Western Screech-Owl (*Megascops kennicottii*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3S4 (Potential Species of Concern)
Global Rank: G4G5

Modeling Overview

Created by: Braden Burkholder
Creation Date: March 4, 2022
Evaluator: Dan Bachen
Evaluation Date: March 23, 2022

Inductive Model Goal: To predict the current distribution and relative suitability of breeding habitat for Western Screech-Owl at large spatial scales across its presumed current breeding range in Montana.
Inductive Model Performance: The model appears to somewhat adequately reflect the current distribution and relative suitability of breeding habitat for Western Screech-Owl at larger spatial scales across its presumed current breeding range in Montana. Evaluation metrics indicate an acceptable model fit and the delineation of habitat suitability classes is well supported by the data.
Inductive Model Output:
http://mtnhp.org/models/files/Western_Screech_Owl_ABNSB01040_20220304_modelHex.lpk

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with Western Screech-Owl during the breeding season, across its presumed current breeding range in Montana.
Deductive Model Performance: Ecological systems that Western Screech-Owl is commonly and occasionally associated with seem to vastly overpredict the amount of suitable habitat across its presumed current breeding range in Montana.

Suggested Citation: Montana Natural Heritage Program. 2022. Western Screech-Owl (*Megascops kennicottii*) predicted suitable habitat models created on March 4, 2022. Montana Natural Heritage Program, Helena, MT. 20 pp.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ABNSB01040

Species Model Page: http://mtnhp.org/models/?elcode=ABNSB01040

Inductive Modeling

Model Limitations and Suggested Uses

This model is based on statewide biotic and abiotic environmental layers originally mapped at a variety of spatial scales and standardized to 90×90-meter raster pixels. The spatial accuracy of the training and testing data are varied (typically 20-400 meters) and may result in additional statistical noise in the model. As a result, model outputs may not be appropriate for use on smaller areas or at fine spatial scales. **Model outputs should not typically be used for planning efforts on land areas smaller than one quarter of a public land survey system (PLSS) section (<64 hectares)** and model outputs for some species may only be appropriate for broader regional level planning efforts. Models should be interpreted as landscape-level habitat suitability (fundamental niche) and not as estimated distributions of the species (realized niche) since suitable habitat may be unoccupied (Pulliam 2000). **Consequently, model outputs should not be used in place of on-the-ground surveys for species**, and wildlife and land management agency biologists should be consulted about the value of using model output to guide habitat management decisions for regional planning efforts or local projects. See Suggested Contacts for Natural Resource Agencies listed at the end of this report or on our website. In general, we have found across a large number of species representing a wide variety of plant and animal taxa that experts believe optimal and moderate suitability classes represent landscapes where suitable habitat is often more continuous while the low suitability class represents landscapes where suitable habitat is often less continuous, scattered, or patchy (see definitions in the Model Outputs and Evaluation section below). We encourage use of these classes for management, planning, permitting, survey, and other decisions accordingly.

Inductive Model Methods

Modeling Process

Presence-only data were extracted from Montana Natural Heritage Program Databases, which serve as a clearinghouse for animal and plant observation data in Montana. These data were then filtered to ensure spatial and temporal accuracy and to reduce spatial autocorrelation (summarized in Table 1). The spatial extent of this model was limited to the presumed geographic range of the species, by season when applicable, in order to accurately assess potentially available habitat.

We then used these data and 44 statewide biotic and abiotic environmental layers at a 90×90-meter pixel scale (Table 2) to construct the model using a maximum entropy algorithm employed in the modeling program Maxent (Phillips et al. 2006, Phillips et al. 2017). Entropy maximization modeling functions by calculating constraint distributions and then applies those constraints to the environmental layers to estimate a predicted suitable habitat distribution. The mean and variance of the environmental layer values (environmental variables) at the training data locations are used to estimate the constraint distributions. Maxent requires that the final predicted distribution fulfills these constraints. Maxent avoids overfitting models to the training data by “regularizing” or relaxing the constraints so that modeled distributions only have to be close to, rather than exactly equal to, the constraint distributions (Elith et al. 2011). The default regularization multiplier of 1.0 was used since species-specific tuning was impractical given the diversity and volume of species modeled in this effort (Merow et al. 2013, Radosavljevic and Anderson 2014). Additionally, we did not use hinge or threshold features at any sample size to minimize potential overfitting by overly complex models (Syfert et al. 2013, De Marco and Nóberga 2018). The Maxent algorithm can successfully train models even when collinearity exists between environmental variables and the practices of removing collinear variables and/or reducing variables results in limited improvement in Maxent model performance (De Marco and Nóberga 2018, Feng et al. 2019); neither method was employed here.

Maxent fits a model by assuming the predicted distribution is uniform in geographic space and moves away from this distribution only to the extent that it is forced to by the constraints of the training data. To do this, Maxent successively modifies the coefficients for each environmental variable via random walk, accepting the modified coefficient if it increases the gain. Gain is a measure of the closeness of the model concentration around the presence samples that is similar to goodness of fit in generalized linear models. The random walk of coefficients continues until either the increase in the gain falls below a set convergence threshold (0.00001) or a set maximum number of iterations are performed (50,000). The gain value at the end of a model run indicates the likelihood of suitability of the presence samples relative to the likelihood for random background points.

We employed a k-folds cross validation methodology, in this case using ten folds for model training and validation (Elith et al. 2011). Each fold consists of 90% of the data designated for training and 10% of the data reserved for testing. Each record is used for training nine times and testing once. Ten models are estimated and averaged to produce the final model presented here.

Model Outputs and Evaluation

The overall gain associated with individual environmental variables (Table 3) can be used as a measure of the relative importance of each variable (Merow et al. 2013). However, the importance of individual environmental variables should be interpreted with caution due to collinearity between variables. The jackknife assessment of contribution by individual environmental variables to training gain (Figure 1) may be more useful in interpreting the relative importance of individual variables. The response curves for the top four contributing environmental variables are shown for reference (Figure 2). These response curves should also be interpreted cautiously because the observation data used to train the models was not gathered under a probabilistic sampling scheme. If enough observations were available to train and evaluate the model, thresholds are estimated for low, moderate, and optimal habitat suitability; details of this process are presented in Table 4 and Figure 3.

The initial model output is a spatial dataset of continuous logistic values that ranges from 0-1 with lower values representing areas predicted to be less suitable habitat and higher values representing areas predicted to be more suitable habitat (Figures 4 & 5). The standard deviation in the model output across the averaged models is also calculated and plotted as a map to examine spatial variance of model output (Figure 6). The continuous output is reclassified into suitability classes and aggregated within 259-hectare hexagons (Figures 7-9).

In addition to the map of spatial variance in model output, we also evaluated the output of the Maxent model with absolute validation index (AVI) (Hirzel et al. 2006) and deviance (Phillips and Dudik 2008). These metrics are described below in the results (Table 5). True skill statistic (TSS) (Allouche et al. 2006), symmetric extremal dependence index (SEDI) (Wunderlich et al. 2019), and Area Under the Curve (AUC) values are also displayed for reference but are not used for evaluation (Lobo et al. 2008). Finally, a deviance value was calculated for each test data observation as a measure of how well model output matched what the model predicted for the location of test observations and this was plotted with larger symbols indicating larger deviance (see Figure 5). In practice, we have found large deviance values to be associated with records that are incorrectly or imprecisely mapped, problematic areas in underlying environmental layers, regions where species have few observations outside of the core portion of their range, or insufficient models with poor performance.

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	451
Location Data Selection Rule 1 – Valid and Accurate Records	Records associated with breeding activity with <= 1600 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	63
Location Data Selection Rule 2 – Spatially Unique Records	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	43
Season Modeled	Summer Breeding
Number of Model Background Locations[a]	20,254

[a] Background locations are chosen at random and in proportion to the percent of the state covered by a species' geographic range, with a maximum of 60,000 locations. Although these locations only represent ~0.1% of the pixels in any modeled area, this level of sampling is sufficient to estimated distributions of environmental conditions present (Phillips and Dudik 2008).

