Amphibian, Reptile, and Bat Surveys on and around the Dillon Field Office of the Bureau of Land Management: 2009-2011

Prepared for:

Dillon Field Office of the Bureau of Land Management

Prepared by:

Bryce A. Maxell

Montana Natural Heritage Program

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Prepared for:

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EXECUTIVE SUMMARY

Between 2009 and 2011, the Bureau of Land Management implemented a series of three small contracts with the Montana Natural Heritage Program to conduct surveys for amphibian and reptile species on and around the Dillon Field Office. The major goals of these efforts were to: (1) provide more widespread baseline survey coverage for amphibian, reptile, and bat species; (2) conduct visual encounter and dip net surveys of water bodies and wetlands to detect aquatic reptiles or breeding activity of amphibians; (3) conduct passive listening surveys for amphibian species that broadcast nocturnal breeding calls audible over long distances; (4) conduct visual encounter surveys for terrestrial reptiles in rock outcrop and friable soil habitats; (5) conduct passive acoustic ultrasonic acoustic surveys for bats; (6) record observations of all species detected incidentally while field crews were in the region; and (7) integrate all information on structured surveys and detections of animal species into the data systems at the Montana Natural Heritage Program in order to make it readily available to natural resource management personnel and the general public.

Using standardized protocols that have been used across Montana since the year 2000, we conducted 283 visual encounter and dip net surveys for amphibians and aquatic reptiles that breed in, or otherwise inhabit, standing water bodies or wetlands, 1160 passive listening surveys for amphibian species that broadcast nocturnal breeding calls, 29 visual encounter surveys for terrestrial reptiles in rock outcrop and friable soil habitats, and 107 nocturnal acoustic surveys for bats.

Across the Dillon Field Office, surveys resulted in 120 detections of amphibians and aquatic reptiles at standing water bodies or wetlands, 303 detections of amphibians broadcasting nocturnal breeding calls, 6 detections of terrestrial reptiles in rock outcrop and friable soil habitats, and 230 detections of nightly bat species presence using passive ultrasonic detectors. In addition, we recorded 2149 detections of 201 species incidental to our structured survey protocols, including 225 detections of 27 Montana Species of Concern or Potential Species of Concern and 132 detections of 16 Bureau of Land Management Sensitive Species. All structured survey and detection information has been integrated into databases at the Montana Natural Heritage Program where it is available on the Montana Field Guide, Species Snapshot, and Map Viewer websites to inform survey and resource management decisions.

Overall our surveys indicate that: (1) Western Tiger Salamander, Boreal Chorus Frog, and Columbia Spotted Frog occupy a relatively high percentage of standing water bodies in the watershed assessments where they were detected; (2) Boreal Chorus Frog is common and widespread in watershed assessment units where the species was detected; (3) although Plains Spadefoot had only been relatively recently detected in southwest Montana, it was found to be reasonably common and detected at up to one third of passive listening stations in some areas, indicating that its conservation status ranking may need to be reconsidered; (4) there are at least three extant Northern Leopard Frog breeding areas on private lands adjacent to the Jefferson River between Whitehall and just below the Highway 287 bridge that are likely very important to the conservation of the species in the region; (5) there are a number of known or potential reptile species in southwest Montana that have

low detection rates in surveys following standard protocols; (6) evidence indicates that seven of the eleven bat species documented in southwest Montana are relatively common and widespread, while the remaining four are much more restricted in their distribution and rare.

Based on the distribution, status, and predicted habitat suitability information in this report, our observations while in the field, and the scientific literature, the following management actions are recommended: (1) promote the presence of Beaver and their dam building activities to provide year-round habitat for a variety of native species; (2) manage standing water bodies, wetlands, and timber lands to maintain "natural" frequencies and intensities of disturbance from grazing and fire and/or timber harvest; (3) protect rock outcrops and talus slopes, particularly those with cracks and crevices or interstial spaces between rock layers, to protect important habitat for a diversity of wildlife; (4) ensure that all cattle tanks have climb out ramps to allow trapped wildlife to escape drowning; (5) reach out to private land owners that have extant Northern Leopard Frog breeding populations to educate them on the status of the species and ensure that breeding and adjacent terrestrial habitats are protected to ensure population persistence; (6) immediately implement control efforts if either American Bullfrog or Snapping Turtle are detected; (7) implement protective measures if collections of Prairie Rattlesnake result in population declines.

Survey efforts since 2001 have resulted in a drastic improvement in our understanding of the distribution and status of amphibian, reptile and bat species across the region encompassed by the Dillon BLM Field Office. However, there are a number of additional surveys needed for these taxa in this region. These include: (1) floodplain surveys in later summer at low water levels to determine whether additional breeding populations of Northern Leopard Frog are present; (2) passive acoustic listening surveys for Northern Leopard Frogs in the floodplain of the Jefferson River to identify specific locations of breeding sites; (3) passive acoustic surveys for Boreal Chorus Frog and Plains Spadefoot in several areas across the Dillon BLM Field Office; (4) regularly monitor all known Western Toad breeding sites; (5) conduct acoustic surveys for bats in watershed assessments units currently lacking them, possibly using long-term deployments; (6) train BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel and educate the public on the importance of reporting incidental observations of rarely detected species such as Pygmy Short-horned Lizard, Greater Short-horned Lizard, Northern Rubber Boa, North American Racer, and Western Milksnake in order to better understand their distribution and status.

ACKNOWLEDGEMENTS

This project would not have been possible without grants administered by the Dillon Field Office and Montana/Dakotas State Office of the Bureau of Land Management. Katie Benzel and Jim Roscoe recognized the importance of gathering survey information for amphibians and reptiles on and around Bureau of Land Managment lands in the Dillon Field Office and Katie Benzel gave feedback on project implementation, survey prioritization, and assisted with surveys. Lori Anderson assisted with contract management at the Montana/Dakotas State Office of the Bureau of Land Management. At the Montana Natural Heritage Program: Steve Amish, Dan Bachen, Matthew Bell, Danielle Blanc, Anna Breuninger, Andy Brown, Peter Brown, Brent Cascaddan, Eric Dallalio, Ronan Donovan, Ayla Doubleday, Jessica Easley, Erin Fairbank, Erin Farris, Matthew Gates, Bob Haynes, Paul Hendricks, Shannon Hilty, Renee Hoadley, Phil Jellen, Ryan Killackey, Todd Leifer, Robert Lishman, Gary Maag, Lorraine McInnes, Ellison Orcutt, Christie Quarles, Thomas Schemm, David Stagliano, Keif Storrar, Keaton Wilson, Lisa Wilson, Chelsey Whenham, Sarah Young, Ryan Zajac, and Franz Zikesch assisted with site mapping, field surveys, and data entry on this and previous survey efforts in the region; Darlene Patzer assisted with grant administration; Susan Lenard and Braden Burkholder hand reviewed bat call data; Scott Blum and Braden Burkholder assisted with appending records to the Heritage Program's central observation and survey databases and making species occurrence polygons that are used in environmental reviews; Braden Burkholder implemented Python, docxtpl, and jinga2 coding that allowed several iterations of predictive distribution model outputs and reports to be created in a timely manner in order to greatly improve predictive distribution models for amphibian and reptile species; and Dave Ratz developed web applications that allow this and other plant, animal, and habitat information to be easily queried and summarized for resource planning and management decisions.

This project was supported by an agreement between the Montana/Dakotas State Office of the Bureau of Land Management and the Montana Natural Heritage Program, a program of the Montana State Library's Natural Resource Information System operated by the University of Montana (L09AC15419).

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INTRODUCTION

PROJECT NEED

Under the Federal Land Policy and Management Act of 1976, the Bureau of Land Management (BLM) is charged with managing public lands on the basis of multiple-use and sustained yield without the permanent impairment of the productivity of the land and the quality of the environment (BLM 2016). Among other things, to accomplish this for the use and enjoyment of present and future generations, the BLM: (1) creates resource management plans that ensure a coordinated and consistent approach to land management; (2) creates land health standards and conducts land health evaluations, typically at the watershed scale, to ensure that these standards are achieved; and (3) works to recover Endangered Species Act (ESA) listed species and proactively conserve BLM Sensitive species to minimize the likelihood of the future need to list these species under the ESA (BLM Policy Manuals 1601, 4180, & 6840; ESA 1973).

There are 8 species of native amphibians, 7 species of native reptiles, and 11 species of bats that are currently known to occur within the boundaries of the Dillon Field Office of the BLM; Long-toed Salamander (*Ambystoma macrodactylum*), Western Tiger Salamander (*Ambystoma mavortium*), Rocky Mountain Tailed Frog (*Ascaphus montanus*), Western Toad (*Anaxyrus boreas*), Boreal Chorus Frog (*Pseudacris maculata*), Plains Spadefoot (*Spea bombifrons*), Northern Leopard Frog (*Lithobates pipiens*), Columbia Spotted Frog (*Rana luteiventris*), Painted Turtle (*Chrysemys picta*), Northern Rubber Boa (*Charina bottae*), North American Racer (*Coluber constrictor*), Gophersnake (*Pituophis catenifer*), Terrestrial Gartersnake (*Thamnophis elegans*), Common Gartersnake (*Thamnophis sirtalis*), Prairie Rattlesnake (*Crotalus viridis*), Townsend's Big-eared Bat (*Corynorhinus townsendii*), Big Brown Bat (*Eptesicus fuscus*), Spotted Bat (*Euderma maculatum*), Silver-haired Bat (*Lasionycteris noctivagans*), Hoary Bat (*Lasiurus cinereus*), California Myotis (*Myotis californicus*), Western Small-footed Myotis (*Myotis ciliolabrum*), Long-eared Myotis (*Myotis evotis*), Little Brown Myotis (*Myotis lucifugus*), Fringed Myotis (*Myotis thysanodes*) and Long-legged Myotis (*Myotis volans*) (Maxell 2000, Maxell et al. 2003, Maxell 2004, Werner et al. 2004, Maxell 2009, Maxell et al. 2009, Hanauska-Brown et al. 2014, Maxell 2015a & 2015b, Maxell et al. 2016a & 2016b, MTNHP 2017). As of October 2017, the Western Toad, Plains Spadefoot, Northern Leopard Frog, Townsend's Big-eared Bat, Spotted Bat, and Fringed Myotis are all listed as BLM Sensitive and Montana Species of Concern (MTNHP & MTFWP 2017, Appendix A).

Furthermore, the potential exists for one additional amphibian species, five additional reptile species, and one additional bat species to occur within the Dillon Field Office: American Bullfrog (*Lithobates catesbeiana*) and Snapping Turtle (*Chelydra serpentina*) as potentially introduced populations; Pygmy Short-horned Lizard (*Phrynosoma douglasii*) and Great Basin Skink (*Plestiodon skiltonianus utahensis*) as potential native populations along the Idaho border between the Upper Horse Prairie and Centennial watershed assessment areas; and Greater Short-horned Lizard (*Phrynosoma hernandesi*), Western Milksnake (*Lampropeltis gentilis*), and Yuma Myotis (*Myotis yumanensis*) as potential native populations on the northern end of the field office.

Objectives

Given the relative lack of baseline information and the need to inform resource management plans and project-level planning efforts with basic information on the distribution and status of amphibian and reptile species, especially those classified as Sensitive, the BLM implemented a series of three small contracts with the Montana Natural Heritage Program to conduct surveys for amphibian and reptile species on and around the Dillon Field Office between 2009 and 2011. The major goals of these efforts were to: (1) provide more widespread baseline survey coverage for amphibian, reptile, and bat species; (2) conduct visual encounter and dip net surveys of water bodies and wetlands to detect aquatic reptiles or breeding activity of amphibians; (3) conduct passive listening surveys for amphibian species that broadcast nocturnal breeding calls audible over long distances; (4) conduct visual encounter surveys for terrestrial reptiles in rock outcrop and friable soil habitats; (5) conduct passive acoustic ultrasonic acoustic surveys for bats; (6) record observations of all species detected incidentally while field crews were in the region; and (7) integrate all information on structured surveys and detections of animal species into the data systems at the Montana Natural Heritage Program in order to make it readily available to natural resource management personnel and the general public.

METHODS

SURVEY TIMING

All field surveys for amphibians and reptiles summarized in this report were conducted between early June and early September when temperatures allowed these species to be active and more readily detectable by observers. The vast majority of visual encounter surveys of standing waters and rock outcrop surveys were conducted between mid-June and the late August. Passive listening surveys for nocturnal calling amphibians were conducted in June during or immediately after periods of rainy weather.

VISUAL ENCOUNTER AND DIP NET SURVEYS OF STANDING WATERS

Site Mapping

Prior to field work, we mapped all potential standing water bodies in a geographic information system using digital topographic maps and National Agriculture Imagery Program aerial imagery (NAIP 2005 and 2009).

Survey Methodology

All standing water bodies and wetlands previously identified on 1:24,000 scale topographic maps and NAIP imagery, or found incidentally, while in the field were surveyed when they were safely accessible and on public land. Field crews used timed visual encounter and dip net surveys in all portions of the water bodies that were less than 50 cm in depth (Heyer et al. 1994, Olson et al. 1997, Maxell 2009). If little emergent vegetation was present, field crews carefully visually examined shallow water environments for the presence of eggs, larvae, or post metamorphic animals. However, in areas with dense emergent vegetation, they intensively sampled with repeated sweeps of the dip net. At sites where water depths dropped off steeply from the shoreline, visual searches and dip netting was performed from the shoreline. However, in areas with extensive shallows, field crews systematically searched and dip netted while wading through the area on evenly spaced transects.

Digital photographs of each site were taken from a vantage point that, where possible, allows the entire site to be seen in the context of surrounding habitats. Species identifications were made using the photographs and keys in Maxell et al. (2003) and Werner et al. (2004). Species detection and habitat information was recorded on a standardized datasheet (Appendix B).

Washing and Decontamination Procedures

In order to prevent the spread of fungal and viral pathogens, care was taken to wash mud, aquatic vegetation, and other materials off of dip nets, boots, socks, and other equipment prior to departing from a site. Survey gear was left to dry in the sun for as long as possible between sites. Dip nets, boots, socks, and other survey equipment were decontaminated with a mixture of 10% bleach (4 ounces or one-half cup per gallon of water) between any sites where dead, dying, or ill animals were encountered, and between sites on different sides of divides separating major drainage basins. This was accomplished by washing gear in tubs or by simply spraying washed gear down with a pressurized sprayer containing 10% bleach and allowing it to dry in the sun.

Passive Listening Surveys for Nocturnal Calling Amphibians

We conducted nocturnal passive listening surveys for spring-breeding amphibians on nights during and after rainfall events between the 3 and 22 June when air temperatures were above 50 °F (10 °C) and wind and precipitation conditions were suitable for aurally detecting choruses of male amphibians broadcasting advertisement calls to females from potential breeding sites. Passive listening surveys involve slowly driving roads in the evening and night hours under weather conditions potentially presenting visual hazards. Therefore, we selected road routes to ensure the safety of surveyors and the ability of surveyors to detect calling amphibians. We avoided routes with high traffic volumes and listening stations with loud noises that would interfere with species detections.

Vehicles were stopped every mile or two of each survey route in low lying areas suitable for containing pooled water; GPS units assisted with locating stream crossings or water bodies most likely to contain suitable habitat. At each stop, surveyors passively listened for choruses of male amphibians for a minimum of 5 minutes without interference from vehicle or other noises before proceeding to the next stop. When choruses were detected, species identifications were verified using recordings in Davidson (1996) which are also posted on the Montana Field Guide at fieldguide.mt.gov. Surveyors estimated both the bearing of, using a compass, and the distance to, all breeding choruses detected at each listening station. Survey route, listening station, breeding chorus, and other incidentally detected species information were all recorded on a standardized datasheet (Appendix C). The true location of breeding sites was subsequently identified in the office using listening station locations in combination with bearing and distance estimates and digital topographic maps and high-resolution aerial photographs (NAIP 2005 and 2009) in a geographic information system.

Visual Encounter Surveys of Rock Outcrops and Friable Soils

Site Mapping and Definition

Prior to field work, we mapped potential cliff, talus, and rock outcrop habitats in a geographic information system using National Agriculture Imagery Program aerial imagery (NAIP 2005 and 2009). Areas targeted for survey were accessible on public land, had large areas of likely rock outcrop or friable soils, and often had southern aspects. Individual sites were assigned names according to the 1:24,000 U.S. Geological Survey quarter-quadrangle they occurred in (e.g., Lower_Redrock_Lake_SW_1, Lower_Redrock_Lake_SW_2, etc.).

Cliff, talus, rock outcrop, and, in the case of Greater Short-horned Lizard, friable soil habitats of up to 400 x 400 square meters in size were targeted for survey as individual sites; larger features were broken into multiple survey locations smaller than 400 x 400 meters based on natural breaks such as a drainage or area with reduced amounts of cover objects.

Survey Methodology

Upon arriving at a site, surveyors coordinated with one another on likely survey routes in order to minimize overlap in area surveyed. Surveyors then used timed visual encounter surveys in all portions of the site. They slowly moved through survey areas, visually searching for basking reptiles and potential rock crevices and cover rocks at distances of up to 15-meters.

Rock cracks and crevices detected were visually examined, with a headlamp if necessary, and were probed with a potato rake while listening and watching for animal movements. Where possible, cover-objects were lifted to reveal species hiding under them. In these cases, surveyors used a potato rake to lift the cover object and took care to keep the cover object between them and species potentially sheltering under the cover object in order to avoid being bitten by Prairie Rattlesnake. Surveyors also used potato rakes to probe rock crevices while listening and watching for animal movements. Surveyors noted times at first detection and incidental observations of other animals in write-in-rain notebooks.

Digital photographs of each site were taken from a vantage point that, where possible, allows the entire site to be seen in the context of surrounding habitats. Species identifications were made using the photographs and keys in Maxell et al. (2003) and Werner et al. (2004). Species detection and habitat information was recorded on a standardized datasheet (Appendix D).

Given the extremely low success rates of these surveys in 2007 and 2009 as well as surveys conducted in western Montana by the statewide Diversity Monitoring Project (Hanauska-Brown et al. 2014), surveys in 2010 and 2011 focused on simply traveling through potential habitats and quickly exploring the most promising cracks and crevices or cover rocks to improve the chances of making incidental observations instead of protracted focal survey efforts.

Acoustic Surveys for Bats

Field Sampling

One or two Petterson D240x acoustic detectors attached to an Iriver MP3 player/recorder (typically the iFP-899 model, but also the H320 Zoom model) were deployed in a variety of habitat covertypes in the evenings near campsites incidental to other field work. When more than one detector was deployed, they were spaced a minimum of 400 meters apart in order to ensure independence between surveys. Petterson D240x detector settings were: normal, time expanded output, high gain, auto trigger, low trigger level, high frequency trigger source, and 1.7 seconds of real-time recording. Iriver iFP-899 settings were: Channels = Mono; Frequency = 44 kHz; Encoder bitrate = 160 kilobytes per second; Connection Type = exterior line-in with 1 second autosynch and record volume of 48. H320 Zoom recorder settings were: File Format = MPEG layer 3; Encoder bitrate = 160 kilobytes per second; Frequency = 44.1 kHz; Source = Line In; Channels = Mono; File Split Options = N/A; Prerecord time = 1s; Clear Recording Directory = N/A; Clipping light = N/A, Trigger settings = repeat, stop, 1s, -25db, 0s, - 40db, 2 s, 1s; Automatic Gain Control = N/A; AGC Clip Time = N/A. Variables recorded at each acoustic survey site included both categorical and quantitative descriptions of habitat, quality of the habitat, and potential threats to the habitat (Appendix E).

Acoustic detectors and recording devices were housed inside weatherproof containers that were mounted on conduit attached to a piece of rebar pounded into the ground as an anchor point. Detectors and recorders were turned on shortly before dusk to capture the first emerging bats of the evening and were collected each morning at various times after sunrise. Batteries in the detectors and/or recorders sometimes died during the deployment period, especially on cold nights.

However, the detector/recorder units likely recorded consistently for the first six hours after deployment. Detectors were collected each morning and .wav files were downloaded to a laptop computer and attributed with q-quad, location, basic habitat descriptions, and other survey information.

Call Analysis

Call analysis was performed using Sonobat 3.0™ (SonoBat 2012), which was the first version of Sonobat with automated species recognition capabilities through use of a hierarchical discriminant function analyses based on up to 72 different call characteristics (e.g. duration, upper slope, lower slope, maximum frequency). However, this software package does make regular errors in species identification. Thus, in order to verify the call identification results of this automated program, at least one call sequence per species per site was confirmed by hand using criteria outlined in the Montana Bat and White-Nose Syndrome Surveillance Plan and Protocols (Maxell 2015b).

STATISTICS

Proportions (p) and standard errors (SE) of proportions of standing water bodies, passive listening stations, and rock outcrop survey sites where species were detected were calculated as follows where n = number of sites surveyed and d = number of sites with detections:

$$p = {}^{d}/_{n}$$

$$\mathrm{SE} = \sqrt{\frac{(p(1-p)}{n}}$$

HABITAT SUITABILITY MODELING

Inductive and deductive predicted habitat suitability models were created for all amphibian, reptile, and bat species known from, or with the potential to occur in, the Dillon BLM Field Office (Appendix F).

Inductive Model Methods

Presence-only data were obtained from this and other survey efforts housed in Montana Natural Heritage Program Databases (MTNHP 2017). Data were filtered to ensure spatial and temporal accuracy and to reduce spatial auto-correlation (summarized in Appendix F, Table 1 for each species). We then used these data and 19 statewide biotic and abiotic layers (see Environmental Layer Information table in Appendix F) within the known geographic range extents of each species to construct inductive models using a maximum entropy algorithm employed in the modeling program Maxent (Phillips et al. 2006). Entropy maximization modeling functions by first calculating constraints and then applying the constraints to estimate a predicted distribution. The mean, variance, and other parameters of the 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 of 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).

Maxent fits a model by first assuming the predicted distribution is perfectly uniform in geographic space and moves away from this distribution only to the extent that it is forced to by the constraints. Constrained by training data, 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 threshold or a set maximum number of iterations are performed. 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. The overall gain associated with individual environmental variables can be used as a measure of the relative importance of each variable (Merow et al. 2013). 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.

<u>Inductive Model Outputs and Evaluation</u>

The initial inductive 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 (Appendix F, Figures 3 & 5-7 for each species). The standard deviation in the model output across the averaged models was also calculated and plotted as a map to examine spatial variance of model output (Appendix F, Figure 4 for each species). If enough observations were available to train and evaluate the models, the continuous output was reclassified into suitability classes - unsuitable, low suitability, moderate suitability, and high suitability (Appendix F, Figures 8 & 9 for each species). Environmental layer contributions to model fit and thresholds for defining habitat suitability classes are presented for each species (Appendix F, Tables 2 & 3 for each species).

In addition to the map of spatial variance in model output, we also evaluated the output of the Maxent models with absolute validation index (AVI) (Hirzel et al. 2006) and deviance (Phillips and Dudik 2008). These metrics are presented for each species (Appendix F, Table 4 for each species). 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 the location of test observations and this was plotted with larger symbols indicating larger deviance (Appendix F, Figure 6 for each species). In theory, everywhere a test observation was located, the logistic value should have been 1.0. The deviance value for each test observation is calculated as -2 times the natural log of the associated logistic output value.

<u>Deductive Model Methods</u>

Deductive models are based on the 2016 statewide land cover classifications at 30×30 meter raster pixels (MTNHP 2016). 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 classified as commonly associated, occasionally associated, or not associated with each ecological system (Appendix F, Table 5 for each species). 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.

Deductive Model Outputs and Evaluation

The deductive model output is a spatial dataset of categorical habitat suitability based on ecological system associations (commonly or occasionally associated) within the species' known range (Appendix F, Figure 10 for each species) and resulting tabular estimates of the area of commonly and occasionally associated habitat (Appendix F, Table 6 for each species). We evaluated this model output based on known or potential distribution and habitat use in Montana and AVI (Hirzel et al. 2006) using presence-only data (Appendix F, Table 7 for each species).

STORAGE & AVAILABILITY OF DATA

All amphibian, reptile, and bat survey information, site photographs, locations of detections of animals, and predicted habitat suitability models are stored in databases at the Montana Natural Heritage Program in the Montana State Library in Helena and are made available online through the Montana Natural Heritage Program's Species Snapshot, Montana Field Guide, and Map Viewer web applications so that it is integrated with other survey and incidental observation data and more readily available for resource management plans and project-level planning efforts http://mtnhp.org

Results

SUMMARY OF SURVEY EFFORT

Between 2009 and 2011, we conducted 283 visual encounter and dip net surveys for amphibians and aquatic reptiles that breed in, or otherwise inhabit, standing water bodies or wetlands, 1160 passive listening surveys for amphibian species that broadcast nocturnal breeding calls, 29 visual encounter surveys for terrestrial reptiles in rock outcrop and friable soil habitats, and 107 nocturnal acoustic surveys for bats on and in surrounding areas of the Dillon BLM Field Office (Table 1).

Our surveys of potential standing water bodies in 2009-2011, combined with watershed-based surveys conducted in 2001-2003 (Maxell 2004) has resulted in the survey of a high percentage of potential standing water bodies identified on topographic maps and aerial imagery on public lands across the Dillon BLM Field Office (Figure 2). Of the 283 potential standing water body sites surveyed in 2009-2011, 163 held standing waters capable of supporting amphibian reproduction or aquatic reptiles (Table 1).

The 1160 passive listening surveys of nocturnal calling amphibians covered most regions on and to the north of the Dillon BLM Field Office within the known or potential range of Boreal Chorus Frog and Plains Spadefoot which are the only two species with male breeding calls that can be detected over large distances (Figures 3, 10, & 11; Tables 3 & 4)..Areas still lacking passive acoustic surveys for these species include: (1) the Madison Valley above Ennis including Highway 87 to Raynolds Pass and the Antelope Basin and Horn Creek roads; (2) the northern edge of the Red Rock Lakes; (3) the Sweetwater Road from Ruby River Reservoir to Dillon (4) Highway 278 from Dillon to Badger Pass; and (5) the Grasshopper Creek drainage from Interstate 15 to Bannack. Surveys of these areas may result in additional range extensions for these two species and are likely the least expensive way of monitoring their status over time.

The 29 visual encounter surveys of rock outcrops and friable soil sites had extremely low detection rates as compared to similar surveys conducted in eastern Montana in recent years (Table 5, Hanauska-Brown et al. 2014, Maxell 2016). As a result, these surveys were mostly discontinued after 2009 and efforts were refocused on simply traveling through potential habitats during the course of other field work and quickly exploring the most promising cracks and crevices or cover rocks to improve the chances of making incidental observations.

The 107 nocturnal acoustic surveys for bats provided widespread baseline survey coverage for bats across, and to the north of, the Dillon BLM Field Office (Figure 5, MTNHP 2017). Watershed assessment units with higher densities of BLM land ownership still lacking acoustic or other surveys for bats include the lower portions of Upper Horse Prairie, large portions of Sage Creek and Blacktail, central portions of SW Highlands, and the southeastern portion of the South Tobacco Roots (Figure 5).

In addition to these survey efforts, the floodplain of the Jefferson River was walked in the vicinity of Three Forks and between Cardwell and Whitehall in order to identify areas with extant Northern Leopard breeding populations (Figure 12, Table 7). Additional surveys of the Jefferson River floodplain upstream of Whitehall are warranted.

SUMMARY OF SPECIES DETECTIONS

Surveys resulted in 120 detections of amphibians and aquatic reptiles at standing water bodies or wetlands (Table 2), 303 detections of amphibians broadcasting nocturnal breeding calls (Tables 3 & 4), 6 detections of terrestrial reptiles in rock outcrop and friable soil habitats (Table 5), and 230 detections of nightly bat species presence using passive ultrasonic detectors (Table 6). In addition, we recorded 2149 detections of 201 species incidental to our structured survey protocols, including 225 detections of 27 Montana Species of Concern or Potential Species of Concern and 132 detections of 16 Bureau of Land Management Sensitive Species (Table 7). Surveys and incidental observations filled in distributional information for amphibian, reptile, and bat species on BLM lands across the Dillon BLM Field Office (Figures 6 through 33).

While amphibian and aquatic reptile surveys at standing water bodies resulted in estimates of the proportion of sites occupied in various BLM watershed assessment units by Western Tiger Salamander, Boreal Chorus Frog, Columbia Spotted Frog, Terrestrial Gartersnake, and Common Gartersnake (Table 2), the 2009 through 2011 surveys were widely scattered in order to target sites on BLM lands that had not been surveyed as part of the broader watershed-based survey efforts conducted from 2001 to 2003 (Maxell 2004, 2009). Thus, it is recommended that the watershed and site occupancy rates from those surveys be relied on as a more accurate measure of the recent status of these species at standing water bodies within the boundaries of the Dillon BLM Field Office. However, occupancy rates reported in Table 2 clearly indicate that Western Tiger Salamander, Boreal Chorus Frog, and Columbia Spotted Frog occupy a relatively high percentage of standing water bodies in the watershed assessments where they were detected; generally ranging from 0.323 to 1.0, 0.194 to 0.8, and 0.353 to 0.75, respectively). Predicted suitable habitat models also support the widespread presence of suitable habitat for these species across large portions of the Dillon BLM Field Office (Appendix F).

Passive listening surveys for nocturnal calling amphibians supported the widespread nature and common status of Boreal Chorus Frog in watershed assessment units where the species was detected; generally ranging from 0.345 to 0.752 when the species was detected at more than a handful of listening stations (Table 4). For a species that has only recently been recognized as occurring within the boundaries of the Dillon BLM Field Office (Maxell et al. 2003; Maxell 2004), Plains Spadefoot was reasonably common, being detected in five watershed assessment units with listening station detection proportions ranging as high as 0.353 (Table 4). The vast majority of Plains Spadefoot detections on or near the Dillon BLM Field Office were made during the 2009 through 2011 survey efforts, with major gaps in the species' known range being filled in (Figure 11). Predicted suitable habitat models indicate that it is very possible that the species may eventually be detected in the Madison River and lower Ruby River valleys (Appendix F). Passive listening surveys for nocturnal calling amphibian species are recommended for these areas. From a conservation status ranking perspective, Plains Spadefoot's state rank of S3 (MTNHP and FWP 2017) may need to be reconsidered given how commonly the species was detected during calling survey efforts in 2009 through 2011 (Figure 11, Tables 3 & 4, Maxell 2016). However, most of the breeding effort was on private lands in major valleys and the species was not detected breeding in standing waters on BLM Lands (Figure 11, Table 2).

Long-toed Salamander was only detected in the Upper Big Hole watershed assessment unit (Table 2). Previous detections (Figure 6) and predicted habitat suitability model output (Appendix F) indicate that all BLM lands in the Upper Big Hole watershed assessment unit may be occupied by this species. Similarly, presence of Long-toed Salamanders on higher elevation forested BLM lands on the northern and western portions of the Upper Horse Prairie and Grasshopper watershed assessement units seem very likely (Figure 6, Appendix F).

Western Toad was only detected at two standing water bodies during the 2009 through

2011 surveys (Table 2) and the species is generally rare, although widespread (detected in 23 percent of watersheds, but only 3 percent of sites), across the Dillon BLM Field Office after having undergone declines across western Montana apparently as a result of the introduction of chytrid fungus (*Batrachochytrium dendrobatidis*) (Maxell et al. 2003, Maxell 2004, 2009). Predicted suitable habitat output indicates that the best habitat for Western Toad is in and near forested lands across the Dillon BLM Field Office (Appendix F) and there were 12 incidental detections of the species in these areas (Figure 9, Table 7). Regular monitoring of all Western Toad breeding sites within the boundaries of the Dillon BLM Field Office is recommended. Furthermore, these and other standing water bodies that may serve as breeding sites for this species should be managed to maintain "natural" frequencies and intensities of disturbance from grazing and fire and/or timber harvest as the species has been shown to respond positively to disturbances such as fire and timber harvest (Maxell 2009).

Northern Leopard Frog was not detected during any surveys of standing water bodies, but was detected incidentally at 21 different locations in the floodplain of the Jefferson River near the mouth of Sand Creek below Highway 287, and between Cardwell and Whitehall (Figure 12, Table 7). It is clear that there are at least three distinct breeding areas in the valley bottom on private lands adjacent to the Jefferson River in these areas. This is a significant finding because Northern Leopard Frog has undergone declines and extirpations across western Montana apparently as a result of the introduction of chytrid fungus (*Batrachochytrium dendrobatidis*) (Maxell et al. 2003, Maxell 2004, 2009). Predicted suitable habitat output indicates that additional areas of the floodplain along the Jefferson River between Three Forks and Twin Bridges, the lower Ruby River between Sheridan and Twin Bridges, the lower Beaverhead River between Dillon and Twin Bridges, and the Madison River downstream of the middle portion of the Madison Valley may still contain suitable habitat and remnant breeding populations (Appendix F). Additional surveys of these floodplain areas should be conducted in later summer at low water levels to determine whether additional breeding populations are present. Furthermore, passive acoustic listening surveys should be conducted near the time of ice off of standing water bodies (approximately late March) near the breeding areas identified during these surveys to identify specific locations of breeding sites. Management agencies should reach out to private land owners that have extant breeding populations to educate them on the status of the species and ensure that breeding and adjacent terrestrial habitats are protected to ensure the persistence of these populations.

Rocky Mountain Tailed Frog was not detected during any of our structured surveys or incidentally and only appears potentially capable of occurring in a handful of small sections of headwater streams on BLM lands in the Upper Big Hole watershed assessment area; Big Lake Creek, Rock Creek, and Moose Creek (Figure 8, Appendix F).

As with previous survey efforts in the region (Maxell 2004, 2009), Terrestrial Gartersnake and Common Gartersnake were detected across the Dillon BLM Field Office with Terrestrial Gartersnake being more frequently encountered during surveys of standing water bodies and rock outcrops as well as incidentally; 35 versus 5 incidental detections, respectively (Figures 20 & 21, Tables 2, 5, & 7). Similar to the pond breeding amphibians assessed during this survey it is recommended that the watershed and site occupancy rates from the 2001 through 2003 surveys (Maxell 2004, 2009) be relied on as a more accurate measure of the recent status of these species at standing water bodies within the boundaries of the Dillon BLM Field Office. Both species are more frequently encountered in valley bottoms which have the highest predicted habitat suitability (Appendix F). Although both species do occur at higher elevations, Common Gartersnake, an amphibian prey specialist, appears to be more restricted to areas with high densities of amphibian breeding populations while Terrestrial Gartersnake, a generalist predator, is more widespread and is predicted to have more suitable habitat at higher elevations (Figures 20 & 21, Appendix F).

Painted Turtle was not detected during any surveys of standing water bodies, but was detected incidentally at 4 different locations in the floodplain of the Jefferson River near Cardwell and Three Forks (Figure 15, Table 7). Predicted suitable habitat output indicates that additional areas of the floodplain along the Jefferson River between Three Forks and Cardwell and Whitehall and Twin Bridges, as well as the Beaverhead River below Dillon, may support breeding populations (Appendix F). Surveys of these floodplain areas should be conducted in later summer at low water levels in conjuction with Northern Leopard Frog surveys.

Despite a great deal of focal effort to detect Greater Short-horned Lizard in grassland and shrubland habitats with sandy and gravelly soils, we failed to detect the species during the 2009 through 2011 surveys. The species is known historically in southwest Montana from three vague locations in "Gallatin County" and near Logan dating to 1888, 1900, 1903, and 1953. More recently, during 2011, an extant population was confirmed in the vicinity of the Big M trail system just west of the Montana Tech campus on the west side of Butte with additional sightings through 2017 (MTNHP 2017). A predicted suitable habitat model using data from across the species' known range in Montana, but not including the recent records on the west side of Butte, predicts the area where the population has been documented as low to moderately suitable habitat (Appendix F). Furthermore, the model also identifies areas near the historic Logan records and other valley bottoms with montane sagebrush steppe and Rocky Mountain lower montane foothill and valley grassland habitat cover types on sandy gravelly soils as low to moderately suitable habitat (Appendix F). Recent experiences surveying for animals in the Butte population indicate extremely low detection probabilities for the species. Thus, it is very possible that there are extant populations in southwestern Montana that have gone undetected or unreported in recent decades. Complicating matters is the potential presence of Pygmy Short-horned Lizard in southwestern Montana along the Idaho Border. There is a 1936 record from the "Centennial Valley" that has been confirmed as a Pygmy Short-horned Lizard (Maxell et al. 2003) and a botanist conducting vegetation surveys on BLM lands off the Everson Creek Road near Lemhi Pass reported seeing an unidentified Short-horned Lizard species in an area dominated by montane sagebrush steppe and Rocky Mountain lower montane foothill and valley grassland habitat cover types on sandy gravelly soils in the early 2000s. Sandhills habitat in the Centennial Valley and the area near Lemhi Pass were searched systematically with visual encounter surveys for a total of greater than 30 person hours of search time in 2011 with no detections. Thus, an educational effort for BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel, as well as local members of the public, is likely the best way to accumulate incidental observations of this species in the future.

There were also no detections of Northern Rubber Boa during our 2009 through 2011 surveys. However, there are records of this very cryptic species from across the Dillon BLM Field Office and the species likely occurs in all watershed assessment units despite the lack of records and apparently low suitability of habitat in many areas (Figure 17, Appendix F). Again, an educational effort for BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel, as well as local members of the public, is likely the best way to accumulate incidental observations of this species in the future.

North American Racer was not detected during any focal surveys of rock outcrops or areas with friable soils, but was detected incidentally at 5 locations across the Dillon BLM Field Office (Figure 18, Table 7). Low to moderately suitable habitat is predicted for this species in the Jefferson, Beaverhead, Ruby, and Madison River Valleys as well as the Interstate 15 corridor (Appendix F). Again, an educational effort for BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel, as well as local members of the public, is likely the best way to accumulate incidental observations of this species in the future.

Western Milksnake was not detected during any focal surveys of rock outcrops or areas with friable soils during our 2009 through 2011 surveys on the Dillon BLM Field Office and there are no confirmed records of the species in the region (MTNHP 2017). However, there have been unconfirmed reports of the species in the area around Lewis and Clark Caverns and Logan and predicted suitable habitat models indicate the presence of a fair amount of low to moderately suitable habitat along river corridors where rock outcrops are present in those areas (Appendix F). This species is very cryptic in its nocturnal habits (Werner et al. 2004, Maxell et al. 2009), so it is very possible that the species has gone undetected or unreported in the region. Again, an educational effort for BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel, as well as local members of the public, is likely the best way to accumulate incidental observations of this species in the future.

Gophersnake was detected on only a single rock outcrop survey, but was detected at 8 additional locations incidentally during the 2009 to 2011 survey efforts (Tables 5 & 7). The species has primarily been documented in and near the Madison and Rochester watershed assessment units, but records and predicted suitable habitat models indicate species may be present in most lower elevation valleys below 6000 feet elevation (Figure 19, Appendix F).

Prairie Rattlesnake was detected on 2 rock outcrop surveys, but was detected at 6 additional locations incidentally during the 2009 to 2011 survey efforts (Tables 5 & 7). Records and predicted suitable habitat models indicate species may be present in most lower elevation valleys and typically below 7000 feet elevation (Figure 22, Appendix F). This species is the only amphibian or reptile species not protected from commercial collection in Montana and collectors are known to regularly come to denning sites in Montana to collect large numbers of animals for use in rattlesnake roundup festivals in southern states where native populations have been decimated (Maxell et al. 2009). Thus, it is important to continue to document the status and distribution of the species.

Introduced populations of American Bullfrog and Snapping Turtle were not detected during our 2009 through 2011 surveys on the Dillon BLM Field Office. However, there have been well documented recent records for Snapping Turtle near Bozeman and Butte and there were recent unconfirmed reports of American Bullfrog in the canyon below Ennis Lake. Both species have successfully established introduced populations in several low elevation settings in western Montana (Figure 14) and American Bullfrogs have become established on a lengthy stretch of the Yellowstone River near Billings (Sepulveda et al. 2015, MTNHP 2017). Furthermore, predictive suitable habitat models for both species indicate that it might be possible for either to become established in floodplain habitats in the Three Forks to Whitehall section of the Jefferson River and possibly upstream to Twin Bridges, Dillon, and Sheridan in the case of Snapping Turtle (Appendix F). Both species can negatively impact native wildlife species (Bury and Whelan 1984, Maxell et al. 2009). Thus, detections of either species need to be taken seriously and animals or populations should be removed if detected. Our surveys below Ennis Lake indicate that the presence of American Bullfrog in this area is almost certainly a false report. American Bullfrog breeding calls can be confused with the sound of wing reverberations produced by Common Nighthawk (*Chordeiles minor*) during display flights and it is believed that a number of false reports of American Bullfrog have been a result of confusion with this sound.

