitability. The future SH predictions were based on climate models based on 2007 IPPC emission scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100) as compiled by the Climate Wizard collaboration.

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
Trees							
Abies concolor	1	10.0	43.1	25.8	9.1	40.2	39.5
	2	12.3	20.1	21.1	16.5	32.4	21.7
	3	77.6	36.8	53	74.5	27.4	38.8
Abies lasiocarpa	1	15.8	20	11.2	11.5	29.7	19.6
	2	12.1	23	14.6	16.9	14.8	13.3
	3	72	57	74.2	71.6	55.6	67.1
Acer glabrum	1	19.6	26.7	6.4	9.2	31.5	15.5
	2	10.2	23.3	12.2	20.5	13.6	7
	3	70.1	50	81.4	70.3	54.9	77.5
Acer grandidentatum	1	10.1	32.4	14.4	14.4	39.3	15
	2	13.9	26.6	10.5	14	29.2	15.4
	3	76	41.1	75.1	71.6	31.5	69.6
Acer negundo	1	7.6	26.7	30.3	6	32.7	30.1
	2	15.9	19.2	14.5	13.4	24.7	13.5
	3	76.4	54.1	55.2	80.6	42.6	56.5
Carnegiea gigantea	1	29.2	71.1	50.7	16.7	65.3	62.5
	2	47.4	21.2	31.2	49.9	21.6	21
	3	23.4	7.7	18.2	33.3	13.1	16.5
Fraxinus velutina	1	12.3	54.6	46.5	5.6	32	28
	2	12.4	28.6	46.3	4.2	40.7	37.3
	3	75.3	16.8	7.2	90.2	27.4	34.7
Juglans major	1	5.6	59.6	57	6.3	57.2	58.6
	2	14.7	26.2	21.9	14.3	33	25.6
	3	79.7	14.2	21.1	79.4	9.8	15.9
Juniperus coahuilensis	1	16.4	64	53.9	14.7	68.8	29.1
	2	40.7	21.4	21.7	14.8	18.4	28.8
	3	42.9	14.6	24.4	70.5	12.8	42
Juniperus deppeana	1	11.8	32.9	18.9	8.1	16	14.7
	2	15.4	21.9	14.6	7.8	41.9	15.1
	3	72.8	45.2	66.5	84.1	42.1	70.2
Juniperus monosperma	1	18.5	45.7	34.1	17.6	48.2	34.8
	2	29.3	30.4	21.5	17.9	27.2	34.4
	3	52.2	23.8	44.4	64.5	24.6	30.8
Juniperus osteosperma	1	16.3	32.3	16.6	22	36.8	23.3
	2	15.6	21.6	17.3	20.3	30.2	25.3
	3	68.1	46.1	66.1	57.7	32.9	51.4
Juniperus scopulorum	1	10.9	36.9	34.7	11.8	32.9	31.5
	2	19.2	29.1	19.6	14	29.9	26.4
	3	69.9	34	45.8	74.2	37.2	42.1

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
Olneya tesota	1	34.5	56.6	28.8	34.1	57.1	24.8
	2	32.9	30	30.1	31	30.7	27.3
	3	32.6	13.4	41.1	34.9	12.2	47.9
Parkinsonia florida	1	23.7	40.3	59.9	13.3	59.5	63
	2	52.2	34.9	27.2	36.9	29.4	22.7
	3	24.1	24.8	12.9	49.8	11.1	14.3
Parkinsonia microphylla	1	39.1	54.6	21.1	40.7	57.7	28.7
	2	27.7	30.1	29.8	31.7	32.8	36.8
	3	33.1	15.4	49.2	27.5	9.6	34.6
Picea engelmannii	1	12.6	23.1	12.6	12.9	23.7	21.6
	2	12.7	15.1	12.6	15.3	23.8	18.2
	3	74.7	61.8	74.8	71.9	52.5	60.2
Picea pungens	1	10.3	23.9	23.4	9.8	35.4	27.1
	2	14.1	17.9	17	10.4	16.1	25.6
	3	75.6	58.2	59.6	79.8	48.5	47.3
Pinus aristata	1	5.5	63.4	66.4	11	50.6	44.1
	2	33.3	19	11	10.3	32.6	47.1
	3	61.2	17.7	22.6	78.7	16.9	8.9
Pinus contorta	1	16.7	35.1	16.6	11.8	57.9	59.5
	2	18.5	23	15	33.1	19.5	21.3
	3	64.9	41.9	68.4	55.1	22.6	19.2
Pinus edulis	1	14.1	28.2	24.9	14.2	28.7	29.2
	2	20.4	21.8	17.2	16.9	25.1	24.5
	3	65.5	50	57.9	68.8	46.2	46.3
Pinus flexilis	1	3.3	54.5	56.1	1.4	60.1	78.3
	2	8.2	26.9	22.9	6.1	34.7	17.7
	3	88.5	18.6	21.1	92.5	5.2	4
Pinus monophylla	1	7.4	63.2	39.7	5.9	55.9	54.1
	2	14.4	19.1	20.2	9.5	32.7	33.8
	3	78.2	17.7	40.1	84.6	11.4	12.1
Pinus ponderosa	1	12.1	32.6	29.5	8.1	35.6	35.5
	2	14.8	26.4	24.1	10.3	29.6	27.6
	3	73.1	41	46.4	81.6	34.9	36.9
Pinus strobiformis	1	22.9	64.9	25.1	4.2	58.3	53.5
	2	9.8	6.4	58.7	11.3	25	19.8
	3	67.3	28.6	16.2	84.5	16.7	26.7
Populus angustifolia	1	9	31.8	33.6	9.5	32.8	47.4
	2	17.2	25.7	17.6	16.1	25.6	28
	3	73.7	42.5	48.8	74.5	41.6	24.6
Populus tremuloides	1	10.5	19	15.4	12.6	14.6	21.7