Table 2: Environmental Layers and Corresponding Variables[a]

Layer Name	Variable		Layer Name	Variable
LC_AgDry_97	Developed - Dry Agriculture		NED_AspectEW	Aspect (East-West)
LC_AgIrr_97	Developed - Irrigated Lands		NED_AspectNS	Aspect (North-South)
LC_Alpine_97	Alpine		NED_Elevation	Elevation
LC_Barren_97	Sparse and Barren		NED_Ruggedness	Ruggedness
LC_Developed_97	Developed - All Other		NED_Slope	Slope
LC_ForestBurn_97	Forest - Burned		NED_SRISummer	Summer Solar Radiation
LC_ForestConif_97	Forest - Conifer		NED_SRIWinter	Winter Solar Radiation
LC_ForestDecid_97	Forest - Deciduous		NED_TPI	Topographic Position Index
LC_ForestHarv_97	Forest - Harvested		NHD_Dist2WaterEdge	Distance to Water Edge
LC_ForestInsct_97	Forest - Insect Killed		NHP_AnthroInfl	Anthropogenic Influence
LC_Grassland_97	Grasslands		NRCS_FrostFreeDays	Frost Free Days
LC_IntroVeg_97	Introduced Vegetation		NRCS_REAP	Relative Effective Annual Precipitation
LC_ShrubBurn_97	Shrublands - Burned		PRISM_Precipitation	Annual Precipitation
LC_Shrubland_97	Shrublands		PRISM_WinPrecip	Percent Winter Precipitation
LC_WetRip_97	Wetland & Riparian		SoilGrid_BD	Bulk Density
LC_Dist2Forest	Distance to Forest		SoilGrid_Clay	Percent Clay
MCO_DegreeDays	Degree Days		SoilGrid_EC	Electric Conductivity
MCO_MaxSumTemp	Maximum Summer Temp		SoilGrid_OrgC	Organic Carbon
MCO_MinWinTemp	Minimum Winter Temp		SoilGrid_pH	Soil pH
MCO_NDVI	Normalized Difference Vegetation Index		SoilGrid_Sand	Percent Sand
MTGeol_Dist2Alluv	Distance to Alluvium		SoilGrid_Silt	Percent Silt
MTGeol_Dist2C03	Distance to Carbonate Rock		SoilGrid_TotN	Total Nitrogen

[a] Additional details and sources available in Appendix.

Inductive Model Results

Table 3: Top Ten Contributing Environmental Variables to Model Fit

Variable	Percent Contribution[a]	Variable	Percent Contribution[a]
Developed - All Other	16.1%	Anthropogenic Influence	5.6%
Wetland Riparian	15.7%	Elevation	4.2%
Distance to Forest	12.1%	Organic Carbon	4.0%
Minimum Winter Temp	9.4%	Distance to Water Edge	3.2%
Forest - Conifer	5.9%	Frost Free Days	2.8%

[a] Relative contributions of the variables to the model based on changes in fit (gain) during iterations of the training algorithm.

Table 4: Habitat Suitability Thresholds and Areas of Suitable Habitat

Measure	Value
Optimal Logistic Threshold[a]	0.646
Moderate Logistic Threshold[b]	**0.196**
Low Logistic Threshold[c]	0.044
Area of predicted optimal habitat within modeled range	2,032.2 km^2
Area of predicted moderate suitability habitat within modeled range	**15,094.4 km^2**
Area of predicted low suitability habitat within modeled range	34,463.4 km^2
Total area of predicted suitable habitat within modeled range	51,590.0 km^2
Area of entire modeled range (percent of Montana)	128,451.3 km^2 (33.8%)

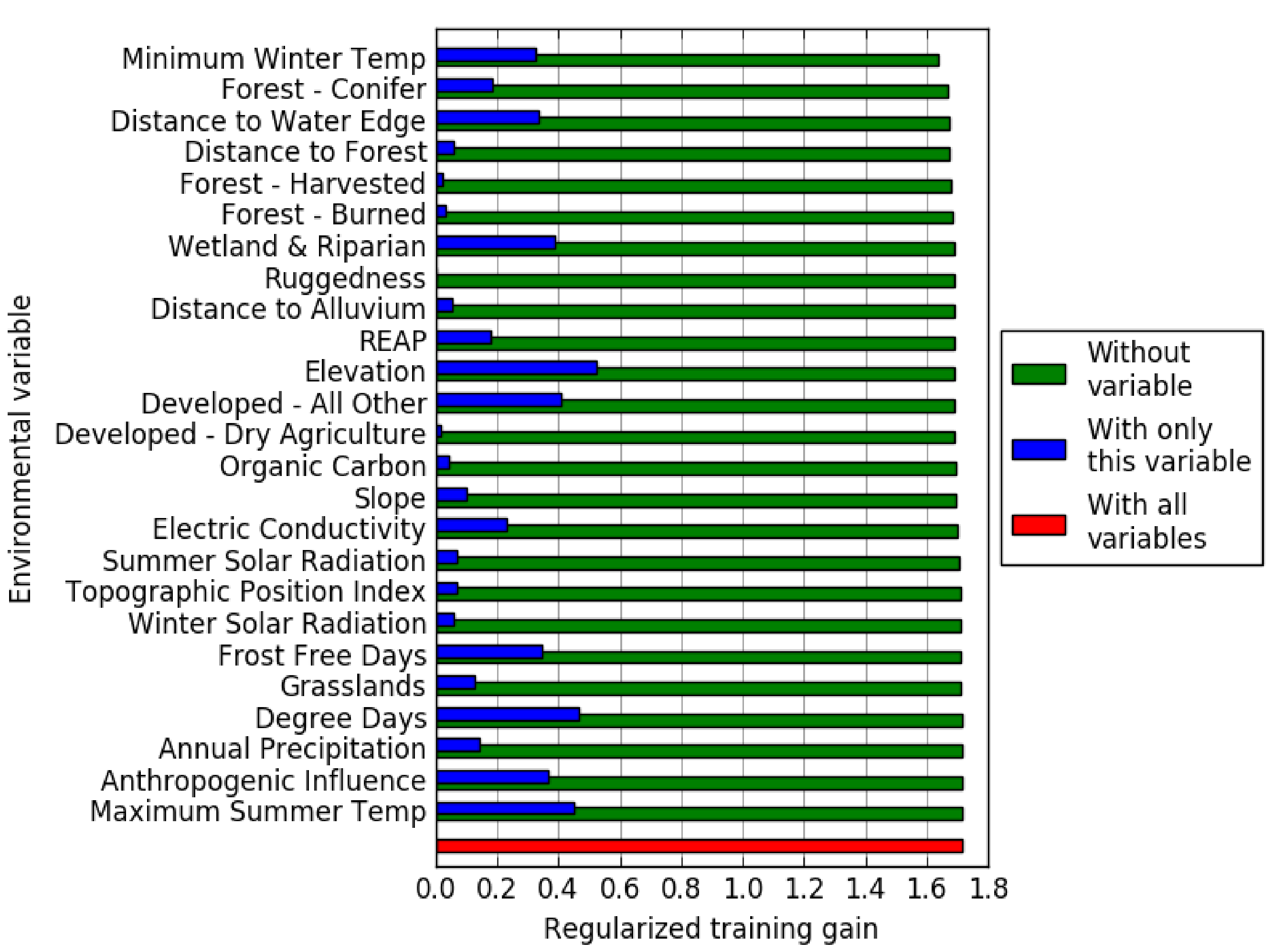
[a] The logistic threshold where the percentage of test observations above the threshold is 10 or more times higher than would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006) (see Figure 3). When sample sizes are small, it may be undetermined.
[b] **This is the cutoff recommended for use in management decisions.** The logistic threshold value where the percentage of test observations above the threshold is greater then what would be expected if the observations were randomly distributed across logistic value classes - in other words, when the modeled habitat is used more often than expected from its proportional availability on the landscape (Hirzel et al. 2006). When sample sizes are small, it may be undetermined.
[c] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area (Phillips et al. 2017). This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species. In practice, habitat with low suitability may represent landscapes of marginal or discontinuous habitat where suitable habitat patches of various sizes are isolated by unsuitable habitat.

Table 5: Evaluation Metrics

Metric	Value
Low AVI[a]	83.7%
Moderate AVI[a]	67.4%
Optimal AVI[a]	27.9%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.916 ± 3.002
TSS (Sensitivity + Specificity - 1)[c]	0.5454 (0.6744 + 0.8710 -1)
SEDI[c]	0.7126
Training AUC[d]	0.948
Test AUC[e]	0.856

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold (see Table 4).
[b] A measure of how well model output matched the location of test observations. In theory, everywhere a test location was located, the logistic value should have been 1.0. The deviance value for each test location is calculated as -2 times the natural log of the associated logistic output value. For example, the equivalent deviance values for the low, moderate and optimal logistic thresholds of this model would be 6.229, 3.262 and 0.874, respectively. Deviances for individual test locations are plotted in Figure 5. Average Testing Deviance less than the Moderate Deviance typically indicates good model performance.
[c] Ranges from -1 to 1, with a random or null model performing at a value of 0 and values 0.65 indicating moderate performance (0.8 generally good performance). The moderate threshold (0.196) is used to develop the confusion matrix for Sensitivity and Specificity metrics. Note that Specificity is calculated based on pseudo-absences (not true absences) and may be biased when large areas are modeled as moderate or optimal suitable habitat.
[d] The area under a curve obtained by plotting the true positive rate against 1 minus the false positive rate for model training observations (averaged over 10 folds). Values range from 0 to 1 with a random or null model performing at a value of 0.5.
[e] The same metric described in [d], but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental variables to training gain. Variables are ordered by reduction in gain without that variable (green), from greatest to least impact. Only the 25 most influential variables[a] are shown.