Nine of the eleven species of bats that have been documented on the Dillon BLM Field Office were detected with our deployment of 107 nightly ultrasonic acoustic detector stations between 2009 and 2011 (Table 6). Five of these were commonly detected and widespread species as indicated by observation records, predicted suitable habitat models and the overall proportion (SE) of the acoustic detector stations they were detected at. These included Silver-haired Bat at 0.505 (0.048), Hoary Bat at 0.318 (0.045), Western Small-footed Myotis at 0.308 (0.045), Long-eared Myotis at 0.28 (0.043), and Little Brown Myotis at 0.57 (0.048), most of which showed some evidence of being more likely to be detected and having higher habitat suitability at lower elevations (Figures 26, 27, 29, 30, & 31; Table 6, Appendix F).

Two bat species are much more common and widespread than represented by the proportion of acoustic detector stations they were detected at because their call sequences are very difficult to definitively confirm: Big Brown Bat was confirmed at only 0.093 (0.028) of the detectors and Long-legged Myotis was detected at only 0.009 (0.009) of the detectors (Maxell 2015b). Both species appear to be relatively common and widespread across the Dillon BLM Field Office as indicated by observation records from mist netting and output of the predicted suitable habitat models (Figures 24 and 33, Appendix F). Mist netting, genetic testing of droppings, and roost surveys where animals are identified in hand are much more reliable methods of detecting these species.

California Myotis and Fringed Myotis both appear to be relatively rare and mostly limited to lower elevation sites as indicated by the proportion of detectors they were detected at (0.047 (0.02) and 0.019 (0.013), respectively), the limited number of records for the species from non-acoustic data sources (Figures 28 & 32), and the output of predicted suitable habitat models indicating that they are mostly limited to lower elevations (Appendix F).

Neither Townsend's Big-eared Bat or Spotted Bat were definitively detected at any of the 107 passive ultrasonic acoustic detectors we deployed. Both species appear to be uncommon across the Dillon BLM Field Office, often restricted to relatively lower elevations, and, in the case of Spotted Bat, restricted to landscapes with large cliff habitats (Figures 23 & 25, Appendix F). Both species can be hard to detect acoustically (Maxell 2015b). Townsend's Big-eared Bat has extremely quiet calls and often fail to trigger diagnostic recordings unless they are immediately adjacent to a microphone. Spotted Bat often flies too high to be detected by acoustic stations and they fly long distances over pathways that may not be repeated. Long term monitoring of the status of these and most other bat species is probably better accomplished with year-round ultrasonic acoustic detector deployments (e.g., Maxell et al. 2016a, 2016b).

MODEL LIMITATIONS & USES

Inductive and deductive models in Appendix F are based on statewide biotic and abiotic layers originally mapped at a variety of spatial scales and standardized to 90 × 90 meter raster pixels. Furthermore, 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. 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.

Future Survey Recommendations

Survey efforts since 2001 have resulted in a drastic improvement in our understanding of the distribution and status of amphibian, reptile and bat species across the region encompassed by the Dillon BLM Field Office. However, there are a number of additional surveys needed for these taxa in this region. These include:

1) Floodplain surveys in later summer at low water levels to determine whether additional breeding populations of Northern Leopard Frog are present in the following areas: (a) the Jefferson River between Three Forks and Twin Bridges; (b) the lower Ruby River between Sheridan and Twin Bridges; (c) the lower Beaverhead River between Dillon and Twin Bridges; and (d) the Madison River downstream of the middle portion of the Madison Valley. Painted Turtles in and adjacent to the floodplain should be recorded as part of these surveys.

2) Passive acoustic listening surveys for Northern Leopard Frogs in the floodplain of the Jefferson River near the mouth of Sand Creek below Highway 287 and between Cardwell and Whitehall around the time of ice-off of standing water bodies (approximately late March) to identify specific locations of breeding sites.

3) Passive acoustic surveys for Boreal Chorus Frog and Plains Spadefoot in the following areas: (a) the Madison Valley above Ennis including Highway 87 to Raynolds Pass and the Antelope Basin and Horn Creek roads; (b) the northern edge of the Red Rock Lakes; (c) the Sweetwater Road from Ruby River Reservoir to Dillon; (d) Highway 278 from Dillon to Badger Pass; and (e) the Grasshopper Creek drainage from Interstate 15 to Bannack.

4) Regular monitoring of all known Western Toad breeding sites

5) Acoustic surveys for bats in the following watershed assessment units which have high densities of BLM lands, but currently lack acoustic or other surveys for bats: (a) the lower portions of Upper Horse Prairie; (b) large portions of Sage Creek and Blacktail; (c) central portions of SW Highlands; and (d) the southeastern portion of the South Tobacco Roots (Figure 5). Long term assessment and monitoring of the status of bats in these areas may be best accomplished with year-round ultrasonic acoustic detector deployments such as those summarized in Maxell et al. (2016a & 2016b).

6) Efforts should be made to train BLM, U.S. Forest Service, and Fish, Wildlife, and Parks personnel and educate the public on the importance of reporting incidental observations of rarely detected species such as Pygmy Short-horned Lizard, Greater Short-horned Lizard, Northern Rubber Boa, North American Racer, and Western Milksnake. This is likely the best way to accumulate incidental observations to inform distribution and status assessments of these species.

7) Passive listening surveys for nocturnal calling amphibians, visual encounter and dip net surveys for amphibians and aquatic reptiles at standing water bodies, and widespread mist net or acoustic surveys for bats should be repeated at something like 10-15 year intervals in order to reassess the distribution and conservation status of these species and populations over time in the context of land management assessment and planning efforts.

Management Recommendations

All structured survey and detection information included in this report has been integrated into databases at the Montana Natural Heritage Program where it is available on the Montana Field Guide, Species Snapshot, and Map Viewer websites to inform survey and management decisions. We encourage all biologists and natural resource managers to use this information in their review, planning, and decision processes.

Based on the distribution, status, and predicted habitat suitability information in this report, our observations while in the field, and the scientific literature, the following management actions are recommended:

1) Promote the presence of Beaver (Appendix F) and their dam building activities on landscapes across the Dillon BLM Field Office to maintain high water tables and late season instream flows in watersheds with permanent to semipermanent flow, rewater dry watersheds, and provide better connectivity between isolated populations of amphibians and other species that are dependent on surface waters (Funk et al. 2005, Amish 2006).

2) Manage standing water bodies, wetlands, and timber lands to maintain “natural” frequencies and intensities of disturbance from grazing and fire and/or timber harvest in order to promote the maintenance of habitats required by amphibians such as the Western Toad which has been shown to respond positively to disturbances such as fire and timber harvest (Maxell 2009) and bats which use snags and loose bark created by fire as roosting habitat (Maxell 2015a).

3) Protect rock outcrops and talus slopes, particularly those with cracks and crevices or interstial spaces between rock layers, to provide important habitat for a diversity of wildlife, including bats, reptiles, small terrestrial mammals, birds, invertebrates, and other species.

4) Ensure that all cattle tanks have climb out ramps that will allow wildlife that has fallen into the tank to climb out (see Taylor and Tuttle 2007).

5) Management agencies should reach out to private land owners that have extant Northern Leopard Frog breeding populations to educate them on the status of the species and ensure that breeding and adjacent terrestrial habitats are protected to ensure population persistence.

6) Immediately implement control efforts if either American Bullfrog or Snapping Turtle are detected within the Dillon BLM Field Office due to their abililty to negatively impact native wildlife species (Bury and Whelan 1984, Maxell et al. 2009)

7) Prairie Rattlesnake is the only amphibian or reptile species not protected from commercial collection in Montana and collectors are known to regularly come to denning sites in Montana to collect large numbers of animals for use in rattlesnake roundup festivals in southern states where native populations have been decimated (Maxell et al. 2009). Thus, it is important to continue to document the status and distribution of this species and implement protective measures if declines occur.

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Figure 1. Watershed assessement units within the Dillon Field Office of the BLM where surveys were conducted. BLM lands are shown in yellow, U.S. Forest lands are in green, and state lands are in light purple and blue.

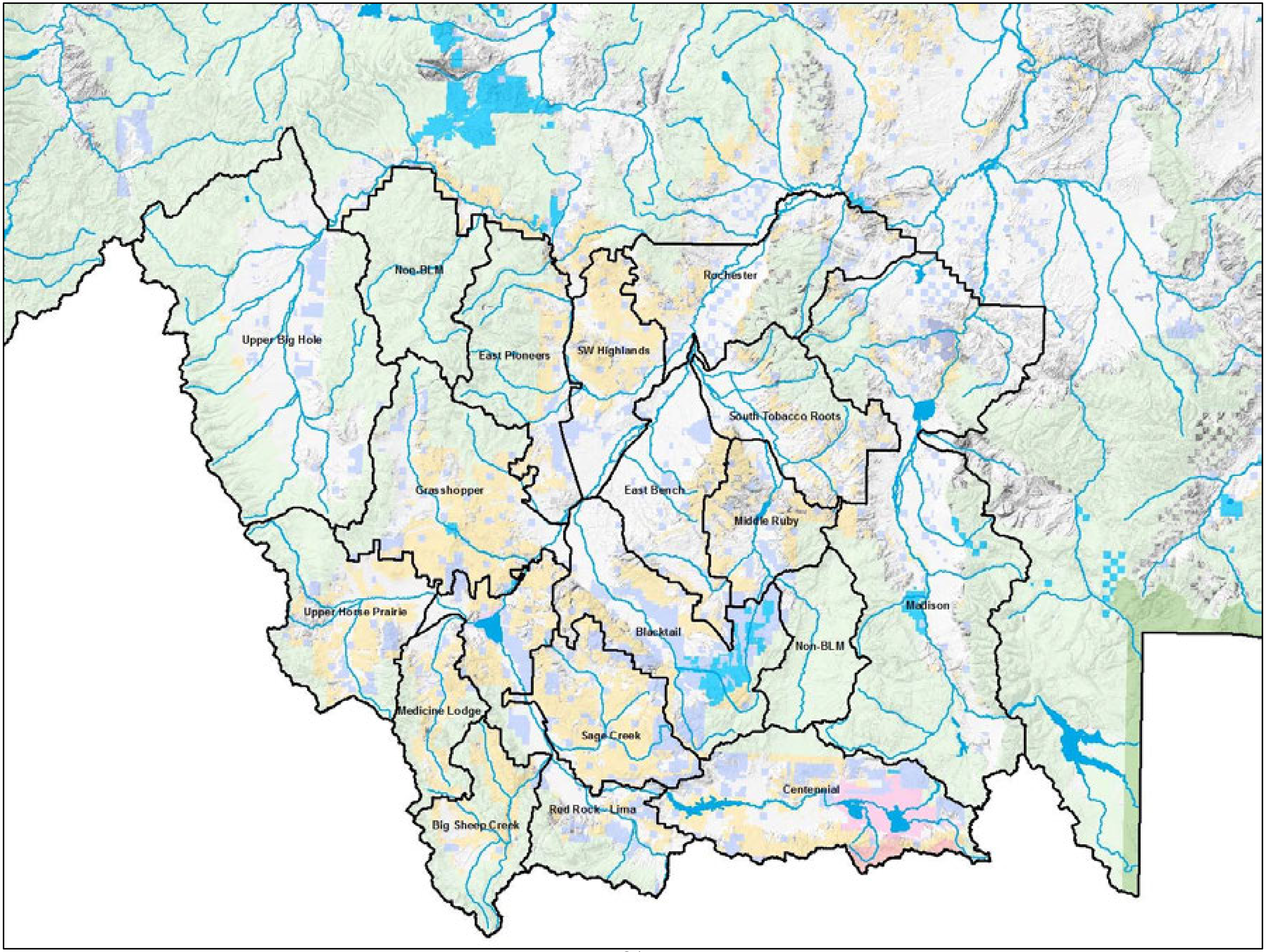


Figure 2. Overview of visual encounter and dip net surveys for amphibians and aquatic reptiles at standing water bodies and wetlands (black dots).

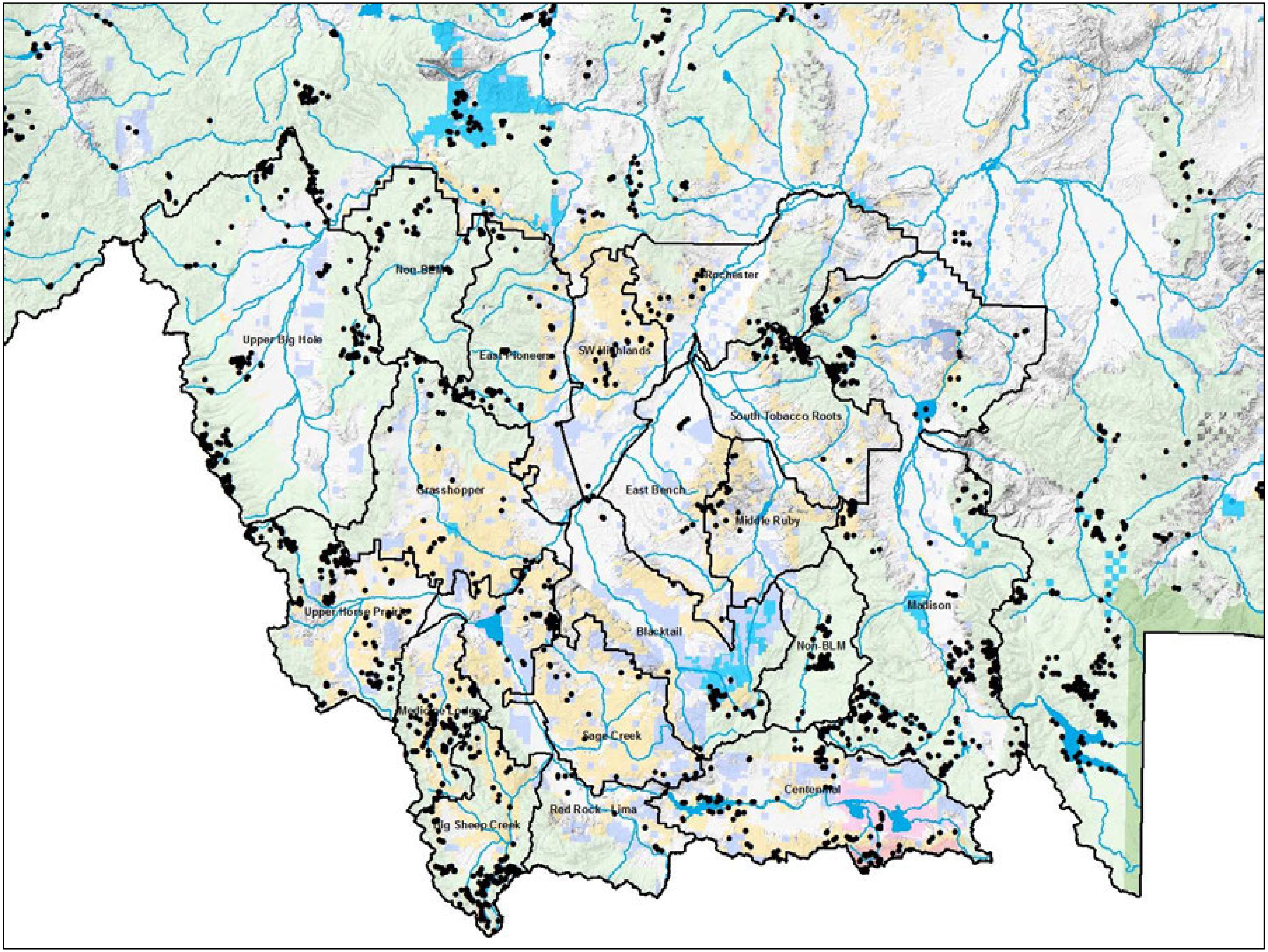


Figure 3. Overview of passive listening surveys for nocturnal calling amphibians (black dots).

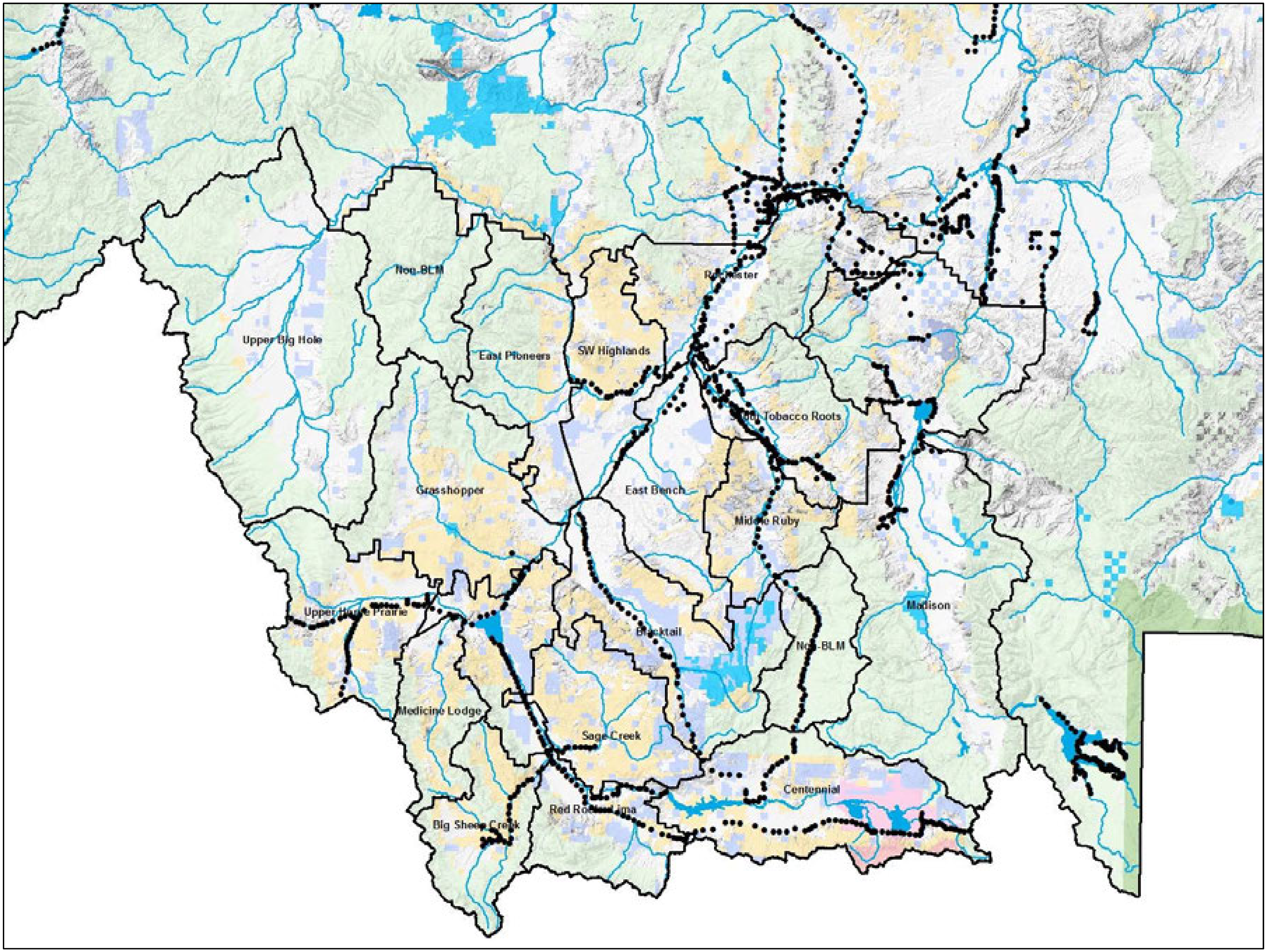


Figure 4. Overview of visual encounter surveys for terrestrial reptiles at rock outcrop and friable soil sites (black dots).

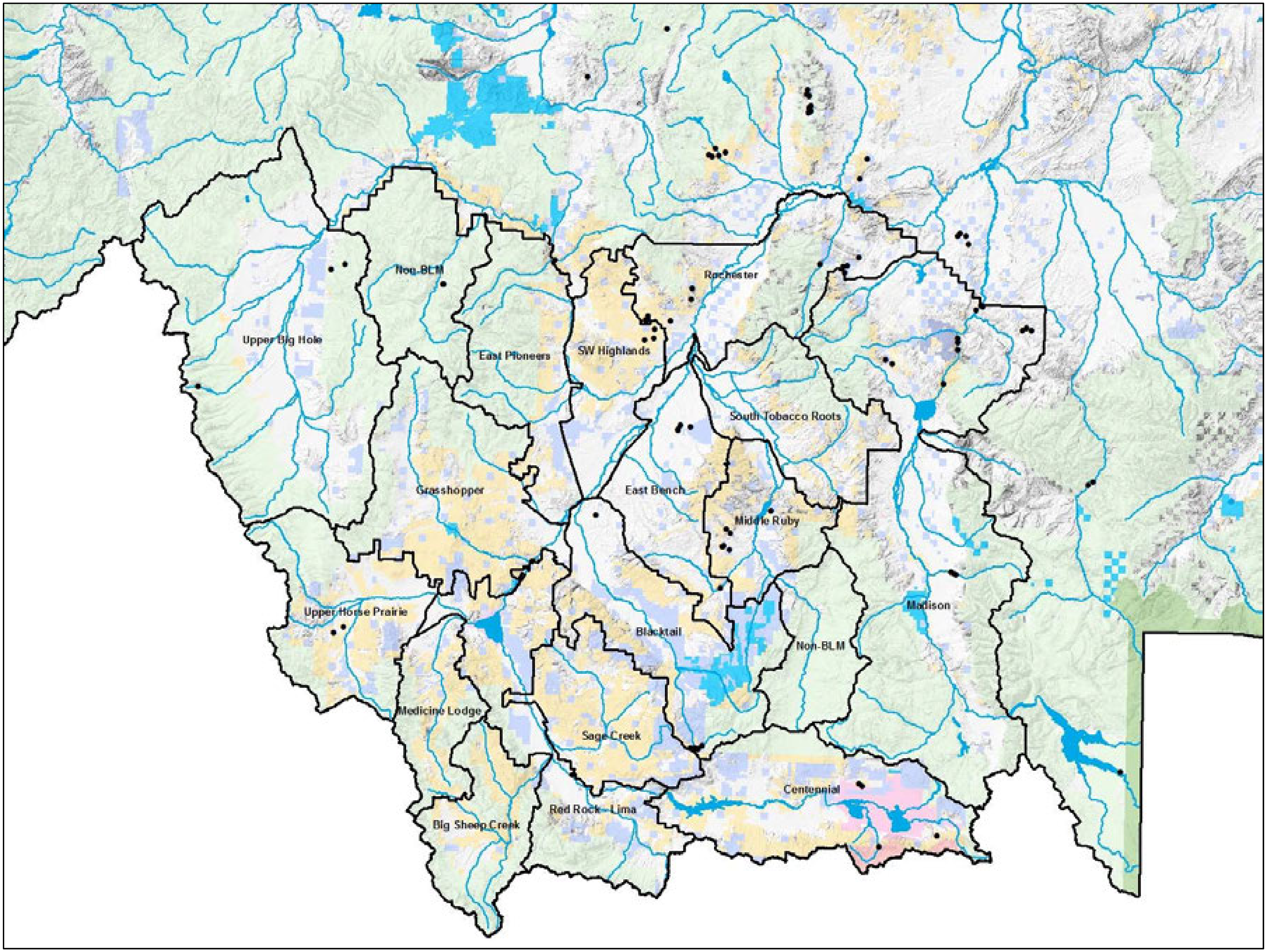


Figure 5. Overview of bat acoustic (red crosses), mistnet (blue stars), active season roost (black diamond), and hibernacula roost (purple triangle) surveys.

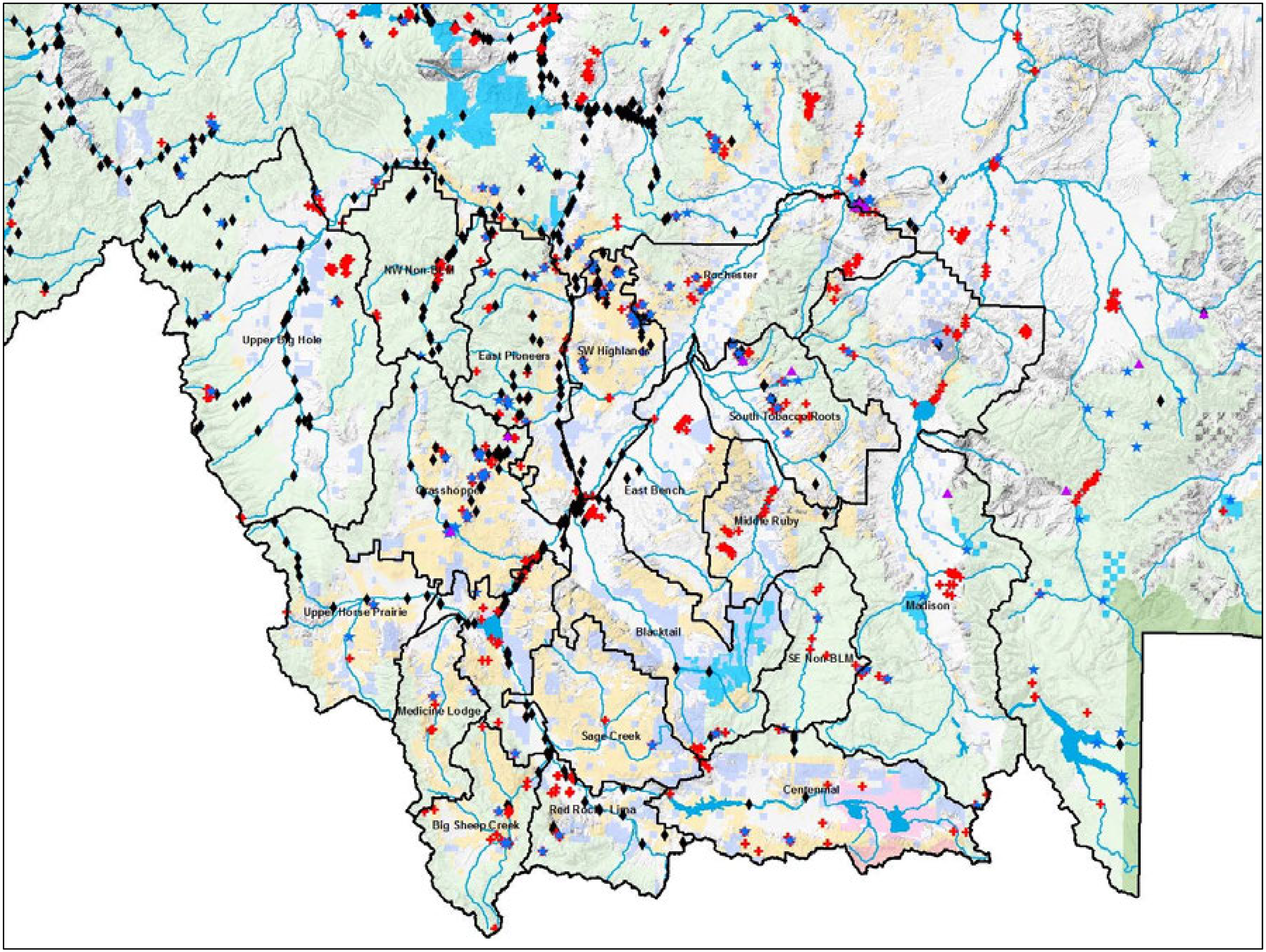


Figure 6. Overview of detections of Long-toed Salamander (red cross). See Figure 2 for an overview of visual encounter and dipnet survey locations capable of detecting the species. See Table 2 for summaries of the proportion of suitable standing water body surveys the species was detected at.

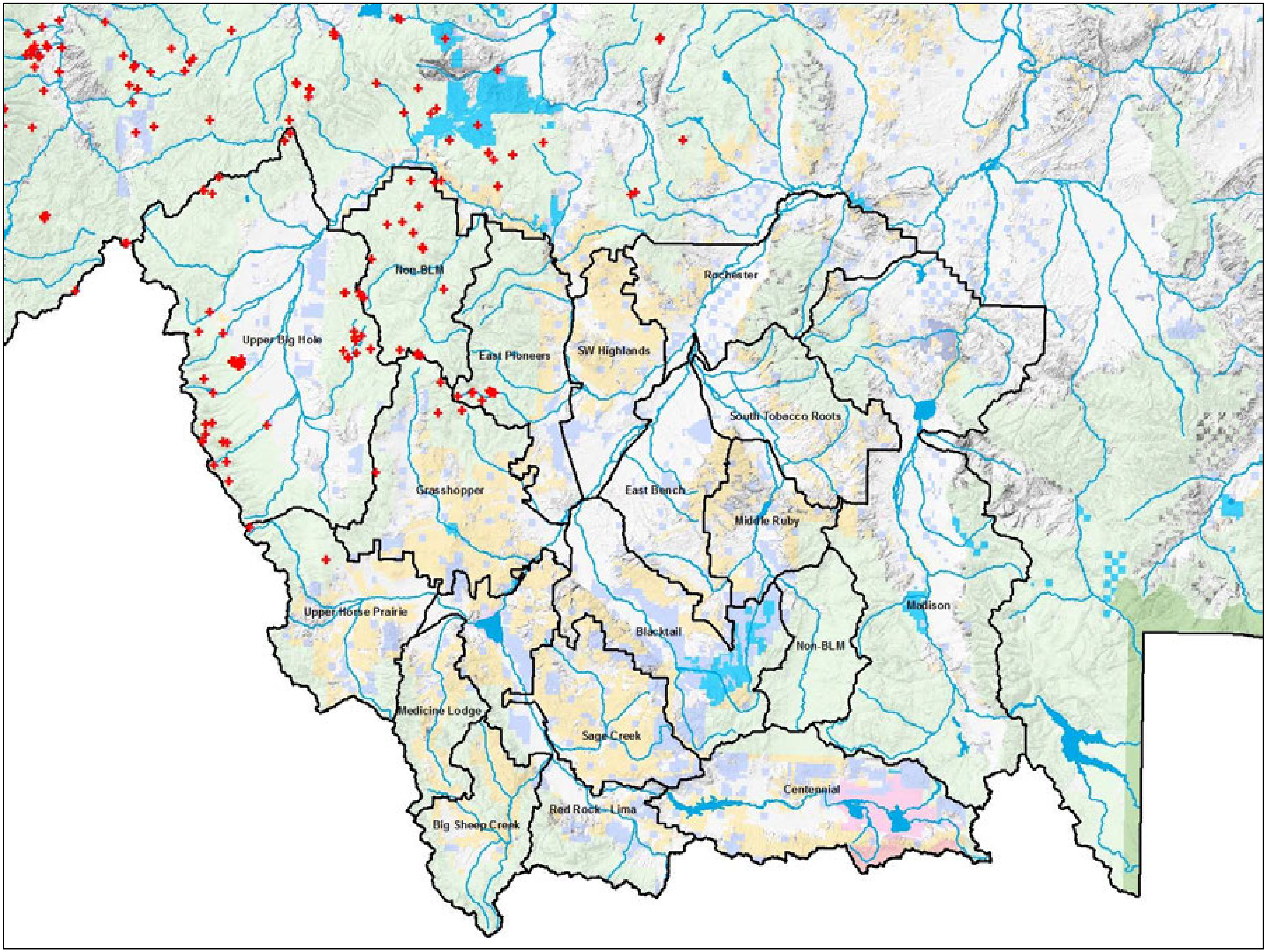


Figure 7. Overview of detections of Western Tiger Salamander (red cross). See Figure 2 for an overview of visual encounter and dipnet survey locations capable of detecting the species. See Table 2 for summaries of the proportion of suitable standing water body surveys the species was detected at.

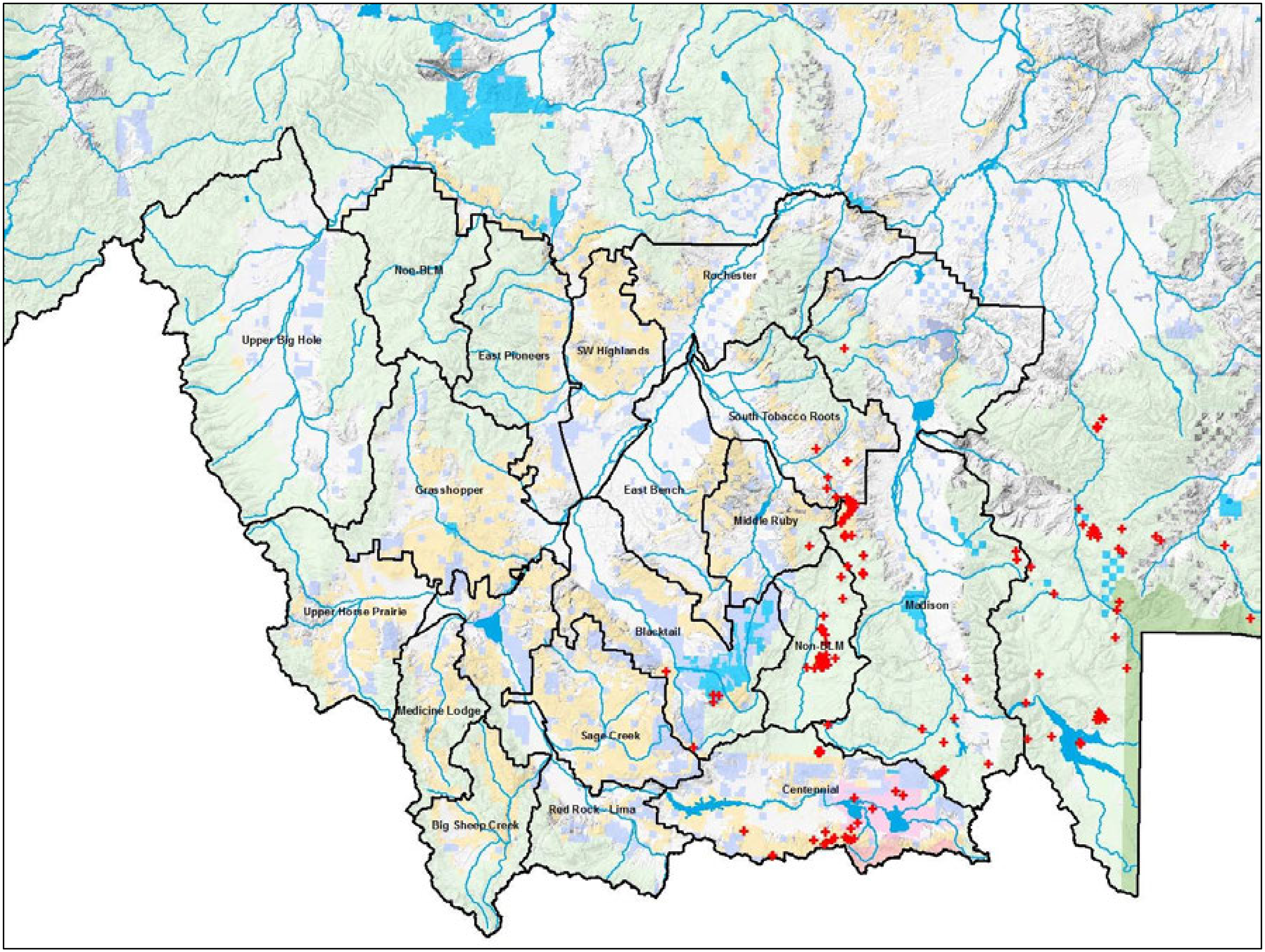


Figure 8. Overview of detections of Rocky Mountain Tailed Frog. This species was not targeted or detected incidentally with this survey effort.

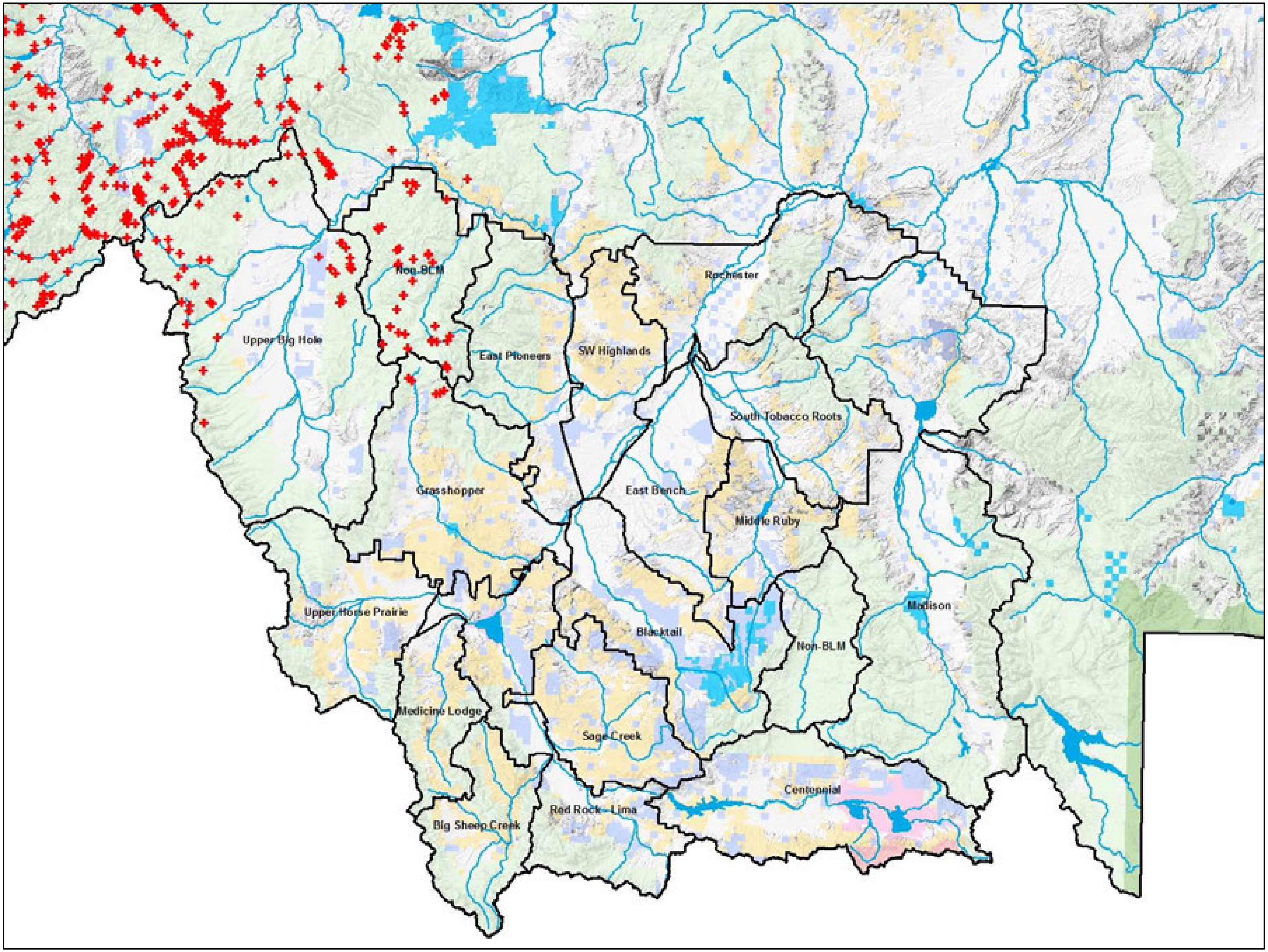


Figure 9. Overview of detections of Western Toad. See Figure 2 for an overview of visual encounter, dipnet survey locations capable of detecting the species. See Table 2 for a summary of the proportion of suitable standing water body surveys the species was detected at.