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	15	13.2	10.8	12.5	18.5	21.8
	3	74.5	67.8	73.8	74.9	66.9	56.5
Prosopis glandulosa	1	46.3	43.8	20.6	42.9	37.1	33.3
	2	39.1	25	24.4	34.8	35.9	40.9
	3	14.6	31.2	55	22.3	26.9	25.8
Prosopis velutina	1	48.5	23	13.7	44.9	23.1	11
	2	32.3	12.9	20.5	24.2	23	20.5
	3	19.1	64.1	65.9	31	53.9	68.5
Pseudotsuga menziesii	1	12.2	26.2	23.6	13.2	28.2	19.5
	2	20.9	17.5	13.8	12.4	23.9	20.9
	3	66.9	56.3	62.6	74.4	47.9	59.6
Quercus arizonica	1	8.5	43.2	29.2	3.7	38.7	20.1
	2	6.5	37.5	38	4.6	17	16.4
	3	85	19.3	32.8	91.7	44.3	63.5
Quercus emoryi	1	10	28.8	13.2	7.5	32.8	28.9
	2	6.9	35.6	19.3	10.1	33.8	21.3
	3	83.1	35.6	67.5	82.4	33.3	49.8
Quercus gambelii	1	13.9	22.6	20.6	9.2	22.5	26.9
	2	18	18.8	15.9	15.7	22.5	15.7
	3	68.1	58.6	63.5	75.2	55	57.4
Quercus grisea	1	8.8	47.7	61.8	6.3	46.2	44.6
	2	22.7	33.9	23.9	7.9	33.7	35.9
	3	68.5	18.4	14.3	85.8	20.1	19.4
Quercus havardii	1	16.1	66.3	31.7	3.4	91.2	83.4
	2	14.2	25.8	36.1	27.8	5.9	10.1
	3	69.8	7.9	32.3	68.8	2.9	6.5
Yucca brevifolia	1	13	47.4	36.8	4	60.5	68.5
	2	20.5	26.6	23.3	15.4	28.3	17.9
	3	66.5	26	39.9	80.6	11.3	13.6
Shrubs							
Acacia constricta	1	13.1	44.6	37.4	9.4	49	49.9
	2	22.9	26.3	21.3	15.5	30.4	30.3
	3	64	29	41.2	75.2	20.6	19.8
Acacia greggii	1	23.3	27.2	21	10.2	33.7	48.8
	2	20.3	26.8	24	19.9	24.4	25
	3	56.4	46.1	55	69.8	41.8	26.2
Ambrosia deltoidea	1	4.8	49.9	61.2	5	75.4	82.5
	2	18.7	44.8	15.8	37.6	18.4	11
	3	76.4	5.3	22.9	57.5	6.2	6.6
Ambrosia dumosa	1	25.6	54.1	30.7	13.6	63.1	46.8

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	23.3	27.5	33.8	28	20.6	22.7
	3	51.2	18.4	35.5	58.4	16.3	30.5
Amelanchier alnifolia	1	15.8	31.5	17.8	18.4	39.5	29.6
	2	23.5	26.2	12	34.6	21.4	15.7
	3	60.7	42.2	70.3	47	39.1	54.7
Amelanchier utahensis	1	11.6	33.7	18.6	10.6	34.1	25
	2	13.6	25.4	15.8	18.6	24.6	14.3
	3	74.8	40.9	65.6	70.7	41.2	60.7
Arctostaphylos patula	1	11.7	63.4	27.2	19.4	59.5	38.7
	2	10.5	25.8	30.3	17.3	33.9	43.3
	3	77.9	10.8	42.4	63.3	6.6	18
Arctostaphylos pringlei	1	3.4	37.8	58.9	5.3	77.1	71.4
	2	17.4	23.9	11.5	13.3	13.1	28.3
	3	79.2	38.3	29.6	81.5	9.8	0.4
Arctostaphylos pungens	1	10.7	59.8	35.5	9.6	72	60.8
	2	22.8	17.8	16.7	22.9	12.1	25.6
	3	66.5	22.4	47.9	67.5	15.8	13.6
Arctostaphylos uva-ursi	1	7.5	29.4	40.5	9.9	39.3	43.5
	2	23.5	13	13	18.1	27.8	23.8
	3	68.9	57.6	46.5	71.9	33	32.7
Artemisia arbuscula	1	9.6	61.7	39.1	3.8	85.6	72
	2	11.7	25.1	31.9	13	12.8	21.1
	3	78.7	13.2	29	83.2	1.6	6.9
Artemisia bigelovii	1	20.6	54.1	25	10	56.7	51.8
	2	17.7	23.9	29.1	20.3	26.8	25.5
	3	61.7	22	45.9	69.8	16.6	22.7
Artemisia filifolia	1	24.2	39.7	31.4	11	34	56.7
	2	27.6	29.3	27.6	29.1	27.8	21.4
	3	48.2	31	41	60	38.1	21.8
Artemisia frigida	1	10.1	47.7	28	18.4	46.9	24.8
	2	21.7	23.4	13.1	16.4	23.5	27.9
	3	68.3	28.9	58.9	65.2	29.6	47.3
Artemisia nova	1	11.7	47.1	25.5	14.8	44	33.9
	2	19.8	21.5	15.1	14.8	39.4	33.8
	3	68.5	31.4	59.4	70.4	16.6	32.3
Artemisia tridentata	1	17.6	32.2	15.5	21	35.7	35.4
	2	16.2	22.8	16.8	28	19.8	26.5
	3	66.2	45	67.6	51	44.5	38
Atriplex canescens	1	35.1	35.5	12.2	29.6	31.4	27.8
	2	20.7	22.3	20.6	25.6	31.7	32.1