[a] Interpretation of individual environmental variables should be approached cautiously and may be inappropriate due to covariance between variables.

Figure 2. Response curves for the top four contributing environmental variables, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental variables are available upon request.

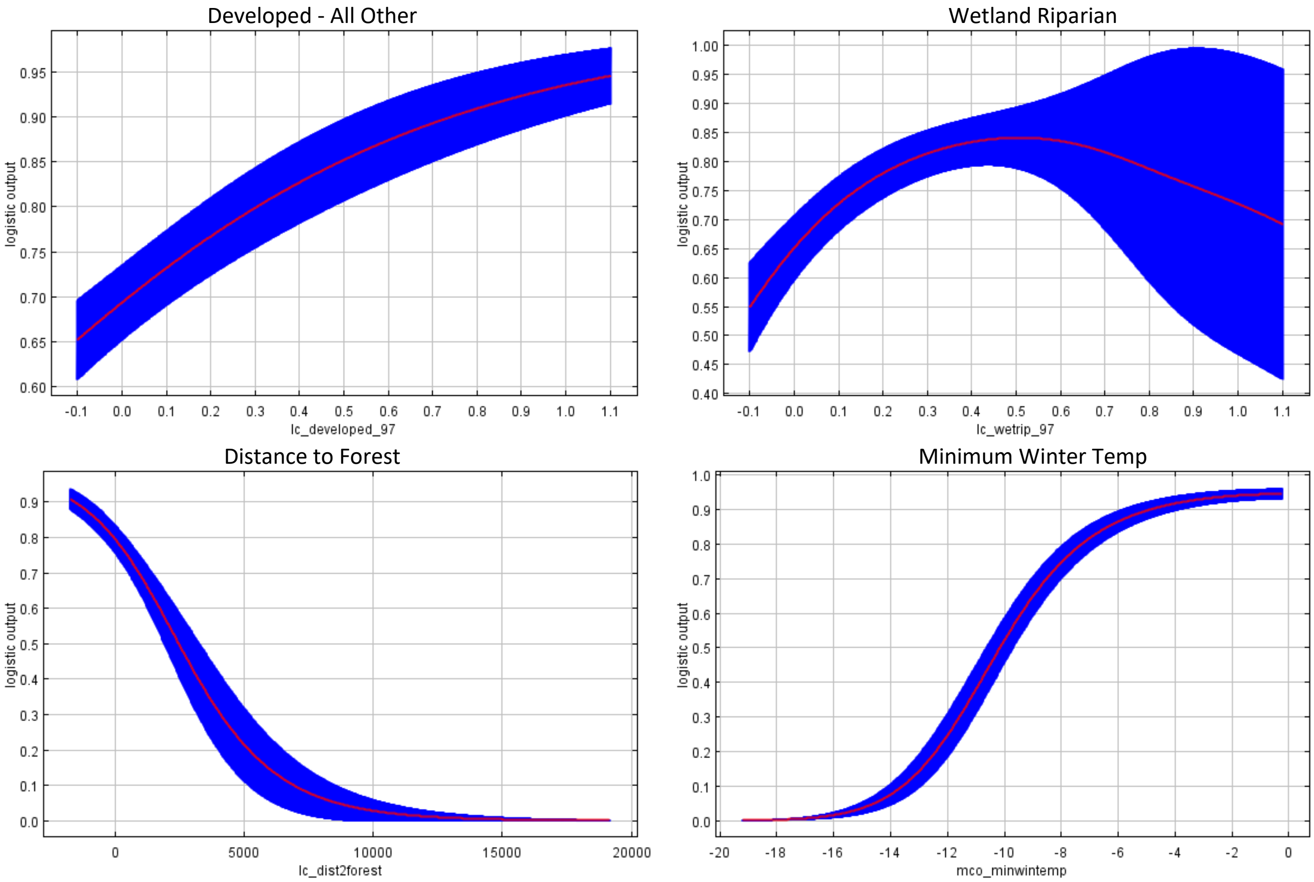
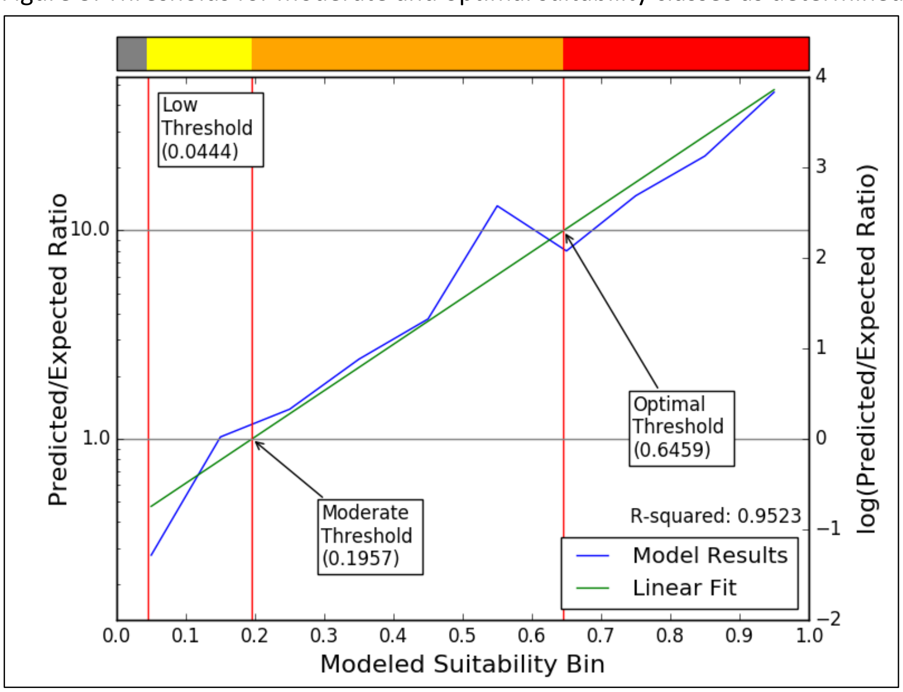


Figure 3. Thresholds for moderate and optimal suitability classes as determined by linear fit.



Inductive Model Map Outputs

Figure 4. Continuous habitat suitability model logistic output (90-meter pixels); white area is not modeled.

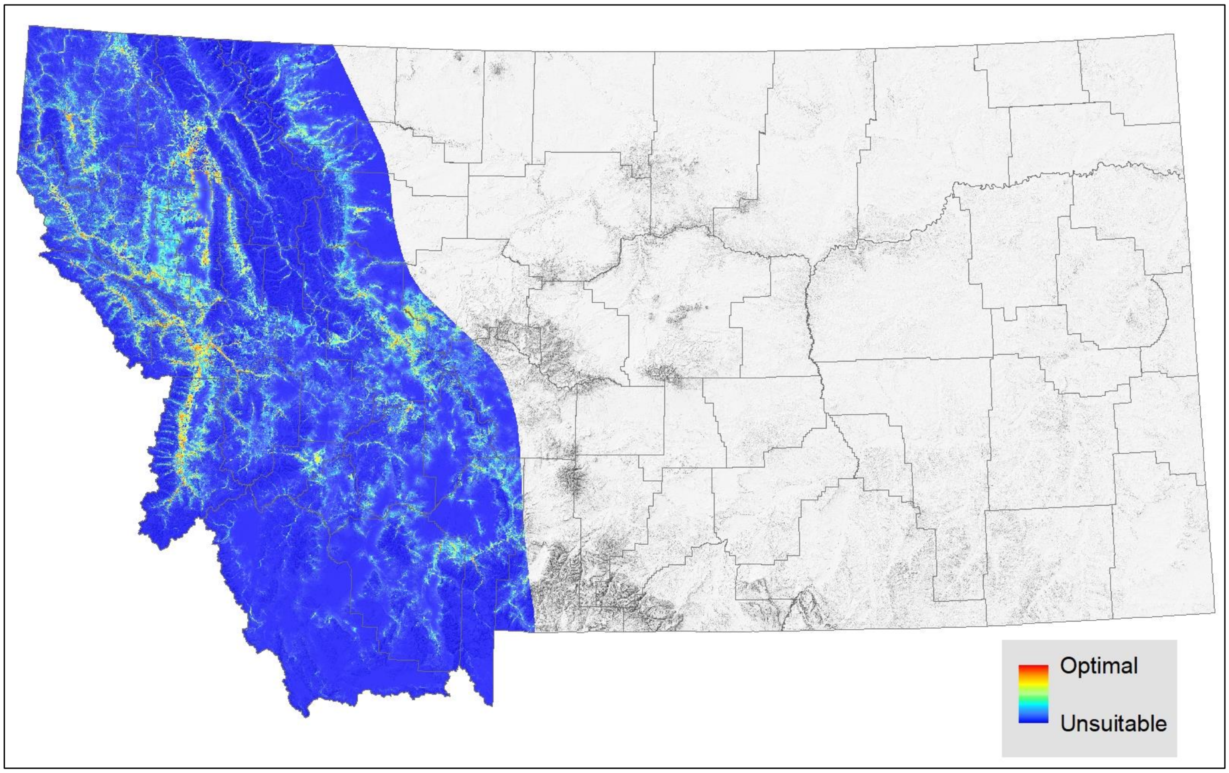


Figure 5. Continuous habitat suitability model output with relative deviance for each observation. Low deviance points fall within optimal or moderate habitat; high deviance points are in generally unsuitable habitat.