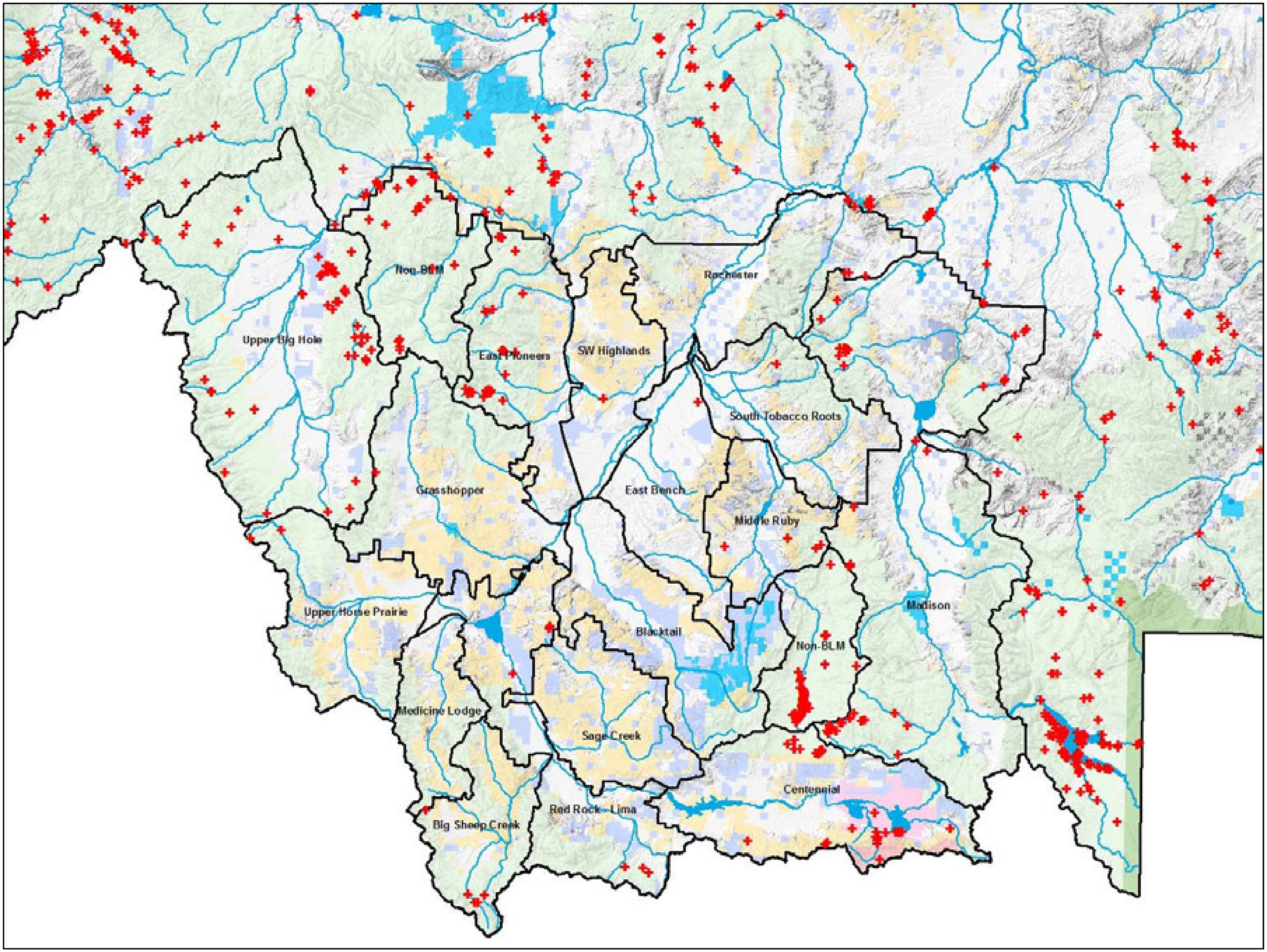


Figure 10. Overview of detections of Boreal Chorus Frog. See Figures 2 and 3 for an overview of visual encounter, dipnet, and passive listening survey locations capable of detecting the species. See Tables 2, 3, and 4 for summaries of the proportion of suitable standing water body and passive listening station surveys the species was detected at.

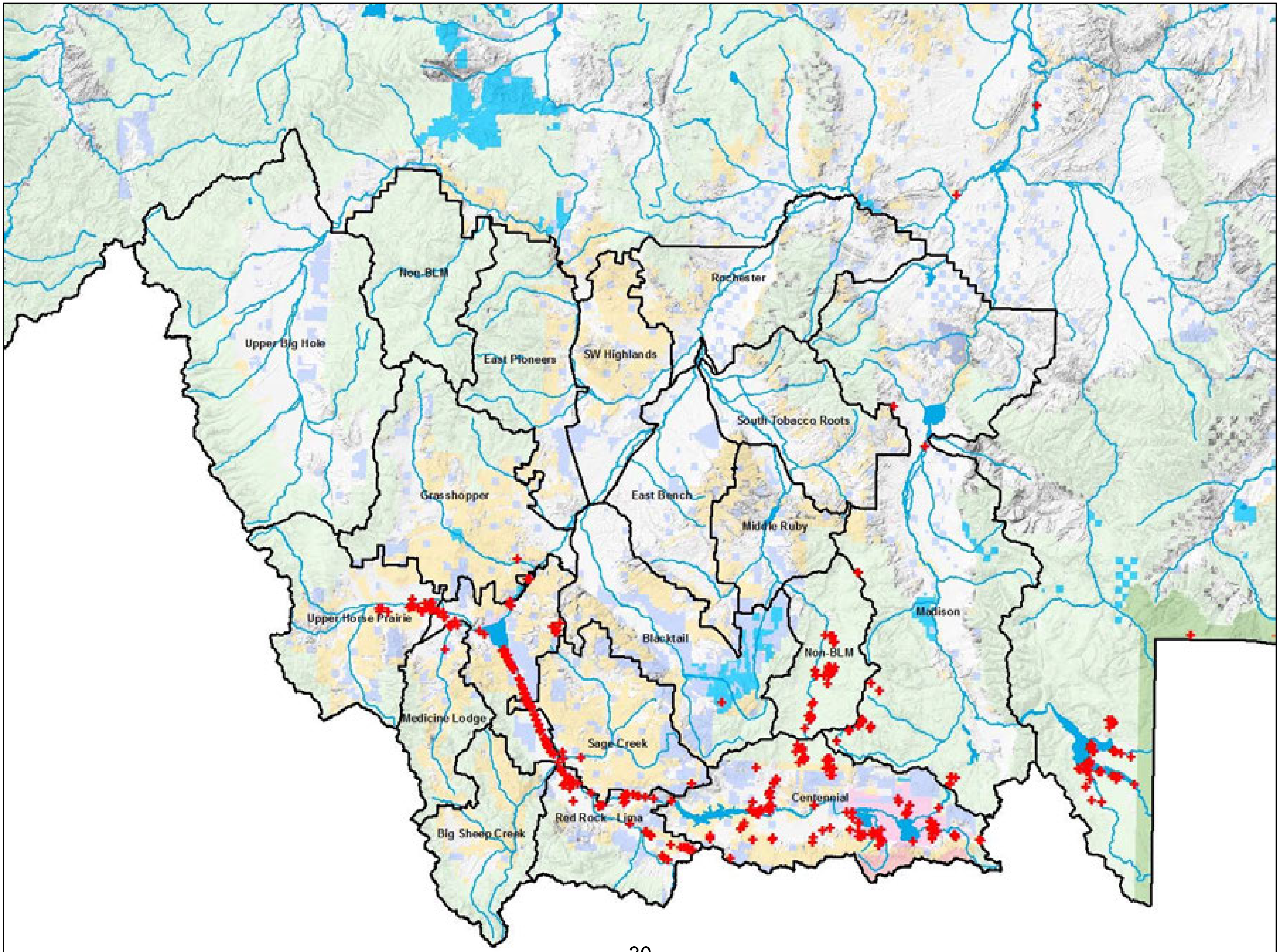


Figure 11. Overview of detections of Plains Spadefoot. See Figures 2 and 3 for an overview of visual encounter, dipnet, and passive listening survey locations capable of detecting the species. See Tables 2, 3, and 4 for summaries of the proportion of suitable standing water body and passive listening station surveys the species was detected at.

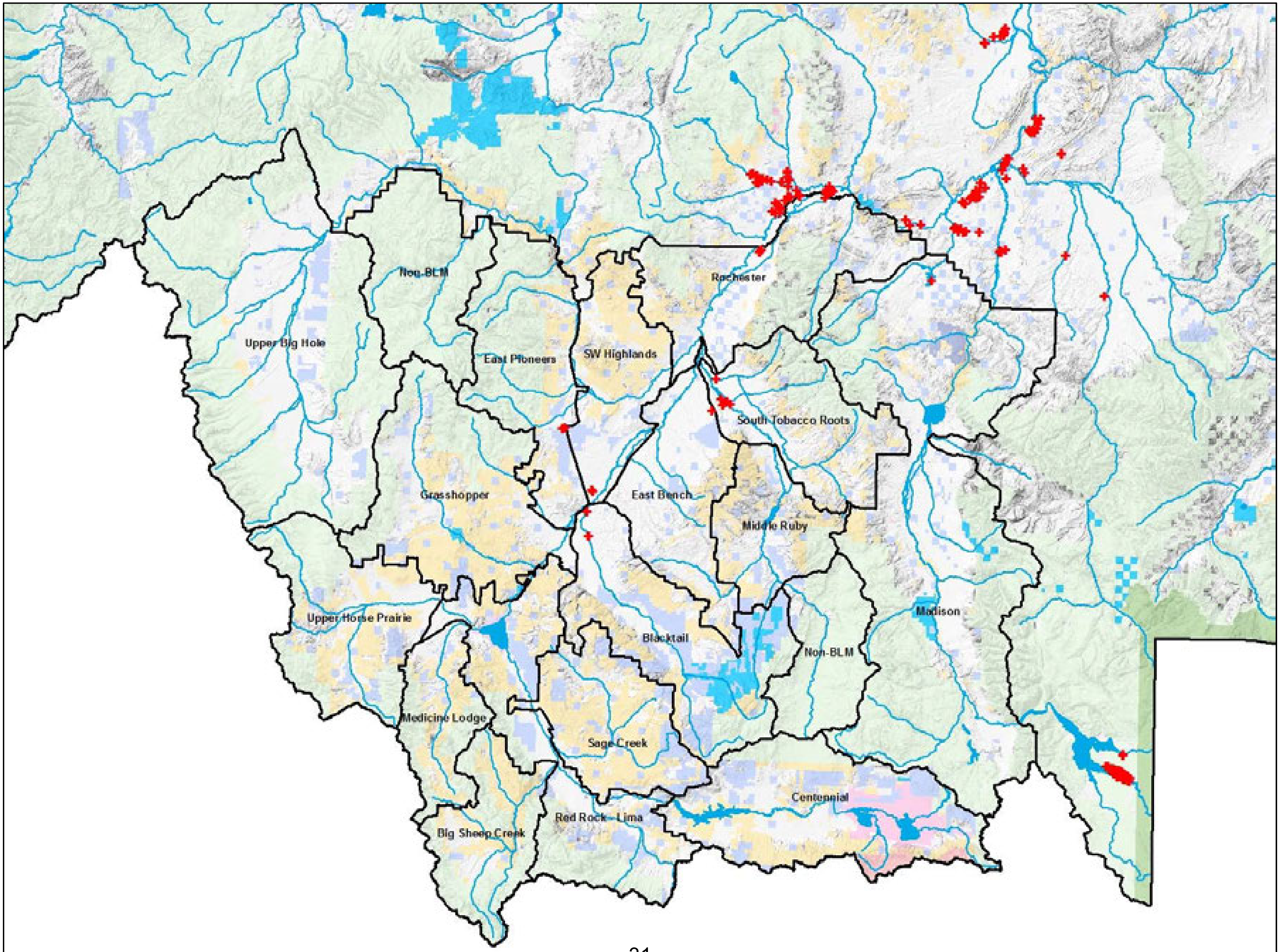


Figure 12. Overview of detections of Northern Leopard Frog; records prior to 1990 (purple) and after 1990 (red). See Figure 2 for an overview of visual encounter and dipnet surveys locations capable of detecting the species. The species was not detected during suitable standing water body or acoustic surveys. However it was detected while walking floodplain habitats near Cardwell.

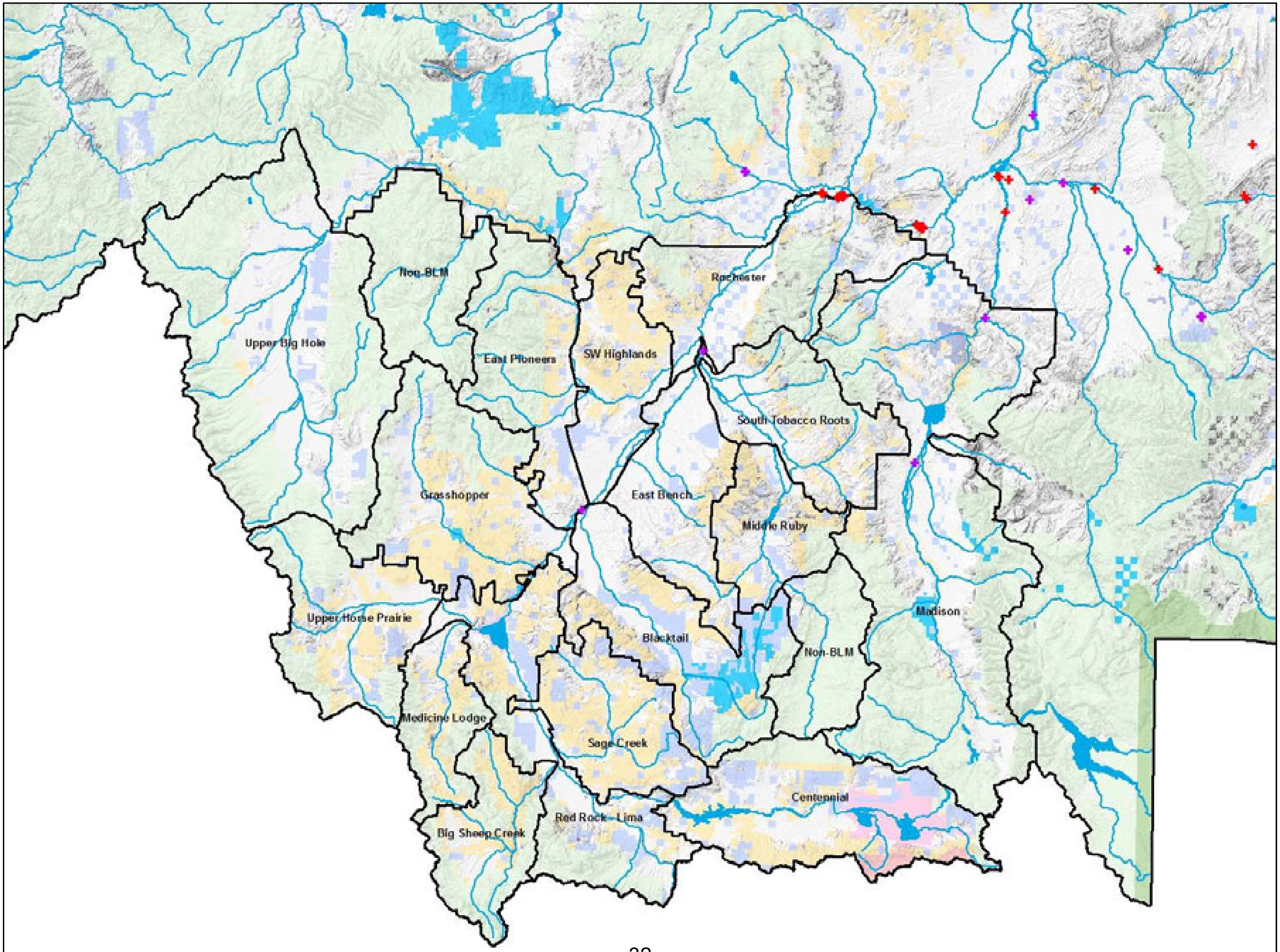


Figure 13. Overview of detections of Columbia Spotted Frog. See Figure 2 for an overview of visual encounter, dipnet survey locations capable of detecting the species. See Table 2 for a summary of the proportion of suitable standing water body surveys the species was detected at.

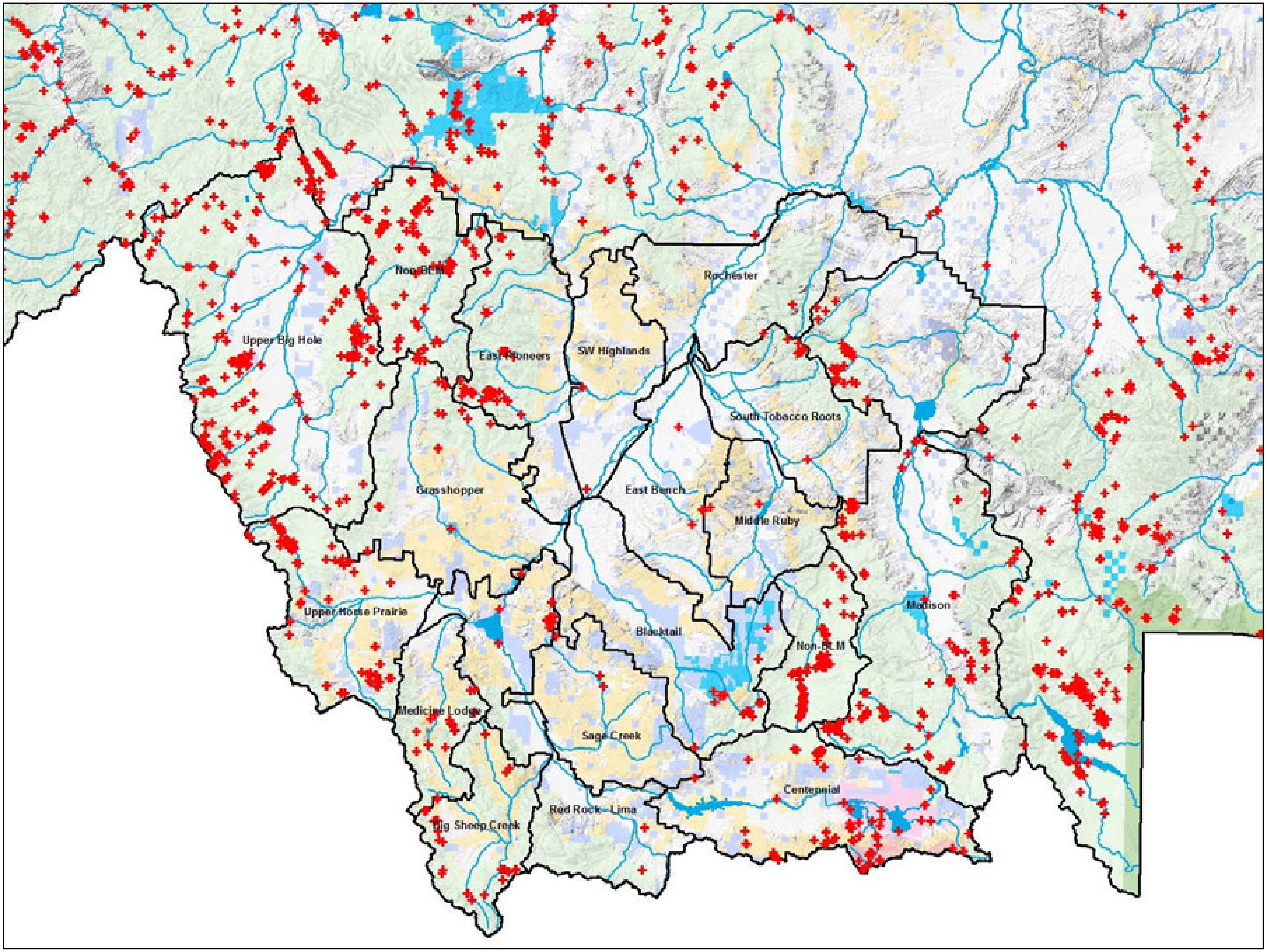


Figure 14. Overview of detections of Snapping Turtle introductions.

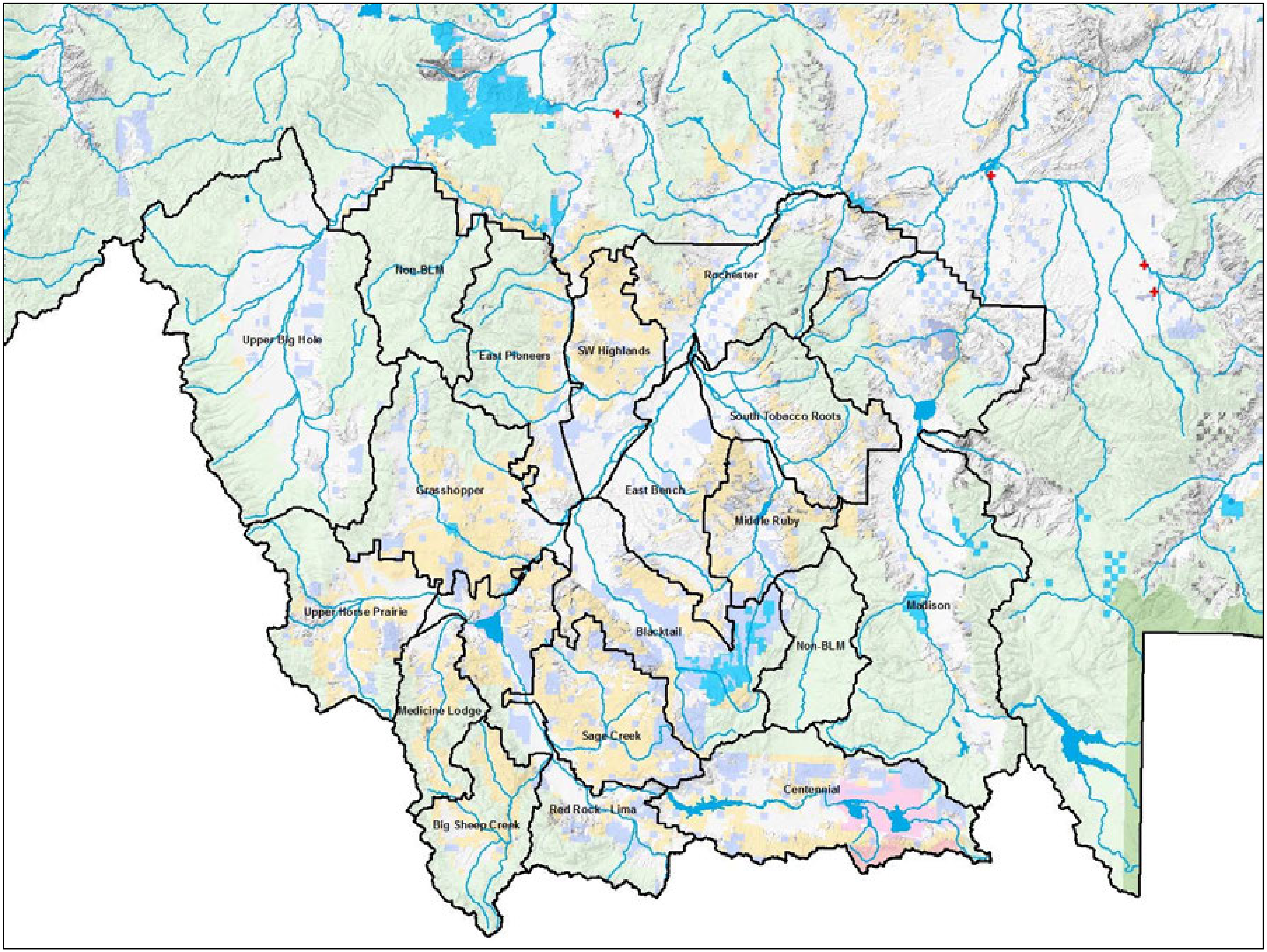


Figure 15. Overview of detections of Painted Turtle. See Figure 2 for an overview of visual encounter and dipnet survey locations capable of detecting the species. The species was not detected during our surveys of standing water bodies, but was detected incidentally.

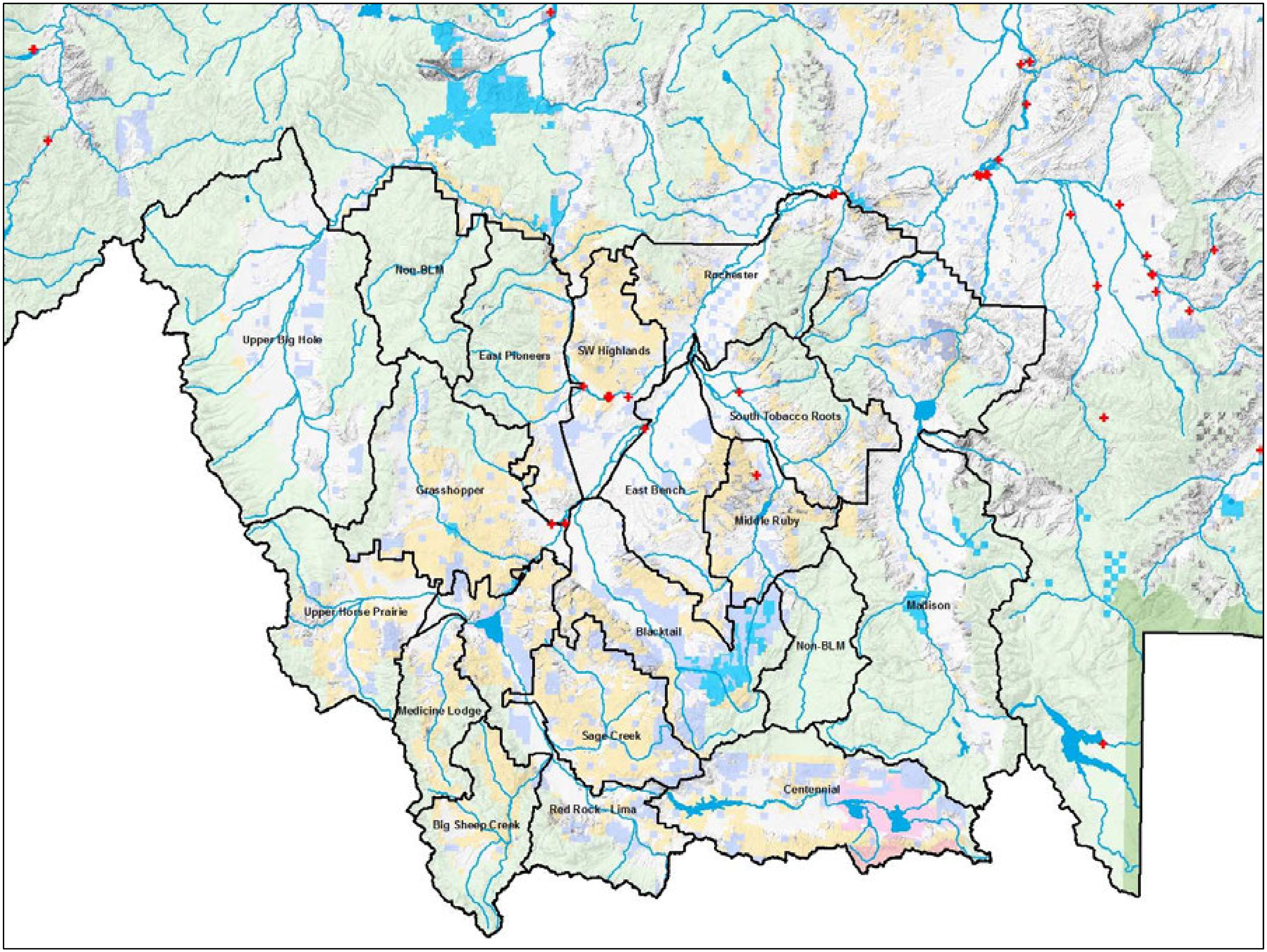


Figure 16. Overview of detections of Greater Short-horned Lizard. Detections near Three Forks and the Gallatin Valley were made prior to 1954. The extant population on the west side of Butte was first detected in 2011. Surveys on friable soils targeting this species were performed in the Centennial Sandhills near Lemhi Pass and in the Sage Creek drainage. Informing BLM personnel and local private land owners about the species' preference for sandy to gravelly soils in grasslands and shrublands with good solar exposure is likely the best way to accumulate incidental observations.

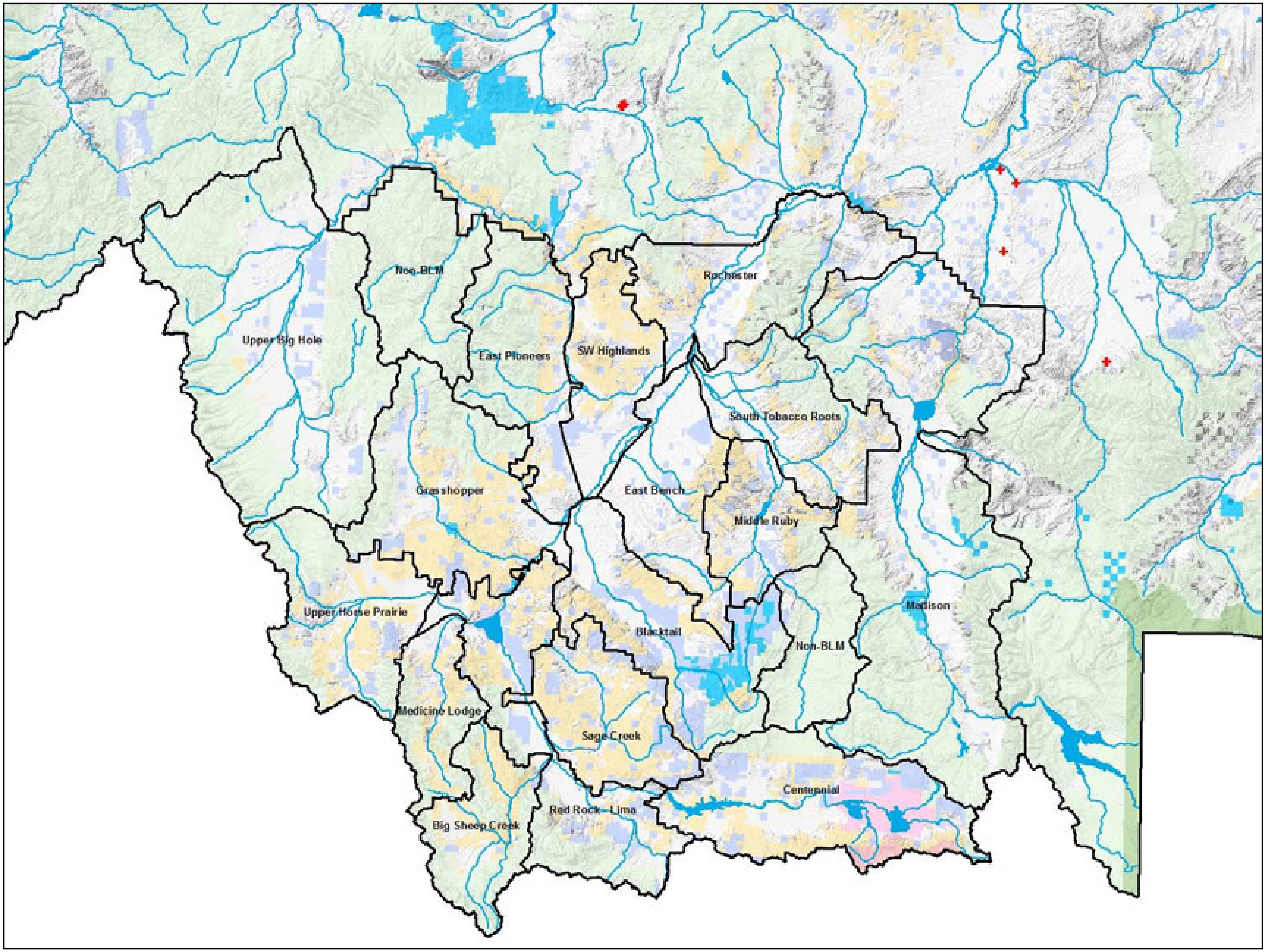


Figure 17. Overview of detections of Northern Rubber Boa. This species was not detected incidentally or during any of our formal surveys. Education of BLM personnel and local private citizens is likely the best way to accumulate incidental observations of the species.

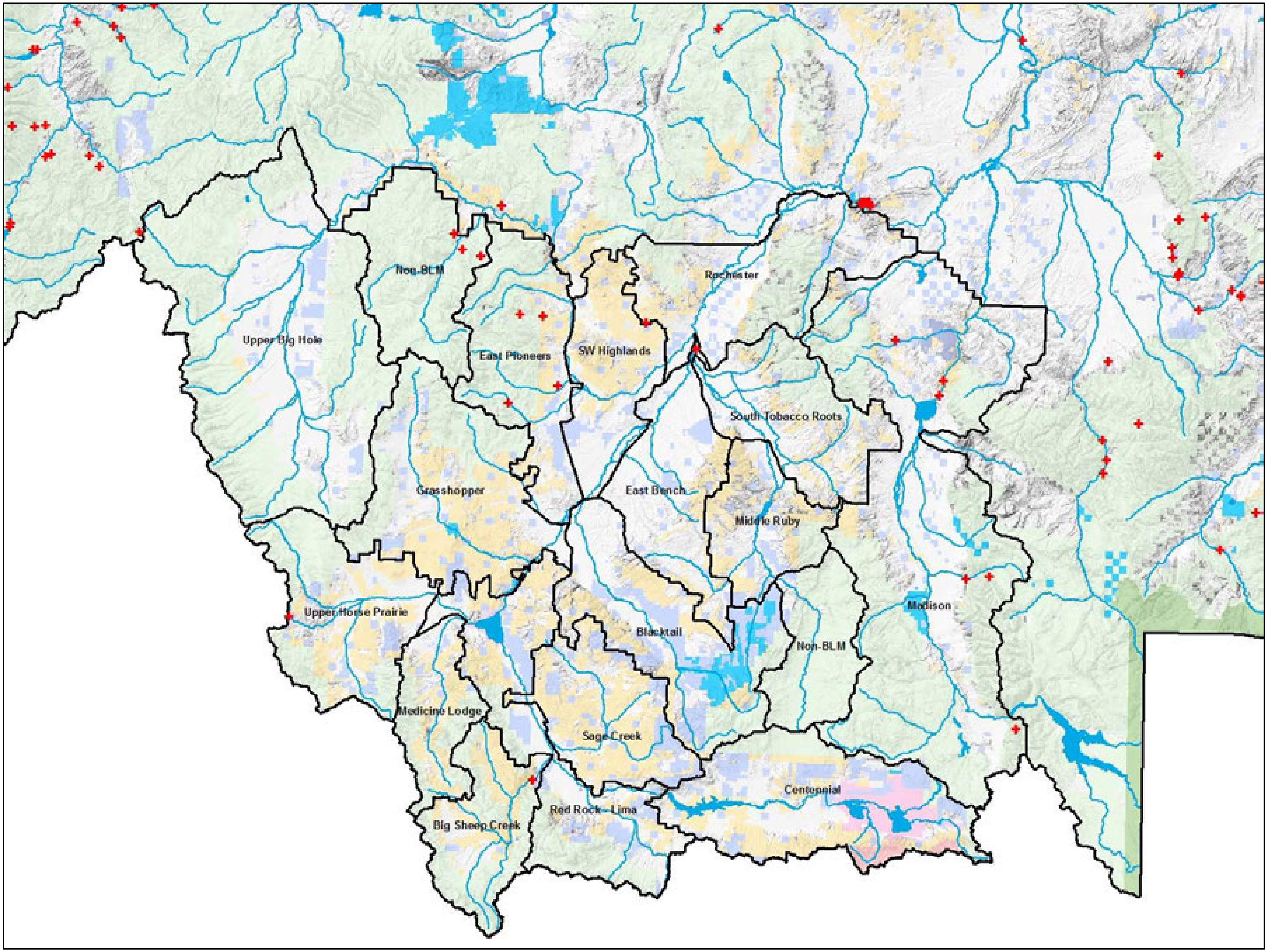


Figure 18. Overview of detections of North American Racer. See Figure 4 for an overview of visual encounter survey locations at rock outcrop and friable soil sites capable of detecting the species. The species was not detected during formal surveys, but was detected incidentally.

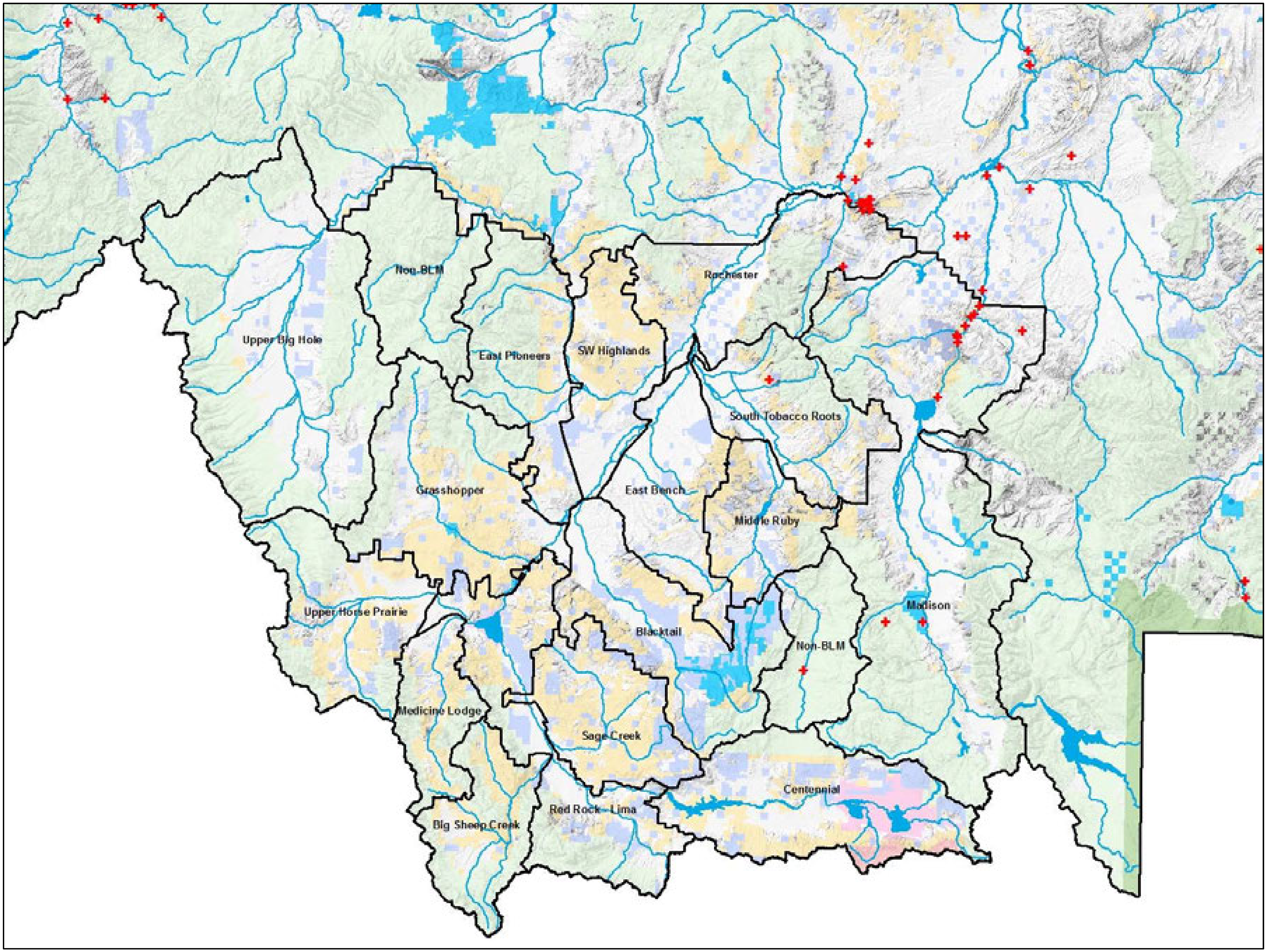


Figure 19. Overview of detections of Gophersnake. See Figure 4 for an overview of visual encounter survey locations at rock outcrop and friable soil sites capable of detecting the species. See Table 5 for summaries of the proportion of rock outcrop surveys the species was detected at.