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	3	44.2	42.2	67.2	44.9	36.9	40.1
Atriplex confertifolia	1	18.9	36.3	21.7	17.4	53.7	34.2
	2	23.8	23.1	17.1	25.5	20.9	23.3
	3	57.3	40.7	61.2	57	25.3	42.5
Atriplex corrugata	1	5.3	27.4	29.9	5.9	45.1	26
	2	8.2	28.4	19.2	6.6	20.6	23.1
	3	86.5	44.2	50.9	87.5	34.3	50.9
Atriplex gardneri	1	5.3	45.8	16.8	1.8	37.6	9.4
	2	6.9	30	12.9	3.1	19.9	5.4
	3	87.9	24.1	70.4	95.1	42.5	85.2
Atriplex hymenelytra	1	7.9	66.9	48.7	7.2	57	67.7
	2	19.6	14.5	19.8	18.5	39.6	26.3
	3	72.5	18.6	31.5	74.3	3.5	6
Atriplex obovata	1	45.8	28.4	10.4	39.6	40.9	16.6
	2	20.4	19.9	23.2	15.3	28.1	42.9
	3	33.8	51.7	66.4	45	31	40.5
Atriplex polycarpa	1	14.5	59.6	28.5	17.9	55	25.1
	2	16	27	25.9	11.8	33.3	38.1
	3	69.6	13.4	45.6	70.4	11.6	36.8
Baccharis sarothroides	1	18.5	50	23.3	14.5	68.5	57.1
	2	13.2	23.8	32.5	38.4	25.4	21.5
	3	68.3	26.2	44.2	47.2	6.1	21.4
Canotia holacantha	1	8.2	59.1	57	0.2	34.8	86.9
	2	20.4	16.3	22.9	1.7	49.6	8.3
	3	71.5	24.6	20.1	98.1	15.6	4.8
Ceanothus greggii	1	3.9	60.8	52.9	0.6	79.5	79.1
	2	6.2	22.2	33.5	3.3	11.8	14.6
	3	89.9	17	13.6	96.1	8.6	6.3
Cercocarpus intricatus	1	1.4	82.9	82.1	2.3	83.1	81.8
	2	10	12.9	11.5	15.3	15.8	12.6
	3	88.6	4.2	6.3	82.4	1.1	5.6
Cercocarpus ledifolius	1	8.2	43.8	25.9	7.4	57.9	28.5
	2	9.1	21.3	23.3	5.2	28.8	40.7
	3	82.6	34.9	50.9	87.4	13.2	30.8
Cercocarpus montanus	1	9.3	35.4	41.4	8.3	27.3	34.4
	2	25.8	20.8	15	17.4	26.4	16.4
	3	64.9	43.8	43.6	74.3	46.3	49.2
Chrysothamnus depressus	1	4.9	56.1	56.4	5.6	50.1	69.8
	2	10.2	25.9	27.4	17.7	22.5	22.1

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	3	84.9	18	16.2	76.7	27.3	8.1
Chrysothamnus greenei	1	4.9	46.9	30	2.9	61.9	53.7
	2	10.9	29.4	13.4	8.1	26.5	19.1
	3	84.3	23.7	56.5	89	11.6	27.2
Chrysothamnus viscidiflorus	1	8.6	48.3	26.8	3.6	70.9	74.7
	2	12.4	24.7	18.5	12.8	22.5	21
	3	79	27	54.6	83.6	6.6	4.3
Coleogyne ramosissima	1	17.8	42.2	19.5	6.6	50.7	75.5
	2	11.1	21.6	31.2	23.5	31.2	21.3
	3	71.1	36.1	49.3	69.8	18	3.2
Encelia farinosa	1	10.6	48.7	39.3	6.4	72.4	61.2
	2	15	26.7	27.8	11.3	20.8	34.9
	3	74.4	24.6	32.9	82.3	6.8	4
Ephedra nevadensis	1	25.1	53.9	33.4	25	39.3	39
	2	25.9	24.8	32.3	21.3	43.1	45.8
	3	49	21.3	34.3	53.7	17.6	15.1
Ephedra torreyana	1	41.1	32	12.8	37.9	38.1	22
	2	20.8	22.5	25.4	21	36.7	39.7
	3	38.2	45.6	61.8	41.1	25.2	38.3
Ephedra trifurca	1	41.9	42.8	24.9	30.5	58.3	49.4
	2	33.4	37.6	31.3	43.2	22.5	34.9
	3	24.7	19.6	43.8	26.4	19.2	15.8
Ephedra viridis	1	22.4	40.7	21.3	22	45.6	40.9
	2	19.6	28.3	24.3	28.3	32.3	31.7
	3	58	31	54.4	49.7	22.1	27.4
Ericameria linearifolia	1	4.5	29.1	52.4	0.2	82	94.2
	2	9.3	34	25.3	3.3	17.4	5.8
	3	86.1	36.9	22.3	96.5	0.6	0
Ericameria nauseosa	1	9.1	50.2	33.6	6.3	56.1	37
	2	12.4	22.2	24.8	9.5	22.5	24.4
	3	78.5	27.6	41.5	84.2	21.5	38.6
Eriogonum fasciculatum	1	2.7	84.9	74.9	1.1	83.7	75
	2	14	9.9	14.3	5.2	14	15.5
	3	83.3	5.3	10.8	93.7	2.3	9.5
Eriogonum wrightii	1	14.8	63.2	69.2	15.1	49.7	69.5
	2	44.4	24.8	23.1	39.7	40	26.4
	3	40.8	11.9	7.6	45.2	10.3	4.2
Fallugia paradoxa	1	22.6	64.2	26.8	19.1	62.8	41
	2	24.1	25.1	25.1	23.9	28	32.8