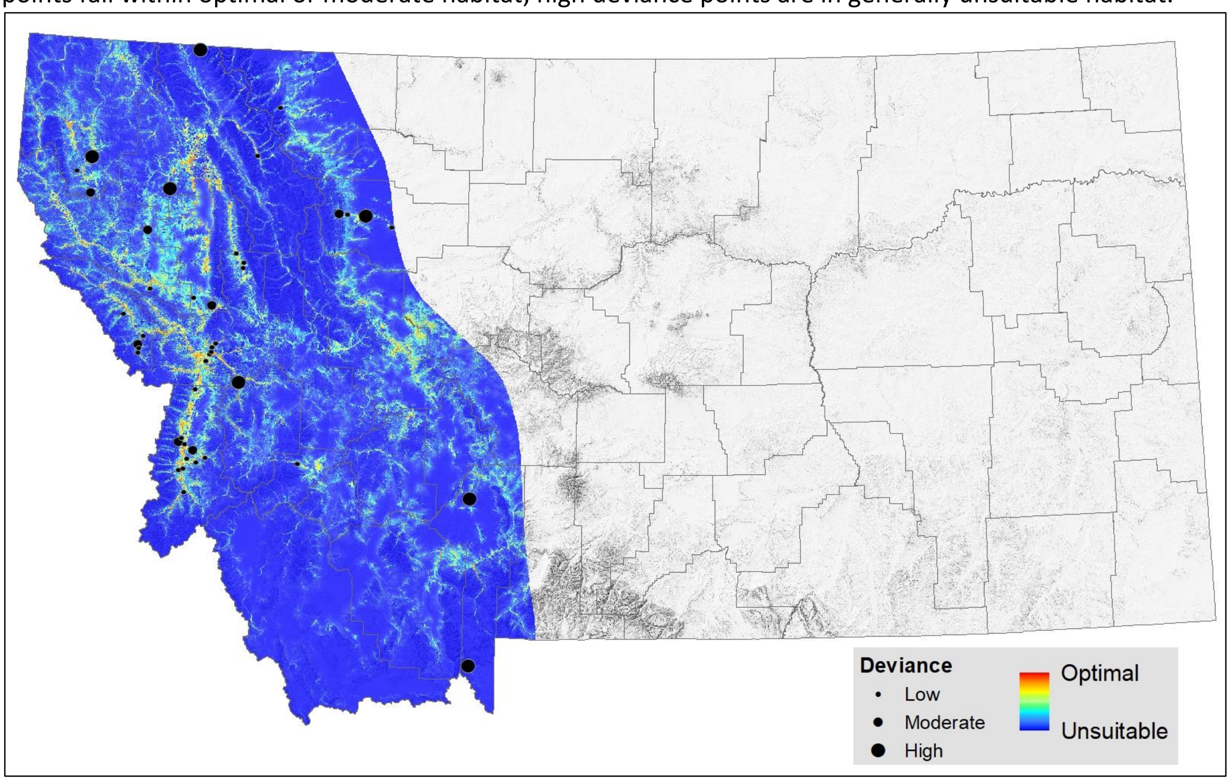


Figure 6. Standard deviation in the model output across the averaged models. Lower deviance (a solid blue map) indicates a better fitting model with lower variability between model iterations.

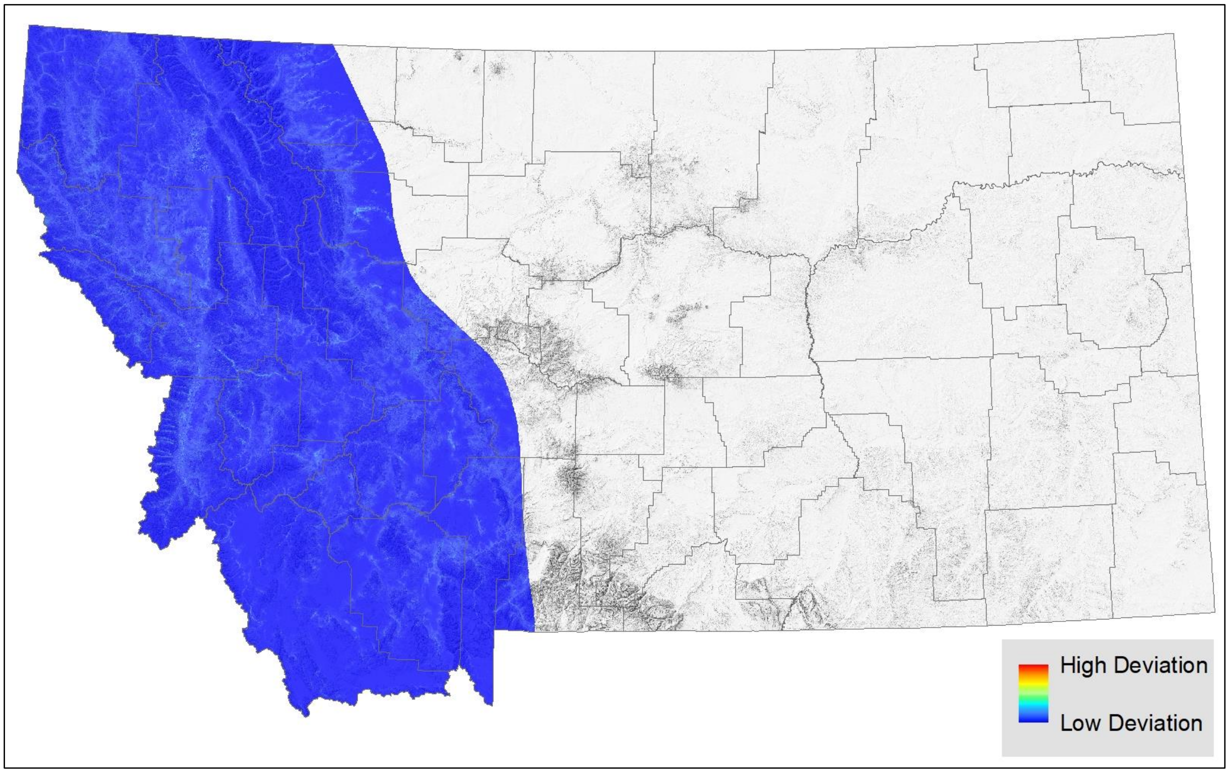


Figure 7. Model output for 90-meter pixels classified into habitat suitability classes.