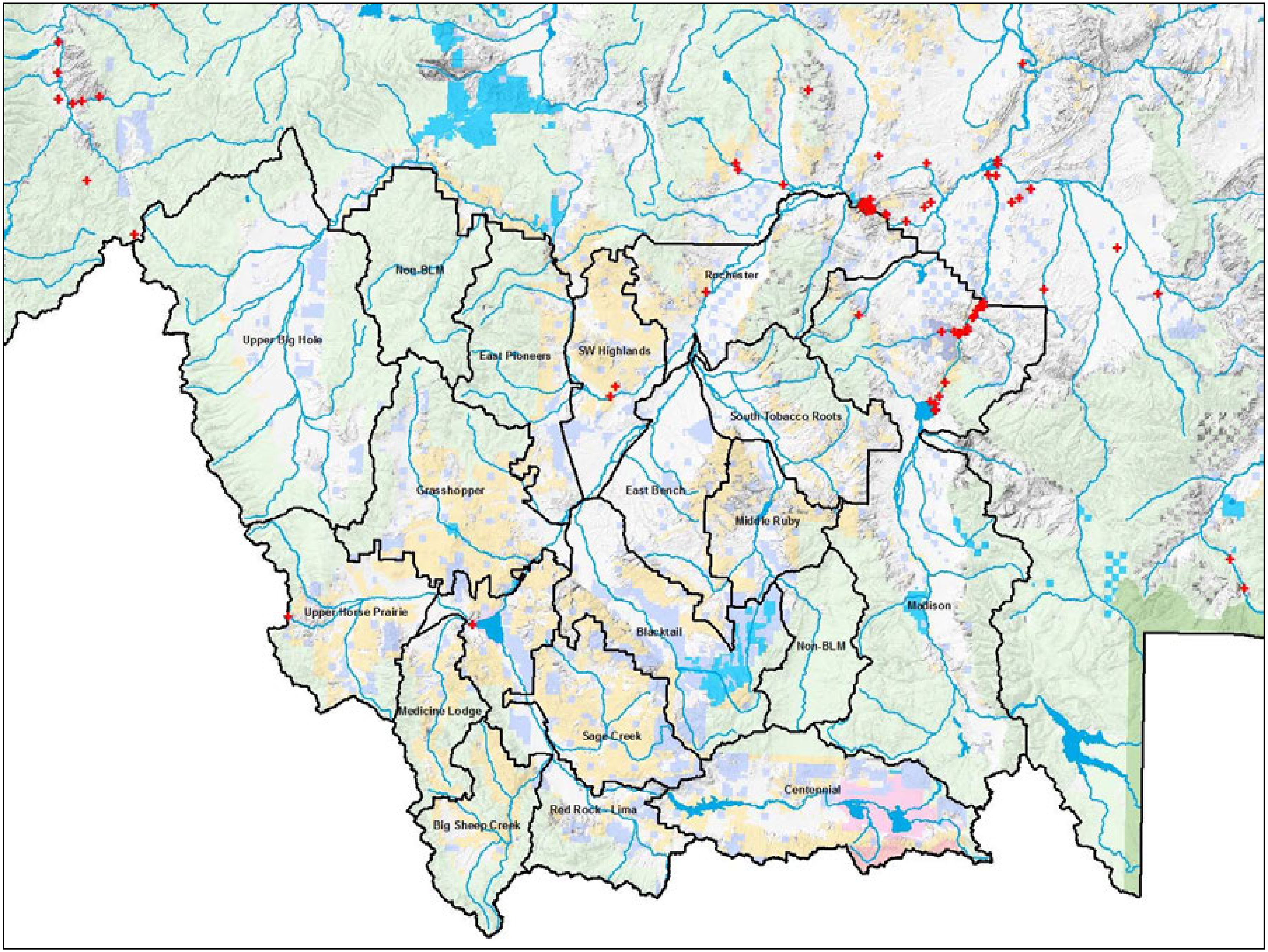


Figure 20. Overview of detections of Terrestrial Gartersnake. See Figure 2 for an overview of visual encounter and dipnet survey locations capable of detecting the species. See Tables 2 and 5 for summaries of the proportion of standing water body and rock outcrop surveys the species was detected at.

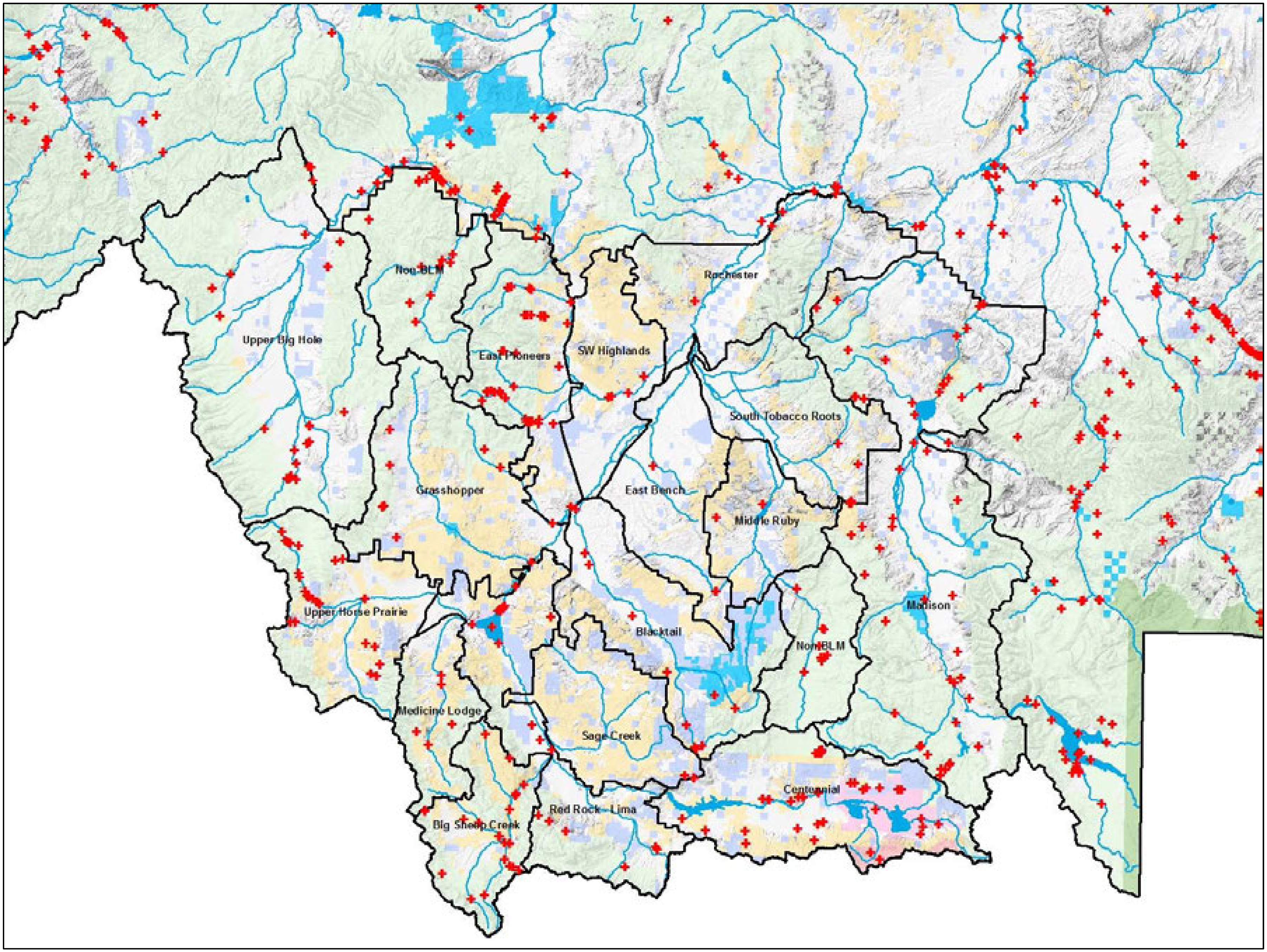


Figure 21. Overview of detections of Common Gartersnake. See Figure 2 for an overview of visual encounter and dipnet survey locations capable of detecting the species. See Tables 2 and 5 for summaries of the proportion of standing water body and rock outcrop surveys the species was detected at.

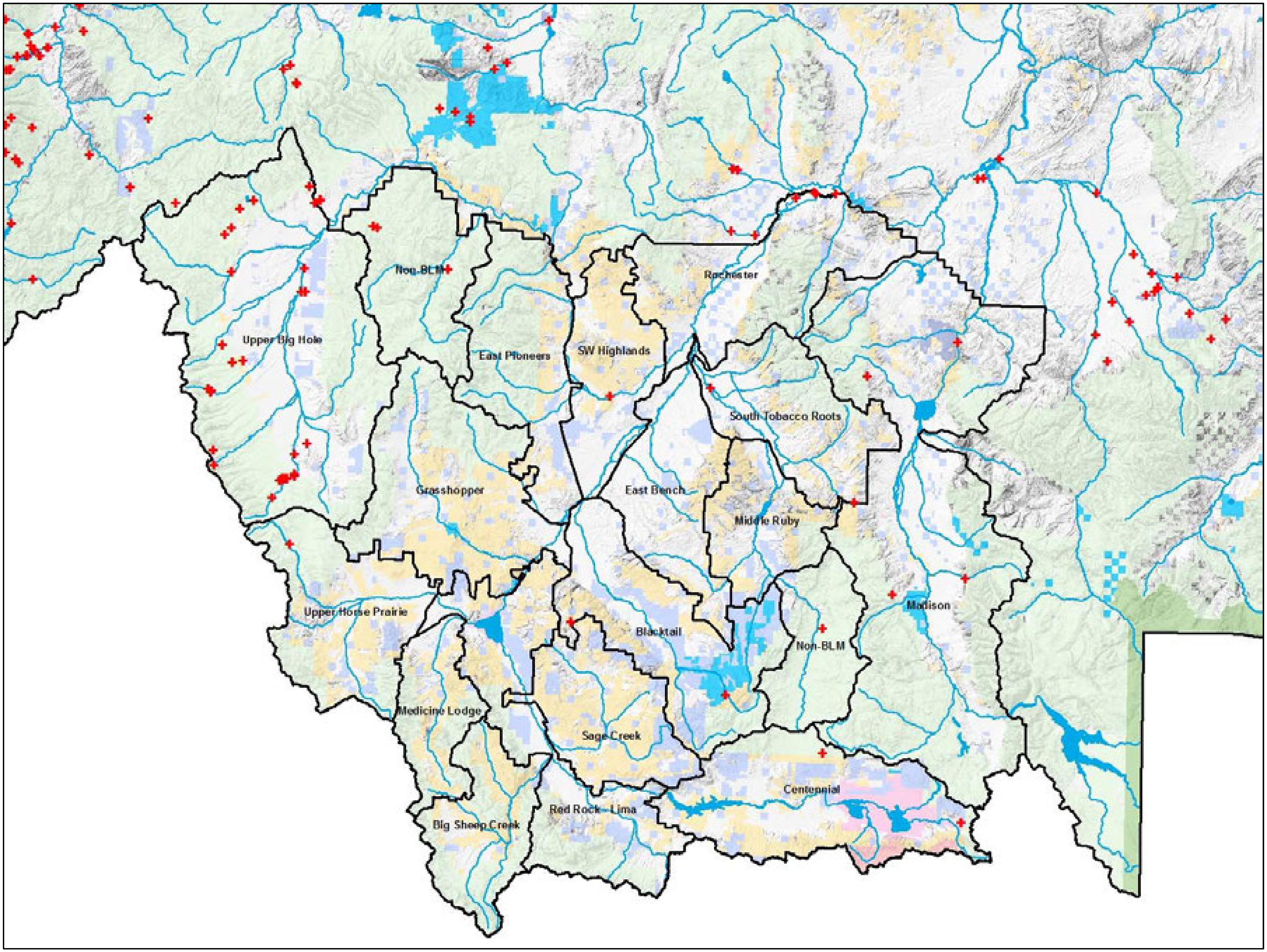


Figure 22. Overview of detections of Prairie Rattlesnake. See Figure 4 for an overview of visual encounter survey locations at rock outcrop and friable soil sites capable of detecting the species. See Table 5 for a summary of the proportion of these surveys the species was detected at.

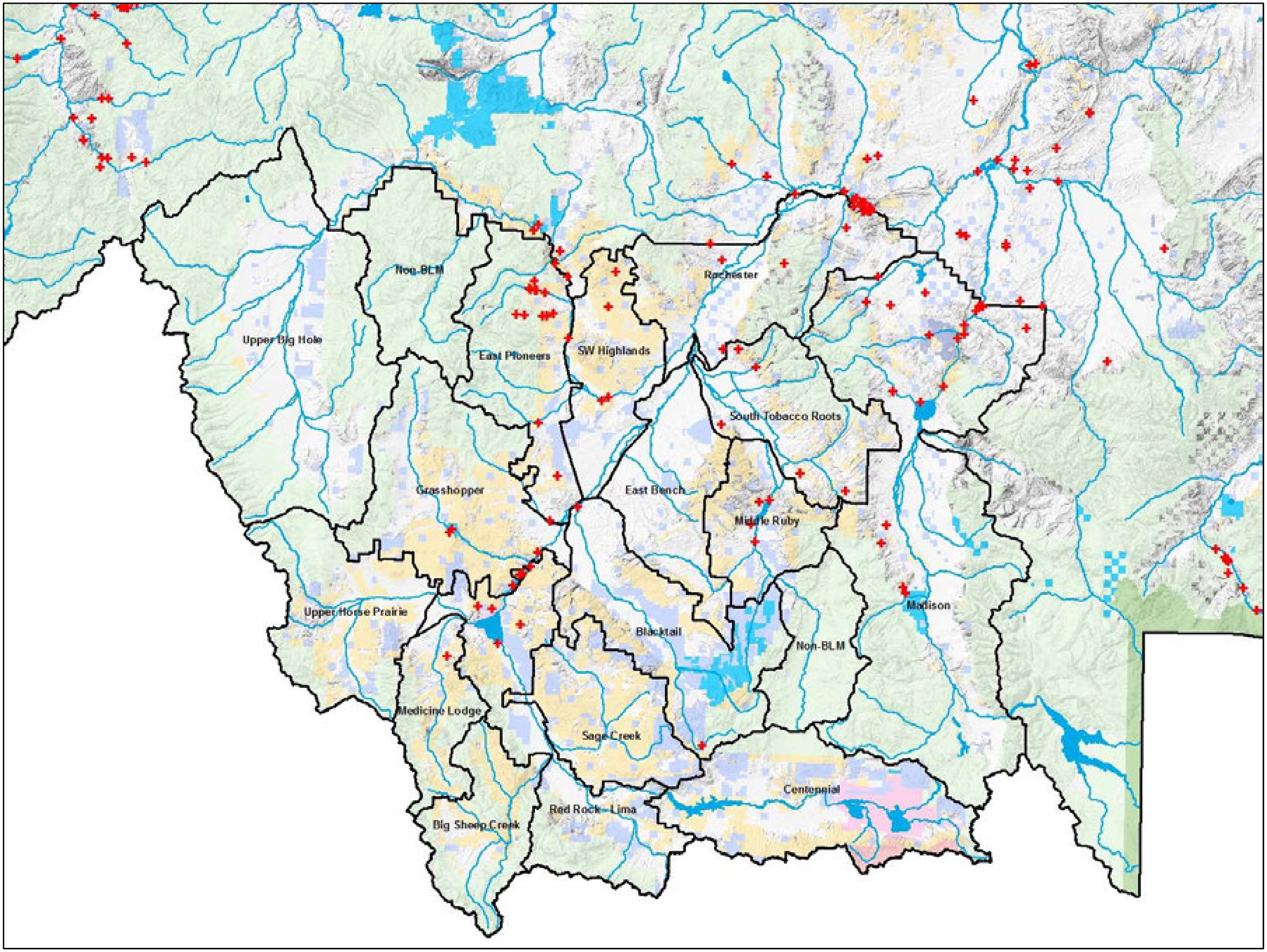


Figure 23. Overview of detections of Towsend's Big-eared Bat. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

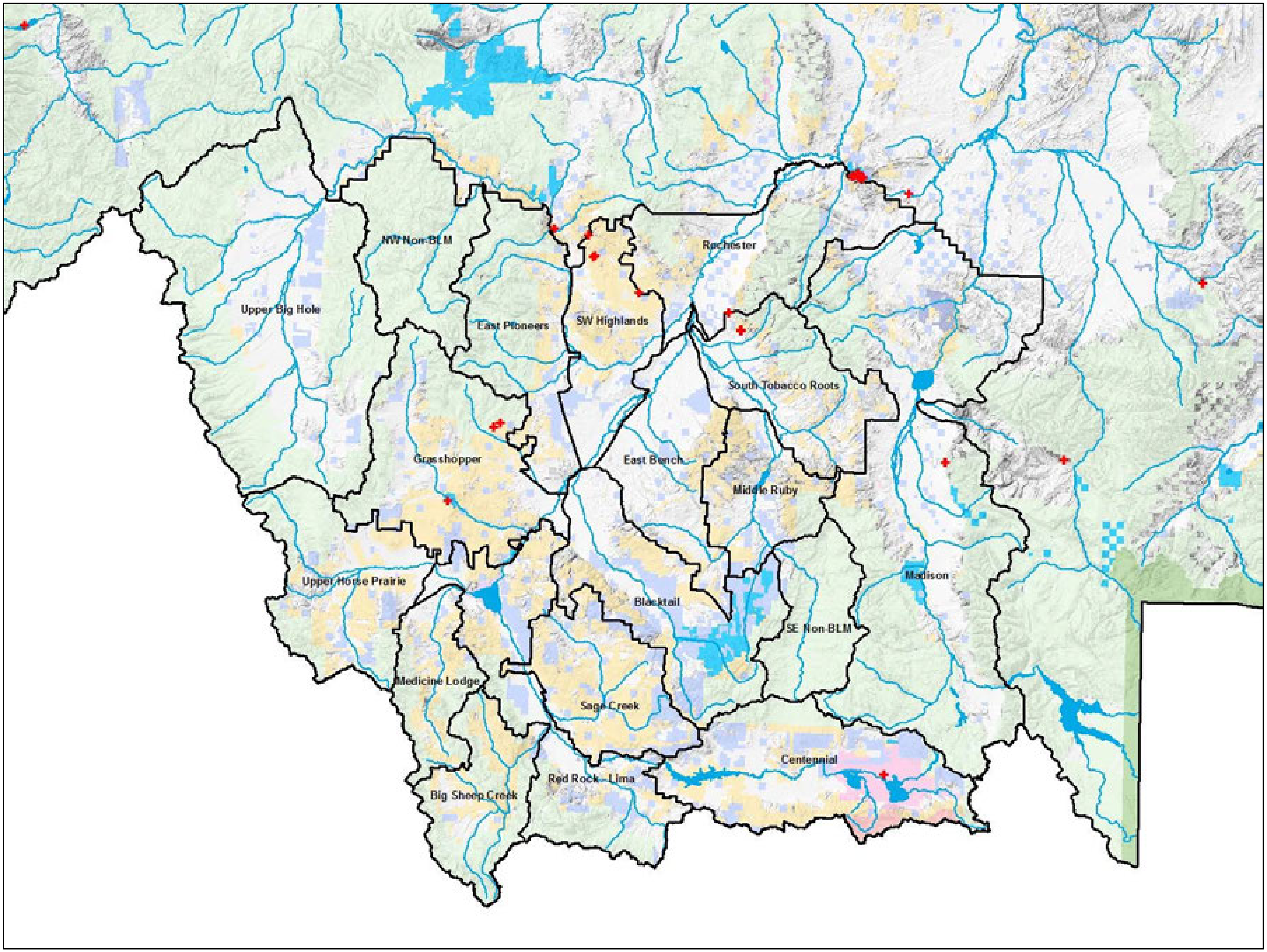


Figure 24. Overview of detections of Big Brown Bat. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

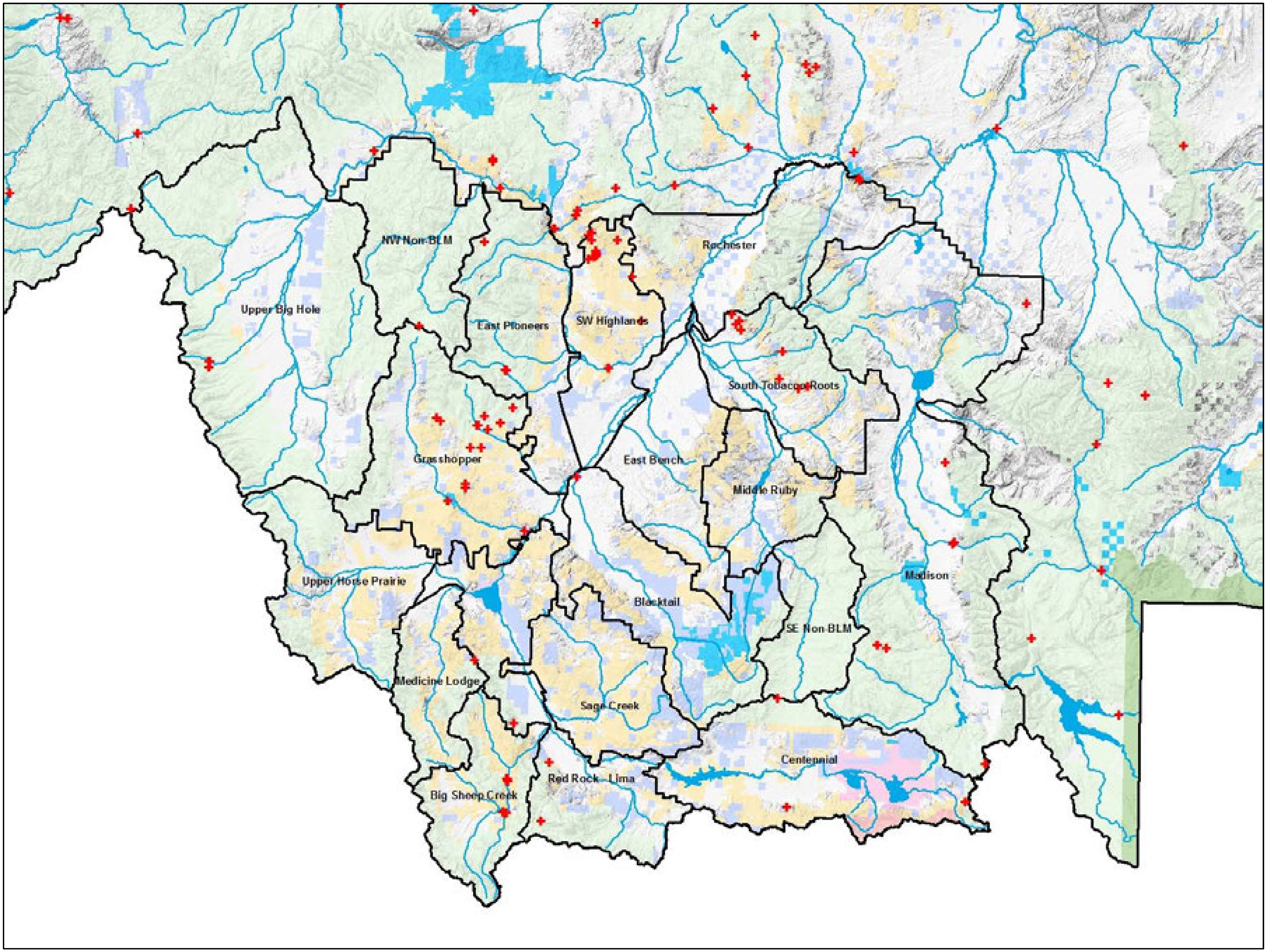


Figure 25. Overview of detections of Spotted Bat. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

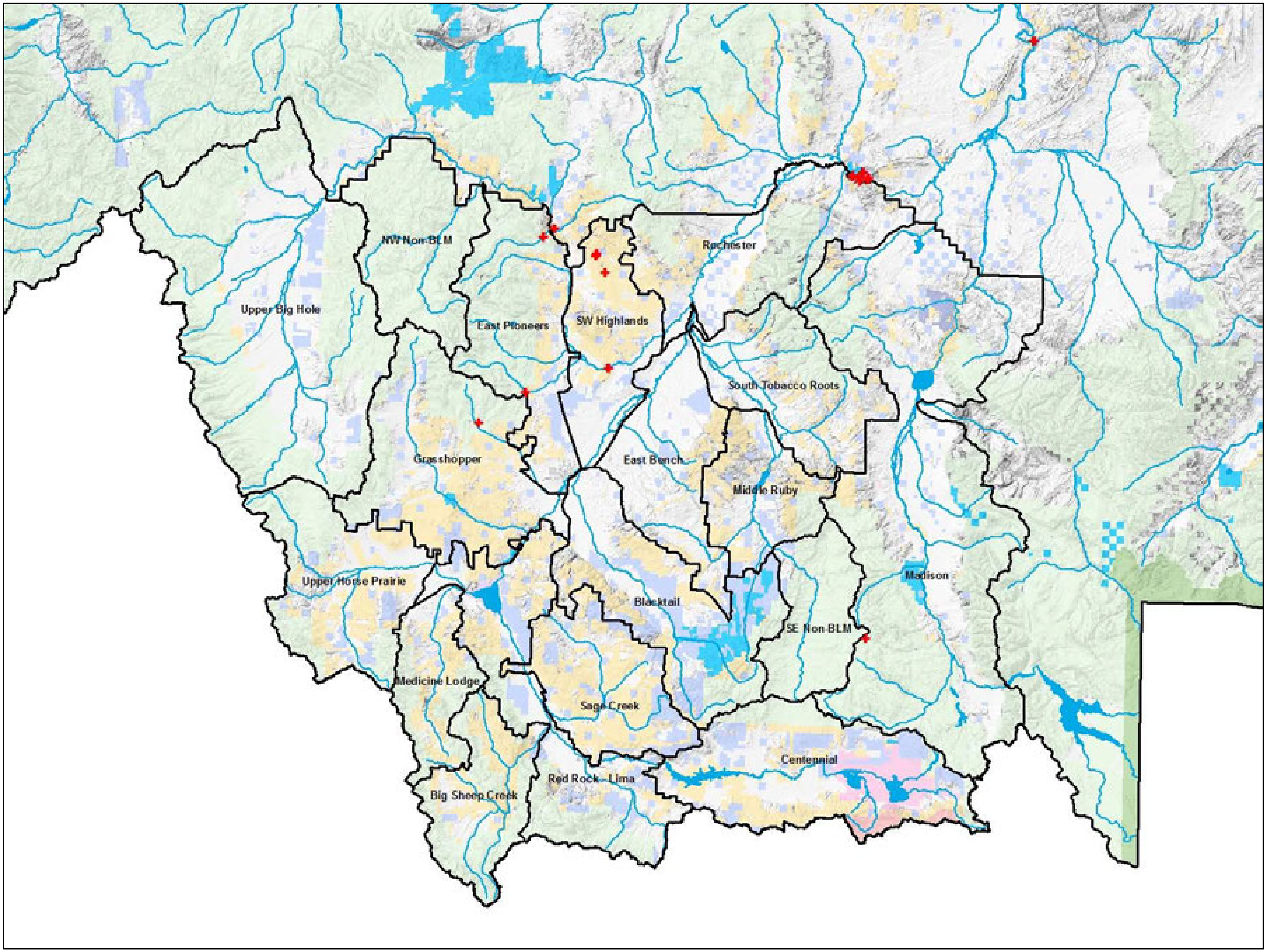


Figure 26. Overview of detections of Silver-haired Bat. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

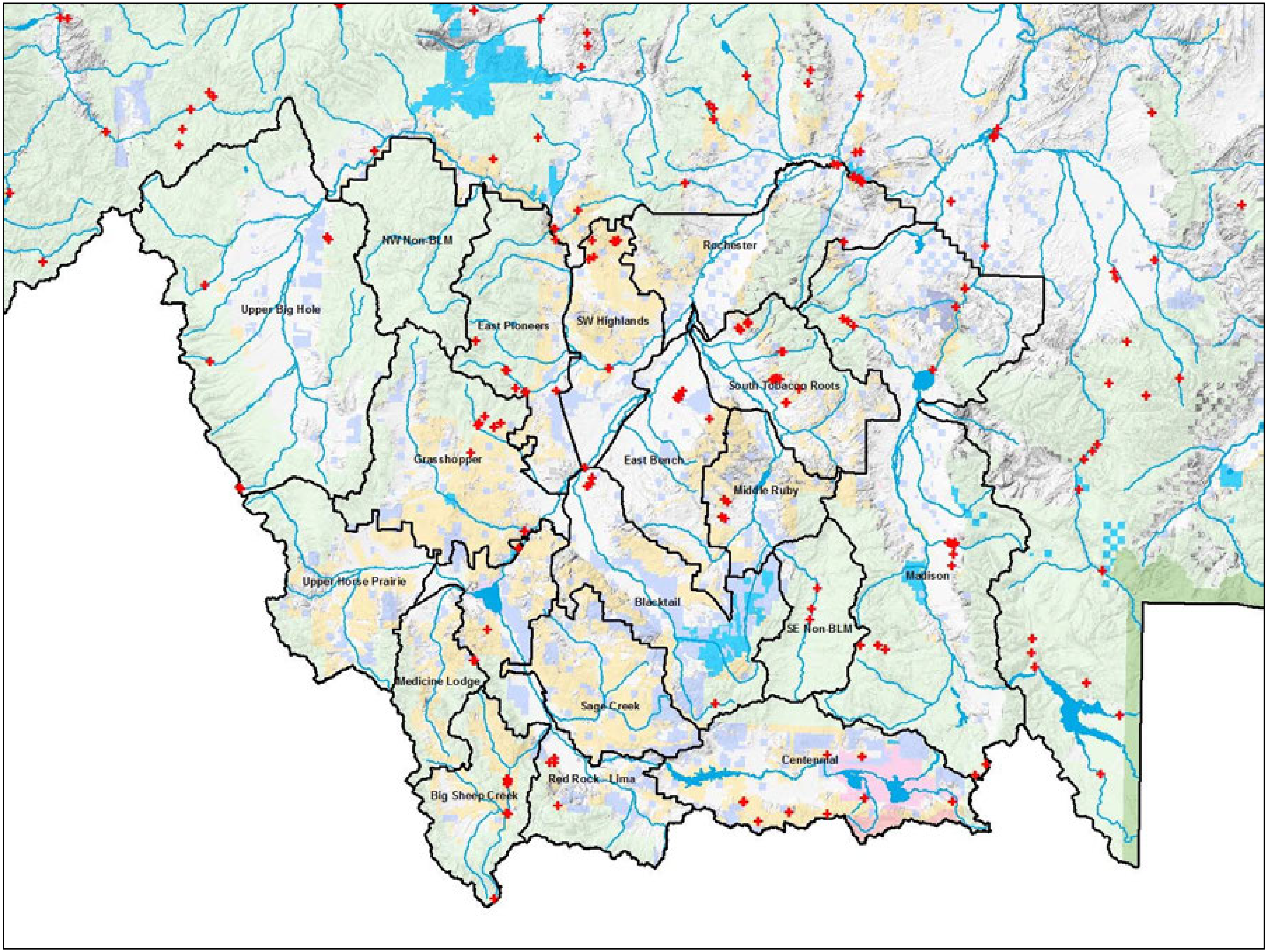


Figure 27. Overview of detections of Hoary Bat. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

Figure 28. Overview of detections of California Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

Figure 29. Overview of detections of Western Small-footed Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for summary of proportion of nightly acoustic surveys the species was detected at.

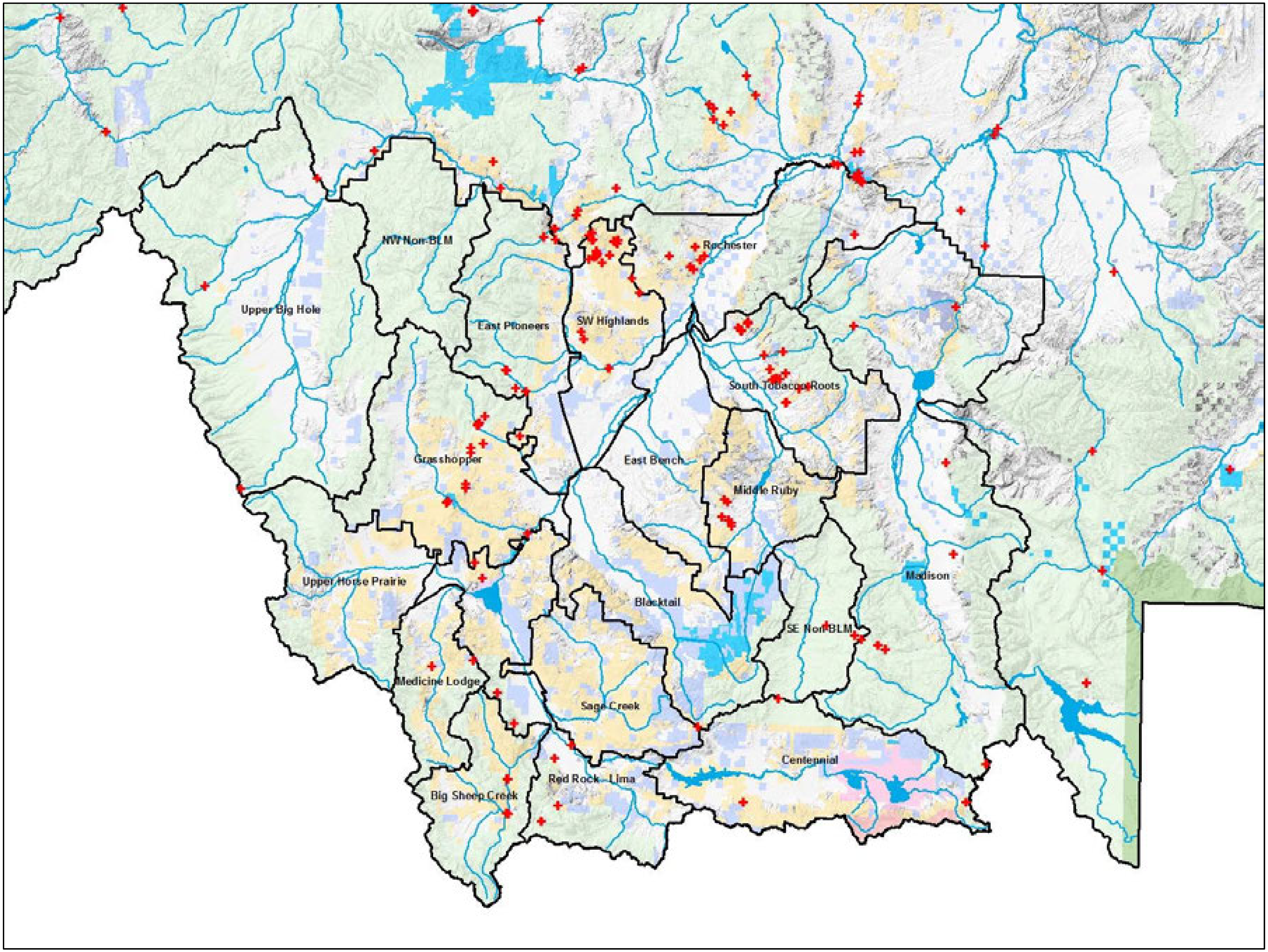


Figure 30. Overview of detections of Long-eared Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

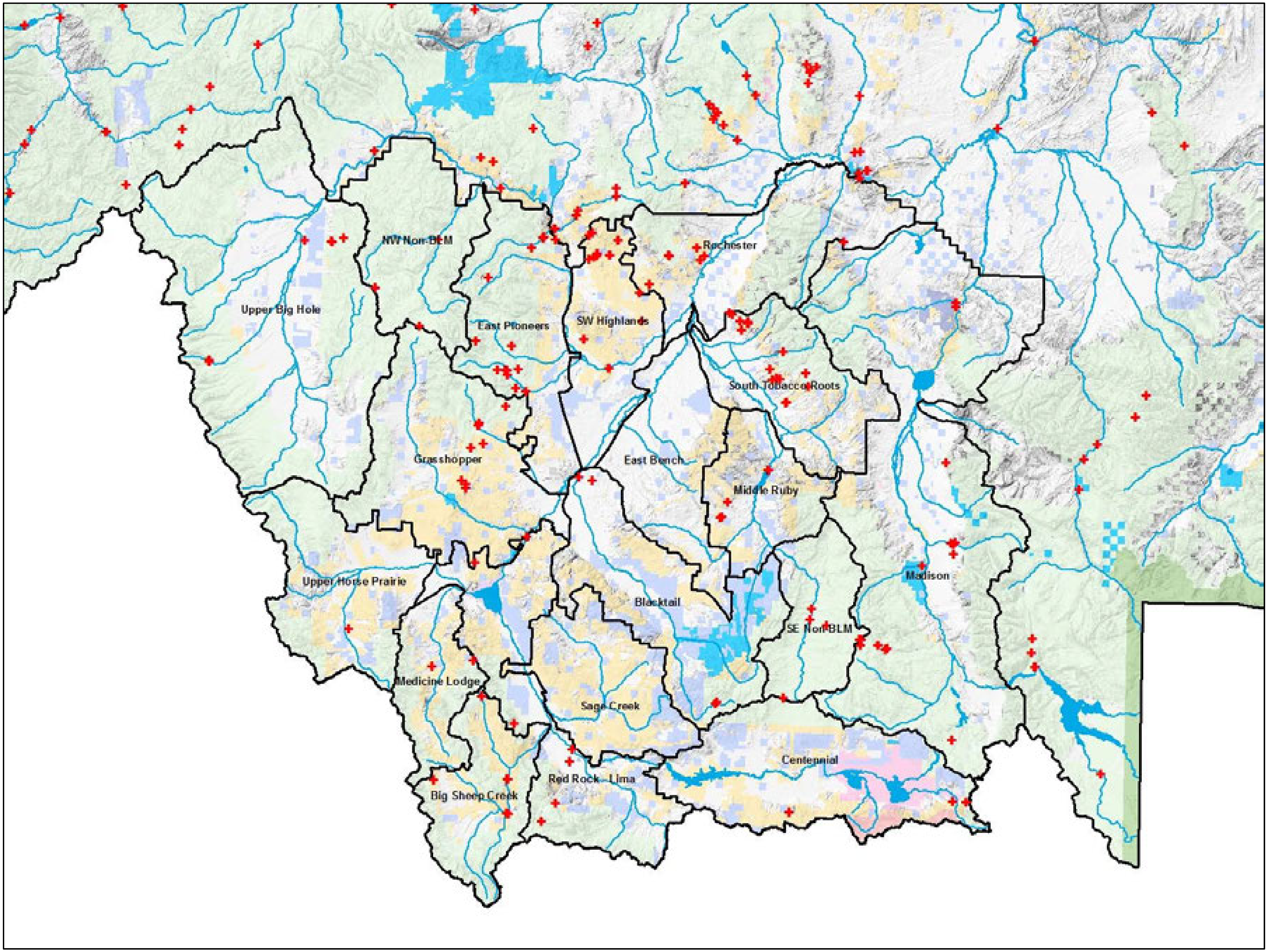


Figure 31. Overview of detections of Little Brown Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

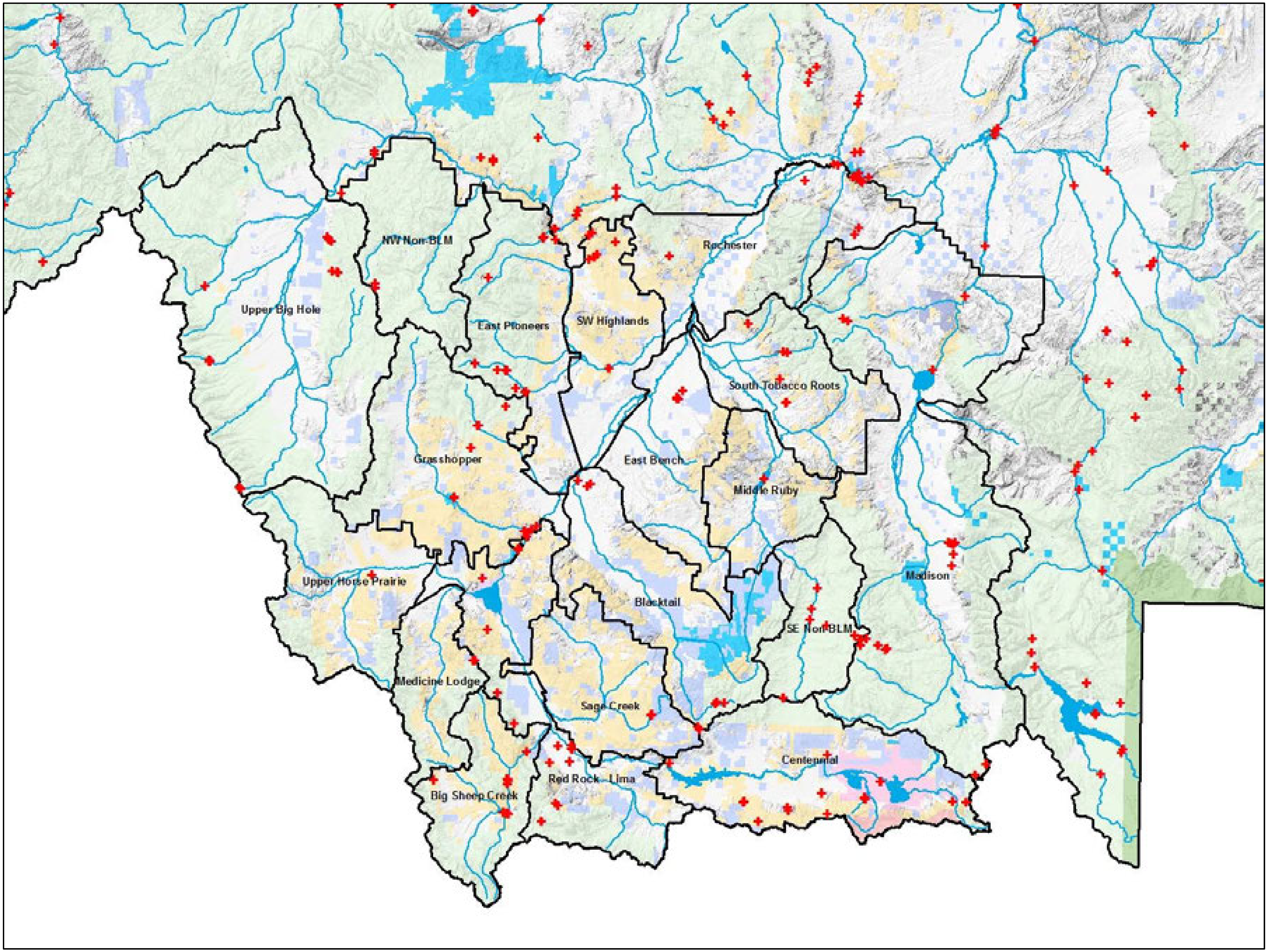


Figure 32. Overview of detections of Fringed Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

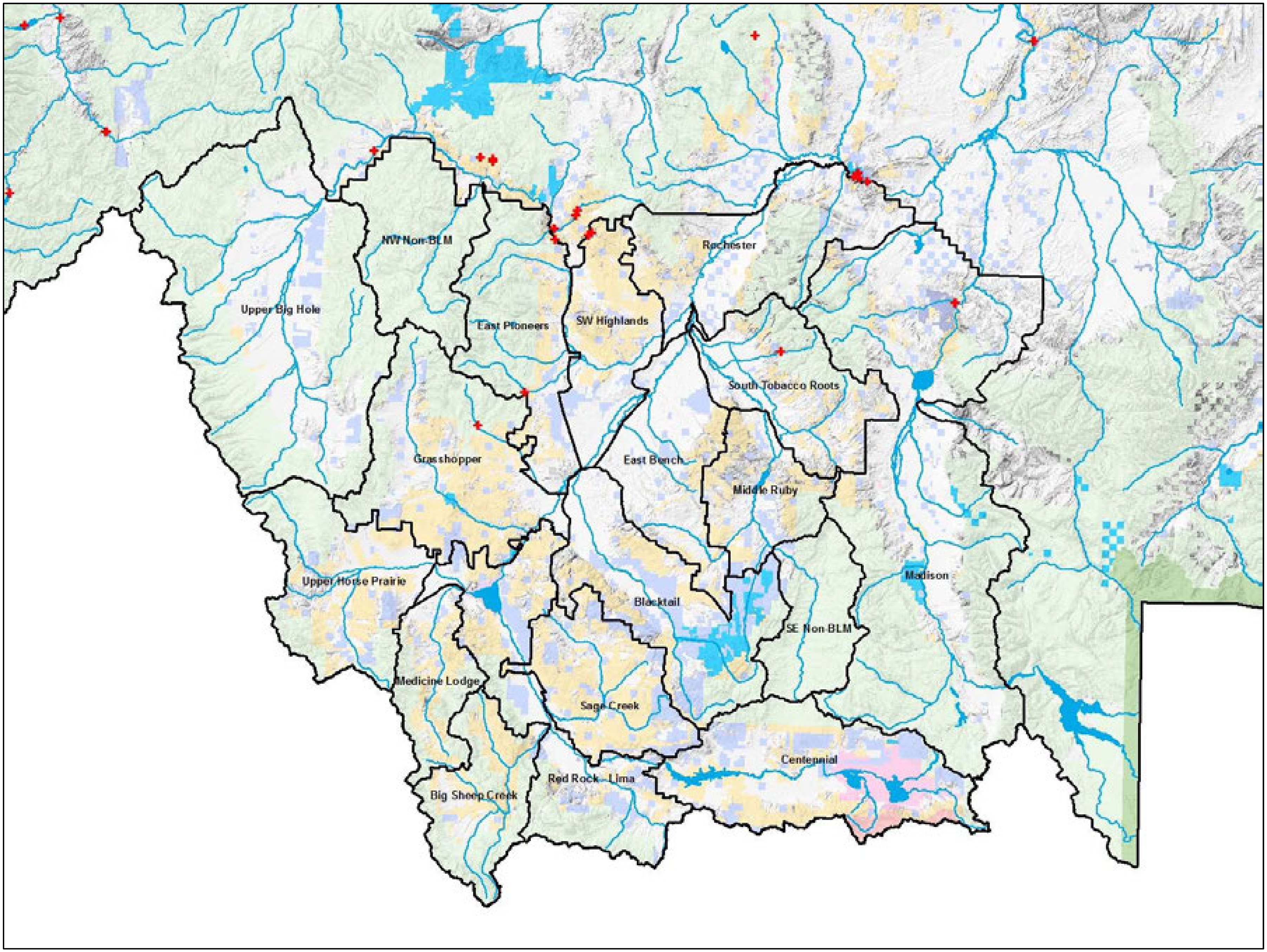


Figure 33. Overview of detections of Long-legged Myotis. See Figure 5 for an overview of bat acoustic, mistnet, active season roost, and hibernacula roost surveys capable of detecting the species. See Table 6 for a summary of the proportion of the nightly acoustic surveys the species was detected at.