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	3	53.3	10.7	48.2	57.1	9.2	26.3
Flourensia cernua	1	2.8	62.9	78.6	10.8	49.6	39.1
	2	17.5	25.2	12.6	8.1	40.5	51.8
	3	79.7	11.8	8.8	81.1	10	9.2
Fouquieria splendens	1	49.4	32.8	13	42.5	43.4	28.3
	2	21	37.5	30.7	37	41.3	32.4
	3	29.6	29.7	56.2	20.5	15.3	39.3
Garrya flavescens	1	7.1	55.9	50.9	0.3	86.2	91.4
	2	9	25.9	39.7	28.4	7.1	1
	3	83.9	18.1	9.4	71.3	6.7	7.6
Garrya wrightii	1	7.8	29.4	39	5.2	24.4	50.1
	2	14	25.6	21.6	11.8	40.2	22.3
	3	78.2	45	39.4	83	35.5	27.6
Grayia spinosa	1	16.8	50.5	37.1	17	62.3	45
	2	18.2	30.7	34.2	20.4	29.4	37.4
	3	65	18.8	28.7	62.6	8.2	17.6
Gutierrezia microcephala	1	19.5	52.4	37.5	14.2	48.8	40.6
	2	18	29.6	40.6	14.8	32.1	38.9
	3	62.5	18	21.9	71.1	19.1	20.5
Gutierrezia sarothrae	1	14.8	35.3	12.2	14.6	36.3	31.7
	2	15.2	24.5	11.9	24.8	27.5	18.7
	3	70	40.2	75.9	60.7	36.2	49.6
Hymenoclea salsola	1	7.8	64	35	9	50.6	57.4
	2	10.2	19.8	27	14.4	42.5	35.6
	3	82	16.2	38	76.6	6.9	7
Juniperus communis	1	14.6	27.7	18.8	31.7	28.3	18.8
	2	21.8	18.1	12.6	12.5	37.2	47.6
	3	63.6	54.2	68.6	55.8	34.4	33.6
Krascheninnikovia lanata	1	15.2	45.9	34.2	18.4	56.3	41.1
	2	19.2	28	27.1	18.5	33.2	40.8
	3	65.5	26.1	38.8	63.1	10.5	18.1
Larrea tridentata	1	23	33.3	18.5	18.9	26.3	37.8
	2	25.8	23.6	16.5	31.8	34.2	22.5
	3	51.2	43.2	65.1	49.2	39.5	39.7
Lupinus argenteus	1	26	45.7	15	1.6	61.4	82.3
	2	11.1	49.2	35.4	14.3	36.2	9.3
	3	62.9	5	49.6	84	2.4	8.4
Lycium andersonii	1	9.4	47.9	48.2	17.2	42.2	43.2

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	18.6	25.8	24.4	21.2	24.1	35.1
	3	72	26.3	27.4	61.6	33.7	21.7
Lycium pallidum	1	0.1	79.9	96.8	0.2	88.5	97.3
	2	5.5	13.4	2.3	7.8	9.6	2.7
	3	94.4	6.7	0.9	92	1.9	0
Mahonia repens	1	16.6	23.3	19.8	14.2	22.3	24.8
	2	21.1	20.2	15.6	18.8	23.1	18.8
	3	62.3	56.5	64.6	67	54.6	56.4
Menodora spinescens	1	1.2	49.9	60.2	0.9	69	63
	2	2.4	31.2	31.2	2.3	23.8	25.7
	3	96.4	18.9	8.6	96.7	7.1	11.3
Mimosa aculeaticarpa	1	14.4	38.8	31.2	4.9	34	47.7
	2	16.4	27.9	27.4	13.5	34.3	17.4
	3	69.2	33.3	41.4	81.5	31.7	34.9
Opuntia basilaris	1	4.1	66.1	62	4.7	82.1	70
	2	10.2	25.6	25.1	10.9	16.2	30
	3	85.7	8.3	12.9	84.5	1.7	0
Opuntia engelmannii	1	8.9	62.1	26.6	11.7	74.6	27.7
	2	13.8	24.7	17.1	7.3	19.1	44.6
	3	77.3	13.2	56.3	81	6.3	27.7
Parthenium incanum	1	12.6	51.8	59.9	12.3	55.7	69.9
	2	52.9	20.7	14.3	33	31.3	26
	3	34.5	27.5	25.8	54.8	13	4.2
Paxistima myrsinites	1	13.7	33.8	18.8	20.8	37.5	13.6
	2	16.5	23	15.6	17.2	22.8	16.5
	3	69.8	43.2	65.6	62	39.8	69.9
Picrothamnus desertorum	1	4.8	61.7	63.8	0.2	94.6	96.4
	2	15.1	20.3	20.4	5.2	5.4	3.6
	3	80.1	18.1	15.8	94.6	0	0
Prunus fasciculata	1	5.9	59.1	34.7	1.8	62.2	85.3
	2	9.8	21.7	21	10.5	37.8	14.7
	3	84.3	19.2	44.2	87.7	0	0
Prunus virginiana	1	18.8	27.2	17	14.9	31.8	29.8
	2	19.3	26.6	16.5	24.9	24.3	17.8
	3	61.9	46.2	66.5	60.3	43.9	52.4
Purshia mexicana	1	18.4	59.2	30.1	19.8	62.1	52.7
	2	24.5	27.1	22.6	32.9	23.6	31.7
	3	57.1	13.7	47.3	47.4	14.3	15.6
Purshia stansburiana	1	10.3	45.2	48.2	11.7	40.4	43.4

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	18	31.5	27.7	20.8	35.9	24.3
	3	71.7	23.3	24	67.5	23.7	32.4
Purshia tridentata	1	20.7	31.8	21.4	13.3	34.5	44.9
	2	17.6	24.3	25.1	19.9	30.7	30.1
	3	61.6	43.9	53.5	66.8	34.8	25
Quercus turbinella	1	16.9	33.8	51	9.4	48.6	48.4
	2	29.3	35.6	29.4	14.7	30.7	31
	3	53.8	30.6	19.6	75.9	20.8	20.6
Rhus microphylla	1	8.9	52.3	65.1	13.9	60.7	67.7
	2	33.1	24.4	17.5	34.1	27.8	27.5
	3	58	23.3	17.3	52	11.5	4.7
Rhus ovata	1	0.6	41.1	17.1	0	95.4	100
	2	0.1	58	82.9	0.6	0	0
	3	99.2	0.9	0	99.4	4.6	0
Rhus trilobata	1	17.5	44.7	42.9	12.9	48.9	34.3
	2	24.3	27	31	15.6	32.4	28.3
	3	58.2	28.3	26.1	71.6	18.7	37.5
Ribes cereum	1	16	42.6	34	18.9	37.6	33.8
	2	21.6	27.4	25.2	18.6	30.2	34.2
	3	62.4	30	40.8	62.5	32.3	32
Ribes montigenum	1	11.9	45.7	34.7	4.9	46.2	46.4
	2	18.7	25.6	22.1	9.8	29.4	23.3
	3	69.4	28.7	43.2	85.3	24.4	30.2
Robinia neomexicana	1	11	52.8	28.8	7.5	63.1	79.2
	2	14	24.9	22.6	32.6	26.7	18.1
	3	75	22.4	48.6	59.9	10.3	2.7
Rosa woodsii	1	9.7	42.3	44.9	6.6	43.9	45.5
	2	15.3	29.7	28.5	10.9	24.4	27.5
	3	75	28	26.6	82.5	31.7	27
Salazaria mexicana	1	5.8	75.3	49.7	2.8	63.6	42.7
	2	10.6	16.3	27	4.5	27.1	26.3
	3	83.6	8.4	23.3	92.7	9.3	31
Salix geyeriana	1	12.2	33.1	66.5	1.8	54.5	95.9
	2	40	16.1	20.3	51.9	7.5	3.3
	3	47.8	50.9	13.2	46.3	38	0.8
Sarcobatus vermiculatus	1	18.6	51.1	40.4	12	45.8	44.4
	2	31.6	24.4	23.8	19	26.8	28.1
	3	49.8	24.5	35.8	69	27.4	27.5
Shepherdia canadensis	1	30.3	22.1	7.1	29.9	17.1	10