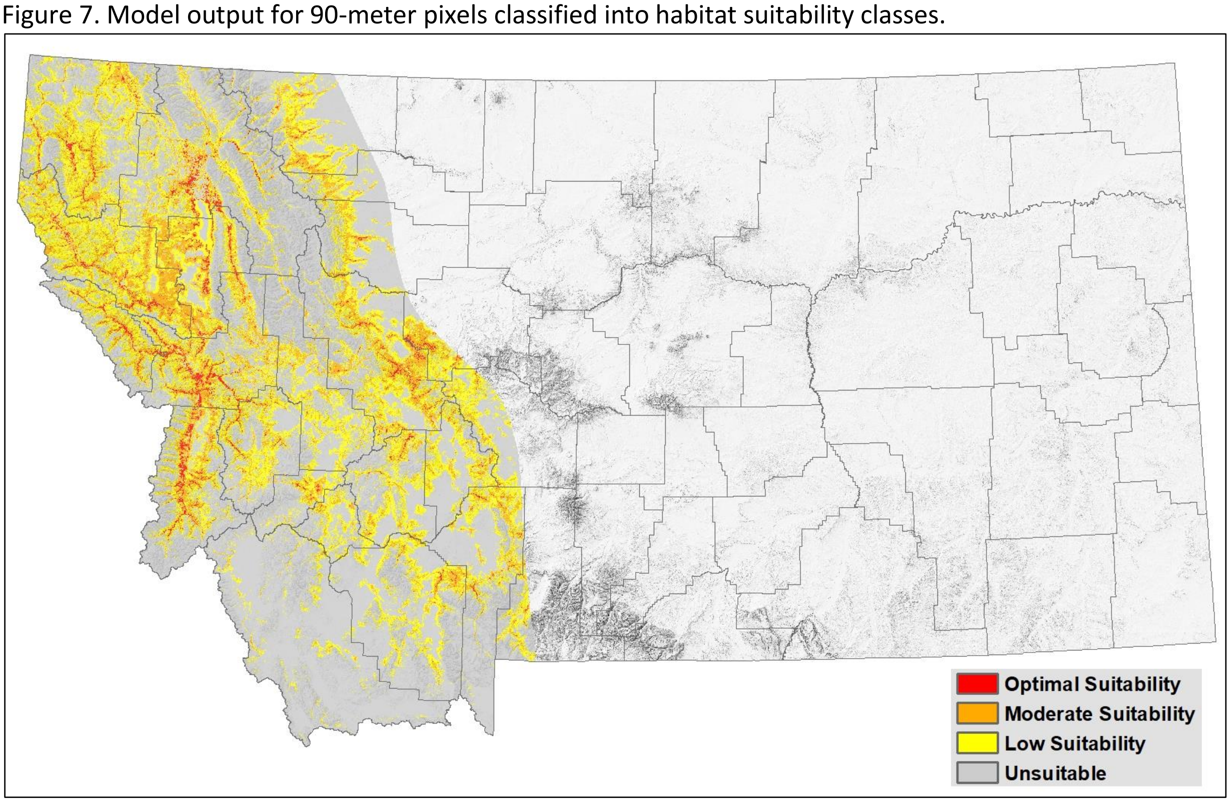


Figure 8. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.

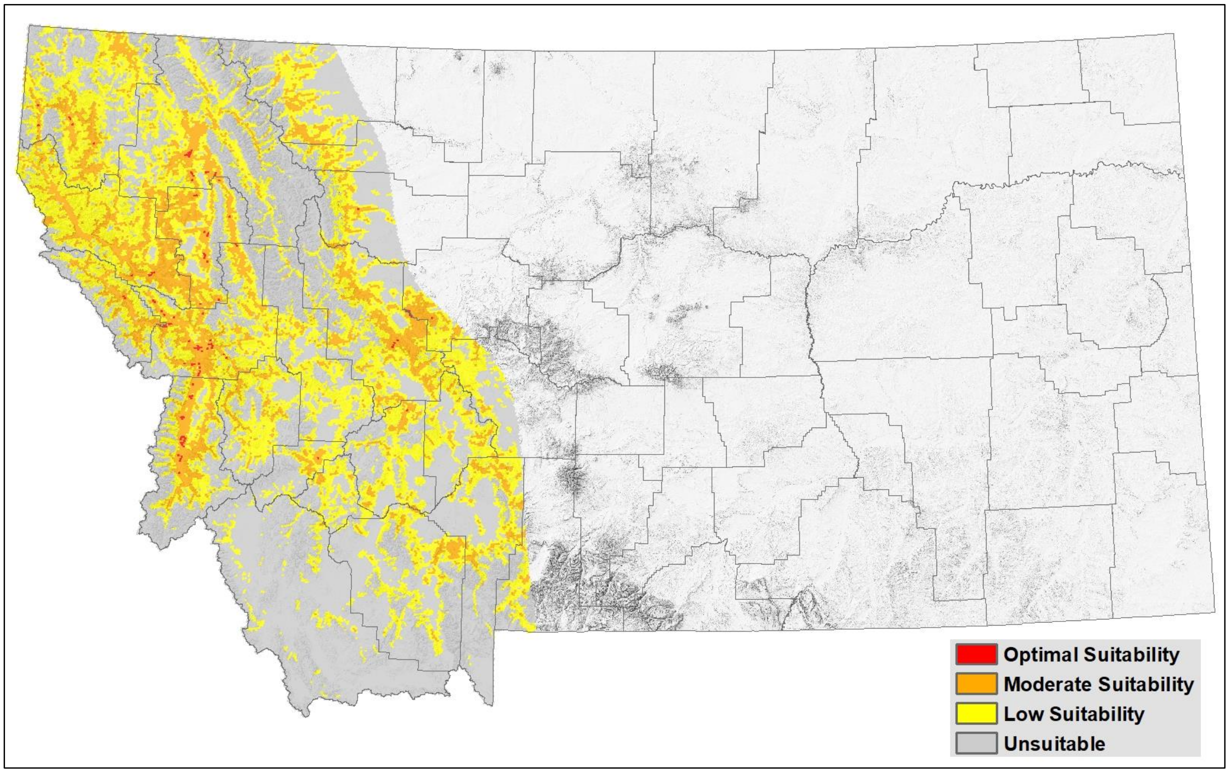
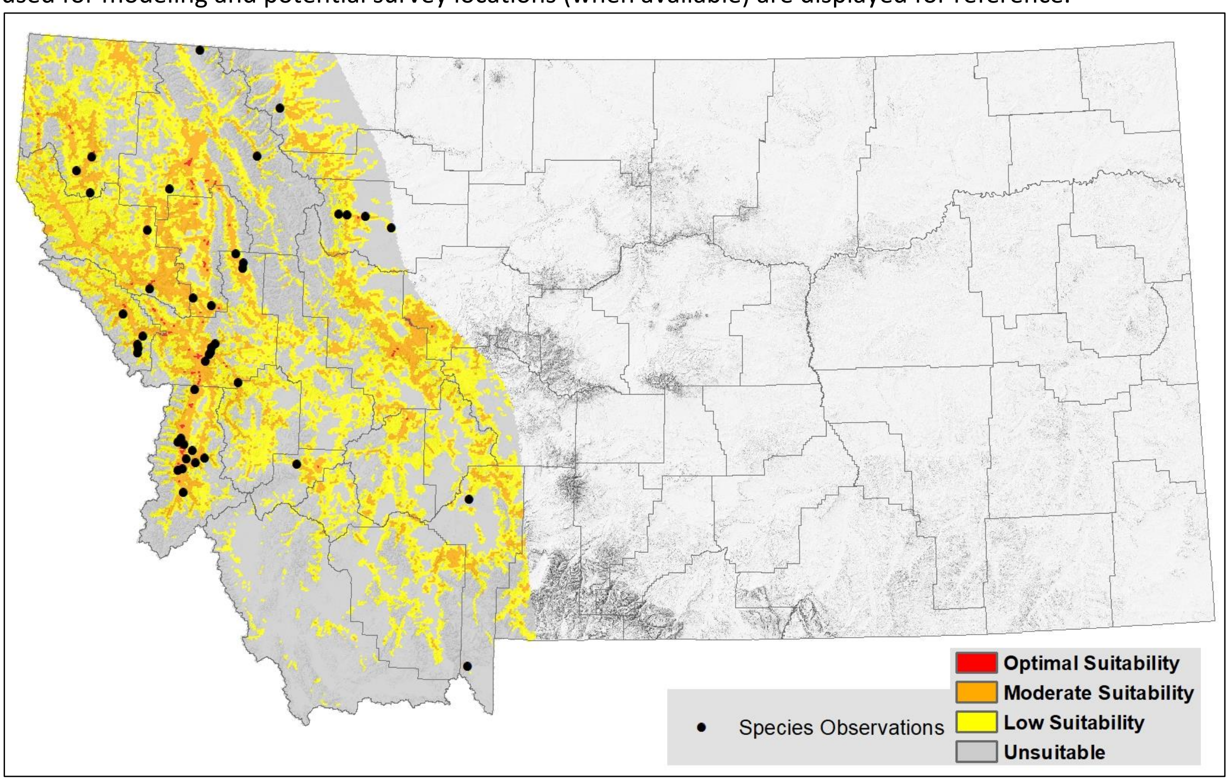


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons; observations used for modeling and potential survey locations (when available) are displayed for reference.



Deductive Modeling

Model Limitations and Suggested Uses

Species associations with ecological systems should be used to generate lists of potential species that may occupy broader landscapes for the purposes of landscape-level planning. Users of this information should be aware that the land cover data used to generate species associations was only intended to be used at broader landscape scales. Land cover mapping accuracy is particularly problematic when the systems occur as small patches or where the land cover types have been altered over the past decade. Thus, particular caution should be used when using the associations in assessments of smaller areas (e.g. less than one quarter of a public land survey system (PLSS) section, 64 hectares). Model outputs should not be used in place of on-the-ground surveys for species, and wildlife and land management agency biologists should be consulted about the value of using these associations to guide habitat management decisions for regional planning efforts or local projects. See Suggested Contacts for State and Federal Natural Resource Agencies attached to this document. Data used in model evaluation often have locational uncertainties that exceed the 30-meter pixel size of the land cover dataset, potentially intersecting incorrect ecological systems. Additionally, the habitat within a pixel may have been assigned to the wrong ecological system or the habitat may have been modified. As a result, evaluation metrics may be skewed low, especially for species occupying ecotones or patchy ecological systems. Finally, users should note that ecological systems associated with a species are only mapped within the range of that species, although portions of that ecological system may occur elsewhere.