Table 1. Summary of amphibian, reptile, and bat survey efforts on the Dillon Field Office of the BLM in 2009, 2010, and 2011.

Watershed Assessment Unit	Year	No. Potential Standing Water Body Sites Surveyed	No. Sites Surveyed with Suitable Standing Water Habitats	No. Passive Listening Stations Surveyed	No. Reptile Surveys	No. Bat Acoustic Surveys
Big Sheep Creek	2010	4	3			1
	2011	19	16	31		1
Blacktail	2010					8
	2011	4	1	44		
Centennial	2011	45	31	113	4	5
East Bench	2009			1		
	2010	7	5	15		7
	2011	1	0	6		
East Pioneers	2010	13	3			1
	2011	1	1			
Grasshopper	2010	19	8			9
	2011			5		
Madison	2009			27	5	1
	2010			23		11
	2011	18	12	53	2	1
Medicine Lodge	2011	5	2	2		
Middle Ruby	2009			3		
	2010	18	6	1		10
	2011			19		
Red Rock - Lima	2010	4	4			9
	2011	6	5	125		
Rochester	2009			47	7	5
	2010	11	2	47		3
	2011			2		
Sage Creek	2011	10	5	15		
South Tobacco Roots	2009			49		
	2010			32		
	2011	4	3	10		
SW Highlands	2009				1	
	2010	9	0	28		2
	2011			5		

Watershed Assessment Unit	Year	No. Potential Standing Water Body Sites Surveyed	No. Sites Surveyed with Suitable Standing Water Habitats	No. Passive Listening Stations Surveyed	No. Reptile Surveys	No. Bat Acoustic Surveys
Upper Big Hole	2009	44	39			
	2010					11
Upper Horse Prairie	2010	41	17			
	2011			58	2	
NW Non-BLM	2010					2
SE Non-BLM				36		
Outside Dillon FO [1]	2009			115	8	15
	2010			173		5
	2011			75		
Total		283	163	1160	34	107

[1] Surveys were mostly in valley bottoms to the immediate north of the Dillon Field Office in order to better understand the distribution of Plains Spadefoot and Northern Leopard Frog.

Table 2. Species detected and proportion of sites surveyed that contained suitable standing water habitats that they were detected at on the BLM Dillon Field Office. The table is sorted first by watershed assessment unit, then year, then taxonomically. Rows with empty cells for common and scientific name and state rank indicate statistics for sites where no species were detected on a given year. See Appendix A for Montana status and state rank definitions.

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
Big Sheep Creek	2010				1	0.333 (0.272)
Big Sheep Creek	2010	Columbia Spotted Frog	*Rana luteiventris*	S4	2	0.667 (0.272)
Big Sheep Creek	2010	Terrestrial Gartersnake	*Thamnophis elegans*	S5	1	0.333 (0.272)
Big Sheep Creek	2011				7	0.438 (0.124)
Big Sheep Creek	2011	Columbia Spotted Frog	*Rana luteiventris*	S4	9	0.563 (0.124)
Blacktail	2011	Western Tiger Salamander	*Ambystoma mavortium*	S4	1	1 (0)
Blacktail	2011	Terrestrial Gartersnake	*Thamnophis elegans*	S5	1	1 (0)
Centennial	2011				8	0.258 (0.079)
Centennial	2011	Western Tiger Salamander	*Ambystoma mavortium*	S4	10	0.323 (0.084)
Centennial	2011	Western Toad	*Anaxyrus boreas*	S2	1	0.032 (0.032)
Centennial	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	6	0.194 (0.071)
Centennial	2011	Columbia Spotted Frog	*Rana luteiventris*	S4	16	0.516 (0.09)
East Bench	2010				2	0.4 (0.219)
East Bench	2010	Columbia Spotted Frog	*Rana luteiventris*	S4	3	0.6 (0.219)
East Pioneers	2010				3	1 (0)
East Pioneers	2011	Plains Spadefoot	*Spea bombifrons*	S3	1	1 (0)
Grasshopper	2010				5	0.625 (0.171)
Grasshopper	2010	Columbia Spotted Frog	*Rana luteiventris*	S4	3	0.375 (0.171)
Madison	2011				2	0.167 (0.108)
Madison	2011	Western Tiger Salamander	*Ambystoma mavortium*	S4	6	0.5 (0.144)
Madison	2011	Western Toad	*Anaxyrus boreas*	S2	1	0.083 (0.08)
Madison	2011	Columbia Spotted Frog	*Rana luteiventris*	S4	9	0.75 (0.125)
Madison	2011	Terrestrial Gartersnake	*Thamnophis elegans*	S5	1	0.083 (0.08)
Medicine Lodge	2011				2	1 (0)
Middle Ruby	2010				5	0.833 (0.152)
Middle Ruby	2010	Columbia Spotted Frog	*Rana luteiventris*	S4	1	0.167 (0.152)
Red Rock - Lima	2010				4	1 (0)
Red Rock - Lima	2011				1	0.2 (0.179)
Red Rock - Lima	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	4	0.8 (0.179)
Red Rock - Lima	2011	Columbia Spotted Frog	*Rana luteiventris*	S4	1	0.2 (0.179)
Red Rock - Lima	2011	Terrestrial Gartersnake	*Thamnophis elegans*	S5	2	0.4 (0.219)
Rochester	2010				2	1 (0)
Sage Creek	2011				5	1 (0)
South Tobacco Roots	2011	Western Tiger Salamander	*Ambystoma mavortium*	S4	3	1 (0)
South Tobacco Roots	2011	Columbia Spotted Frog	*Rana luteiventris*	S4	1	0.333 (0.272)
South Tobacco Roots	2011	Common Gartersnake	*Thamnophis sirtalis*	S4	1	0.333 (0.272)
Upper Big Hole	2009				15	0.385 (0.078)
Upper Big Hole	2009	Long-toed Salamander	*Ambystoma*	S4	10	0.256 (0.07)
Upper Big Hole	2009	Columbia Spotted Frog	*Rana luteiventris*	S4	18	0.462 (0.08)
Upper Big Hole	2009	Common Gartersnake	*Thamnophis sirtalis*	S4	2	0.051 (0.035)
Upper Horse Prairie	2010				11	0.647 (0.116)
Upper Horse Prairie	2010	Columbia Spotted Frog	*Rana luteiventris*	S4	6	0.353 (0.116)

*Painted Turtle was not detected during our surveys of lentic sites, but was detected incidentally.

Table 3. Summary of survey effort and detections at passive listening stations by year and watershed assessment unit on the BLM Dillon Field Office. See Figures 3, 10, and 11 for the spatial distribution of passive listening stations and species detections.

Year and Assessment Unit	No. Non-Detections	No. Boreal Chorus Frog Detections	No. Plains Spadefoot Detections	Total No. Stations Surveyed
2009 Total	**216**		**26**	**242**
East Bench	1			1
Madison	27			27
Middle Ruby	3			3
Rochester	45		2	47
South Tobacco Roots	49			49
Outside Dillon FO[1]	91		24	115
2010 Total	**247**		**72**	**319**
East Bench	14		1	15
Madison	22		1	23
Middle Ruby	1			1
Rochester	44		3	47
South Tobacco Roots	26		6	32
SW Highlands	28			28
Outside Dillon FO[1]	112		61	173
2011 Total	**394**	**193**	**12**	**599**
Big Sheep Creek	30	1		31
Blacktail	41		3	44
Centennial	49	64		113
East Bench	6			6
Grasshopper	4	1		5
Madison	52	1		53
Medicine Lodge	2			2
Middle Ruby	19			19
Red Rock - Lima	31	94		125
Rochester	2			2
Sage Creek	7	8		15
SE Non-BLM	32	4		36
South Tobacco Roots	10			10
SW Highlands	5			5
Upper Horse Prairie	38	20		58
Outside Dillon FO[1]	66		9	75
Grand Total	**857**	**193**	**110**	**1160**

[1] Surveys were mostly in valley bottoms to the immediate north of the Dillon Field Office in order to better understand the distribution of Plains Spadefoot and Northern Leopard Frog.

Table 4. Summary of species detected and proportion of passive listening stations they were detected at on the BLM Dillon Field Office. The table is sorted first by watershed assessment unit, then year. Rows with empty cells for common and scientific name and state rank indicate statistics for assessment units where no species were detected on a given year. See Appendix A for Montana status and state rank definitions.

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
Big Sheep Creek	2011				30	0.968 (0.032)
Big Sheep Creek	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	1	0.032 (0.032)
Blacktail	2011				41	0.932 (0.038)
Blacktail	2011	Plains Spadefoot	*Spea bombifrons*	S3	3	0.068 (0.038)
Centennial	2011				49	0.434 (0.047)
Centennial	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	64	0.566 (0.047)
East Bench	2009				1	1 (0)
East Bench	2010				14	0.933 (0.064)
East Bench	2010	Plains Spadefoot	*Spea bombifrons*	S3	1	0.067 (0.064)
East Bench	2011				6	1 (0)
Grasshopper	2011				4	0.8 (0.179)
Grasshopper	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	1	0.2 (0.179)
Madison	2009				27	1 (0)
Madison	2010				22	1 (0)
Madison	2010	Plains Spadefoot	*Spea bombifrons*	S3	1	1 (0)
Madison	2011				52	0.981 (0.019)
Madison	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	1	0.019 (0.019)
Medicine Lodge	2011				2	1 (0)
Middle Ruby	2009				3	1 (0)
Middle Ruby	2010				1	1 (0)
Middle Ruby	2011				19	1 (0)
Red Rock - Lima	2011				31	0.248 (0.039)
Red Rock - Lima	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	94	0.752 (0.039)
Rochester	2009				45	0.957 (0.029)
Rochester	2009	Plains Spadefoot	*Spea bombifrons*	S3	2	0.043 (0.029)
Rochester	2010				44	0.936 (0.036)
Rochester	2010	Plains Spadefoot	*Spea bombifrons*	S3	3	0.064 (0.036)
Rochester	2011				2	1 (0)
Sage Creek	2011				7	0.467 (0.129)
Sage Creek	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	8	0.533 (0.129)
SE Non-BLM	2011				32	0.889 (0.052)
SE Non-BLM	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	4	0.111 (0.052)
South Tobacco Roots	2009				49	1 (0)
South Tobacco Roots	2010				26	0.813 (0.069)
South Tobacco Roots	2010	Plains Spadefoot	*Spea bombifrons*	S3	6	0.188 (0.069)
South Tobacco Roots	2011				10	1 (0)
SW Highlands	2010				28	1 (0)
SW Highlands	2011				5	1 (0)
Upper Horse Prairie	2011				38	0.655 (0.062)
Upper Horse Prairie	2011	Boreal Chorus Frog	*Pseudacris maculata*	S4	20	0.345 (0.062)
Outside Dillon FO	2009				91	0.791 (0.038)
Outside Dillon FO	2009	Plains Spadefoot	*Spea bombifrons*	S3	24	0.209 (0.038)

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
Outside Dillon FO	2010				112	0.647 (0.036)
Outside Dillon FO	2010	Plains Spadefoot	*Spea bombifrons*	S3	61	0.353 (0.036)
Outside Dillon FO	2011				66	0.88 (0.038)
Outside Dillon FO	2011	Plains Spadefoot	*Spea bombifrons*	S3	9	0.12 (0.038)

Table 5. Detection summaries for reptile surveys in watershed assessment units of the BLM Dillon Field Office. The table is sorted first by assessment unit, then year, then taxonomically. Rows with empty cells for common and scientific name and state rank indicate statistics for sites where no species were detected on a given year. See Appendix A for Montana status and state rank definitions. Given the extremely low success rates of surveys in 2009 as well as other surveys conducted in 2007 Heritage Program and statewide Diversity Monitoring Program crews (Hanauska-Brown et al. 2014), our surveys in 2010 and 2011 focused on simply traveling through potential habitats and making incidental observations instead of protracted focal survey efforts.

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
Centennial	2011				4	1 (0)
Madison	2009				3	0.6 (0.219)
Madison	2009	Terrestrial Gartersnake	*Thamnophis elegans*	S5	1	0.2 (0.179)
Madison	2009	Common Gartersnake	*Thamnophis sirtalis*	S4	1	0.2 (0.179)
Madison	2011				1	0.5 (0.354)
Madison	2011	Terrestrial Gartersnake	*Thamnophis elegans*	S5	1	0.5 (0.354)
Rochester	2009				7	1 (0)
SW Highlands	2009				1	1 (0)
Upper Horse Prairie	2011				2	1 (0)
Outside Dillon FO	2009				6	0.75 (0.153)
Outside Dillon FO	2009	Prairie Rattlesnake	*Crotalus viridis*	S4	2	0.25 (0.153)
Outside Dillon FO	2009	Gophersnake	*Pituophis catenifer*	S5	1	0.125 (0.117)

Table 6. Detection summaries for bat acoustic surveys in watershed assessment units of the BLM Dillon Field Office. The table is sorted first by assessment unit, then year, then by scientific name. See Appendix A for Montana status and state rank definitions.

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
Big Sheep Creek	2010	Big Brown Bat	*Eptesicus fuscus*	S4	1	1 (0)
Big Sheep Creek	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	1	1 (0)
Big Sheep Creek	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	1 (0)
Big Sheep Creek	2010	Long-eared Myotis	*Myotis evotis*	S4	1	1 (0)
Big Sheep Creek	2010	Little Brown Myotis	*Myotis lucifugus*	S3	1	1 (0)
Big Sheep Creek	2011	Long-eared Myotis	*Myotis evotis*	S4	1	1 (0)
Big Sheep Creek	2011	Little Brown Myotis	*Myotis lucifugus*	S3	1	1 (0)
Blacktail	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	4	0.5 (0.177)
Blacktail	2010	Hoary Bat	*Lasiurus cinereus*	S3	2	0.25 (0.153)
Blacktail	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	0.125 (0.117)
Blacktail	2010	Long-eared Myotis	*Myotis evotis*	S4	1	0.125 (0.117)
Blacktail	2010	Little Brown Myotis	*Myotis lucifugus*	S3	4	0.5 (0.177)
Centennial	2011	Silver-haired Bat	*Lasionycteris noctivagans*	S4	3	0.6 (0.219)
Centennial	2011	Hoary Bat	*Lasiurus cinereus*	S3	2	0.4 (0.219)
Centennial	2011	Long-eared Myotis	*Myotis evotis*	S4	1	0.2 (0.179)
Centennial	2011	Little Brown Myotis	*Myotis lucifugus*	S3	4	0.8 (0.179)
East Bench	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	6	0.857 (0.132)
East Bench	2010	Little Brown Myotis	*Myotis lucifugus*	S3	4	0.571 (0.187)
East Pioneers	2010	Hoary Bat	*Lasiurus cinereus*	S3	1	1 (0)
Grasshopper	2010	Big Brown Bat	*Eptesicus fuscus*	S4	1	0.111 (0.105)
Grasshopper	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	3	0.333 (0.157)
Grasshopper	2010	Hoary Bat	*Lasiurus cinereus*	S3	2	0.222 (0.139)
Grasshopper	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	0.111 (0.105)
Grasshopper	2010	Long-eared Myotis	*Myotis evotis*	S4	1	0.111 (0.105)
Grasshopper	2010	Little Brown Myotis	*Myotis lucifugus*	S3	8	0.889 (0.105)
Madison	2009	Silver-haired Bat	*Lasionycteris noctivagans*	S4	1	1 (0)
Madison	2010	Big Brown Bat	*Eptesicus fuscus*	S4	3	0.273 (0.134)
Madison	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	7	0.636 (0.145)
Madison	2010	Hoary Bat	*Lasiurus cinereus*	S3	8	0.727 (0.134)
Madison	2010	California Myotis	*Myotis californicus*	S4	3	0.273 (0.134)
Madison	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	0.091 (0.087)
Madison	2010	Long-eared Myotis	*Myotis evotis*	S4	4	0.364 (0.145)
Madison	2010	Little Brown Myotis	*Myotis lucifugus*	S3	7	0.636 (0.145)
Madison	2011	Silver-haired Bat	*Lasionycteris noctivagans*	S4	1	1 (0)
Madison	2011	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	1 (0)
Madison	2011	Long-eared Myotis	*Myotis evotis*	S4	1	1 (0)
Middle Ruby	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	4	0.4 (0.155)
Middle Ruby	2010	Hoary Bat	*Lasiurus cinereus*	S3	6	0.6 (0.155)
Middle Ruby	2010	California Myotis	*Myotis californicus*	S4	1	0.1 (0.095)
Middle Ruby	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	6	0.6 (0.155)
Middle Ruby	2010	Long-eared Myotis	*Myotis evotis*	S4	3	0.3 (0.145)
Middle Ruby	2010	Little Brown Myotis	*Myotis lucifugus*	S3	1	0.1 (0.095)

Watershed Assessment Unit	Year	Common Name	Scientific Name	State Rank	No. Sites Detected	Proportion (SE) of Sites Detected
NW Non-BLM	2010	Long-eared Myotis	*Myotis evotis*	S4	1	0.5 (0.354)
NW Non-BLM	2010	Little Brown Myotis	*Myotis lucifugus*	S3	1	0.5 (0.354)
Red Rock - Lima	2010	Big Brown Bat	*Eptesicus fuscus*	S4	1	0.111 (0.105)
Red Rock - Lima	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	4	0.444 (0.166)
Red Rock - Lima	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	2	0.222 (0.139)
Red Rock - Lima	2010	Long-eared Myotis	*Myotis evotis*	S4	2	0.222 (0.139)
Red Rock - Lima	2010	Little Brown Myotis	*Myotis lucifugus*	S3	7	0.778 (0.139)
Rochester	2009	Silver-haired Bat	*Lasionycteris noctivagans*	S4	2	0.4 (0.219)
Rochester	2009	Hoary Bat	*Lasiurus cinereus*	S3	1	0.2 (0.179)
Rochester	2009	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	5	1 (0)
Rochester	2009	Long-eared Myotis	*Myotis evotis*	S4	1	0.2 (0.179)
Rochester	2009	Little Brown Myotis	*Myotis lucifugus*	S3	2	0.4 (0.219)
Rochester	2009	Long-legged Myotis	*Myotis volans*	S4	1	0.2 (0.179)
Rochester	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	1	0.333 (0.272)
Rochester	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	0.333 (0.272)
Rochester	2010	Long-eared Myotis	*Myotis evotis*	S4	1	0.333 (0.272)
Rochester	2010	Little Brown Myotis	*Myotis lucifugus*	S3	2	0.667 (0.272)
SW Highlands	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	2	1 (0)
Upper Big Hole	2010	Big Brown Bat	*Eptesicus fuscus*	S4	2	0.182 (0.116)
Upper Big Hole	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	2	0.182 (0.116)
Upper Big Hole	2010	Hoary Bat	*Lasiurus cinereus*	S3	1	0.091 (0.087)
Upper Big Hole	2010	California Myotis	*Myotis californicus*	S4	1	0.091 (0.087)
Upper Big Hole	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	1	0.091 (0.087)
Upper Big Hole	2010	Long-eared Myotis	*Myotis evotis*	S4	6	0.545 (0.15)
Upper Big Hole	2010	Little Brown Myotis	*Myotis lucifugus*	S3	6	0.545 (0.15)
Outside Dillon FO	2009	Big Brown Bat	*Eptesicus fuscus*	S4	2	0.133 (0.088)
Outside Dillon FO	2009	Silver-haired Bat	*Lasionycteris noctivagans*	S4	10	0.667 (0.122)
Outside Dillon FO	2009	Hoary Bat	*Lasiurus cinereus*	S3	8	0.533 (0.129)
Outside Dillon FO	2009	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	9	0.6 (0.126)
Outside Dillon FO	2009	Long-eared Myotis	*Myotis evotis*	S4	5	0.333 (0.122)
Outside Dillon FO	2009	Little Brown Myotis	*Myotis lucifugus*	S3	10	0.667 (0.122)
Outside Dillon FO	2009	Fringed Myotis	*Myotis thysanodes*	S3	2	0.133 (0.088)
Outside Dillon FO	2010	Silver-haired Bat	*Lasionycteris noctivagans*	S4	3	0.6 (0.219)
Outside Dillon FO	2010	Hoary Bat	*Lasiurus cinereus*	S3	3	0.6 (0.219)
Outside Dillon FO	2010	Western Small-footed Myotis	*Myotis ciliolabrum*	S4	4	0.8 (0.179)
Outside Dillon FO	2010	Long-eared Myotis	*Myotis evotis*	S4	1	0.2 (0.179)
Outside Dillon FO	2010	Little Brown Myotis	*Myotis lucifugus*	S3	3	0.6 (0.219)

Table 7. Species detected incidentally (201), and numbers of unique spatial observations (2,149), across all watershed assessment units and years of survey. The table is sorted first by Special Status Species (SSS), Montana Species of Concern (SOC), and Potential Species of Concern (PSOC), then on numbers of observations, and then taxonomically. See Appendix A for Montana status and state rank definitions.

Montana Status	Common Name	Scientific Name	State Rank	Number of Observations
SSS	Bald Eagle	*Haliaeetus leucocephalus*	S4	12
SOC	Clark's Nutcracker	*Nucifraga columbiana*	S3	57
SOC	Brewer's Sparrow	*Spizella breweri*	S3B	46
SOC	Northern Leopard Frog	*Lithobates pipiens*	S1	21
SOC	Great Blue Heron	*Ardea herodias*	S3	15
SOC	Western Toad	*Anaxyrus boreas*	S2	12
SOC	Sage Thrasher	*Oreoscoptes montanus*	S3B	10
SOC	American White Pelican	*Pelecanus erythrorhynchos*	S3B	9
SOC	Golden Eagle	*Aquila chrysaetos*	S3	8
SOC	Greater Sage-Grouse	*Centrocercus urophasianus*	S2	5
SOC	Ferruginous Hawk	*Buteo regalis*	S3B	4
SOC	Loggerhead Shrike	*Lanius ludovicianus*	S3B	3
SOC	Pygmy Rabbit	*Brachylagus idahoensis*	S3	3
SOC	Western Pearlshell	*Margaritifera falcata*	S2	2
SOC	Plains Spadefoot	*Spea bombifrons*	S3	1
SOC	Common Loon	*Gavia immer*	S3B	1
SOC	White-faced Ibis	*Plegadis chihi*	S3B	1
SOC	Black-necked Stilt	*Himantopus mexicanus*	S3B	1
SOC	Long-billed Curlew	*Numenius americanus*	S3B	1
SOC	Wolverine	*Gulo gulo*	S3	1
PSOC	Short-eared Owl	*Asio flammeus*	S4	4
PSOC	Common Poorwill	*Phalaenoptilus nuttallii*	S4B	2
PSOC	Porcupine	*Erethizon dorsatum*	S4	2
PSOC	Broad-tailed Hummingbird	*Selasphorus platycercus*	S4B	1
PSOC	Rufous Hummingbird	*Selasphorus rufus*	S4B	1
PSOC	Blue-eyed Darner	*Rhionaeschna multicolor*	S2S4	1
PSOC	Red-veined Meadowhawk	*Sympetrum madidum*	S2S3	1
	Wilson's Snipe	*Gallinago delicata*	S5	124
	American Robin	*Turdus migratorius*	S5B	58
	Pronghorn	*Antilocapra americana*	S5	55
	Killdeer	*Charadrius vociferus*	S5B	54
	Sandhill Crane	*Antigone canadensis*	S5B,S2N	53
	Red-tailed Hawk	*Buteo jamaicensis*	S5B	44
	Sora	*Porzana carolina*	S5B	44
	Mountain Chickadee	*Poecile gambeli*	S5	42
	Northern Flicker	*Colaptes auratus*	S5	41
	White-tailed Deer	*Odocoileus virginianus*	S5	41
	Terrestrial Gartersnake	*Thamnophis elegans*	S5	35
	Spotted Sandpiper	*Actitis macularius*	S5B	33
	Common Nighthawk	*Chordeiles minor*	S5B	32
	Black-billed Magpie	*Pica hudsonia*	S5	31
	Belted Kingfisher	*Megaceryle alcyon*	S5B	30
	Coyote	*Canis latrans*	S5	30

Montana Status	Common Name	Scientific Name	State Rank	Number of Observations
	Northern Harrier	*Circus hudsonius*	S4B	29
	Great Horned Owl	*Bubo virginianus*	S5	29
	Song Sparrow	*Melospiza melodia*	S5B	29
	Western Meadowlark	*Sturnella neglecta*	S5B	27
	Gray Catbird	*Dumetella carolinensis*	S5B	26
	Cliff Swallow	*Petrochelidon pyrrhonota*	S5B	25
	Red-breasted Nuthatch	*Sitta canadensis*	S5	25
	Pine Siskin	*Spinus pinus*	S5	25
	Dark-eyed Junco	*Junco hyemalis*	S5B	24
	Common Raven	*Corvus corax*	S5	23
	Raccoon	*Procyon lotor*	S5	23
	Rocky Mountainsnail	*Oreohelix strigosa*	S5	23
	Yellow Warbler	*Setophaga petechia*	S5B	22
	Marsh Wren	*Cistothorus palustris*	S5B	21
	Mountain Bluebird	*Sialia currucoides*	S5B	21
	Mallard	*Anas platyrhynchos*	S5	20
	Northern Pocket Gopher	*Thomomys talpoides*	S5	20
	Red-winged Blackbird	*Agelaius phoeniceus*	S5B	18
	Red Squirrel	*Tamiasciurus hudsonicus*	S5	18
	Elk	*Cervus canadensis*	S5	18
	Osprey	*Pandion haliaetus*	S5B	17
	Mourning Dove	*Zenaida macroura*	S5B	17
	Western Wood-Pewee	*Contopus sordidulus*	S5B	17
	Horned Lark	*Eremophila alpestris*	S5	17
	Cedar Waxwing	*Bombycilla cedrorum*	S5B	17
	Chipping Sparrow	*Spizella passerina*	S5B	17
	Moose	*Alces americanus*	S4	17
	Western Tanager	*Piranga ludoviciana*	S5B	15
	White-crowned Sparrow	*Zonotrichia leucophrys*	S5B	15
	Brewer's Blackbird	*Euphagus cyanocephalus*	S5B	15
	Eastern Kingbird	*Tyrannus tyrannus*	S5B	14
	Yellow-rumped Warbler	*Setophaga coronata*	S5B	14
	Common Merganser	*Mergus merganser*	S5B	13
	Rock Wren	*Salpinctes obsoletus*	S5B	13
	Beaver	*Castor canadensis*	S5	13
	Mule Deer	*Odocoileus hemionus*	S5	13
	Common Green Darner	*Anax junius*	S4S5	13
	Turkey Vulture	*Cathartes aura*	S4B	12
	American Goldfinch	*Spinus tristis*	S5B	12
	Canada Goose	*Branta canadensis*	S5B	11
	American Crow	*Corvus brachyrhynchos*	S5B	11
	Black-capped Chickadee	*Poecile atricapillus*	S5	11
	Spotted Towhee	*Pipilo maculatus*	S5B	11
	Vesper Sparrow	*Pooecetes gramineus*	S5B	11
	American Kestrel	*Falco sparverius*	S5	10
	Prairie Falcon	*Falco mexicanus*	S4	9
	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	S5B	9

Montana Status	Common Name	Scientific Name	State Rank	Number of Observations
	Red Fox	*Vulpes vulpes*	S5	9
	Striped Skunk	*Mephitis mephitis*	S5	9
	Northern Flicker (Red-shafted)	*Colaptes auratus cafer*	SNRB	8
	Barn Swallow	*Hirundo rustica*	S5B	8
	House Wren	*Troglodytes aedon*	S5B	8
	Swainson's Thrush	*Catharus ustulatus*	S5B	8
	Gophersnake	*Pituophis catenifer*	S5	8
	Swainson's Hawk	*Buteo swainsoni*	S4B	7
	White-tailed Jack Rabbit	*Lepus townsendii*	S4	7
	Least Chipmunk	*Tamias minimus*	S4	7
	Columbia Spotted Frog	*Rana luteiventris*	S4	6
	Double-crested Cormorant	*Phalacrocorax auritus*	S5B	6
	Rock Pigeon	*Columba livia*	SNA	6
	Red-naped Sapsucker	*Sphyrapicus nuchalis*	S4B	6
	Downy Woodpecker	*Picoides pubescens*	S5	6
	Ruby-crowned Kinglet	*Regulus calendula*	S5B	6
	Townsend's Solitaire	*Myadestes townsendi*	S5	6
	Brown-headed Cowbird	*Molothrus ater*	S5B	6
	Pika	*Ochotona princeps*	S4	6
	Deer Mouse	*Peromyscus maniculatus*	S5	6
	Muskrat	*Ondatra zibethicus*	S5	6
	Black Bear	*Ursus americanus*	S5	6
	Prairie Rattlesnake	*Crotalus viridis*	S4	6
	Forest Disc	*Discus whitneyi*	S5	6
	Brown Hive	*Euconulus fulvus*	S5	6
	Quick Gloss	*Zonitoides arboreus*	S5	6
	Western Glass-snail	*Vitrina pellucida*	S5	6
	Yellow-breasted Chat	*Icteria virens*	S5B	5
	North American Racer	*Coluber constrictor*	S5	5
	Common Gartersnake	*Thamnophis sirtalis*	S4	5
	Spruce Grouse	*Falcipennis canadensis*	S4	4
	Greater Yellowlegs	*Tringa melanoleuca*	SNA	4
	Wilson's Phalarope	*Phalaropus tricolor*	S4B	4
	Tree Swallow	*Tachycineta bicolor*	S5B	4
	Northern Shrike	*Lanius borealis*	S5N	4
	Columbian Ground Squirrel	*Urocitellus columbianus*	S5	4
	Painted Turtle	*Chrysemys picta*	S4	4
	Boreal Chorus Frog	*Pseudacris maculata*	S4	3
	Blue-winged Teal	*Spatula discors*	S5B	3
	Cinnamon Teal	*Spatula cyanoptera*	S5B	3
	American Avocet	*Recurvirostra americana*	S4B	3
	White-throated Swift	*Aeronautes saxatalis*	S5B	3
	Hairy Woodpecker	*Picoides villosus*	S5	3
	Cordilleran Flycatcher	*Empidonax occidentalis*	S4B	3
	Gray Jay	*Perisoreus canadensis*	S5	3
	Steller's Jay	*Cyanocitta stelleri*	S5	3
	American Dipper	*Cinclus mexicanus*	S5	3

Montana Status	Common Name	Scientific Name	State Rank	Number of Observations
	Warbling Vireo	*Vireo gilvus*	S5B	3
	Wilson's Warbler	*Cardellina pusilla*	S5B	3
	Yellow-headed Blackbird	*Xanthocephalus*	S5B	3
	Mountain Cottontail	*Sylvilagus nuttallii*	S4	3
	Virile Crayfish	*Orconectes virilis*	S5	3
	Striped Meadowhawk	*Sympetrum pallipes*	S5	3
	Spruce Snail	*Microphysula ingersolli*	S5	3
	Green-winged Teal	*Anas crecca*	S5B	2
	Merlin	*Falco columbarius*	S4	2
	Sharp-tailed Grouse	*Tympanuchus phasianellus*	S4	2
	Ring-necked Pheasant	*Phasianus colchicus*	SNA	2
	American Coot	*Fulica americana*	S5B	2
	Solitary Sandpiper	*Tringa solitaria*	SNA	2
	American Three-toed Woodpecker	*Picoides dorsalis*	S4	2
	Say's Phoebe	*Sayornis saya*	S5B	2
	Western Kingbird	*Tyrannus verticalis*	S5B	2
	Violet-green Swallow	*Tachycineta thalassina*	S5B	2
	Hermit Thrush	*Catharus guttatus*	S5B	2
	Lark Sparrow	*Chondestes grammacus*	S5B	2
	Richardson's Ground Squirrel	*Urocitellus richardsonii*	S5	2
	Twelve-spotted Skimmer	*Libellula pulchella*	S5	2
	Cherry-faced Meadowhawk	*Sympetrum internum*	S5	2
	Pied-billed Grebe	*Podilymbus podiceps*	S5B	1
	Western Grebe	*Aechmophorus occidentalis*	S4B	1
	Great Egret	*Ardea alba*	SNA	1
	Gadwall	*Mareca strepera*	S5B	1
	Common Goldeneye	*Bucephala clangula*	S5	1
	Sharp-shinned Hawk	*Accipiter striatus*	S4B	1
	Cooper's Hawk	*Accipiter cooperii*	S4B	1
	Gray Partridge	*Perdix perdix*	SNA	1
	Dusky Grouse	*Dendragapus obscurus*	S4	1
	Virginia Rail	*Rallus limicola*	S5B	1
	Willet	*Tringa semipalmata*	S4B	1
	Calliope Hummingbird	*Selasphorus calliope*	S5B	1
	Canyon Wren	*Catherpes mexicanus*	S4	1
	American Pipit	*Anthus rubescens*	S4B	1
	Red-eyed Vireo	*Vireo olivaceus*	S4B	1
	Townsend's Warbler	*Setophaga townsendi*	S5B	1
	Common Yellowthroat	*Geothlypis trichas*	S5B	1
	Savannah Sparrow	*Passerculus sandwichensis*	S5B	1
	Lincoln's Sparrow	*Melospiza lincolnii*	S5B	1
	Pine Grosbeak	*Pinicola enucleator*	S5	1
	Red Crossbill	*Loxia curvirostra*	S5	1
	Red-tailed Chipmunk	*Tamias ruficaudus*	S4	1
	Yellow-bellied Marmot	*Marmota flaviventris*	S4	1
	Northern Flying Squirrel	*Glaucomys sabrinus*	S4	1
	Bushy-tailed Woodrat	*Neotoma cinerea*	S5	1

Montana Status	Common Name	Scientific Name	State Rank	Number of Observations
	Meadow Vole	*Microtus pennsylvanicus*	S5	1
	Montane Vole	*Microtus montanus*	S5	1
	Long-tailed Weasel	*Mustela frenata*	S5	1
	Badger	*Taxidea taxus*	S4	1
	Mountain Goat	*Oreamnos americanus*	S4	1
	Police Car Moth	*Gnophaela vermiculata*	SNR	1
	Pale Snaketail	*Ophiogomphus severus*	S4S5	1
	American Emerald	*Cordulia shurtleffii*	S4S5	1
	Eight-spotted Skimmer	*Libellula forensis*	S5	1
	Variegated Meadowhawk	*Sympetrum corruptum*	S5	1
	Saffron-winged Meadowhawk	*Sympetrum costiferum*	S4S5	1
	White-faced Meadowhawk	*Sympetrum obtrusum*	S5	1
	Northern Spreadwing	*Lestes disjunctus*	S5	1
	Lyre-tipped Spreadwing	*Lestes unguiculatus*	S5	1
	Boreal Bluet	*Enallagma boreale*	S5	1
	Suboval Ambersnail	*Catinella vermeta*	SNR	1
	Meadow Slug	*Deroceras laeve*	S4	1

APPENDIX A.

HERITAGE PROGRAM RANKS:

DEFINITIONS FOR GLOBAL AND STATE CONSERVATION STATUS RANKS AND MONTANA SPECIES OF CONCERN AND POTENTIAL SPECIES OF CONCERN

Heritage Program Ranks

The international network of Natural Heritage Programs employs a standardized ranking system to denote global (range-wide) and state status. Species are assigned numeric ranks ranging from 1 to 5, reflecting the relative degree to which they are "at-risk". Rank definitions are given below. A number of factors are considered in assigning ranks — the number, size and distribution of known "occurrences" or populations, population trends (if known), habitat sensitivity, and threat. Factors in a species' life history that make it especially vulnerable are also considered (e.g., dependence on a specific pollinator).