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	20.7	17.3	10.4	16.2	19.2	18.4
	3	49	60.5	82.4	53.9	63.6	71.6
Simmondsia chinensis	1	40.4	61.7	14.3	18.8	55.8	35.3
	2	25.6	23.8	22.5	35.7	33.9	18.5
	3	34	14.6	63.2	45.6	10.3	46.2
Suaeda moquinii	1	37.5	44.4	21	28.1	52.7	31.5
	2	28.7	27.3	27.4	30.5	25.8	29
	3	33.8	28.3	51.6	41.5	21.4	39.5
Symphoricarpos albus	1	8.7	44	48.3	6.4	47.7	64.5
	2	26.8	24.2	15.6	26.8	29.2	15.3
	3	64.5	31.8	36.1	66.8	23.1	20.2
Symphoricarpos oreophilus	1	15.5	35.5	18.6	11.9	53.4	56.9
	2	11.3	34.7	25.5	25.9	32.1	26.2
	3	73.2	29.8	56	62.1	14.5	16.9
Symphoricarpos rotundifolius	1	10.4	39.2	38.1	10.1	43.9	51.7
	2	21.9	24.8	18.1	28.2	29.2	18.5
	3	67.6	36	43.7	61.8	26.9	29.8
Tetradymia glabrata	1	3.9	49.8	65	1.4	81	80.4
	2	12.1	29.6	21.2	5.9	18.4	19.4
	3	84	20.6	13.8	92.7	0.5	0.2
Tetradymia spinosa	1	23	64.8	38.4	0.3	66.5	92.9
	2	20.5	20.5	43.1	23	10.7	1
	3	56.5	14.8	18.5	76.7	22.7	6.1
Vaccinium myrtillus	1	16.1	22.7	21	10.3	38	51.5
	2	12.7	29.2	26.5	21.3	33	24.9
	3	71.2	48.1	52.5	68.5	29	23.7
Vaccinium scoparium	1	12.7	46.4	18.6	5.9	85.4	66.9
	2	12	25.8	19.7	31.1	6.8	12.7
	3	75.2	27.8	61.7	63	7.8	20.4
Yucca angustissima	1	14.1	57.4	50.8	10.8	74.2	59
	2	34.3	29.4	20.9	22.2	20	28.6
	3	51.6	13.2	28.3	67	5.7	12.4
Yucca baccata	1	15.8	50	21.6	11.4	51.9	45.9
	2	22.1	23.3	15.4	32.5	25.8	16.1
	3	62.1	26.7	63	56.2	22.4	38
Yucca elata	1	24	54.3	23.5	19.7	58.4	56.7
	2	20.3	29.3	27.6	34.3	30.9	32.6
	3	55.7	16.4	48.9	45.9	10.8	10.8

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
Yucca glauca	1	17.1	44.6	26.3	15.9	69.1	58
	2	19.3	41.2	23.2	32.8	19.8	28.2
	3	63.6	14.2	50.6	51.3	11	13.8
Yucca schidigera	1	1.2	88.9	74.2	0	90.6	100
	2	3.3	11.1	25.8	0.4	3.1	0
	3	95.5	0	0	99.6	6.3	0
Ziziphus obtusifolia	1	28	61.7	44.4	12.8	37.3	8.5
	2	49.2	15.9	25.3	4.2	49.7	25.9
	3	22.8	22.4	30.3	83.1	13	65.6
Grasses							
Achnatherum hymenoides	1	21.3	40.6	22.1	18	41.3	28.2
	2	21.9	29.8	21.5	18.2	31.7	27.9
	3	56.8	29.6	56.5	63.9	26.9	43.9
Achnatherum speciosum	1	8.2	60.2	36.5	9.9	81.7	33.8
	2	9.1	32.9	33	5.9	16.6	56.5
	3	82.6	6.9	30.5	84.2	1.7	9.7
Achnatherum thurberianum	1	7.8	43.7	44.2	0	74.6	100
	2	14.2	30.6	24.1	7.9	25.4	0
	3	78	25.7	31.7	92.1	0	0
Bouteloua curtipendula	1	9.3	34.1	21.2	10.1	41.7	23.9
	2	11.4	22	17.3	8.9	30	27.3
	3	79.3	43.9	61.5	81	28.3	48.8
Bouteloua eriopoda	1	11.5	40.7	38.9	13.6	30.5	42.4
	2	21	27.5	21.3	14.3	35.4	40.5
	3	67.5	31.8	39.8	72.1	34.1	17.1
Bouteloua gracilis	1	25	43.5	25.2	20.9	38.4	31
	2	21.9	29	28.7	18.3	37.4	35.5
	3	53.1	27.5	46.1	60.8	24.3	33.5
Bouteloua hirsuta	1	12.6	58.1	30.3	13.8	64.7	30.6
	2	17	22.9	22.6	15.5	18.8	27.3
	3	70.4	18.9	47.2	70.7	16.5	42.1
Dasyochloa pulchella	1	21.6	56.3	46.2	17.1	48.2	41.1
	2	43	24.2	23.3	29.2	24.5	24.2
	3	35.4	19.5	30.5	53.7	27.2	34.7
Elymus elymoides	1	12.3	51	37.4	10.8	49.2	53.8
	2	16.6	29.9	27.7	20.3	33.2	28.5
	3	71.2	19.1	34.9	68.9	17.6	17.7