Deductive Model Methods

Modeling Process

This model is based on the 2017 statewide land cover classifications at 30×30-meter raster pixels (Montana Land Use/Land Cover Dataset). Level 3 ecological systems (90) were used for this model and these data were originally mapped at a scale of 1:100,000. In general, species were associated as using an ecological system if structural characteristics of used habitat documented in the literature were present in the ecological system or large numbers of point observations were associated with the ecological system. However, species were not associated with an ecological system if there was no support in the literature for use of structural characteristics in an ecological system, even if point observations were associated with that system. Species were either commonly associated, occasionally associated, or not associated with each ecological system. This assignment was based on the degree to which the structural characteristics of an ecological system matched the preferred structural habitat characteristics for each species in the literature. The percentage of observations associated with each ecological system relative to the percent of Montana covered by each ecological system was also used to guide assignments of habitat quality. Associations are shown in Table 6.

Model Outputs and Evaluation

The model output is a spatial dataset of categorical habitat suitability based on ecological system associations (commonly or occasionally associated) within the species' presumed range (Figure 10) and resulting tabular estimates of the area of commonly and occasionally associated habitat (Table 7). We evaluated this model output based on known or potential distribution and habitat use in Montana and absolute validation indices (AVI) (Hirzel et al. 2006) using presence-only data (Table 8).

Deductive Model Results

Table 6: Ecological Systems Associated with Western Screech-Owl

Ecological System	Code	Association	Count[a]
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	10
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	8
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	2
Rocky Mountain Subalpine Woodland and Parkland	4233	Common	1
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	1
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	0
Recently burned forest	8501	Common	0
Post-Fire Recovery	8505	Common	0
Harvested forest-tree regeneration	8601	Common	0
Harvested forest-shrub regeneration	8602	Common	0
Harvested forest-grass regeneration	8603	Common	0
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Alpine-Montane Wet Meadow	9217	Common	0
Aspen Forest and Woodland	4104	Occasional	1
Aspen and Mixed Conifer Forest	4302	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 43 observation records used in the inductive model (see Table 1). This may be zero if the number of observations is low or if the ecological system is patchily distributed.

Table 7: Area of Range and Ecological System (ES) Classes

Measure	Value
Area of entire modeled range (percent of Montana)	128,451.3 km2 (33.8%)
Area of Commonly and Occasionally Associated ES	53,934.0 km^2
Area of Commonly Associated ES	52,633.0 km^2
Area of Occasionally Associated ES	1,301.0 km^2

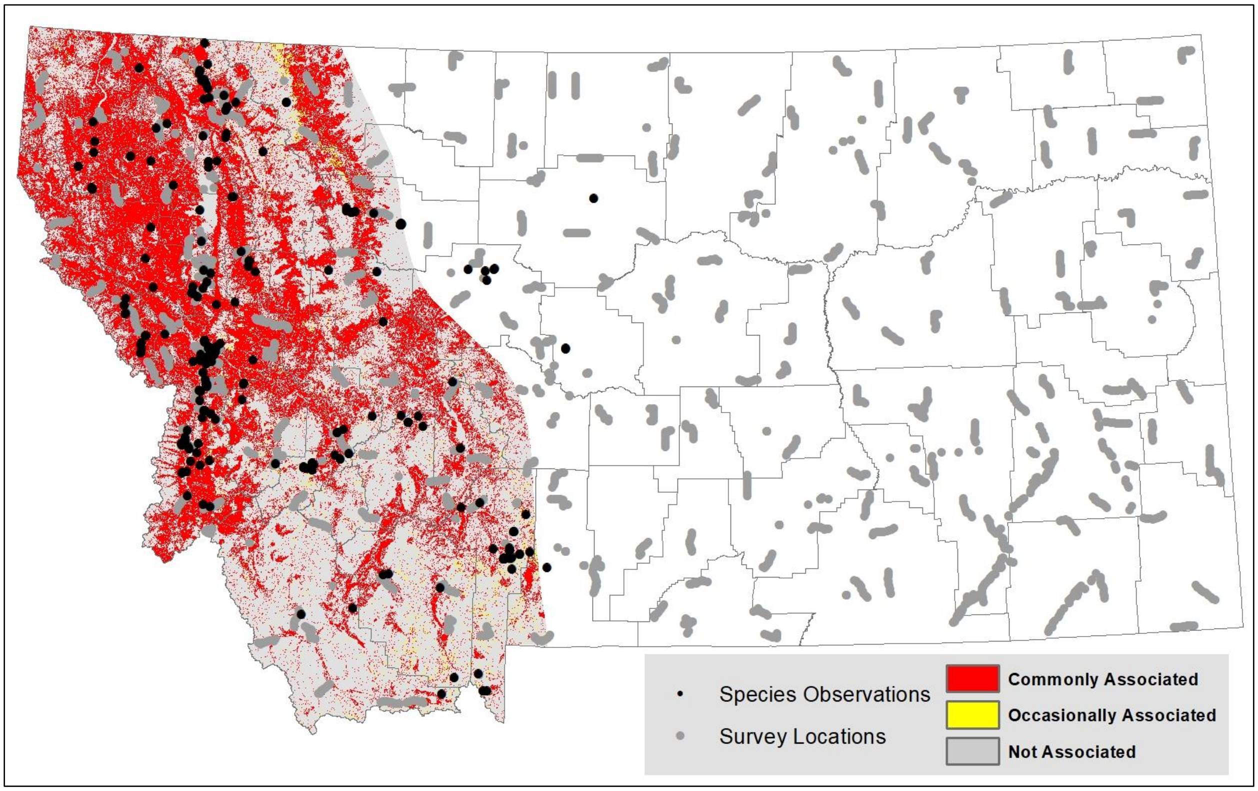
Table 8: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	53.5%
Commonly Associated ES AVI[a]	51.2%
Occasionally Associated ES AVI[a]	2.3%

[a] Absolute Validation Index: The proportion of test locations that fall within the class(es).

Deductive Model Map Output

Figure 10. Deductive model output classified into habitat associations.



Literature Cited

Allouche, O., A. Tsoar, and R. Kadmon. 2006. Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). Journal of Applied Ecology 43: 1223-1232. https://doi.org/10.1111/j.1365-2664.2006.01214.x

Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee, and C. J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions 17: 43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x

Hirzel, A. H., G. Le Lay, V. Helfer, C. Randin, and A. Guisana. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecological Modelling 199: 142-152. https://doi.org/10.1016/j.ecolmodel.2006.05.017

Lobo, J. M., A. Jiménez-Valverde, and R. Real. 2008. AUC: a misleading measure of the performance of predictive distribution models. Global Ecology and Biogeography 17: 145-151. https://doi.org/10.1111/j.1466-8238.2007.00358.x

Merow, C., M. J. Smith, and J. A. Silander Jr. 2013. A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. Ecography 36: 1058-1069. https://doi.org/10.1111/j.1600-0587.2013.07872.x

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190: 231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Phillips, S. J., M. Dudík, R. E. Schapire. 2017. Maxent software for modeling species niches and distributions (Version 3.4.1). Available from: http://biodiversityinformatics.amnh.org/open_source/maxent

Phillips, S. J. and M. Dudík. 2008. Modeling of species distributions with MaxEnt: New extensions and a comprehensive evaluation. Ecography 31: 161-175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Pulliam H. R. 2000. On the relationship between niche and distribution. Ecology Letters 3: 349–361. https://doi.org/10.1046/j.1461-0248.2000.00143.x

Radosavljevic, A., and R. P. Anderson. 2014. Making better Maxent models of species distributions: complexity, overfitting, and evaluation. Journal of Biogeography 41: 629–643. https://doi.org/10.1111/jbi.12227

Syfert M. M., M. J. Smith, and D. A. Coomes. 2013. The effects of sampling bias and model complexity on the predictive performance of Maxent species distribution models. PLoS ONE 8(2): e55158. https://doi.org/10.1371/journal.pone.0055158

Wunderlich, R. F., Y. Lin, J. Anthony, and J. R. Petway. 2019. Two alternative evaluation metrics to replace the true skill statistic in the assessment of species distribution. Nature Conservation 35: 97-116. https://doi.org/10.3897/natureconservation.35.33918