Global Rank Definitions (NatureServe 2003)

G1 Critically imperiled because of extreme rarity and/or other factors making it highly vulnerable to extinction

G2 Imperiled because of rarity and/or other factors making it vulnerable to extinction

G3 Vulnerable because of rarity or restricted range and/or other factors, even though it maybe abundant at some of its locations

G4 Apparently secure, though it may be quite rare in parts of its range, especially at the periphery

G5 Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery

T1-5 Infraspecific Taxon (trinomial) —The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank

State Rank Definitions

S1 At high risk because of extremely limited and potentially declining numbers, extent and/or habitat, making it highly vulnerable to extirpation in the state

S2 At risk because of very limited and potentially declining numbers, extent and/or habitat, making it vulnerable to extirpation in the state

S3 Potentially at risk because of limited and potentially declining numbers, extent and/or habitat, even though it may be abundant in some areas

S4 Uncommon but not rare (although it may be rare in parts of its range), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern

S5 Common, widespread, and abundant (although it may be rare in parts of its range). Not vulnerable in most of its range

COMBINATION RANKS

G#G# or S#S# Range Rank—A numeric range rank (e.g., G2G3) used to indicate uncertainty about the exact status of a taxon

QUALIFIERS

NR	Not ranked
Q	**Questionable taxonomy that may reduce conservation priority**—Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank
X	**Presumed Extinct**—Species believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered
H	**Possibly Extinct**—Species known from only historical occurrences, but may never-the less still be extant; further searching needed
U	**Unrankable**—Species currently unrankable due to lack of information or due to substantially conflicting information about status or trends
HYB	**Hybrid**—Entity not ranked because it represents an interspecific hybrid and not a species
?	**Inexact Numeric Rank**—Denotes inexact numeric rank
C	**Captive or Cultivated Only**—Species at present is extant only in captivity or cultivation, or as a reintroduced population not yet established
A	**Accidental**—Species is accidental or casual in Montana, in other words, infrequent and outside usual range. Includes species (usually birds or butterflies) recorded once or only a few times at a location. A few of these species may have bred on the one or two occasions they were recorded
Z	**Zero Occurrences**—Species is present but lacking practical conservation concern in Montana because there are no definable occurrences, although the taxon is native and appears regularly in Montana
P	**Potential**—Potential that species occurs in Montana but no extant or historic occurrences are accepted
R	**Reported**—Species reported in Montana but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program has not yet received first-hand information; others are old, obscure reports

SYN	**Synonym**—Species reported as occurring in Montana, but the Montana Natural Heritage Program does not recognize the taxon; therefore the species is not assigned a rank
*	A rank has been assigned and is under review. Contact the Montana Natural Heritage Program for assigned rank
B	**Breeding**—Rank refers to the breeding population of the species in Montana
N	**Nonbreeding**—Rank refers to the non-breeding population of the species in Montana

MONTANA ANIMAL SPECIES OF CONCERN

Montana Animal Species of Concern are native Montana animals that are considered to be "at risk" due to declining population trends, threats to their habitats, and/or restricted distribution. Montana Species of Concern are defined as vertebrate animals with a state rank of S1, S2, or S3. Because documentation for invertebrates is typically less complete than for vertebrates, only those ranked S1 or S2 are included as SOC. Invertebrates with a range rank extending below S2 (e.g., S2S3) are included as SOC only if their global ranks are G2G3 or G3, or if experts agree their occurrence in Montana has been adequately documented.

MONTANA ANIMAL SPECIES OF POTENTIAL CONCERN

Montana Potential Animal Species of Concern are animals for which current, often limited, information suggests potential vulnerability or for which additional data are needed before an accurate status assessment can be made. Vertebrate species with a rank indicating uncertainty (SU), a "range rank" extending below the S3 cutoff (e.g., S3S4), or those ranked S4 for which there is limited baseline information on status are considered Potential Species of Concern. Invertebrates of concern with global ranks other than G1, G2, or G3 and with state ranks below S2 or range ranks extending below S2 (e.g., S3S4) are treated as Potential Species of Concern.

APPENDIX B.

DATA FORM FOR

LENTIC BREEDING AMPHIBIAN AND AQUATIC REPTILE SURVEYS

Data Form for Lentic Breeding Amphibian and Aquatic Reptile Surveys

Locality Information

Date	Observer(s)	Owner	Site Detection: Aerial Photo Topo Map NWI Map Incidental	GPS EPE

Strata Number	HUC Number	Site Number	State	County	Map Name

Locality	T	R	S	Section Description

Map Elevation FT	Latitude (decimal degrees)	Longitude (decimal degrees)	Survey Type 0 1 2 3 4 5 6 7 8

Habitat Information

Begin Time	End Time	Total Person Minutes of Search	Camera and Photo Number(s)/Description(s)

Site Dry: Y N	Site Origin: Beaver Water Depressional Manmade Other______________	Support Reproduction? Y N	GIS Mapping 0 1 2 3 4 5 6 7

Habitat Type:	Lake/ Pond	Wetland/ Marsh	Bog/ Fen	Backwater/ Oxbow	Spring/ Seep	Active Beaver Pond	Inactive Beaver Pond	Site Multipooled	Ditch/ Puddle	Reservoir/ Stockpond	Well/ Tank

Weather: Clear Partly Cloudy Overcast Rain Snow	Wind: Calm Light Strong	Air Temp °C	Water Temp °C	Water pH

Color: Clear Stained	Turbidity: Clear Cloudy	Water Connectedness: Permanent Temporary Isolated	Water Permanence: Permanent Temporary	Max Depth: < 1 M 1-2 M >2 M	Percent of Site > 2 M 0 1-25 26-50 51-75 76-100

Site Length:	Site Width:	Percentage of Site Searched: 1-25 26-50 51-75 76-100	Percent of Site at $\leq$ 50 cm Depth: 0 1-25 26-50 51-75 76-100	~ Emergent Veg Area (M^2)

Percent of Site with Emergent Veg: 0 1-25 26-50 51-75 76-100	Percent of Site with Larval Activity: 0 1-25 26-50 51-75 76-100	Rank Emergent Vegetation Species in Order of Abundance: Sedges___Grasses__Cattails___Rushes___Water Lily___Shrubs___Other_____

Primary Substrate of Shallows: Silt/Mud Sand Gravel Cobble Boulder/Bedrock	North Shoreline Characteristics: Shallows Present: Y N Emergent Veg Present: Y N	Distance (M) to Forest Edge:

Grazing Impact: None Light Heavy Structure Heavy Structure and Water Heavy Water	Water Dammed/Diverted Y N	Timber Harvest in Area Y N	Mining Activity Y N

Other Human Impacts Or Modifications:	Fish Detected? Y N	Time at First Detection:	Fish Species If Identified:

Fish Spawning Habitat Present? Y N U	Inlet Width:	Inlet Depth:	Inlet Substrate	Outlet Width	Outlet Depth	Outlet Substrate

Species Information

Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N
Amphibian Species		Time at first detection	E L M J A	No. Egg Masses		5-20mm larvae	≤10 ≤100 ≤1000 ≤10K >10K
20-50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	>50mm larvae	≤10 ≤100 ≤1000 ≤10K >10K	Number Juveniles		Number Adults	
Tissue Number		Voucher Number		Breeding with Fish?	Y N	If breeding with fish is cover present?	Y N

Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	
Reptile Species		Time at first detection	E J A	Number Individuals		SVL in CM		Tissue Number		Voucher Number	

Site Map For Lentic Breeding Amphibian and Aquatic Reptile Surveys

Grid Scale:

N↑

***** Indicate the following locations on the map: **T** = temperature, **G** = GPS reading, **C** = clinometer reading, and **P→** = photo locations and directions of photos. Indicate area with emergent vegetation with cross-hatching and indicate a 2-meter depth contour with a dashed line.

Other Notes:

Compass Bearing	70°	90°	110°	130°	150°	170°	190°	210°
Inclination (degrees)							B -3	

Definitions of Variables on Lentic Breeding Amphibian Survey Data Sheet

Locality Information

Date: Use MM-DD-YY format (e.g. 5/12/00 for May 12 of 2000).
Observers: List names or initials of individuals involved with survey of this site and circle the name of the recorder.
Owner: Use abbreviation of the government agency responsible for managing the land you surveyed. (e.g. USFS, BLM). If private land was surveyed list the owner's full name to indicate that you did not trespass.
Site Detection: Was site detected on aerial photo, topographic map, NWI map, or was it observed incidentally while in the field.
GPS EPE: The estimated positional error reported by the GPS receiver in meters.
Strata Number: The sample strata in which the 6th level HUC watershed lies (one of nine defined in western Montana).
HUC Number: The sample number of the 6th level HUC in one of the nine sample strata defined for western Montana.
Site Number: The number pre-assigned to the water body within each 6th level HUC. If the water body was not pre-assigned a number because it was not on topographic maps or aerial photos then assign it a sequential number and draw it on the topo map.
State: Use the two-letter abbreviation.
County: Use the full county name.
Map Name: List the name of the USGS 7.5-minute (1:24,000 scale) topographic quadrangle map.
Locality: Describe the specific geographic location of the site so that the type of site is described and the straight-line air distance from one or more permanent features on a 7.5-minute (1:24,000 scale) topographic map records the position of the site (e.g., Beaver pond, 1.5 miles south of Elephant Peak and 1.3 miles east of Engle Peak).
T: Record the Township number and whether it is north or south.
R: Record the Range number and whether it is east or west.
S: Record the Section number.
Section Description: Describe the location of the site at the ¼ of ¼ section level (e.g., SENE indicates SE corner of NE corner).
Map Elevation: The elevation of the site as indicated by the topographic map in feet (avoid using elevations from a GPS)
Latitude (decimal degrees): Decimal degrees of latitude of the stop as recorded on a GPS unit in WGS84.
Longitude (decimal degrees): Decimal degrees of longitude of the stop as recorded on a GPS unit in WGS84.
Survey Type: Circle the appropriate number defined as follows: 0 = private land so site was not surveyed; 1 = site not surveyed due to logistics; 2 = site is a lotic spring/seep not worth future survey; 3 = lentic site that is worth future survey; 4 = misidentified as a potential lentic site on the aerial photograph or on the topographic map (e.g., a shadow from a tree or a talus slope) and not worth future survey; 5 = inactive beaver dam that now only has lotic habitat and is not worth future survey; 6 = only lotic habitat is present and the site is not worth future survey, but it appears possible that the meadow was an historic beaver dam complex; 7 = a lentic site because it would hold water for at least a short time period during wetter conditions, but it is not worth future survey because it would never hold enough water long enough to support amphibian reproduction; 8 = site is not worth future survey for some reason other than those listed above.

Habitat Information

Begin Time: List the time the survey began in 24-hour format.
End Time: List the time the survey ended in 24-hour format.
Total Person Minutes of Search: Record the total person minutes the site was searched (e.g. if one person surveys for 15 minutes and another surveys for 30 minutes, but takes 5 minutes to measure a specimen the total person minutes is 40 minutes).
Camera and Photo Number(s) / Description (s): Identify the camera and the number of the photo as viewed on the camera's view screen and a description of the contents of the photograph (e.g., 13 = 1 x ASMO larvae and 14 = 1 x habitat). Take photos of all portions of the site and anything else that may be of interest (e.g., areas with fish versus areas with amphibians).
Site Dry: Circle whether the site was dry or not at the time of the survey.
Site Origin: Circle whether the site origin is glacial, beaver, water (i.e., flooding or spring), depressional, manmade, or describe other origin.
Support Reproduction: Is site capable of supporting reproduction so it is worth resurveying (e.g. in wetter years if now dry)?
GIS Mapping: Circle the appropriate number defined as follows: 0 = site not surveyed; 1 = a 4 in the survey type and site is not worth future survey; 2 = a 2, 5, 6, or 8 in survey type and site is not worth future survey; 3 = 7 in survey type and site is not worth future survey; 4 = a 3 in the survey type and site is dry, but is worth future survey; 5 = a 3 in the survey type and site has ephemeral water and is worth future survey (including high elevation sites that freeze solid); 6 = a 3 in the survey type, site is worth future survey, has emergent vegetation, and has permanent water that lasts all summer long and does not freeze solid in the winter so that it is likely to support aquatic overwintering; 7 = a 3 in the survey type, site is worth future survey, does not have functional amounts of emergent vegetation, and has permanent water that lasts all summer long and does not freeze solid in the winter so that it is likely to support aquatic overwintering.
Habitat Type: Circle the appropriate habitat type of the site being surveyed. If site is multi-pooled water information does not need to be gathered for every pool, but you may wish to record this information on the map. If breeding activity is limited to one pool at a multi-pooled site water information should be recorded for this pool and this should be noted in the comments.
Weather: Circle weather condition during survey.
Wind: Circle wind condition during survey (> 20 mph winds should be classified as strong).
Air Temp: Record air temperature at chest height in the shade. Record temperature in Celsius. °C = (°F – 32)/1.8
Water Temp: Record water temperature where larvae or egg masses are observed or at 2 cm depth 1 meter from the margin of the water body. Record temperature in Celsius. °C = (°F – 32)/1.8
Water pH: Record water pH at the same location water temperature was recorded.
Color: Circle whether the water is clear or stained a tea or rust color from organic acids.
Turbidity: Circle whether water is clear or cloudy.
Water Connectedness: Circle if water body has permanent connection to flowing water (Permanent), is connected to flowing water for a temporary period each year (Temporary), or is never connected to flowing waters or other water bodies (Isolated).

Water Permanence: Circle whether the site contains water throughout the entire year (Permanent), or contains water for only a portion of the year (Temporary).
Max Depth: Circle the category corresponding to the maximum depth of the water body.
Percent of Site > 2 M: Circle the percentage of the site with water depth greater than 2 meters deep.
Site Length: The length of the longest dimension of the standing water body.
Site Width: The width of the second longest dimension of the standing water body.
Percentage of Site Searched: Circle the percentage of the site surveyed.
Percentage of the Site at ≤ 50 cm Depth: Circle the appropriate percentage.
Approximate Area with Emergent Veg (M^2): The approximate area of the site that contains emergent vegetation.
Percentage of Site with Emergent Veg: Circle the percentage of the entire site with emergent vegetation.
Percentage of Site with Larval Activity: Circle the percentage of the site where amphibian larvae were observed.
Rank Emergent Veg Species in Order of Abundance: Record the rank order of abundance in front of the 3 most prevalent emergent vegetation species. If the vegetation present is "other" indicate what it is.
Primary Substrate: Circle the substrate that covers the majority of the bottom of the site.
North Shoreline Characteristics: Circle whether shallows and emergent vegetation are present or absent on the north shoreline.
Distance (M) to Forest Edge: Record the closest distance between the water's edge and the forest margin in meters.
Grazing Impact: Circle the appropriate grazing category defined as follows: no grazing in vicinity of the site; grazing noted in the vicinity of the site, but no major impacts to wetland structure or water quality; heavy structural impacts to site (e.g.,vegetation destroyed creating bare ground, hummocks, pugging, or altered hydroregime); heavy structural impacts and water quality impacted due to animal waste; and water quality impacted due to animal waste.
Water Dammed/Diverted: Circle whether or not water has been dammed or diverted at the site (including blow outs or pits).
Timber Harvest: Circle whether or not timber has been harvested within 200 meters of the site.
Mining Activity: Circle whether or not there is evidence of mining activity within 200 meters of the site.
Other Human Impacts or Modifications: Briefly describe if, how, and when the site has been altered by human activities. If the site has not been altered record none for not altered. If multiple anthropogenic impacts exist document all of these using the back of the data sheet if necessary and qualify approximate timing of impact (e.g., recent versus historic).
Fish Detected?: Circle whether or not fish were detected.
Time at First Detection: If fish were detected, indicate the time in total person minutes of survey when they were first detected.
Fish Species if Identified: List the fish species identified.
Fish Spawning Habitat Present?: Are shallow waters with adequate gravels/cobbles present that would allow salmonid fishes to spawn? An active search for fry is also a good idea.
Inlet Width: What is the average width of the inlet stream in meters?
Inlet Depth: What is the average depth of the inlet stream in centimeters?
Inlet Substrate: What is the primary substrate at the inlet stream (Silt/Mud, Sand, Gravel, Cobble, or Boulder/Bedrock)?
Outlet Width: What is the average width of the outlet stream in meters?
Outlet Depth: What is the average depth of the outlet stream in centimeters?
Outlet Substrate: What is the primary substrate at the outlet stream (Silt/Mud, Sand, Gravel, Cobble, or Boulder/Bedrock)?

Species Information

For each species record the first two letters of the scientific genus and species names for all amphibian and reptile species found at the site (e.g., BUBO for *Bufo boreas*). Record the total number of person minutes of survey required before each life history stage of each species was encountered beside the E (egg), L (larvae), M (metamorph), J (juvenile), or A (adult). Record the number or category of number of each of the specified life history and/or size classes. For amphibians indicate whether they have bred in the same water body where fish are present, and if they have, indicate whether there is protective cover (e.g., extensive shallows with emergent vegetation, a log barrier, talus). Record the tissue number or range of tissue numbers for tissue samples collected (see tissue collection protocols). If the animal was swabbed in preparation for testing the animal for chytrid infection indicate the chytrid sample number in the Tissue Number field. Record the preliminary museum voucher specimen number for voucher specimens collected (see voucher specimen collection protocols).

Site Map for Lentic Breeding Amphibian and Aquatic Reptile Surveys

General: Include a rough sketch of the site including the shape of the site and the shape and spatial relations of surrounding biotic and abiotic features. Indicate the area covered with emergent vegetation with cross-hatching. Indicate a 2-meter depth contour for the water body with a dashed line. Indicate the location where the water temperature was taken, the location where the GPS position was taken, the location where clinometer readings for southern exposure were taken, and the location of any photographs with an arrow indicating the direction in which the photo(s) were taken. Make sure that the orientation of the sketch (i.e. the north arrow) corresponds to the orientation of the site.
Grid Scale: Indicate the approximate scale of the grid lines relative to the site sketched in meters.
Other Notes: Include any other notes of interest in this space. Examples: (1) areas of highest larval density; (2) thoughts on why a species may not have been detected at a site; (3) problems associated with the survey of the site (e.g., dangerous boggy conditions); (4) If a site was dry would it support reproduction during wetter years.
Southern Exposure: From a site on along the northern shoreline that would most likely to be used as an oviposition or larval rearing area (e.g., shallow waters with emergent vegetation in the NW corner of the water body) record the degree inclination from your position to the skyline (e.g., mountain or solid tree line) at each of the eight compass bearings listed. Note that the compass bearings are true north so you will need to adjust your compass according to the map being used to correct for the deviation from magnetic north (15 to 19.5 degrees in western Montana).

APPENDIX C.

DATA FORM FOR

PASSIVE NOCTURAL AMPHIBIAN CALLING SURVEYS

Data Form for Passive Nocturnal Amphibian Calling Surveys

Observer(s) ________________________________ **Start Lat/Long (DD)** ____________________________ **End Lat/Long (DD)** ________________________________

Summary Comments on Survey Route (record temperatures every half hour or 5 stops) ____

____

____

Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	
Date	**Time**	**Weather**	**Latitude (DD)**	**Detection**	**Species Number, Bearing, & Distance to Chorus** (e.g., 5 x ANWO at 230 degrees and 100 m)
			Longitude (DD)	Y / N	

Definitions of Variables on Passive Nocturnal Amphibian Calling Survey Data Sheet

General Instructions

Conduct passive nocturnal amphibian calling surveys for spring-breeding amphibians on nights after rainfall events in the spring between mid-May and mid-June when air temperatures are above 50 °F or 10 °C and wind and precipitation conditions are suitable for aurally detecting choruses of male amphibians at potential breeding sites. Select routes to ensure the safety of the surveyors and the ability of surveyors to detect calling amphibians (i.e., avoid routes with high traffic or loud rushing water). At each stop, surveyors should passively listen for choruses of male amphibians for a minimum of 5 minutes before proceeding to the next stop. When choruses are detected, estimate the bearing (use a compass) and distance of the chorus from the stop location. *Surveys targeting Northern Leopard Frogs (*Lithobates pipiens*) and Columbia Spotted Frogs (*Rana luteiventris*) may be of interest in mid-March. If these species are being targeted for detection, stop locations need to correspond to the margins of potential breeding sites since calls for these species are only audible over short distances even under the best of weather conditions. Carlos Davidson's "Frog and Toad Calls of the Rocky Mountains: Vanishing Voices" is an excellent resource for learning the breeding calls of Montana's amphibian species. Calls can also be found on the Montana Field Guide at fieldguide.mt.gov

Route Information

Observer(s): List full names of individuals involved with full night of passive calling survey for amphibians.
Start Lat/Long (DD): Decimal degrees of latitude and longitude that the amphibian calling survey route began at.
End Lat/Long (DD): Decimal degrees of latitude and longitude that the amphibian calling survey route ended at.
Summary Comments on Survey Route: General narrative of the route from beginning to end including highways/roads traveled and general cover types passed through and overview of land ownership on the route.

Stop Information

Date: Use MM-DD-YY format (e.g. 5/12/00 for May 12 of 2000).
Time: List the time the survey began in 24-hour format.
Weather: Include brief info on weather conditions (e.g., wind speed, precipitation, etc.). At least every five stops or one half our record the air temperature in Celsius. °C = (°F – 32)/1.8
Latitude (DD): Decimal degrees of latitude of the stop as recorded on a GPS unit in WGS84.
Longitude (DD): Decimal degrees of longitude of the stop as recorded on a GPS unit in WGS84.
Species Number, Bearing, and Distance: Record the first two letters of the scientific genus and species names for all amphibian and reptile species detected (e.g., ANWO for *Bufo woodhousii* or SPBO for *Spea bombifrons*). Determine the bearing to the breeding chorus using a compass that has a bearing sighting ring. Estimate the distance to the breeding chorus as best you can. Accurate estimates of distance can often be difficult for even experienced surveyors. It is recommended that inexperienced observers spend at least a portion of a survey night walking to a breeding chorus for each species they are newly detecting in order to get a good sense for how far breeding calls can be heard. If multiple breeding choruses of either the same or different species are detected at a stop, record the bearing and distance to each chorus. For example: 5 x ANWO @ 230 degrees and 100 meters, 10 x SPBO @ 180 degrees and 1,000 meters, 5 x PSMA @ 5 degrees and 10 meters.

Species Codes for Montana Amphibian Species with Detectable Breeding Calls

Western Toad	ANBO
Great Plains Toad	ANCO
Woodhouse's Toad	ANWO
Plains Spadefoot	SPBO
Boreal Chorus Frog	PSMA

Pacific Treefrog	PSRE
American Bullfrog (exotic)	LICA
Northern Leopard Frog*	LIPI
Columbia Spotted Frog*	RALU

*Species with breeding calls that are only audible over short distances.

APPENDIX D.

DATA FORM FOR

ROCK OUTCROP AND FRIABLE SOIL SURVEYS FOR REPTILES

Data Form for Rock Outcrop Surveys for Reptiles

Locality Information

DM Region SE MONTANA	QQUAD	Site No:	Locality:		
State:	County:	Map Name:	T	R	S	Section Description:
Owner:	Map Elevation: FT	Datum	Latitude (decimal degrees)	Longitude (decimal degrees)	

Habitat Information

Date:	Observer(s):	Begin Time:	End Time:	Total Person Minutes of Search:	Area (M^2) Searched:

Percentage of Site Searched: 1-25 26-50 51-75 76-100 | Percent Slope: | Aspect: N NE NW S SE SW E W Flat

Habitat Cover Type As Percent of Site Surveyed:

Cliff/Outcrop	Bluff/Coulee Rim	Talus	Open Conifer Forest	Open Mixed Forest	Shrub/Steppe	Grassland	Other_____________
__________%	____________%	____%	______________%	_____________%	________%	_____%	__________%

Site Overview Photo Taken ☐ | Air Temp: °C | Soil Temp: °C

Photo Description(s)

Weather: Clear Partly Cloudy Overcast Rain Snow | Wind: Calm Light Strong | Potential Hibernaculum Y N

Soil Moisture: Dry Damp Wet Standing Water Snow

Dominant Substrate Type: Bedrock Compressed Soil Sand Detritus Gravel (<4 cm diameter) Cobble (4-30cm diameter) Boulder (>30 cm diameter)

Habitat Description/Threats:

Reptile Species Information

Species:	Number and Time at First Detection (e.g., 2 x juveniles, 25 cm TL @ 10 minutes)	Cover Type at Animal's Location:
Tissue Number (e.g., MTHP5533) Voucher Number & Description:	Substrate Association of Animal (Circle): under wood on/under 4-20cm rock fragments on/under >20cm rock fragments in vegetation on leaf litter in rock fracture Other _______________	
Species:	Number and Time at First Detection (e.g., 2 x juveniles, 25 cm TL @ 10 minutes)	Cover Type at Animal's Location:
Tissue Number (e.g., MTHP5533) Voucher Number & Description:	Substrate Association of Animal (Circle): under wood on/under 4-20cm rock fragments on/under >20cm rock fragments in vegetation on leaf litter in rock fracture Other _______________	
Species:	Number and Time at First Detection (e.g., 2 x juveniles, 25 cm TL @ 10 minutes)	Cover Type at Animal's Location:
Tissue Number (e.g., MTHP5533) Voucher Number & Description:	Substrate Association of Animal (Circle): under wood on/under 4-20cm rock fragments on/under >20cm rock fragments in vegetation on leaf litter in rock fracture Other _______________	
Species:	Number and Time at First Detection (e.g., 2 x juveniles, 25 cm TL @ 10 minutes)	Cover Type at Animal's Location:
Tissue Number (e.g., MTHP5533) Voucher Number & Description:	Substrate Association of Animal (Circle): under wood on/under 4-20cm rock fragments on/under >20cm rock fragments in vegetation on leaf litter in rock fracture Other _______________	

Site Map for Reptile Site Surveys

Grid Scale:

N↑

***** Draw a rough sketch of the site labeling major features such as cliffs, talus slopes, and all habitat cover types. Be sure to indicate where animals were detected and label the following locations on the map: **G** = GPS reading, - - - - - - = area surveyed, and **P→** = photo locations and directions of photos.

Other Notes:

Detection Summary (list surveyors in left column and species detections in others (e.g., 1 @ 5 min)

Surveyor						

Definitions of Variables on Reptile Site Survey Form

Site Information

Strata Number: The sample strata in which the 6^{th} level HUC watershed lies.
HUC Number: The sample number of the 6^{th} level HUC.
Site No: Identify three digit number of the site being surveyed within each sampling block (range 001-999).
Locality: Describe the specific geographic location of the site so that the type of site is described and the straight-line air distance from one or more permanent features on a 7.5-minute (1:24,000 scale) topographic map records the position of the site (e.g., Large talus slope 1.5 miles north of Engle Peak, N side of FS Road 225).
State: Use the two-letter abbreviation.
County: Use the full county name.
Map Name: List the name of the USGS 7.5-minute (1:24,000 scale) topographic quadrangle map.
T: Record the Township number and whether it is north or south.
R: Record the Range number and whether it is east or west.
S: Record the Section number
Section Description: Describe location of the site at the ¼ of ¼ section level (e.g., SENE indicates SE corner of NE corner).
Owner: Use abbreviation of the government agency responsible for managing the land you surveyed. (e.g. USFS, BLM). If private land was surveyed list the owner's full name to indicate that you did not trespass.
Map Elevation: The elevation of the site as indicated by the topographic map in feet (avoid using elevations from a GPS)
Datum: The map datum used, typically WGS84 if off GPS unit on standard setting.
Latitude (decimal degrees): Decimal degrees of latitude of the stop as recorded on a GPS unit in WGS84.
Longitude (decimal degrees): Decimal degrees of longitude of the stop as recorded on a GPS unit in WGS84.

Survey Information

Date: Use MM-DD-YY format (e.g. 05/12/00 for May 12 of 2000).
Observers: List names or initials of individuals involved with survey of this site and circle the name of the recorder.
Begin Time: List the time the survey began in 24-hour format.
End Time: List the time the survey ended in 24-hour format.
Total Person Minutes of Search: Record the total person minutes the site was searched (e.g. if one person surveys for 15 minutes and another surveys for 30 minutes, but takes 5 minutes to measure a specimen the total person minutes is 40 minutes).
Area (M^2) Searched: Area in square meters that was surveyed.
Percent of Site Searched: Circle the appropriate category.
Percent Slope: Percent slope of site. Enter range if variable.
Aspect: Circle primary aspect of the site.
Habitat Cover Type as Percent of Site Surveyed: Identify percent composition of each habitat type within site surveyed.
Photo Frame Number(s) / Descriptions: The number of the photo as viewed on the camera's view screen and a description of the contents of the photograph (e.g., #13 = 1 x Milksnake and #14-18 = 5 x habitat). Take photos of all portions of the site and anything else that may be of interest (e.g., reptile species, potential site threats).
Air Temp: Record air temperature in °C at chest height in the shade. °C = (°F – 32)/1.8
Soil Temp: Record soil temperature in °C at 10 cm depth. °C = (°F – 32)/1.8
Weather: Circle weather condition during survey.
Wind: Circle wind condition during survey (> 20 mph winds should be classified as strong).
Potential Hibernacula: Does the site contain suitable underground refugia (e.g., talus, caves) to support overwintering.
Soil Moisture: Circle the appropriate category.
Dominant Substrate Type: Circle the appropriate category.
Habitat Description/Threats: Note the most prominent characteristics of the site with relation to reptiles (e.g., could the site support overwintering). Also note habitat threats from grazing, logging, mining, flooding, road building, weeds, fire, etc.

Species Information

For each species record the first two letters of the scientific genus and species names for all amphibian and reptile species found at the site (e.g., COCO for *Coluber constrictor*). Record the total number of person minutes of survey required before each life history stage of each species was encountered and the size or size range of the animals encountered. Record the tissue number or range of tissue numbers for tissue samples collected (see tissue collection protocols. Record the preliminary museum voucher specimen number for voucher specimens collected (see voucher specimen collection protocols). Circle the substrate the animal was associated with at time of detection. Record the presence of other species detected at the site (e.g., millipedes), the time at first detection, and the voucher number and description of animals collected (see voucher and tissue collection protocols).

APPENDIX E.

DATA FORM FOR

BAT ACOUSTIC SURVEYS

Bat Acoustic Survey Form

QQuad Name/ ______________________________ **Observer(s)** ______________________________

QQUAD Bat Acoustic Survey Comments ______________________________

Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				
Survey #	**Date**	**Location**	**Latitude (DD)**		**Photo Y / N**
			Longitude (DD)		**Weather**
Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]					
Recorder ID	**Time/Temp Deployed/Collected and other comments:**				

Bat Acoustic Survey Form Page 2

QQUAD ______________________________

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

Survey #	Date	Location	Latitude (DD)	Photo Y / N
			Longitude (DD)	Weather

Habitat [Barren Crop/Ag DecidWoodland ConifWoodland Herbaceous HerbWetland IntroHerbVeg MixedUplandWetland RecentBurnForest Shrubland SteppeSavannah WoodyWetland]

Recorder ID	Time/Temp Deployed/Collected and other comments:

APPENDIX F.

PREDICTED SUITABLE HABITAT MODELS FOR AMPHIBIANS, REPTILES, BATS, AND BEAVER

Environmental Layer Information

Layer	Identifier	Original Scale	Description
Land Cover	catesys	30m	Categorical. Landcover classes (25) from the 2016 Montana Spatial Data Infrastructure Land Cover Framework; Level 2 classes used with a few minor changes including removal of linear and point features: Alpine Grassland and Shrubland, Alpine Sparse and Barren, Conifer-dominated Forest and Woodland (mesic-wet), Conifer-dominated Forest and Woodland (xeric-mesic), Deciduous dominated forest and woodland, Mixed deciduous/coniferous forest and woodland, Lowland/Prairie Grassland, Montane Grassland, Agriculture, Introduced Vegetation/Pasture/Hay, Developed, Mining and Resource Extraction, Wetland or Marsh, Floodplain and Riparian, Open Water, Wet meadow, Harvested Forest, Insect-Killed Forest, Introduced Vegetation, Recently burned, Deciduous Shrubland, Sagebrush Steppe or Desert Scrub, Sagebrush or Saltbush Shrubland, Bluff/Badland/Dune, Cliff/Canyon/Talus http://geoinfo.msl.mt.gov/msdi/land_use_land_cover
Geology	catgeol	vector	Categorical. Basic rock classes (5) as defined by USGS (plus water for large water bodies): Sedimentary, Unconsolidated, Metamorphic, Plutonic, and Volcanic. https://mrdata.usgs.gov/geology/state/state.php?state=MT
Soil Order	catsoilord	Vector	Categorical. Major soil orders (7) as defined by USDA based on STATSGO2 general statewide soil maps, along with non-soil (Rock, Water) classifications: Entisols, Inceptisols, Aridisols, Mollisols, Alfisols, Andisols, and Vertisols. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Soil Regime	catsoiltemp	vector	Categorical. Soil Moisture and Temperature regimes (11) classification pairs as defined by USDA (plus water): Cryic/Udic, Cryic/Udic Ustic, Cryic/Typic Ustic, Cryic/Aridic Ustic, Cryic/Typic Xeric, Frigid/Aquic, Frigid/Udic, Frigid/Typic Ustic, Frigid/Aridic Ustic, Frigid/Typic Xeric, Mesic/Ustic Aridic. http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Elevation	contelev	≈10m	Continuous. Elevation in meters above mean sea level. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Aspect (East-West)	contewasp	≈10m	Continuous. Aspect of slopes, ranging from 1 (east) to -1 (west). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Aspect (North-South)	contnsasp	≈10m	Continuous. Aspect of slopes, ranging from 1 (north) to -1 (south). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Slope	contslope	≈10m	Continuous. Percent slope (x100) of landscape. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Ruggedness	contvrm	≈10m	Continuous. Vector ruggedness measure (0 to 1). https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Summer Solar Radiation	contsumrad	≈10m	Continuous. Solar radiation (WH/m^2) for the day of the summer solstice. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Winter Solar Radiation	contwinrad	≈10m	Continuous. Solar radiation (WH/m^2) for the day of the winter solstice. https://www.sciencebase.gov/catalog/item/4f70aa9fe4b058caae3f8de5
Annual NDVI	contndvi	900m	Continuous. Normalized Difference Vegetation as a measure of yearly mean greenness from the MODIS Terra satellite. ftp://mco.cfc.umt.edu/ndvi/terra/yearly_normals/
Annual Precipitation	contprecip	≈800m	Continuous. Average annual precipitation (mm) for 1981-2010. http://www.prism.oregonstate.edu/normals/
Percent Winter Precipitation	contwinpcp	≈800m	Continuous. Average percent (0 to 1) of the total annual precipitation that occurs during winter (Nov-Apr) for 1981-2010. http://www.prism.oregonstate.edu/normals/
Max Summer Temp	conttmax	800m	Continuous. Average maximum temperature (°C) in July for 1981-2010. ftp://mco.cfc.umt.edu/tmax/monthly_normals/
Min Winter Temp	conttmin	800m	Continuous. Average minimum temperature (°C) in January for 1981-2010. ftp://mco.cfc.umt.edu/tmin/monthly_normals/
Degree Days	contddays	800m	Continuous. Average annual total of degree days (°F) above 32°F for 1981-2010. http://services.cfc.umt.edu/arcgis/rest/services/Atlas/Temperature_CropDegreeDays32F/ImageServer
Distance to Stream	contstrmed	vector	Continuous. Distance to major streams in meters, based on major streams identified in TIGER files or USGS topographic maps (Stream_Lake_1993 dataset). http://ftp.geoinfo.msl.mt.gov/Data/Spatial/NonMSDI/Shapefiles/
Distance to Forest Cover	contfrsted	30m	Continuous. Distance to any forest land cover type in meters. http://geoinfo.msl.mt.gov/msdi/land_use_land_cover

Long-toed Salamander (*Ambystoma macrodactylum*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 5, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 5, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model appears to do a good job of reflecting the distribution of Long-toed Salamander general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics suggest a good model fit. The delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with likely overpredicts the amount of suitable habitat for Long-toed Salamander across the species' known range in Montana. However, management actions that promote the long-term persistence of the commonly associated ecological systems is recommended to promote the long-term persistence of this species.

Suggested Citation: Montana Natural Heritage Program. 2017. Long-toed Salamander (*Ambystoma macrodactylum*) predicted suitable habitat models created on October 05, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAAAA01080

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,602
Location Data Selection Rule 1	Records with <= 800 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	2,157
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	822
Season Modeled	Year-round
Number of Model Background Locations	13,376

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contslope	24.3%	contnsasp	1.2%
contndvi	20.0%	contewasp	1.2%
catsoilord	14.1%	conttmax	1.1%
catesys	10.6%	contddays	1.0%
contwinpcp	5.7%	contwinrad	0.8%
catgeol	5.0%	contprecip	0.7%
contelev	3.6%	conttmin	0.5%
catsoiltemp	3.5%	contvrm	0.4%
contsumrad	3.2%	contstrmed	0.4%
contfrsted	2.6%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.062
Moderate Logistic Threshold[b]	0.317
Optimal Logistic Threshold[c]	0.692
Area of entire modeled range (percent of Montana)	84,830.3 km^2 (22.3%)
Total area of predicted suitable habitat within modeled range	44,241.8 km^2
Area of predicted low suitability habitat within modeled range	30,163.6 km^2
Area of moderate suitability habitat within modeled range	12,694.0 km^2
Area of predicted optimal habitat within modeled range	1,384.2 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	95.0%
Moderate AVI[a]	77.9%
Optimal AVI[a]	29.1%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.852 ± 2.080
Training AUC[c]	0.884
Test AUC[d]	0.875

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.568, 2.301 and 0.737, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

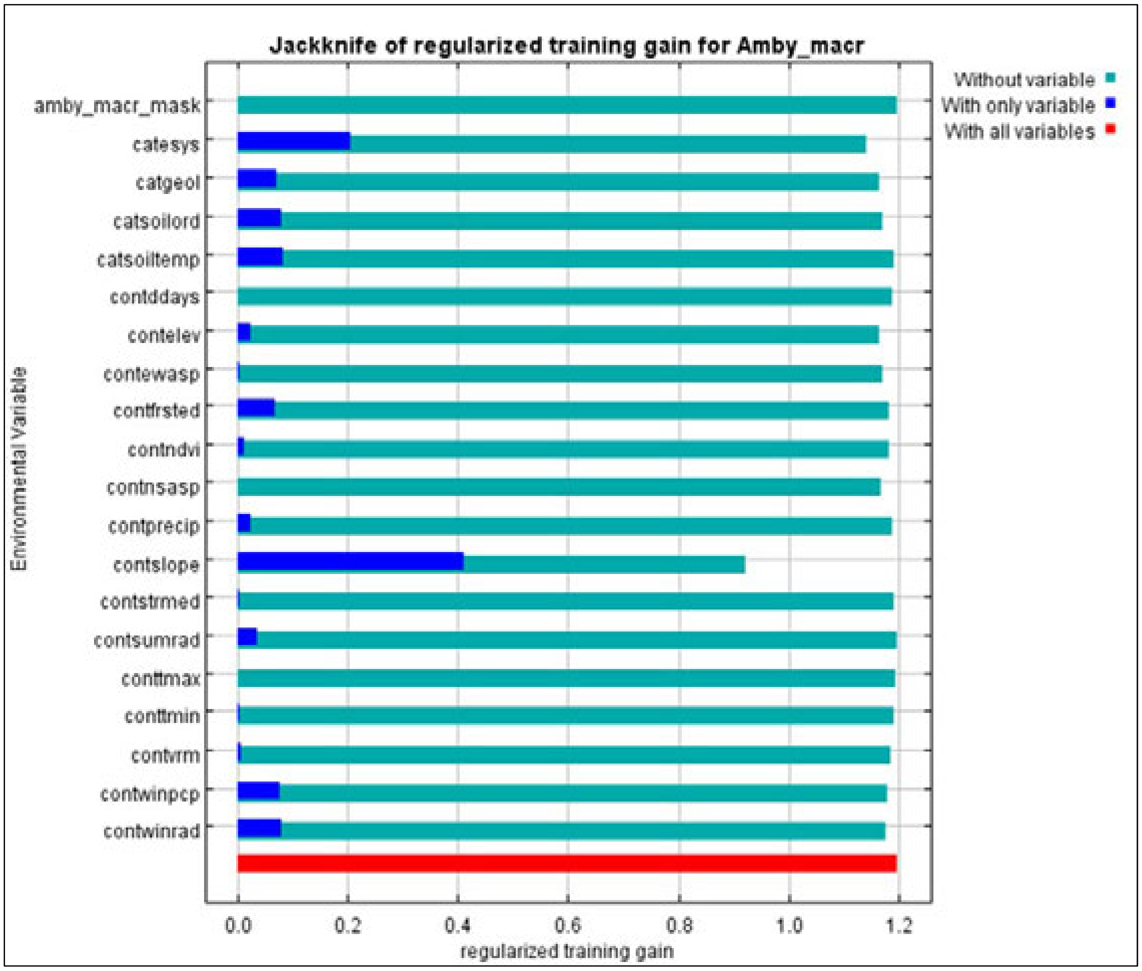


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

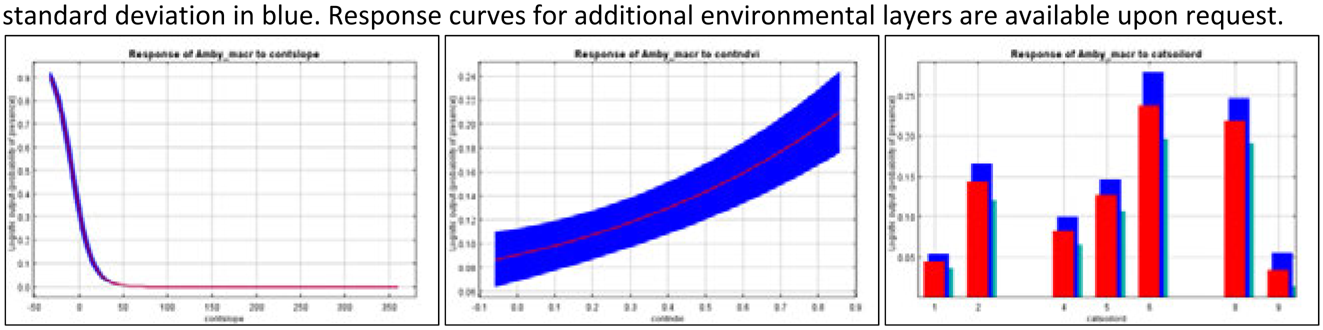


Figure 3. Continuous habitat suitability model output (logistic scale).