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
Elymus glaucus	1	15.6	43.7	14	24.3	46.2	20.2
	2	16.8	24.8	13	21.3	27	23.1
	3	67.6	31.5	73	54.4	26.7	56.6
Elymus trachycaulus	1	18.9	40.2	19.3	16.2	52.7	25.6
	2	21.7	26.7	16.9	20.1	26.5	20.6
	3	59.4	33.1	63.8	63.6	20.8	53.8
Festuca arizonica	1	9.2	45.5	64.1	5.1	35.5	43.4
	2	26.2	22.1	22.5	6.7	39.2	33.3
	3	64.6	32.4	13.4	88.2	25.3	23.3
Festuca brachyphylla	1	20	47.9	34	3.5	68.7	88.5
	2	16.8	34.9	40.4	29.4	22.2	10.5
	3	63.2	17.2	25.6	67.1	9.2	0.9
Festuca idahoensis	1	11.3	59.9	34.3	8.3	78.2	51
	2	19.7	20.2	19.6	26.3	12.1	16
	3	69	20	46.1	65.4	9.7	33
Festuca thurberi	1	20.1	33	20.7	20.7	34.3	27.4
	2	16.7	19.8	24.9	15.2	30	37.3
	3	63.2	47.1	54.4	64.1	35.7	35.2
Hesperostipa comata	1	18.3	46.2	24.3	13.7	44.1	32.2
	2	14.5	28.6	30.6	15.3	31.6	28.9
	3	67.2	25.2	45.1	70.9	24.3	38.9
Hilaria belangeri	1	24.3	39.5	33.9	26.2	58.6	14.3
	2	39	29.3	21.1	11.4	18.5	32.9
	3	36.7	31.2	44.9	62.3	22.9	52.8
Hordeum jubatum	1	9.9	33.6	26.7	8.5	39.9	33.8
	2	18.2	27.2	14.4	14.6	31.7	19.7
	3	71.9	39.2	58.9	77	28.4	46.5
Koeleria macrantha	1	15.4	37.8	23.6	8.9	33.1	31.1
	2	15.8	25	23.1	15.6	28.4	17.8
	3	68.8	37.2	53.3	75.4	38.5	51.2
Leymus cinereus	1	12.9	61.1	37.7	3.7	83	79
	2	23.3	23	21	20.9	11.1	14.1
	3	63.8	15.9	41.3	75.4	5.9	6.9
Muhlenbergia emersleyi	1	14.1	41.8	43.7	5.4	44.5	22.5
	2	26.1	33.6	23.6	12.5	13.7	9.8
	3	59.8	24.5	32.7	82.1	41.8	67.7
Muhlenbergia montana	1	5.1	55.9	44.7	8.4	46	31.6
	2	17.2	19.1	13.2	6.6	32.9	40.5
	3	77.7	25	42	85	21.1	27.9
Muhlenbergia porteri	1	40	53.6	26.2	50.9	53.3	19.3

Species	# of models agreeing	Model agreement for each SH class (% of total area predicted for that suitability class) for two time periods					
		2050			2100		
		DS	IS	MS	DS	IS	MS
	2	30.8	23.3	34	21.9	24.8	44.8
	3	29.2	23.1	39.7	27.2	22	35.9
Pascopyrum smithii	1	18.5	33.2	21.2	11.1	39.8	36.3
	2	15.1	29.6	25.9	17.7	27.2	22.8
	3	66.3	37.2	52.9	71.2	33	40.9
Pleuraphis jamesii	1	19.6	39.4	30.4	14.3	42.9	41.9
	2	26.2	26.8	22.7	19.5	26.5	30.8
	3	54.2	33.7	46.9	66.3	30.6	27.3
Pleuraphis mutica	1	5.9	42.7	39.3	3.2	52.5	65.6
	2	10.6	24.5	22.1	7.6	35.8	27.8
	3	83.5	32.8	38.6	89.2	11.7	6.6
Pleuraphis rigida	1	10.5	48.6	44.5	1.1	64.4	73.5
	2	13.1	31.7	35.5	5.1	20.9	16.4
	3	76.5	19.7	20	93.8	14.7	10.1
Poa fendleriana	1	8.8	32.7	32.8	7.4	24.8	30.7
	2	14.6	26.1	19.7	12	28.3	19
	3	76.6	41.3	47.5	80.6	46.9	50.3
Poa secunda	1	34.3	58.4	17.4	30.6	69	38.7
	2	25.8	21.7	23.2	35.3	20	33.6
	3	40	19.9	59.4	34	11	27.7
Schizachyrium scoparium	1	11.4	42.6	35	7.2	59.1	61.4
	2	13.5	34.3	29.4	19	27.3	23.4
	3	75.1	23.1	35.6	73.8	13.7	15.1
Sporobolus airoides	1	33	39.1	20.9	14	41	51.8
	2	26.4	24.8	26.1	33.6	24	21.5
	3	40.6	36	53.1	52.4	34.9	26.6
Sporobolus cryptandrus	1	14.9	33.9	31.3	3.5	47.4	74.2
	2	11.6	28.7	40.2	14.3	26.3	17.9
	3	73.5	37.4	28.5	82.3	26.3	7.9
Sporobolus flexuosus	1	3.8	51.6	54.8	1.6	72.6	80.1
	2	11.5	29.2	18.4	9.6	21.7	13.4
	3	84.7	19.1	26.8	88.8	5.8	6.5

Table 4. Suitable habitat (SH) vulnerability and potential scores for each of the study plant species (n=166) for two time periods. The vulnerability score represents the SH area, averaged over three future SH models, scenarios, predicted to decrease in the future divided by area predicted as suitable habitat for the species in modern-day. The higher the score, the more SH predicted to be lost and the higher the species' predicted vulnerability. The potential score is the SH, averaged over three future SH models, predicted to be gained in the future divided by the area predicted as SH for the species in modern-day. The higher the potential score, the more SH is predicted to be gained during the future time period. A score greater than 1 indicates the species is predicted to have more SH in the future than was predicted for the modern day. The future SH predictions were based on climate models based on 2007 IPPC emission scenarios B1 (global temperature rise of 2.4°C), A1B (global temperature rise of 2.8°C), and A2 (global temperature rise of 3.4°C) for the time period 2050 (2040–2069) and 2100 (2070–2100) as compiled by the Climate Wizard collaboration.