Appendix

Table A. Detailed Descriptions of Environmental Layers

Layer Name	Class	Variable	Original Scale	Description
LC_AgDry_97	Landcover	Developed - Dry Agriculture	30m	Proportion (0-1) of cells classed as Agriculture without Irrigation within a 97-cell neighborhood (~150m radius).
LC_AgIrr_97	Landcover	Developed - Irrigated Lands	30m	Proportion (0-1) of cells classed as Agriculture with Irrigation within a 97-cell neighborhood (~150m radius).
LC_Alpine_97	Landcover	Alpine	30m	Proportion (0-1) of cells classed as Alpine cover types within a 97-cell neighborhood (~150m radius).
LC_Barren_97	Landcover	Sparse and Barren	30m	Proportion (0-1) of cells classed as Sparse or Barren within a 97-cell neighborhood (~150m radius).
LC_Developed_97	Landcover	Developed - All Other	30m	Proportion (0-1) of cells classed as Developed (e.g. towns, roads, mines) within a 97-cell neighborhood (~150m radius).
LC_ForestBurn_97	Landcover	Forest - Burned	30m	Proportion (0-1) of cells classed as Burned Forest within a 97-cell neighborhood (~150m radius).
LC_ForestConif_97	Landcover	Forest - Conifer	30m	Proportion (0-1) of cells classed as Conifer Forest within a 97-cell neighborhood (~150m radius).
LC_ForestDecid_97	Landcover	Forest - Deciduous	30m	Proportion (0-1) of cells classed as Deciduous Forest within a 97-cell neighborhood (~150m radius).
LC_ForestHarv_97	Landcover	Forest - Harvested	30m	Proportion (0-1) of cells classed as Harvest Forest within a 97-cell neighborhood (~150m radius).
LC_ForestInsct_97	Landcover	Forest - Insect Killed	30m	Proportion (0-1) of cells classed as Insect Killed Forest within a 97-cell neighborhood (~150m radius).
LC_Grassland_97	Landcover	Grasslands	30m	Proportion (0-1) of cells classed as Grassland cover types within a 97-cell neighborhood (~150m radius).
LC_IntroVeg_97	Landcover	Introduced Vegetation	30m	Proportion (0-1) of cells classed as Introduced Vegetation within a 97-cell neighborhood (~150m radius).
LC_ShrubBurn_97	Landcover	Shrublands - Burned	30m	Proportion (0-1) of cells classed as Burned Shrubland within a 97-cell neighborhood (~150m radius).
LC_Shrubland_97	Landcover	Shrublands	30m	Proportion (0-1) of cells classed as Shrubland cover types within a 97-cell neighborhood (~150m radius).
LC_WetRip_97	Landcover	Wetland Riparian	30m	Proportion (0-1) of cells classed as Wetland or Riparian within a 97-cell neighborhood (~150m radius).
LC_Dist2Forest	Landcover	Distance to Forest	30m	Distance in meters to any forest cover type, after consolidating to patches 900m^2.
MCO_DegreeDays	Climate	Degree Days	800m	Average annual total of degree days (°F) above 32°F for 1981-2010.
MCO_MaxSumTemp	Climate	Maximum Summer Temp	800m	Average maximum temperature (°C) in July for 1981-2010.
MCO_MinWinTemp	Climate	Minimum Winter Temp	800m	Average minimum temperature (°C) in January for 1981-2010.
MCO_NDVI	Climate	Normalized Difference Vegetation Index	925m	Normalized Difference Vegetation as a measure of yearly mean greenness from the MODIS Terra satellite, 2000-2014.
MTGeol_Dist2Alluv	Geology	Distance to Alluvium	vector	Distance in meters to alluvial, glacial, or other unconsolidated surface geology types.
MTGeol_Dist2C03	Geology	Distance to Carbonate Rock	vector	Distance in meters to geological units with major components of either limestone or dolostone.

Layer Name	Class	Variable	Original Scale	Description
NED_AspectEW	Landform	Aspect (East-West)	≈10m	Aspect of slopes, ranging from 1 (east) to -1 (west).
NED_AspectNS	Landform	Aspect (North-South)	≈10m	Aspect of slopes, ranging from 1 (north) to -1 (south).
NED_Elevation	Landform	Elevation	≈10m	Elevation in meters above mean sea level.
NED_Ruggedness	Landform	Ruggedness	≈10m	Vector ruggedness measure from 0 (flat) to 1 (rugged), based on 5-cell neighborhood.
NED_Slope	Landform	Slope	≈10m	Percent slope (x100) of landscape.
NED_SRISummer	Landform	Summer Solar Radiation	≈10m	Solar radiation (WH/m^2) for the day of the summer solstice.
NED_SRIWinter	Landform	Winter Solar Radiation	≈10m	Solar radiation (WH/m^2) for the day of the winter solstice.
NED_TPI	Landform	Topographic Position Index	≈10m	Relative topographic position, based on a 5- to 10-cell radius envelope; positive values represent ridges, negative values are valleys/drainages.
NHD_Dist2WaterEdge	Hydrography	Distance to Water Edge	vector	Distance in meters to edges of lakes, reservoirs, streams, or rivers, as mapped in high resolution NHD.
NHP_AnthroInfl	Human	Anthropogenic Influence	vector	An index of human impact on landscape, based on structure density and road use.
NRCS_FrostFreeDays	Climate	Frost Free Days	30m	Estimated number of days without frost: daily minimum temperature 0°C based on a 5 in 10 year probability.
NRCS_REAP	Climate	Relative Effective Annual Precipitation	10m	REAP, an adjusted annual precipitation estimate enhanced with DEM attributes (cm) over 30 years.
PRISM_Precipitation	Climate	Annual Precipitation	≈800m	Average annual precipitation (mm) for 1981-2010.
PRISM_WinPrecip	Climate	Percent Winter Precipitation	≈800m	Average percent (0 to 1) of the total annual precipitation that occurs during winter (Nov-Apr) for 1981-2010.
SoilGrid_BD	Soils	Bulk Density	100m	Bulk density (inversely related to pore space), g/cm^3 (0-5cm depth).
SoilGrid_Clay	Soils	Percent Clay	100m	Percent Clay in soil (0-5cm depth).
SoilGrid_EC	Soils	Electric Conductivity	100m	Electric conductivity (measure of salinity) of soil, dS/m (x100) (0-5cm depth).
SoilGrid_OrgC	Soils	Organic Carbon	100m	Soil organic carbon, % weight (x1000) (0-5cm depth).
SoilGrid_pH	Soils	Soil pH	100m	Soil pH (0-5cm depth).
SoilGrid_Sand	Soils	Percent Sand	100m	Percent Sand in soil (0-5cm depth).
SoilGrid_Silt	Soils	Percent Silt	100m	Percent Silt in soil (0-5cm depth); derived, based on Sand and Clay percentages.
SoilGrid_TotN	Soils	Total Nitrogen	100m	Total nitrogen in soil, % weight (x1000) (0-5cm depth).

Data Sources/Environmental Layer Name Prefix Key

LC - Montana Land Use/Land Cover Dataset (MSDI)

MCO - Montana Climate Office (MSDI)

MTGeol - Montana Bureau of Mines Geology (MSDI)

NED - National Elevation Dataset (MSDI)

NHD - National Hydrological Dataset (MSDI)

NHP - NHP Data (unpublished)

NRCS - Natural Resources Conservation Service (MSDI)

PRISM - PRISM Climate Group (OSU)

SoilGrid - US48 Soil Grids 100m (PSU)

Data Use Terms and Conditions

• Montana Natural Heritage Program (MTNHP) products and services are based on biological data and the objective interpretation of those data by professional scientists. MTNHP does not advocate any particular philosophy of natural resource protection, management, development, or public policy.

• MTNHP has no natural resource management or regulatory authority. Products, statements, and services from MTNHP are intended to inform parties as to the state of scientific knowledge about certain natural resources, and to further develop that knowledge. The information is not intended as natural resource management guidelines or prescriptions or a determination of environmental impacts. MTNHP recommends consultation with appropriate state, federal, and tribal resource management agencies and authorities in the area where your project is located.

• Information on the status and spatial distribution of biological resources produced by MTNHP are intended to inform parties of the state-wide status, known occurrence, or the likelihood of the presence of those resources. **These products are not intended to substitute for field-collected data, nor are they intended to be the sole basis for natural resource management decisions.**

• MTNHP does not portray its data as exhaustive or comprehensive inventories of rare species or biological communities. **Field verification of the absence or presence of sensitive species and biological communities will always be an important obligation of users of our data.**

• MTNHP responds equally to all requests for products and services, regardless of the purpose or identity of the requester.

• Because MTNHP constantly updates and revises its databases with new data and information, products will become outdated over time. Interested parties are encouraged to obtain the most current information possible from MTNHP, rather than using older products. We add, review, update, and delete records on a daily basis. Consequently, we strongly advise that you update your MTNHP data sets at a minimum of every three months for most applications of our information.

• MTNHP data require a certain degree of biological expertise for proper analysis, interpretation, and application. Our staff is available to advise you on questions regarding the interpretation or appropriate use of the data that we provide. Contact information for MTNHP staff is posted at: http://mtnhp.org/contact.asp

• The information provided to you by MTNHP may include sensitive data that if publicly released might jeopardize the welfare of threatened, endangered, or sensitive species or biological communities. This information is intended for distribution or use only within your department, agency, or business. Subcontractors may have access to the data during the course of any given project but should not be given a copy for their use on subsequent, unrelated work.