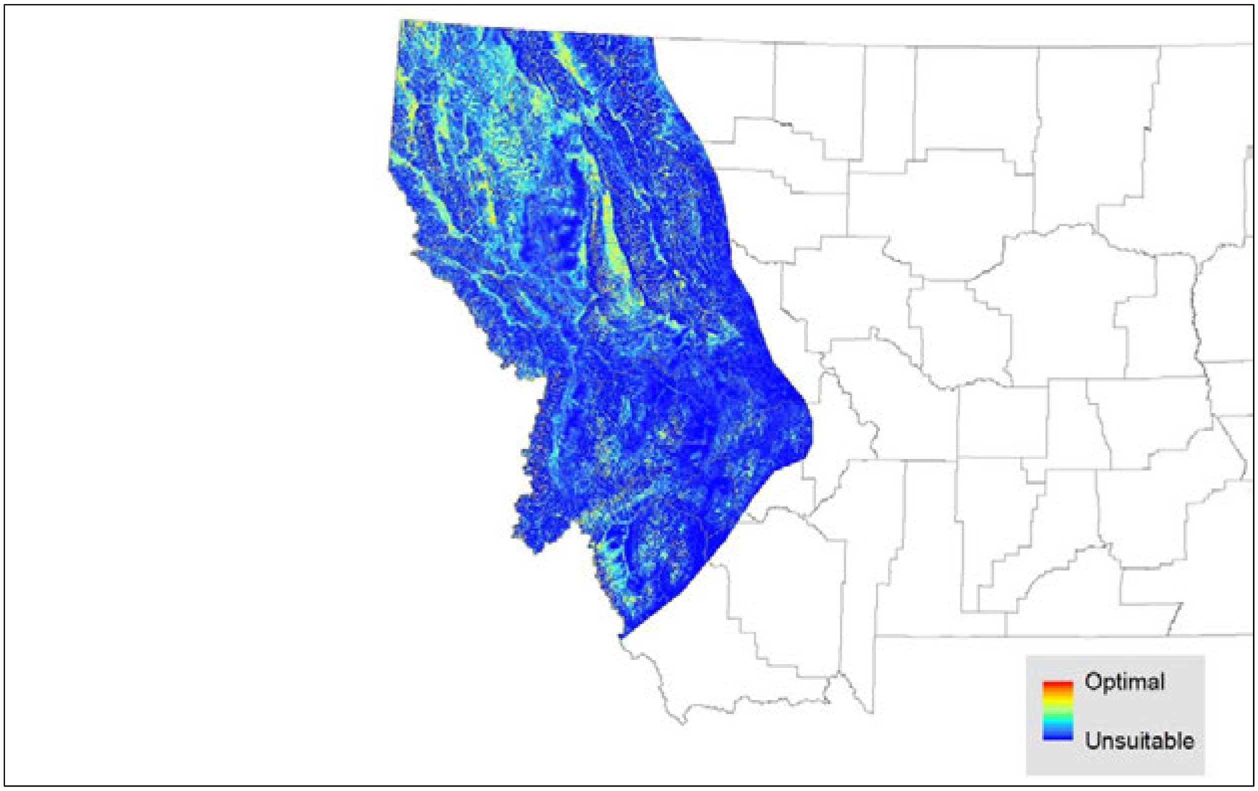


Figure 4. Standard deviation in the model output across the averaged models.

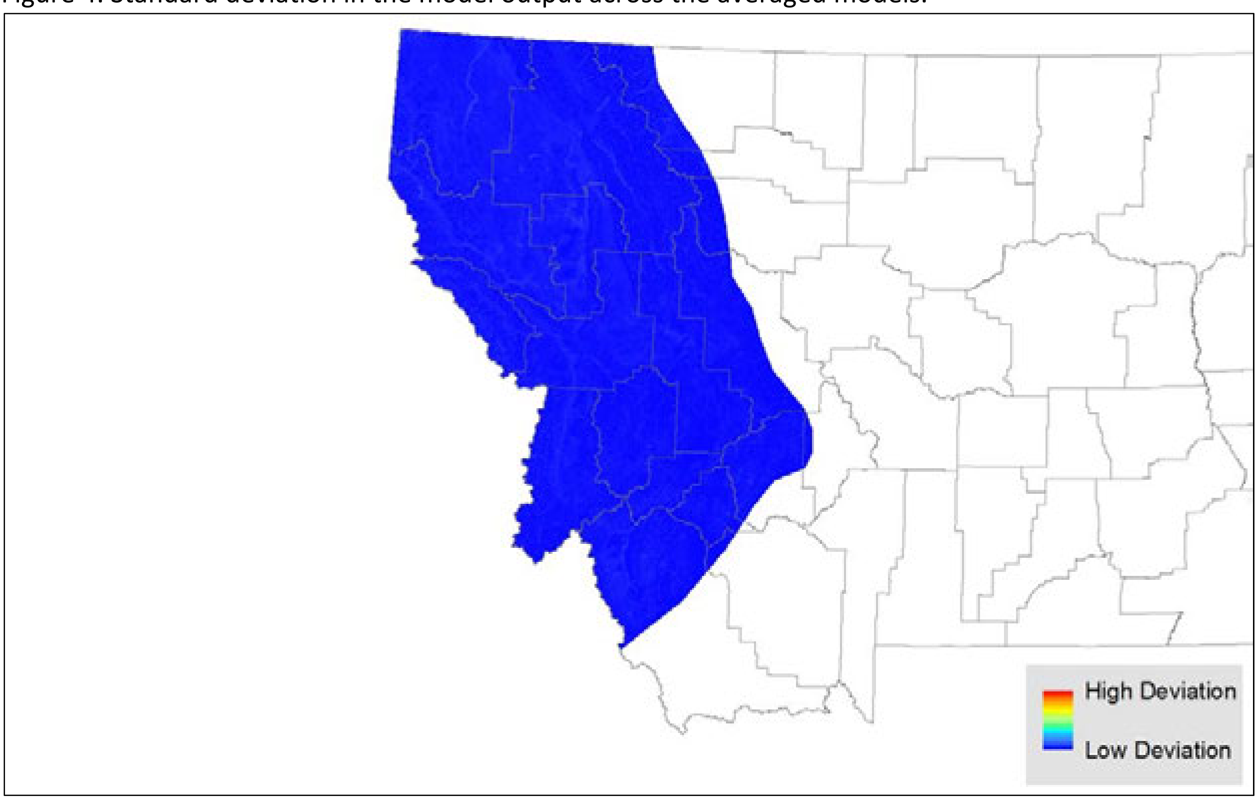


Figure 5. Continuous habitat suitability model output with the 822 observations used for modeling.

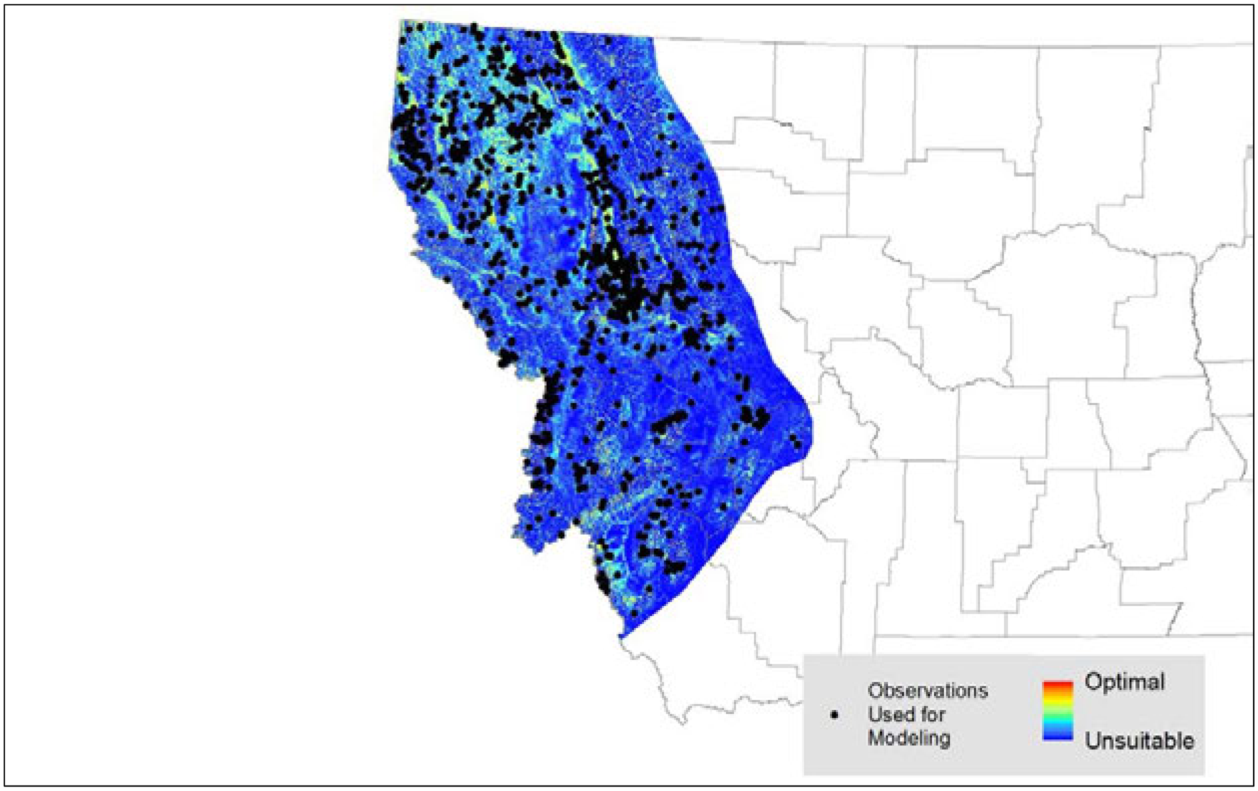


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

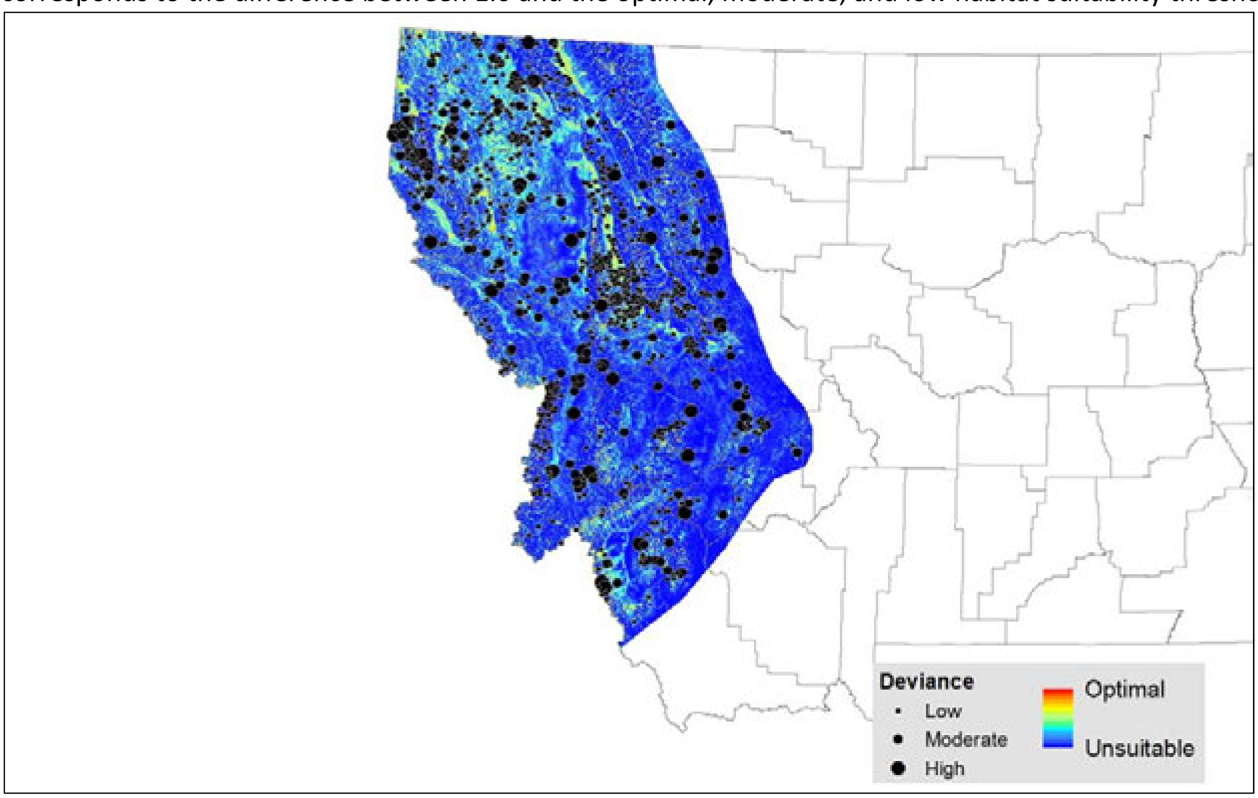


Figure 7. Continuous habitat suitability model output with all 2,602 observations (black) and survey locations that could have detected the species (gray).

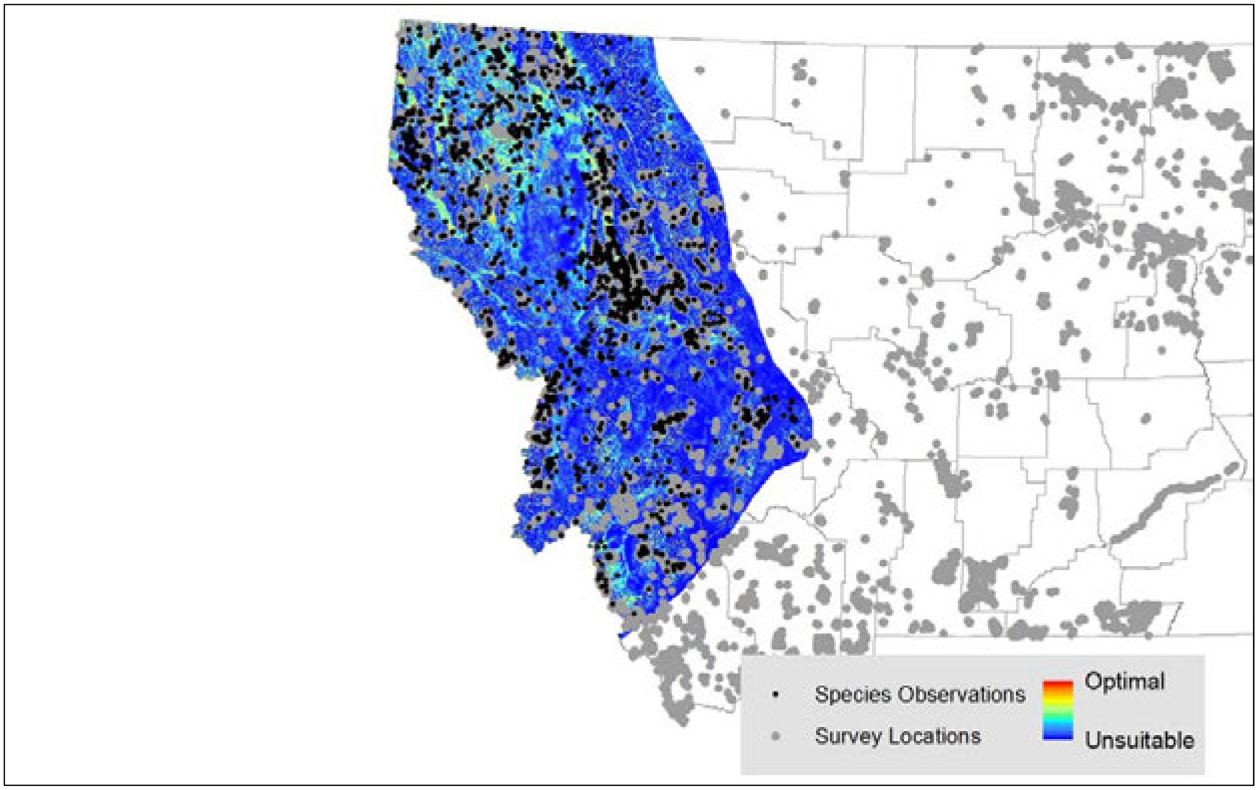


Figure 8. Model output classified into habitat suitability classes.

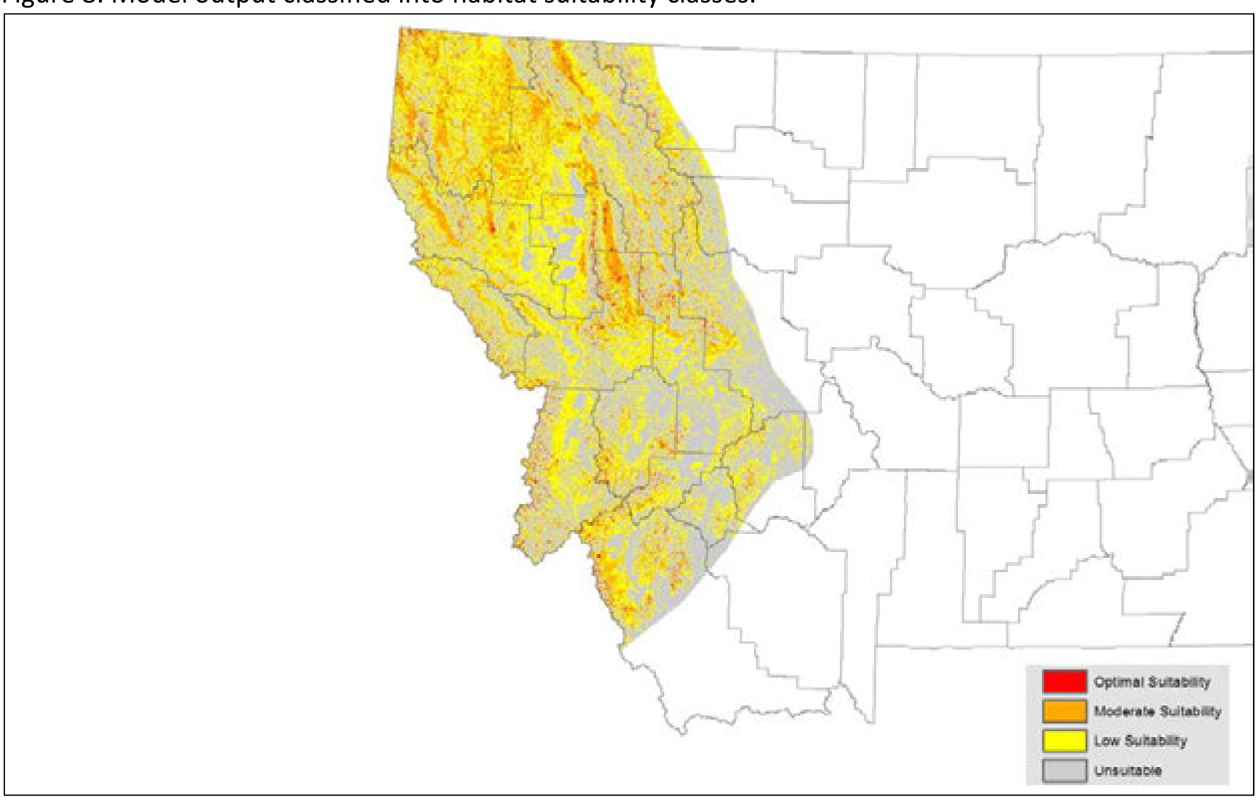
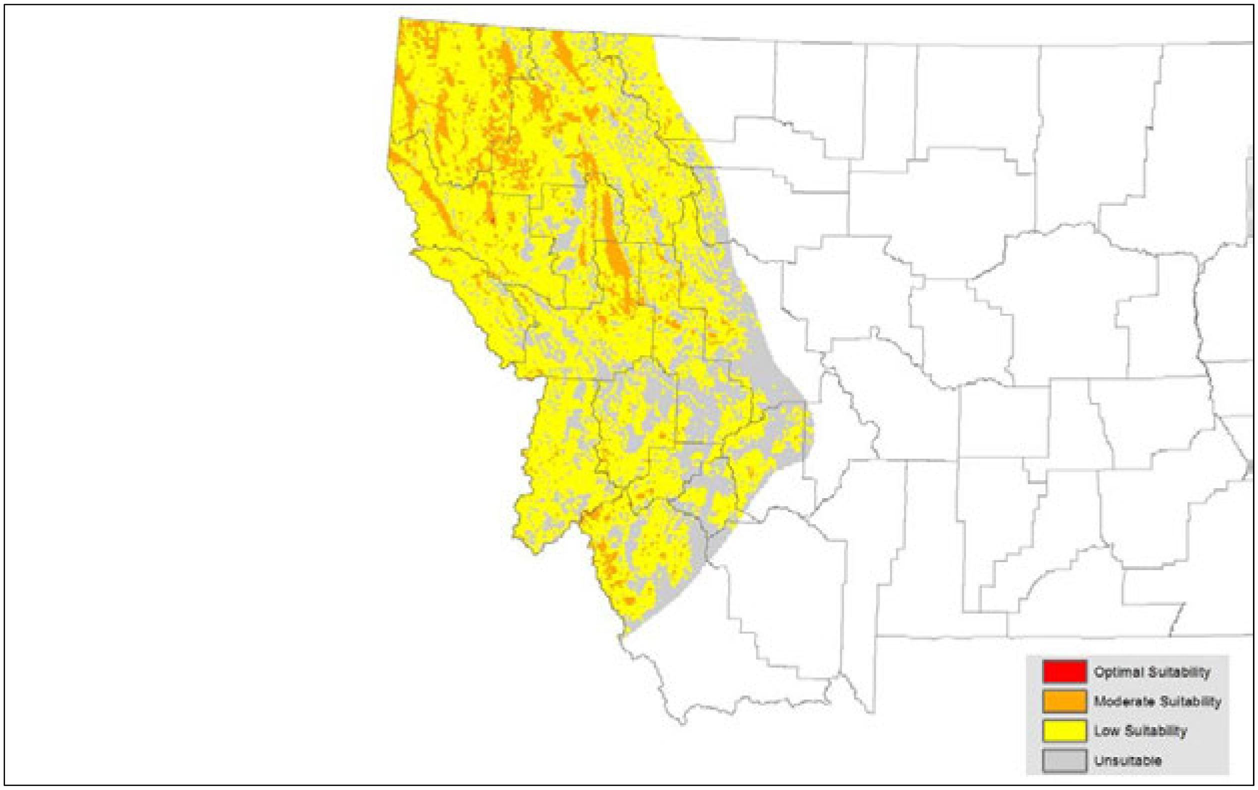


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Long-toed Salamander

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	120
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	106
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	81
Open Water	11	Common	69
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	52
Alpine-Montane Wet Meadow	9217	Common	52
Rocky Mountain Lodgepole Pine Forest	4237	Common	47
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	45
Recently burned forest	8501	Common	29
Post-Fire Recovery	8505	Common	25
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	15
Rocky Mountain Subalpine Woodland and Parkland	4233	Common	14
Insect-Killed Forest	8700	Common	14
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	13
Harvested forest-tree regeneration	8601	Common	12
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	9
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	6
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	5
Emergent Marsh	9222	Common	5
Rocky Mountain Subalpine-Montane Fen	9234	Common	5
Aspen and Mixed Conifer Forest	4302	Common	4
Rocky Mountain Subalpine Deciduous Shrubland	5326	Common	4
Rocky Mountain Conifer Swamp	9111	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Occasional	40
Aspen Forest and Woodland	4104	Occasional	6
Montane Sagebrush Steppe	5455	Occasional	6
Low Intensity Residential	22	Occasional	4
Harvested forest-grass regeneration	8603	Occasional	4
Developed, Open Space	21	Occasional	1
Quarries, Strip Mines and Gravel Pits	31	Occasional	0
Pasture/Hay	81	Occasional	0
Harvested forest-shrub regeneration	8602	Occasional	0
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 822 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

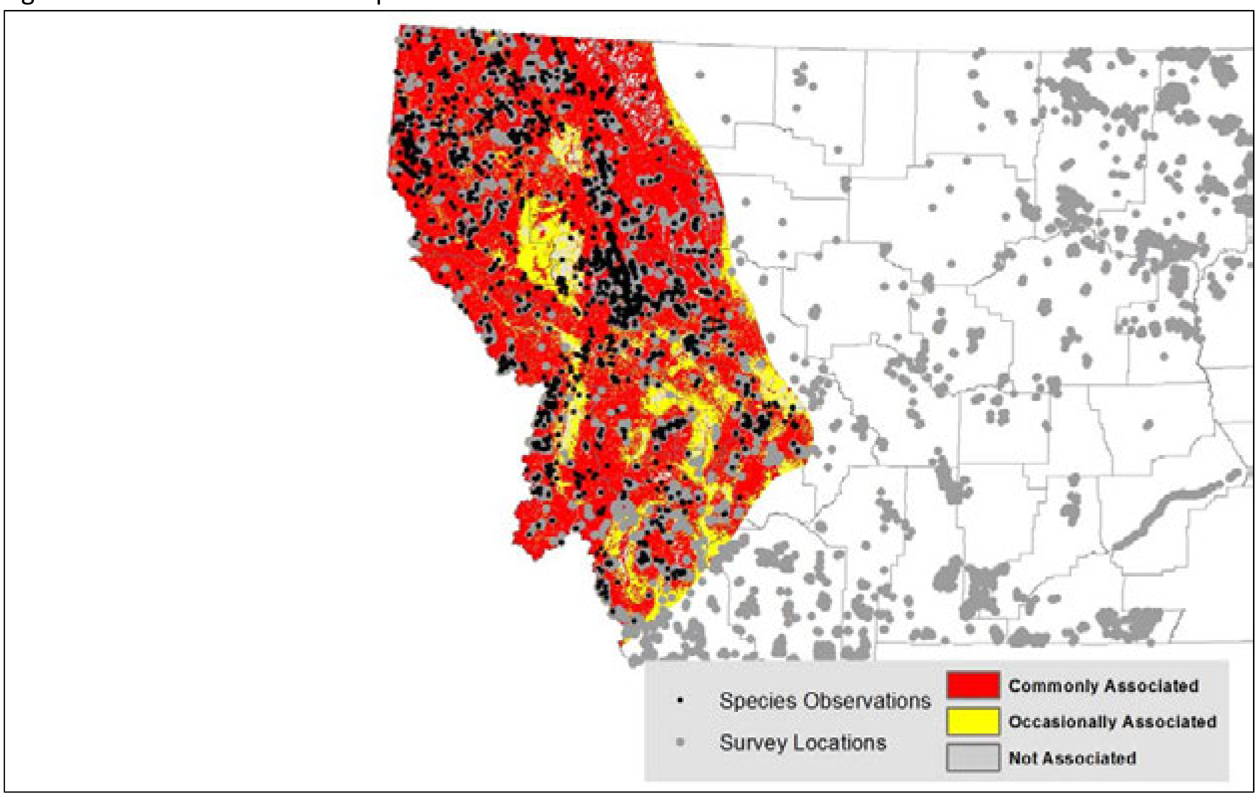
Measure	**Value**
Area of entire modeled range (percent of Montana)	84,830.3 km^2 (22.3%)
Area of Commonly and Occasionally Associated ES	78,811.0 km^2
Area of Commonly Associated ES	64,227.0 km^2
Area of Occasionally Associated ES	14,584.0 km^2

Table 7: Evaluation Metrics

Metric	**Value**
Commonly and Occasionally Associated ES AVI[a]	96.6%
Commonly Associated ES AVI[a]	89.2%
Occasionally Associated ES AVI[a]	7.4%

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

Figure 10. Deductive model output classified into habitat associations.



Western Tiger Salamander (*Ambystoma mavortium*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 5, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 5, 2017
Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model appears to do a reasonably good job of representing the distribution of Western Tiger Salamander general year-round habitat suitability at larger spatial scales across the species' known range in Montana with a little bit of a blocky appearance due to the importance of soil orders. Evaluation metrics suggest a good model fit and the delineation of habitat suitability classes is reasonably well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do a good job of spatially representing the amount of suitable habitat for Western Tiger Salamander across the species' known range in Montana and should be used in tandem with the inductive model output.

Suggested Citation: Montana Natural Heritage Program. 2017. Western Tiger Salamander (*Ambystoma mavortium*) predicted suitable habitat models created on October 05, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAAAA01142

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,755
Location Data Selection Rule 1	Records with <= 400 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,286
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	745
Season Modeled	Year-round
Number of Model Background Locations	46,143

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	37.0%	contndvi	1.0%
catsoilord	18.4%	contddays	0.6%
contslope	11.5%	conttmin	0.6%
contsumrad	11.1%	contelev	0.5%
catsoiltemp	5.2%	contfrsted	0.4%
catgeol	4.9%	contwinpcp	0.4%
contstrmed	3.7%	contprecip	0.1%
contewasp	1.6%	contvrm	0.0%
conttmax	1.5%	contwinrad	0.0%
contnsasp	1.2%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.090
Moderate Logistic Threshold[b]	0.389
Optimal Logistic Threshold[c]	0.786
Area of entire modeled range (percent of Montana)	292,648.5 km^2 (76.9%)
Total area of predicted suitable habitat within modeled range	205,574.9 km^2
Area of predicted low suitability habitat within modeled range	127,105.7 km^2
Area of moderate suitability habitat within modeled range	75,926.5 km^2
Area of predicted optimal habitat within modeled range	2,542.7 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.

[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.

[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.0%
Moderate AVI[a]	69.1%
Optimal AVI[a]	11.3%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.611 ± 1.201
Training AUC[c]	0.812
Test AUC[d]	0.797

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.

[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 4.811, 1.887 and 0.482, respectively. Deviances for individual test locations are plotted in Figure 6.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

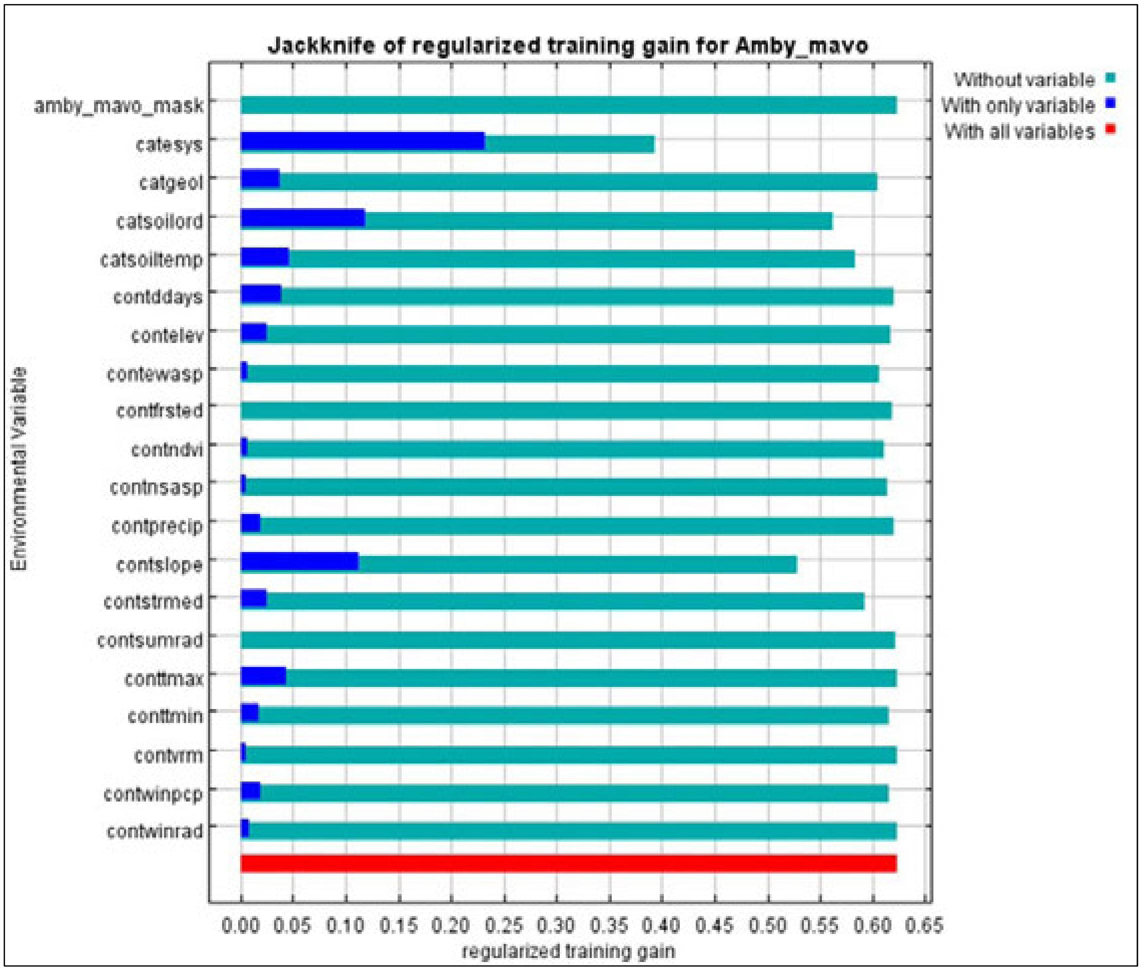


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

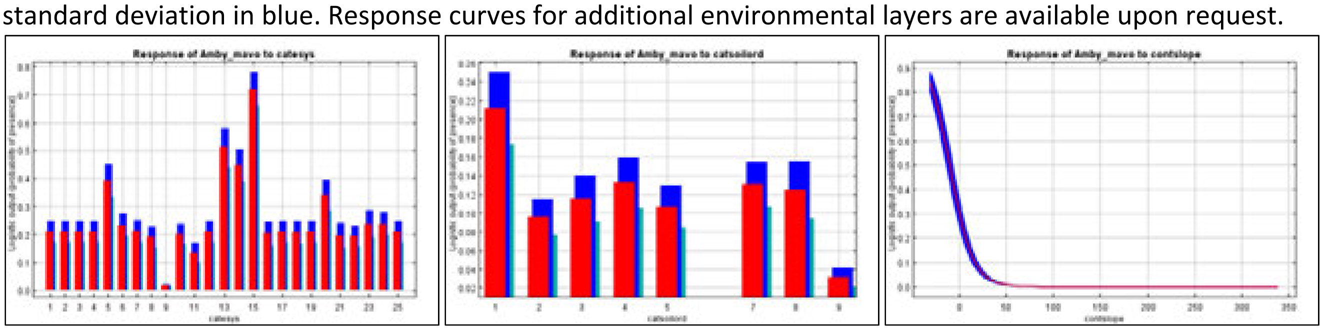


Figure 3. Continuous habitat suitability model output (logistic scale).

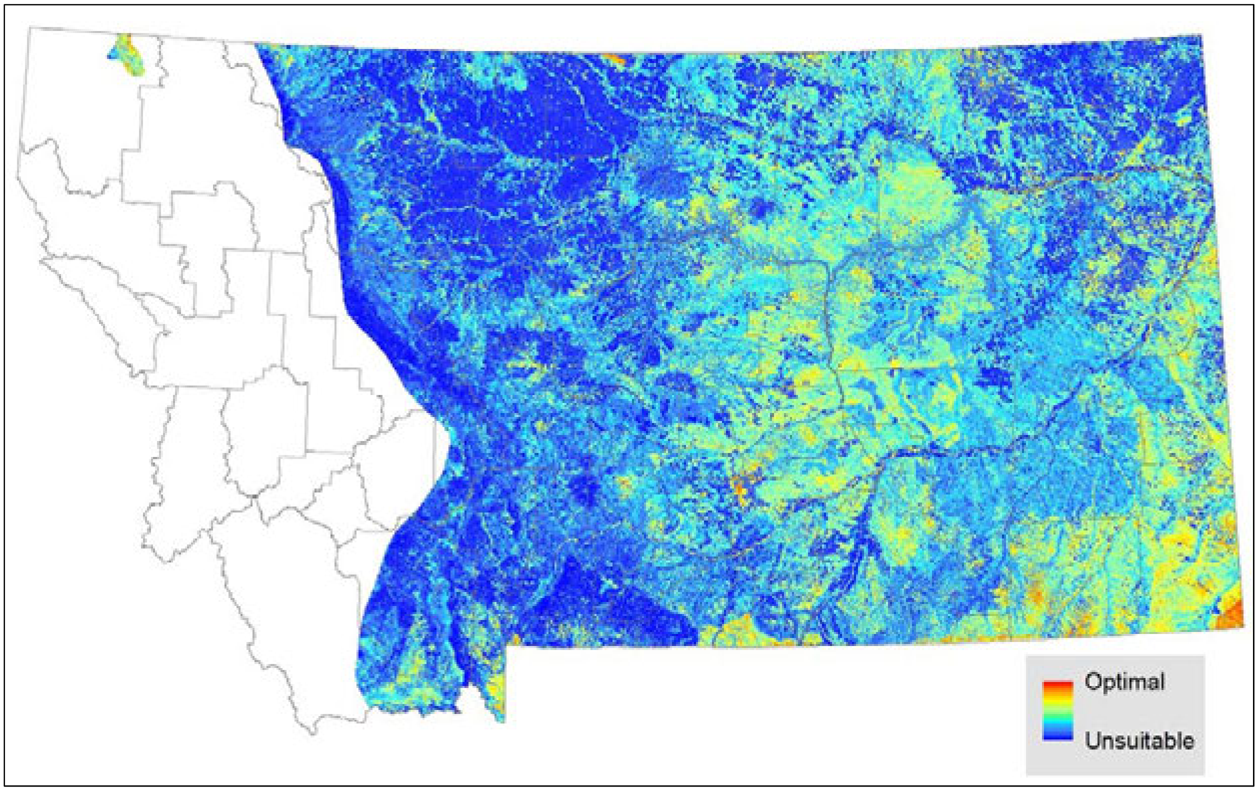


Figure 4. Standard deviation in the model output across the averaged models.