Species	Vulnerability score		Potential score	
Time Period	2050	2100	2050	2100
Trees				
Abies concolor	0.712	0.761	0.232	0.297
Abies lasiocarpa	0.473	0.549	0.317	0.24
Acer glabrum	0.362	0.43	1.548	1.87
Acer grandidentatum	0.514	0.52	0.945	1.371
Acer negundo	0.694	0.731	1.247	1.673
Carnegiea gigantea	0.553	0.638	0.577	0.51
Fraxinus velutina	0.86	0.901	0.383	0.519
Juglans major	0.866	0.876	0.255	0.564
Juniperus coahuilensis	0.638	0.702	1.02	1.715
Juniperus deppeana	0.564	0.669	0.214	0.255
Juniperus monosperma	0.564	0.711	0.254	0.294
Juniperus osteosperma	0.517	0.543	0.222	0.269
Juniperus scopulorum	0.689	0.737	0.332	0.433
Olneya tesota	0.449	0.419	0.843	0.914
Parkinsonia florida	0.6	0.727	1.642	1.852
Parkinsonia microphylla	0.393	0.45	0.61	0.757
Picea engelmannii	0.498	0.605	0.165	0.126
Picea pungens	0.65	0.762	0.892	0.787
Pinus aristata	0.766	0.874	0.393	0.412
Pinus contorta	0.47	0.733	0.464	0.242
Pinus edulis	0.568	0.669	0.264	0.407
Pinus flexilis	0.922	0.967	0.122	0.115
Pinus monophylla	0.788	0.91	0.122	0.076
Pinus ponderosa	0.705	0.823	0.156	0.247
Pinus strobiformis	0.766	0.885	0.185	0.082
Populus angustifolia	0.706	0.815	0.379	0.393
Populus tremuloides	0.512	0.66	0.29	0.248
Prosopis glandulosa	0.275	0.471	0.879	1.456
Prosopis velutina	0.222	0.248	1.067	1.31
Pseudotsuga menziesii	0.546	0.632	0.304	0.353
Quercus arizonica	0.859	0.838	0.548	0.778
Quercus emoryi	0.673	0.78	0.49	0.607
Quercus gambelii	0.545	0.665	0.43	0.515
Quercus grisea	0.823	0.901	0.362	0.315
Quercus havardii	0.739	0.866	1.107	0.878

Species	Vulnerability score		Potential score	
Time Period	2050	2100	2050	2100
Yucca brevifolia	0.691	0.894	0.846	0.748
Shrubs				
Acacia constricta	0.473	0.549	0.317	0.24
Acacia greggii	0.668	0.835	0.692	0.75
Ambrosia deltoidea	0.846	0.817	0.277	0.282
Ambrosia dumosa	0.593	0.69	0.374	0.391
Amelanchier alnifolia	0.423	0.465	0.567	0.773
Amelanchier utahensis	0.592	0.597	0.415	0.497
Arctostaphylos patula	0.763	0.752	0.36	0.655
Arctostaphylos pringlei	0.846	0.92	0.266	0.379
Arctostaphylos pungens	0.652	0.818	0.377	0.343
Arctostaphylos uvaursi	0.686	0.768	0.857	0.625
Artemisia arbuscula	0.825	0.92	0.083	0.019
Artemisia bigelovii	0.607	0.795	0.526	0.511
Artemisia filifolia	0.549	0.747	1.175	1.412
Artemisia frigida	0.591	0.626	0.368	0.43
Artemisia nova	0.586	0.747	0.269	0.226
Artemisia tridentata	0.486	0.59	0.095	0.067
Atriplex canescens	0.325	0.524	0.701	0.826
Atriplex confertifolia	0.475	0.606	0.306	0.231
Atriplex corrugata	0.822	0.831	0.288	0.187
Atriplex gardneri	0.732	0.764	0.249	0.211
Atriplex hymenelytra	0.783	0.876	0.173	0.432
Atriplex obovata	0.271	0.498	2.215	2.657
Atriplex polycarpa	0.678	0.718	0.405	0.523
Baccharis sarothroides	0.666	0.678	0.381	1.081
Canotia holacantha	0.819	0.992	0.454	0.461
Ceanothus greggii	0.938	0.983	0.121	0.087
Cercocarpus intricatus	0.95	0.924	0.079	0.182
Cercocarpus ledifolius	0.775	0.884	0.158	0.085
Cercocarpus montanus	0.67	0.71	0.619	0.77
Chrysothamnus depressus	0.907	0.885	0.276	0.355
Chrysothamnus greenei	0.773	0.916	0.423	0.466
Chrysothamnus viscidiflorus	0.72	0.926	0.079	0.025
Coleogyne ramosissima	0.66	0.868	0.806	0.786
Encelia farinosa	0.781	0.913	0.247	0.182
Ephedra nevadensis	0.589	0.704	0.654	0.706