• MTNHP data are made freely available. **Duplication of hard-copy or digital MTNHP products with the intent to sell is prohibited without written consent by MTNHP.** Should you be asked by individuals outside your organization for the type of data that we provide, please refer them to MTNHP.

• MTNHP and appropriate staff members should be appropriately acknowledged as an information source in any third-party product involving MTNHP data, reports, papers, publications, or in maps that incorporate MTNHP graphic elements. The following is a suggested data citation format: *Montana Natural Heritage Program. {date type} for {species or species group} in {geographic filter, if applicable} Montana [Data set]. Retrieved January 1, 2020. Available from: http://mtnhp.org*

• Sources of our data include museum specimens, published and unpublished scientific literature, field surveys by state and federal agencies and private contractors, and reports from knowledgeable individuals. MTNHP actively solicits and encourages additions, corrections and updates, new observations or collections, and comments on any data we provide.

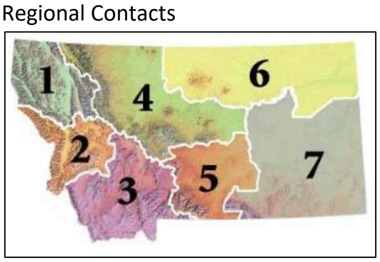
• MTNHP staff and contractors do not cross or survey privately-owned lands without express permission from the landowner. However, the program cannot guarantee that information provided to us by others was obtained under adherence to this policy.

Suggested Contacts for Natural Resource Management Agencies

As required by Montana statute (MCA 90-15), the Montana Natural Heritage Program works with state, federal, tribal, nongovernmental organizations, and private partners to ensure that the latest animal and plant distribution and status information is incorporated into our databases so that it can be used to inform a variety of permitting and planning processes and management decisions. We encourage you to contact state, federal, and tribal resource management agencies in the area where your project is located and review the permitting overviews by the Montana Department of Environmental Quality, the Montana Department of Natural Resources and Conservation and the Index of Environmental Permits for Montana for guidelines relevant to your efforts. In particular, we encourage you to contact the Montana Department of Fish, Wildlife, and Parks for the latest data and management information regarding hunted and high-profile management species and to use the U.S. Fish and Wildlife Service's Information Planning and Consultation (IPAC) website regarding U.S. Endangered Species Act listed Threatened, Endangered, or Candidate species.

For your convenience, we have compiled a list of relevant agency contacts and links below; check our website for updates.

Montana Fish, Wildlife, and Parks

Fish Species	Zachary Shattuck zshattuck@mt.gov (406) 444-1231 or Eric Roberts eroberts@mt.gov (406) 444-5334
American Bison Black-footed Ferret Black-tailed Prairie Dog Bald Eagle Golden Eagle Common Loon Least Tern Piping Plover Whooping Crane	Kristina Smucker ksmucker@mt.gov (406) 444-5209
Grizzly Bear Greater Sage Grouse Trumpeter Swan Big Game Upland Game Birds Furbearers	Brian Wakeling Brian.Wakeling@mt.gov (406) 444-3940
Managed Terrestrial Game and Nongame Animal Data	Smith Wells – MFWP Data Analyst smith.wells@mt.gov (406) 444-3759
Fisheries Data	Ryan Alger – MFWP Data Analyst ryan.alger@mt.gov (406) 444-5365
Wildlife and Fisheries Scientific Collector's Permits	https://fwp.mt.gov/buyandapply/commercialwildlifeandscientificpermits/scientific Kammi McClain for Wildlife Kammi.McClain@mt.gov (406) 444-2612 Kim Wedde for Fisheries kim.wedde@mt.gov (406) 444-5594
Fish and Wildlife Recommendations for Subdivision Development	Charlie Sperry CSperry@mt.gov (406) 444-3888 See also: https://fwp.mt.gov/conservation/living-with-wildlife/subdivision-recommendations
Regional Contacts 	Region 1 - Kalispell (406) 752-5501 fwprg12@mt.gov Region 2 - Missoula (406) 542-5500 fwprg22@mt.gov Region 3 - Bozeman (406) 577-7900 fwprg3@mt.gov Region 4 - Great Falls (406) 454-5840 fwprg42@mt.gov Region 5 - Billings (406) 247-2940 fwprg52@mt.gov Region 6 - Glasgow (406) 228-3700 fwprg62@mt.gov Region 7 - Miles City (406) 234-0900 fwprg72@mt.gov

Montana Department of Agriculture
General Contact Information: https://agr.mt.gov/About/Office-Locations/Office-Locations-and-Field-Offices
Noxious Weeds: https://agr.mt.gov/Noxious-Weeds

Montana Department of Environmental Quality
Permitting and Operator Assistance for all Environmental Permits: https://deq.mt.gov/Permitting

Montana Department of Natural Resources and Conservation
Overview of, and contacts for, licenses and permits for state lands, water, and forested lands: http://dnrc.mt.gov/licenses-and-permits

Stream Permitting (310 permits) and an overview of various water and stream related permits (e.g., Stream Protection Act 124, Federal Clean Water Act 404, Federal Rivers and Harbors Act Section 10, Short-term Water Quality Standard for Turbidity 318 Authorization, etc.). http://dnrc.mt.gov/divisions/cardd/conservation-districts/the-310-law

Flood and Fire Resources: http://dnrc.mt.gov/flood-and-fire

Bureau of Land Management
Montana Field Office Contacts:

Billings	(406) 896-5013
Butte	(406) 533-7600
Dillon	(406) 683-8000
Glasgow	(406) 228-3750
Havre	(406) 262-2820
Lewistown	(406) 538-1900
Malta	(406) 654-5100
Miles City	(406) 233-2800
Missoula	(406) 329-3914

United States Army Corps of Engineers
Montana Regulatory Office for federal permits related to construction in water and wetlands
(406) 441-1375 https://www.nwo.usace.army.mil/Missions/Regulatory-Program/Montana/

United States Environmental Protection Agency
Environmental information, notices, permitting, and contacts https://www.epa.gov/mt
Gateway to state resource locators https://www.envcap.org/srl/index.php

United States Fish and Wildlife Service
Information Planning and Conservation (IPAC) website: https://ecos.fws.gov/ipac/
Montana Ecological Services Field Office (406) 449-5225 https://www.fws.gov/montanafieldoffice/

United States Forest Service

Regional Office Contacts – Missoula			
Wildlife Program Leader	Tammy Fletcher	tammy.fletcher2@usda.gov	(406) 329-3086
Wildlife Ecologist	Cara Staab	cara.staab@usda.gov	(406) 329-3677
Fish Program Leader	Scott Spaulding	scott.spaulding@usda.gov	(406) 329-3287
Fish Ecologist	Cameron Thomas	cameron.thomas@usda.gov	(406) 329-3087
TES Program	Lydia Allen	lydia.allen@usda.gov	(406) 329-3558
Interagency Grizzly Bear Coordinator	Scott Jackson	scott.jackson@usda.gov	(406) 329-3664
Acting Regional Botanist	Amanda Hendrix	amanda.hendrix@usda.gov	(651) 447-3016
Regional Vegetation Ecologist	Mary Manning	marry.manning@usda.gov	(406) 329-3304
Invasive Species Program Manager	Michelle Cox	michelle.cox2@usda.gov	(406) 329-3669

Tribal Nations

Assiniboine Gros Ventre Tribes – Fort Belknap Reservation
Assiniboine Sioux Tribes – Fort Peck Reservation
Blackfeet Tribe - Blackfeet Reservation
Chippewa Creek Tribe - Rocky Boy's Reservation
Crow Tribe – Crow Reservation
Little Shell Chippewa Tribe
Northern Cheyenne Tribe – Northern Cheyenne Reservation
Salish Kootenai Tribes - Flathead Reservation

Natural Heritage Programs and Conservation Data Centres in Surrounding States and Provinces

Alberta Conservation Information Management System
British Columbia Conservation Data Centre
Idaho Natural Heritage Program
North Dakota Natural Heritage Program
Saskatchewan Conservation Data Centre
South Dakota Natural Heritage Program
Wyoming Natural Diversity Database

Invasive Species Management Contacts and Information

Aquatic Invasive Species

Montana Fish, Wildlife, and Parks Aquatic Invasive Species staff
Montana Department of Natural Resources and Conservation's Aquatic Invasive Species Grant Program
Montana Invasive Species Council (MISC)
Upper Columbia Conservation Commission (UC3)

Noxious Weeds

Montana Weed Control Association Contacts Webpage
Montana Biological Weed Control Coordination Project
Montana Department of Agriculture - Noxious Weeds
Montana Weed Control Association
Montana Fish, Wildlife, and Parks - Noxious Weeds
Montana State University Integrated Pest Management Extension
Integrated Noxious Weed Management after Wildfires
Fire Management and Invasive Plants