Species	Vulnerability score		Potential score	
Time Period	2050	2100	2050	2100
Ephedra torreyana	0.329	0.496	1.068	1.335
Ephedra trifurca	0.384	0.574	1.009	1.213
Ephedra viridis	0.523	0.638	0.366	0.466
Ericameria linearifolia	0.903	0.988	0.507	0.115
Ericameria nauseosa	0.779	0.843	0.232	0.244
Eriogonum fasciculatum	0.917	0.969	0.221	0.197
Eriogonum wrightii	0.718	0.749	0.63	1.132
Fallugia paradoxa	0.536	0.688	0.728	0.799
Flourensia cernua	0.905	0.884	0.546	1.09
Fouquieria splendens	0.315	0.392	1.196	1.529
Garrya flavescens	0.908	0.883	0.142	0.387
Garrya wrightii	0.79	0.869	0.263	0.419
Grayia spinosa	0.725	0.758	0.437	0.376
Gutierrezia microcephala	0.733	0.797	0.322	0.652
Gutierrezia sarothrae	0.437	0.591	0.301	0.365
Hymenoclea salsola	0.823	0.877	0.341	0.49
Juniperus communis	0.462	0.61	0.339	0.274
Krascheninnikovia lanata	0.685	0.754	0.335	0.252
Larrea tridentata	0.398	0.576	0.89	1.227
Lupinus argenteus	0.579	0.928	0.748	0.651
Lycium andersonii	0.791	0.736	1.482	1.734
Lycium pallidum	0.98	0.973	0.121	0.192
Mahonia repens	0.485	0.591	0.659	0.655
Menodora spinescens	0.981	0.982	0.53	0.408
Mimosa aculeaticarpa	0.697	0.839	0.398	0.464
Opuntia basilaris	0.919	0.933	0.147	0.072
Opuntia engelmannii	0.693	0.837	0.331	0.37
Parthenium incanum	0.602	0.793	1.492	1.445
Paxistima myrsinites	0.541	0.428	0.682	1.139
Picrothamnus desertorum	0.885	0.981	0.185	0.029
Prunus fasciculata	0.825	0.953	0.178	0.552
Prunus virginiana	0.461	0.569	0.616	0.648
Purshia mexicana	0.574	0.691	0.543	0.73
Purshia stansburiana	0.799	0.738	0.395	0.696
Purshia tridentata	0.557	0.761	0.457	0.376
Quercus turbinella	0.71	0.836	0.337	0.379
Rhus microphylla	0.763	0.775	0.522	0.634

Species	Vulnerability score		Potential score	
Time Period	2050	2100	2050	2100
Rhus ovata	0.995	0.998	0.044	0.006
Rhus trilobata	0.699	0.737	0.282	0.382
Ribes cereum	0.652	0.69	0.459	0.553
Ribes montigenum	0.697	0.879	0.314	0.105
Robinia neomexicana	0.712	0.832	0.196	0.261
Rosa woodsii	0.811	0.864	0.277	0.239
Salazaria mexicana	0.882	0.935	0.385	0.221
Salix geyeriana	0.728	0.812	0.794	0.47
Sarcobatus vermiculatus	0.602	0.766	0.322	0.222
Shepherdia canadensis	0.215	0.345	1.454	1.047
Simmondsia chinensis	0.302	0.515	2.333	2.311
Suaeda moquinii	0.383	0.515	1.481	1.263
Symphoricarpos albus	0.71	0.801	0.603	0.639
Symphoricarpos oreophilus	0.641	0.774	0.24	0.194
Symphoricarpos rotundifolius	0.685	0.722	0.794	0.935
Tetradymia glabrata	0.91	0.971	0.44	0.3
Tetradymia spinosa	0.708	0.908	0.294	0.101
Vaccinium myrtillus	0.646	0.784	0.509	0.336
Vaccinium scoparium	0.626	0.783	0.42	0.247
Yucca angustissima	0.665	0.816	0.402	0.45
Yucca baccata	0.499	0.643	0.453	0.717
Yucca elata	0.542	0.708	0.618	0.88
Yucca glauca	0.599	0.728	0.212	0.166
Yucca schidigera	0.981	0.999	0.13	0.069
Ziziphus obtusifolia	0.486	0.681	1.77	4.019
Grasses				
Achnatherum hymenoides	0.503	0.639	0.187	0.218
Achnatherum speciosum	0.85	0.899	0.134	0.061
Achnatherum thurberianum	0.818	0.974	0.119	0.034
Bouteloua curtipendula	0.676	0.764	0.277	0.45
Bouteloua eriopoda	0.702	0.814	0.886	1.039
Bouteloua gracilis	0.543	0.668	0.146	0.17
Bouteloua hirsuta	0.68	0.706	0.447	0.766
Dasyochloa pulchella	0.555	0.633	2.104	2.354
Elymus elymoides	0.748	0.807	0.177	0.223
Elymus glaucus	0.448	0.481	1.101	0.689
Elymus trachycaulus	0.467	0.58	0.72	0.44

Species	Vulnerability score		Potential score	
Time Period	2050	2100	2050	2100
Festuca arizonica	0.807	0.911	0.689	0.791
Festuca brachyphylla	0.72	0.876	0.569	0.43
Festuca idahoensis	0.679	0.732	0.499	0.265
Festuca thurberi	0.563	0.679	0.659	0.491
Hesperostipa comata	0.654	0.723	0.291	0.374
Hilaria belangeri	0.467	0.554	0.98	1.566
Hordeum jubatum	0.623	0.746	0.783	0.641
Koeleria macrantha	0.622	0.706	0.858	1.071
Leymus cinereus	0.666	0.889	0.11	0.023
Muhlenbergia emersleyi	0.685	0.67	0.525	0.66
Muhlenbergia montana	0.782	0.871	0.611	0.731
Muhlenbergia porteri	0.43	0.418	1.196	1.809
Pascopyrum smithii	0.599	0.723	0.562	0.56
Pleuraphis jamesii	0.557	0.745	0.311	0.331
Pleuraphis mutica	0.838	0.946	1.001	0.898
Pleuraphis rigida	0.837	0.969	0.644	0.406
Poa fendleriana	0.737	0.761	0.575	0.944
Poa secunda	0.365	0.541	0.123	0.067
Schizachyrium scoparium	0.773	0.849	0.212	0.2
Sporobolus airoides	0.414	0.677	0.772	0.71
Sporobolus cryptandrus	0.78	0.915	0.513	0.495
Sporobolus flexuosus	0.887	0.95	0.959	0.621

Appendix B Assessment Results for the 166 Plant Species: Spatial Models Figures 1 to 166.

http://pubs.usgs.gov/of/2012/1020/of2012-1020_appendix_b/: *Assessment Results for the 166 Plant Species: Spatial Models Figures 1 to 166*. The data are presented as a single large PDF; as one PDF each for trees, shrubs, and grasses; and as a set of 166 single-page PDFs—one for each of the species (2.6 GB total).