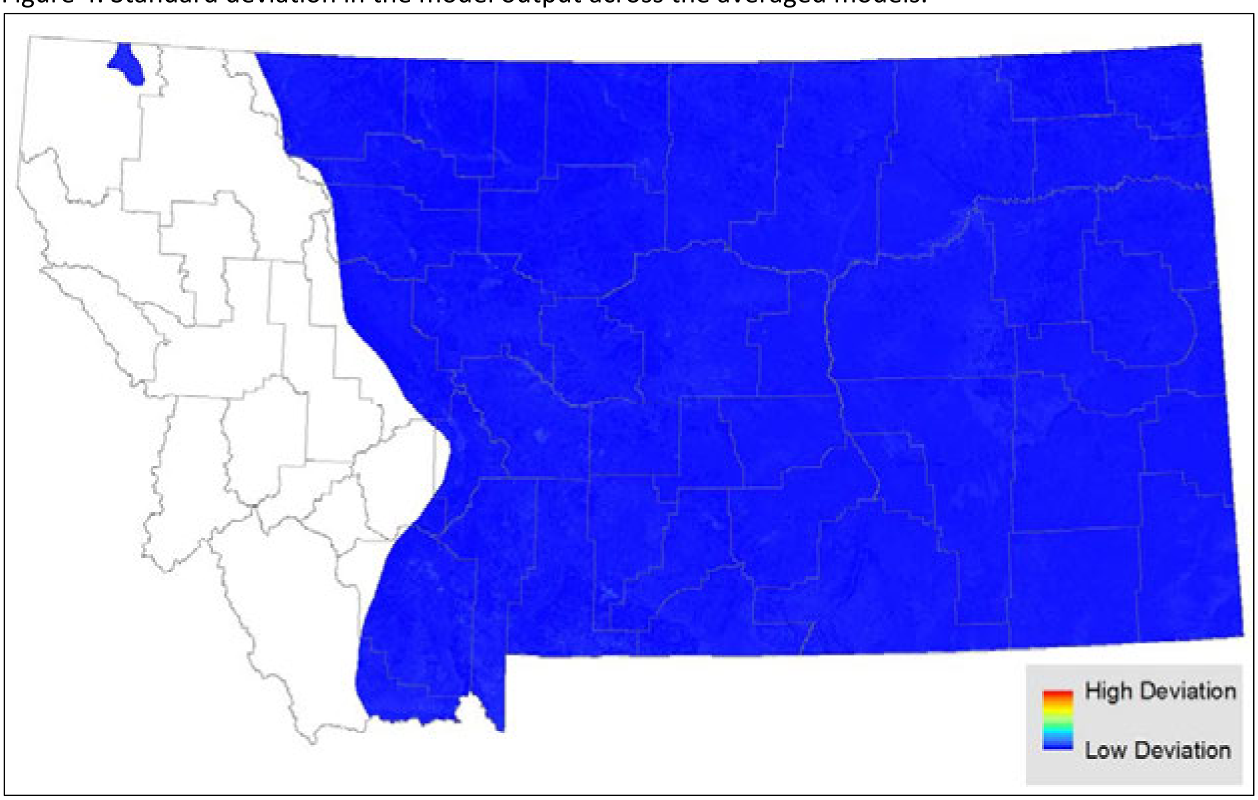


Figure 5. Continuous habitat suitability model output with the 745 observations used for modeling.

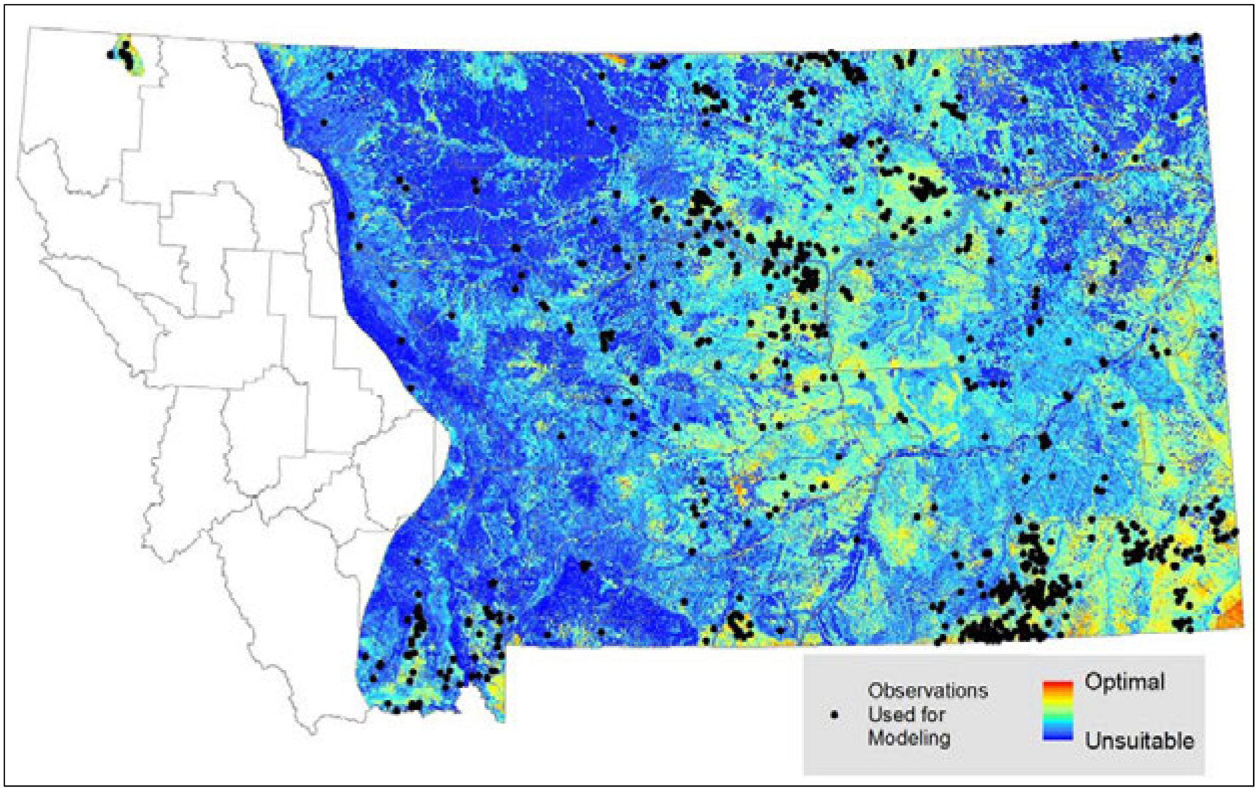


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

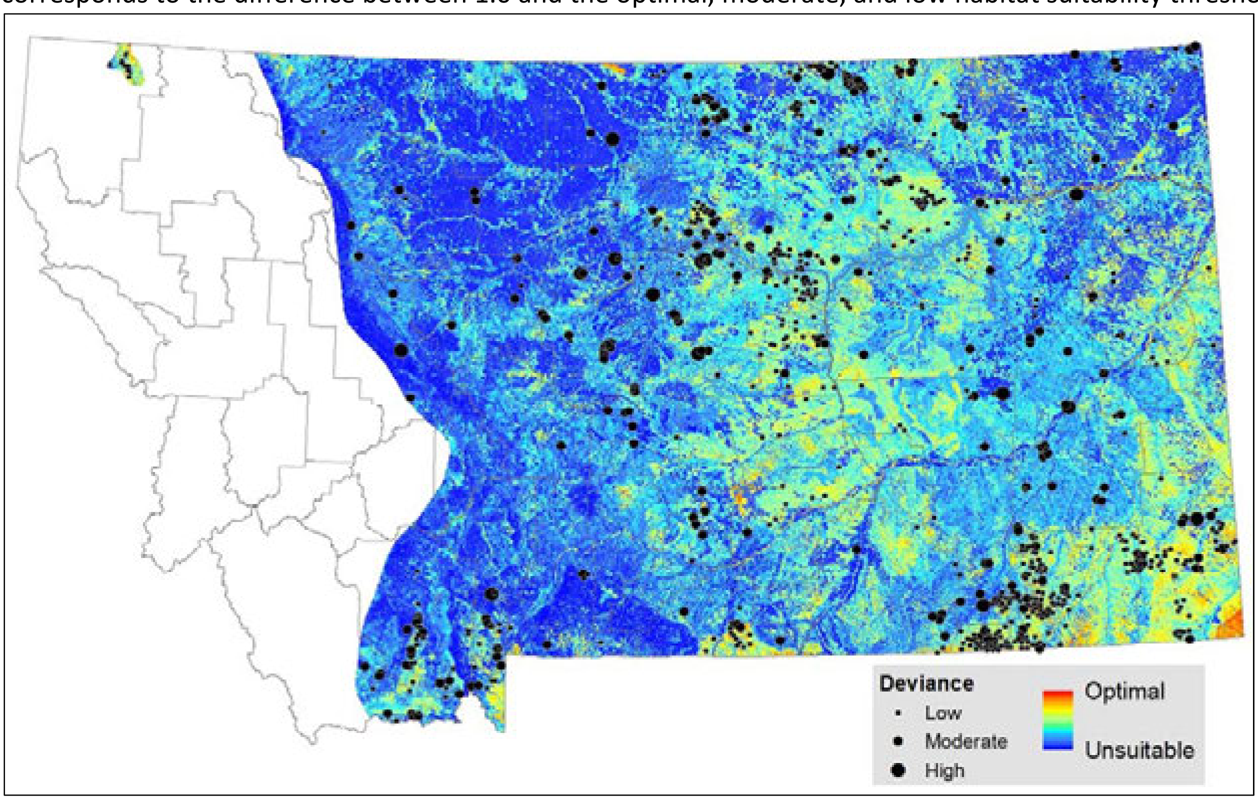


Figure 7. Continuous habitat suitability model output with all 1,755 observations (black) and survey locations that could have detected the species (gray).

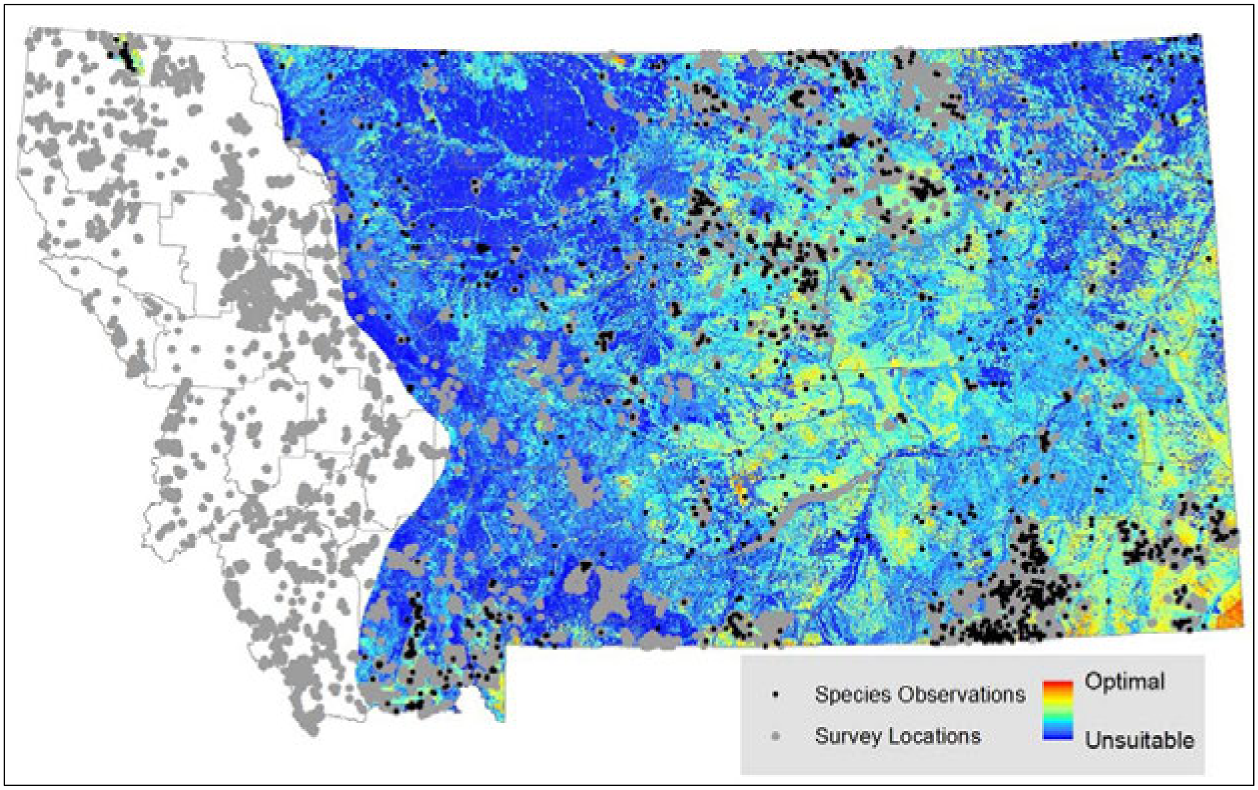


Figure 8. Model output classified into habitat suitability classes.

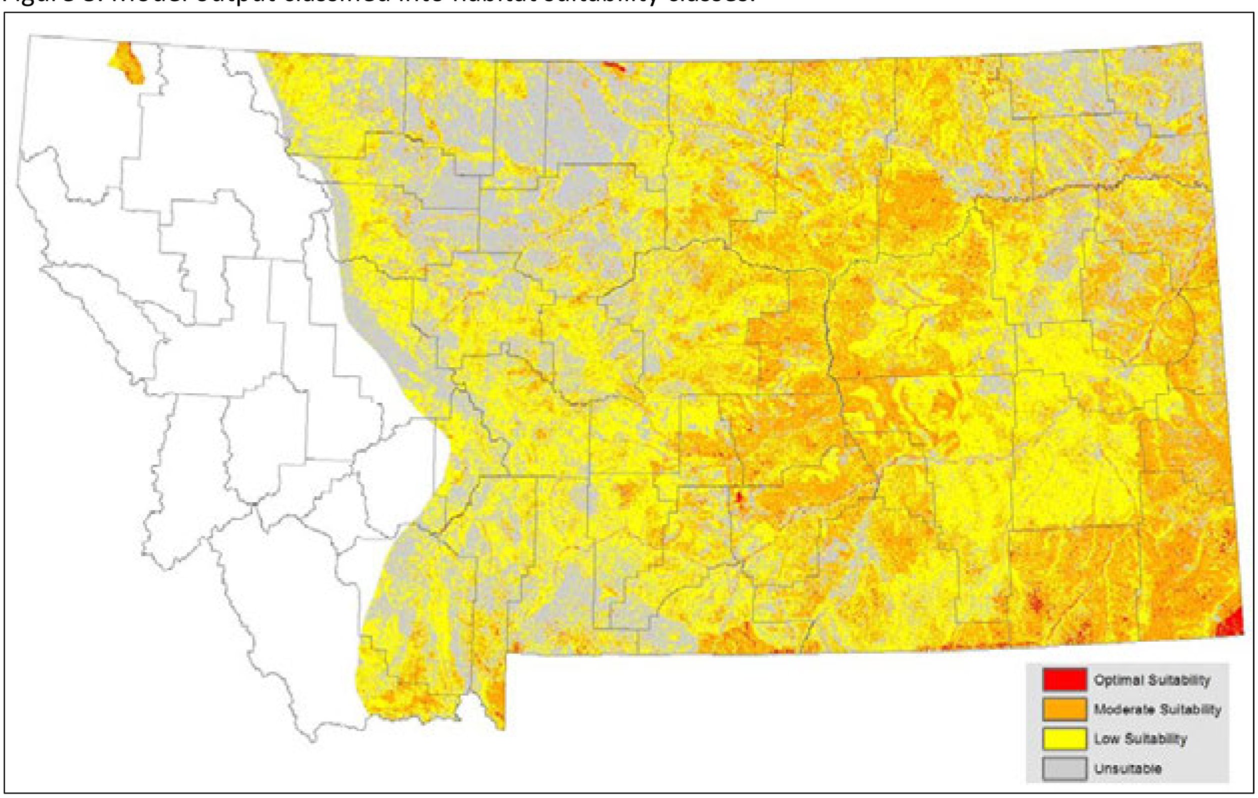
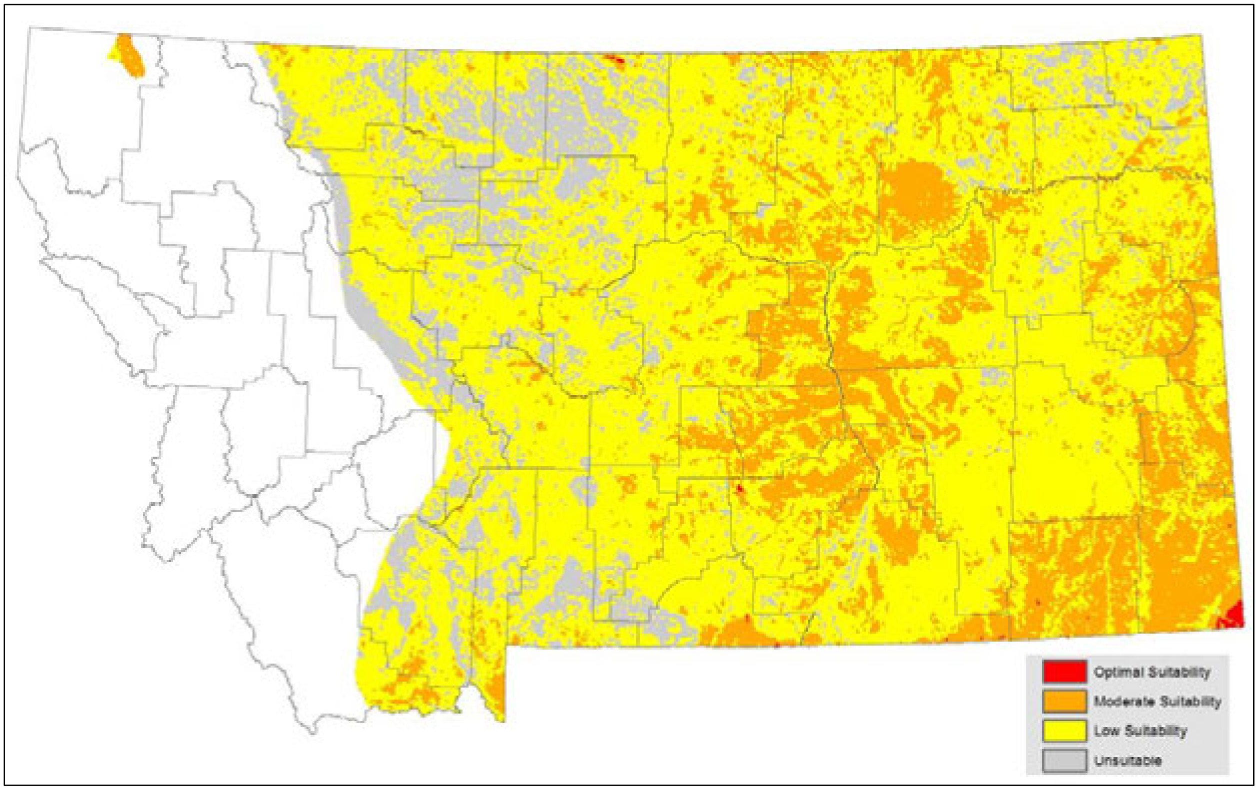


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Western Tiger Salamander

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	181
Big Sagebrush Steppe	5454	Common	116
Great Plains Riparian	9326	Common	100
Open Water	11	Common	48
Great Plains Badlands	3114	Common	27
Recently burned forest	8501	Common	22
Recently burned grassland	8502	Common	20
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	18
Montane Sagebrush Steppe	5455	Common	16
Great Plains Prairie Pothole	9203	Common	15
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Common	12
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	11
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	11
Mat Saltbush Shrubland	5203	Common	9
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	8
Great Plains Sand Prairie	7121	Common	7
Post-Fire Recovery	8505	Common	7
Greasewood Flat	9103	Common	7
Great Plains Wooded Draw and Ravine	4328	Common	6
Aspen Forest and Woodland	4104	Common	5
Great Plains Shrubland	5262	Common	5
Burned Sagebrush	8504	Common	5
Great Plains Saline Depression Wetland	9256	Common	4
Low Sagebrush Shrubland	5209	Common	2
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	2
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Common	2
Recently burned shrubland	8503	Common	2
Great Plains Floodplain	9159	Common	2
Alpine-Montane Wet Meadow	9217	Common	2
Emergent Marsh	9222	Common	2
Great Plains Closed Depressional Wetland	9252	Common	2
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	1
Shale Badland	3139	Common	0
Great Plains Cliff and Outcrop	3142	Common	0
Active and Stabilized Dune	3160	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Introduced Upland Vegetation - Annual Grassland	8404	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Rocky Mountain Lodgepole Pine Forest	4237	Occasional	9
Pasture/Hay	81	Occasional	5

Table 5: Ecological Systems Associated with Western Tiger Salamander

Ecological System	**Code**	**Association**	**Count[a]**
Cultivated Crops	82	Occasional	4
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Occasional	4
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Occasional	4
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	2
Low Intensity Residential	22	Occasional	1
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	1
Developed, Open Space	21	Occasional	0
Wyoming Basin Cliff and Canyon	3173	Occasional	0
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Occasional	0
Mountain Mahogany Woodland and Shrubland	4303	Occasional	0
Rocky Mountain Wooded Vernal Pool	9162	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 745 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

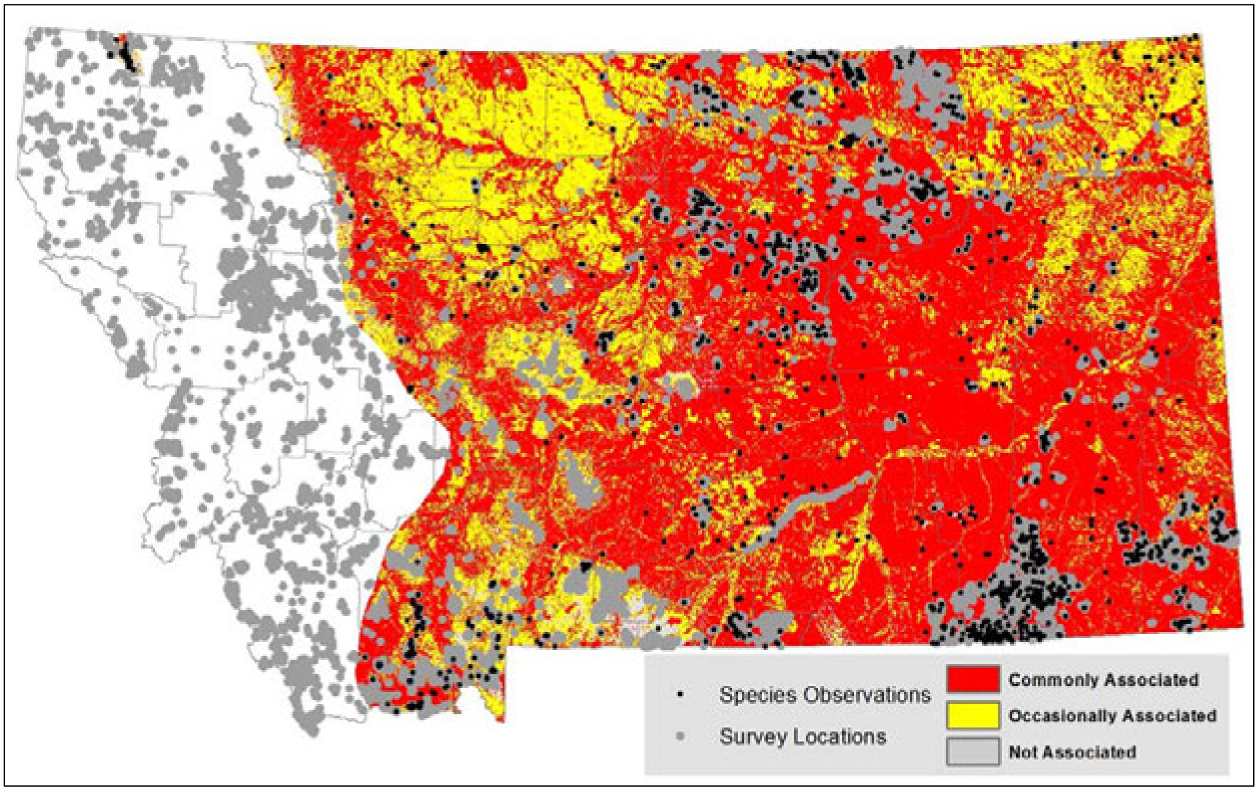
Measure	**Value**
Area of entire modeled range (percent of Montana)	292,648.5 km^2 (76.9%)
Area of Commonly and Occasionally Associated ES	281,788.0 km^2
Area of Commonly Associated ES	199,746.0 km^2
Area of Occasionally Associated ES	82,042.0 km^2

Table 7: Evaluation Metrics

Metric	**Value**
Commonly and Occasionally Associated ES AVI[a]	94.9%
Commonly Associated ES AVI[a]	90.9%
Occasionally Associated ES AVI[a]	4.0%

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

Figure 10. Deductive model output classified into habitat associations.



Rocky Mountain Tailed Frog (*Ascaphus montanus*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model appears to generally reflect the distribution of Rocky Mountain Tailed Frog year-round habitat suitability at larger spatial scales across the species' known range in Montana. Furthermore, evaluation metrics suggest an acceptable model fit and the delineation of habitat suitability classes is well-supported by the data. Note that distance to stream was not identified as one of the most important variables for model fit. This likely results from the fact that the small headwater streams that the species is dependent on are not included in the stream layer; ruggedness of the landscape, which came out as the most important variable to model fit, is almost certainly a correlated proxy for these headwater streams.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the summer, across the species' known summer range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with appear to overpredict the amount of suitable habitat for Rocky Mountain Tailed Frog across the species' known summer range in Montana; again resulting from the lack of adequate mapping of headwaters streams.

Suggested Citation: Montana Natural Heritage Program. 2017. Rocky Mountain Tailed Frog (*Ascaphus montanus*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABA01020

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,324
Location Data Selection Rule 1	Records during summer with <= 900 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,563
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	822
Season Modeled	Summer
Number of Model Background Locations	11,118

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contvrm	13.6%	contwinrad	4.5%
catsoiltemp	9.7%	contelev	3.3%
conttmax	9.4%	contddays	3.1%
contslope	9.2%	contnsasp	2.4%
contndvi	9.1%	contstrmed	0.9%
catesys	7.6%	conttmin	0.6%
contsumrad	7.0%	contprecip	0.5%
contwinpcp	6.8%	contfrsted	0.4%
catsoilord	6.3%	contewasp	0.4%
catgeol	5.1%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.064
Moderate Logistic Threshold[b]	0.302
Optimal Logistic Threshold[c]	0.715
Area of entire modeled range (percent of Montana)	70,513.9 km^2 (18.5%)
Total area of predicted suitable habitat within modeled range	42,708.1 km^2
Area of predicted low suitability habitat within modeled range	31,456.7 km^2
Area of moderate suitability habitat within modeled range	10,167.3 km^2
Area of predicted optimal habitat within modeled range	1,084.1 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	96.5%
Moderate AVI[a]	70.8%
Optimal AVI[a]	27.5%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.884 ± 1.779
Training AUC[c]	0.879
Test AUC[d]	0.868

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.498, 2.397 and 0.671, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

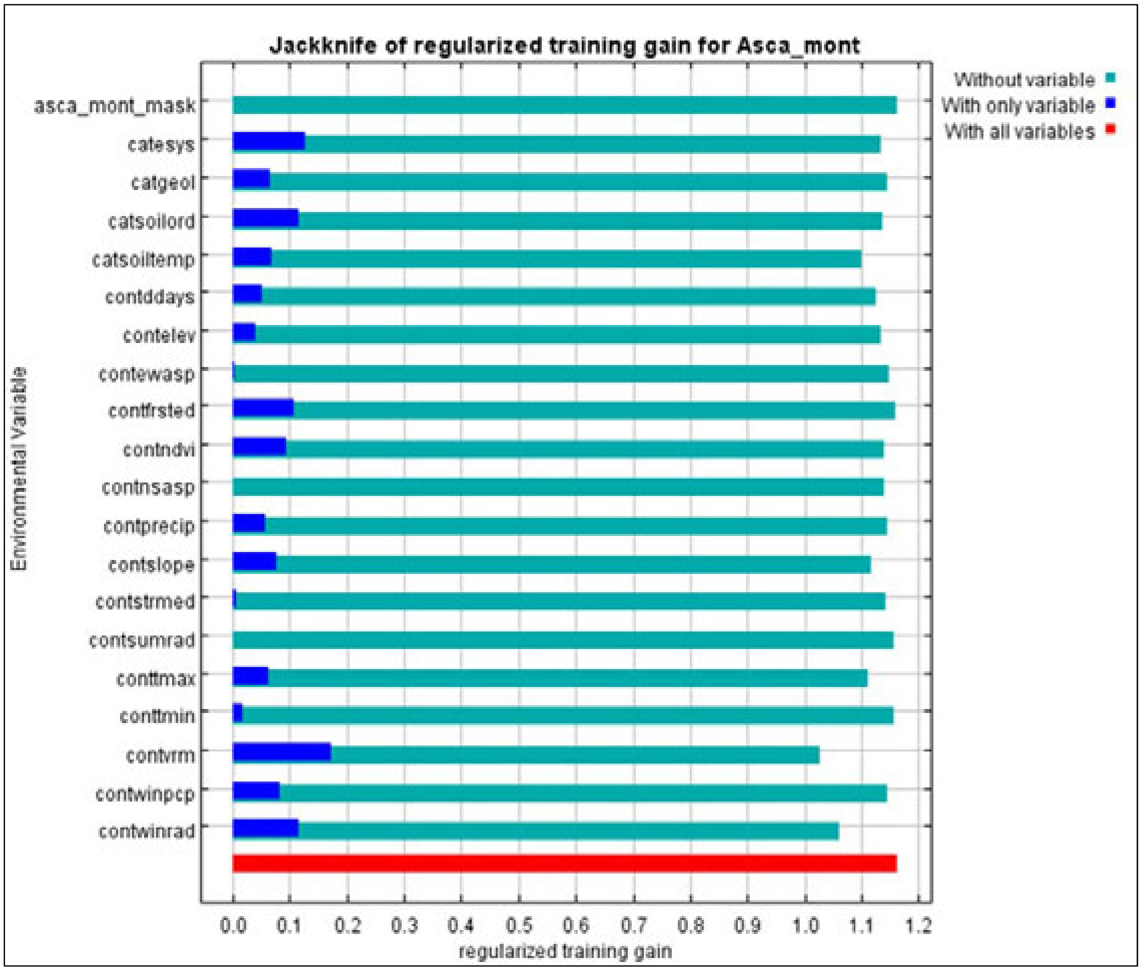


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

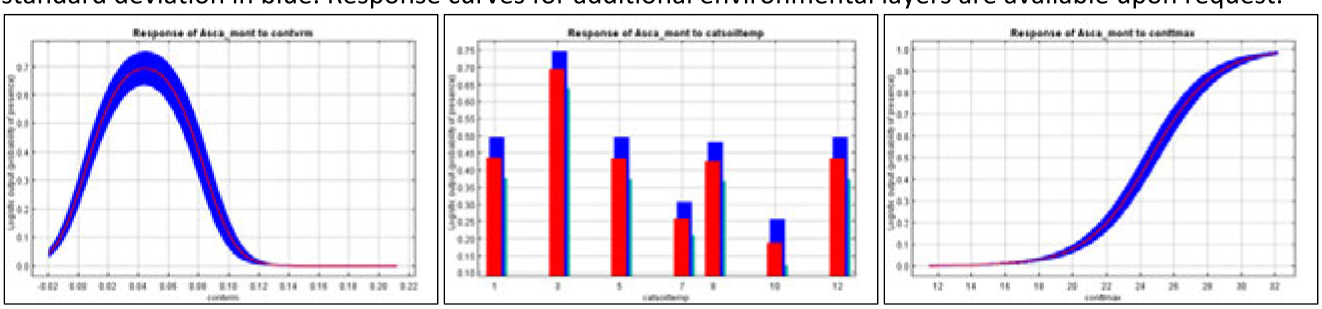


Figure 3. Continuous habitat suitability model output (logistic scale).

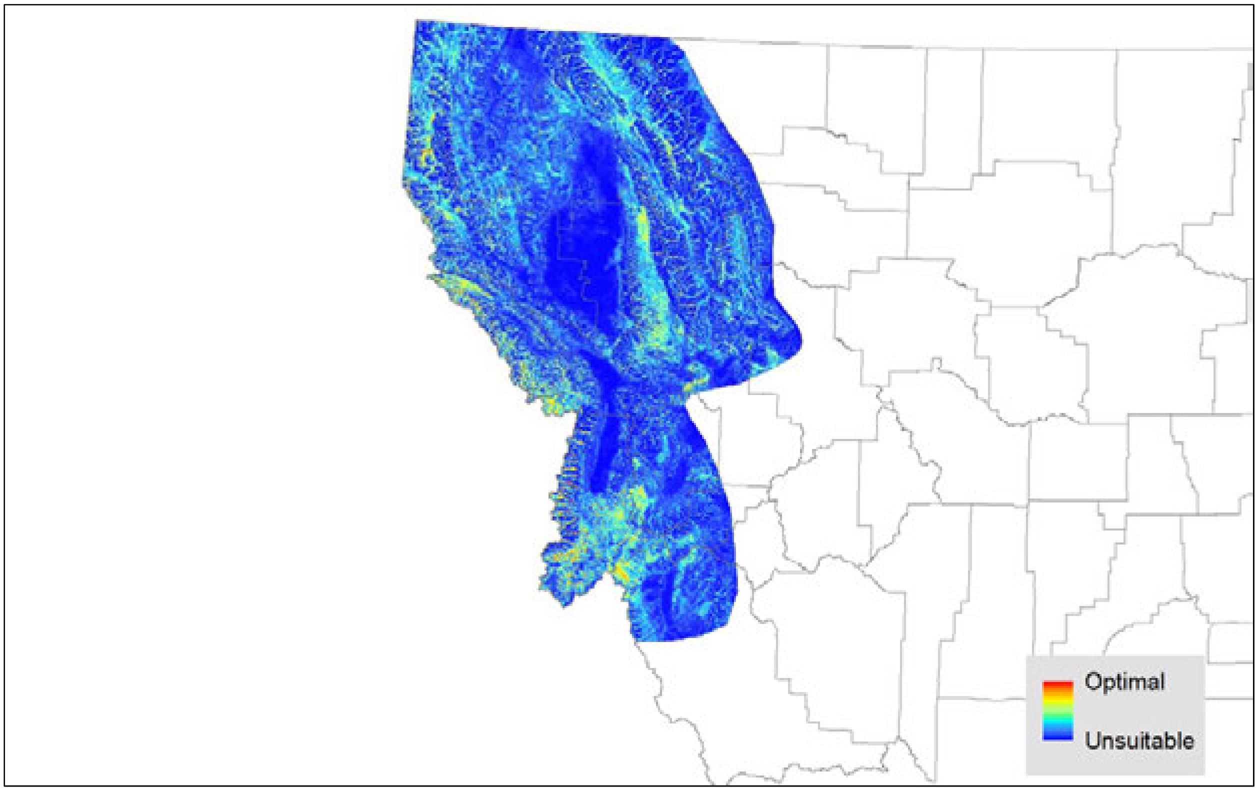


Figure 4. Standard deviation in the model output across the averaged models.

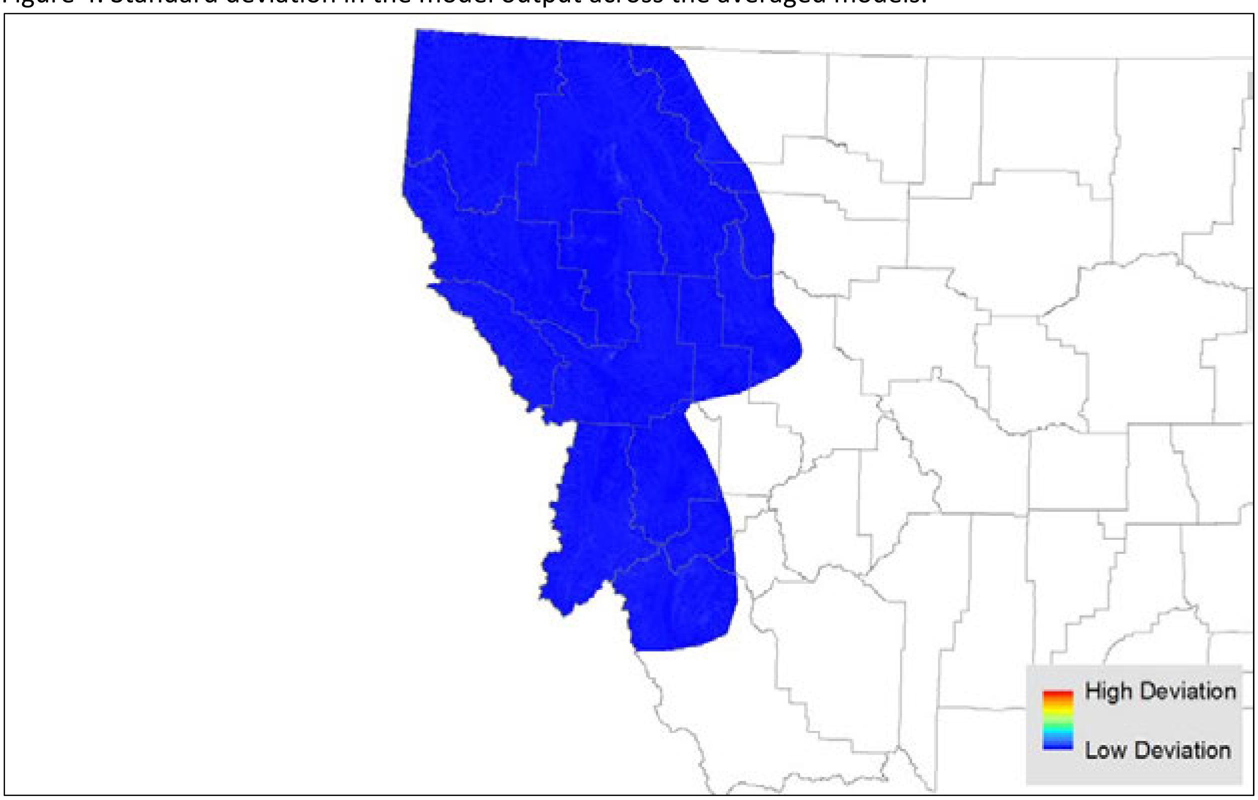


Figure 5. Continuous habitat suitability model output with the 822 observations used for modeling.

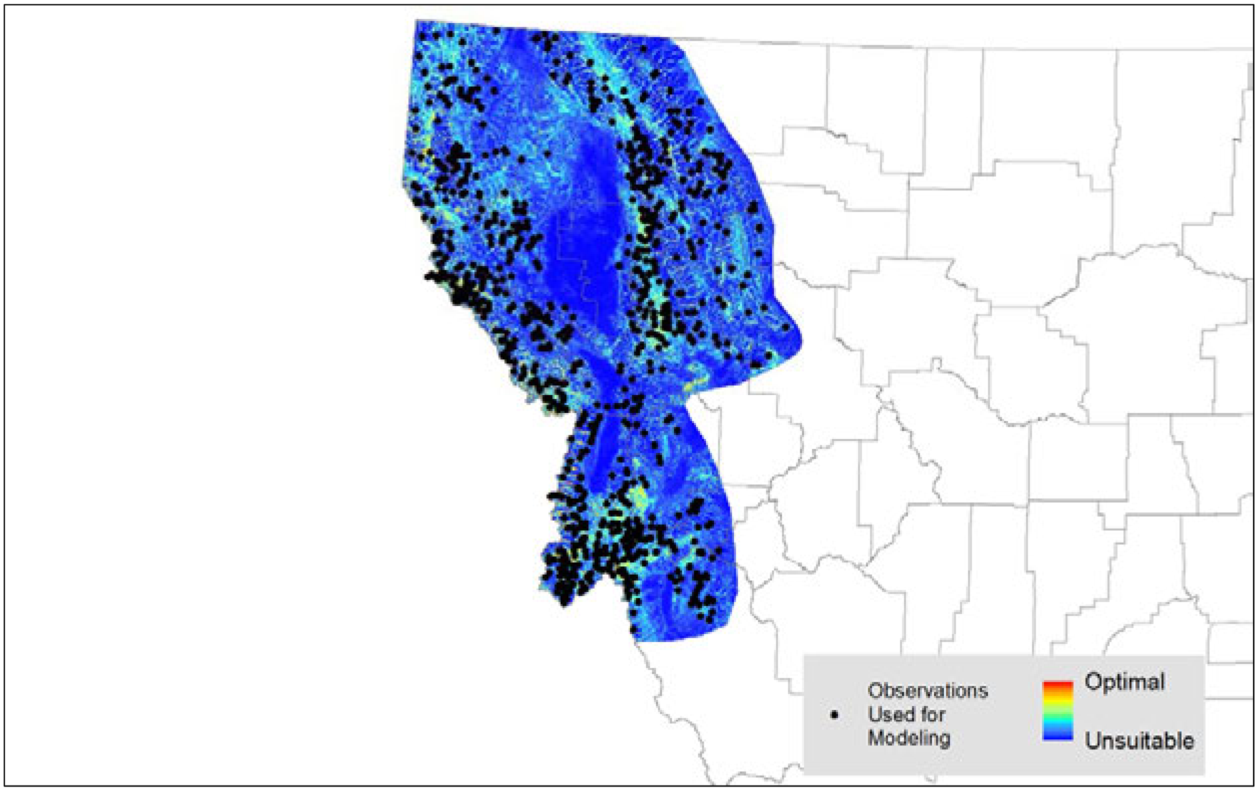


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

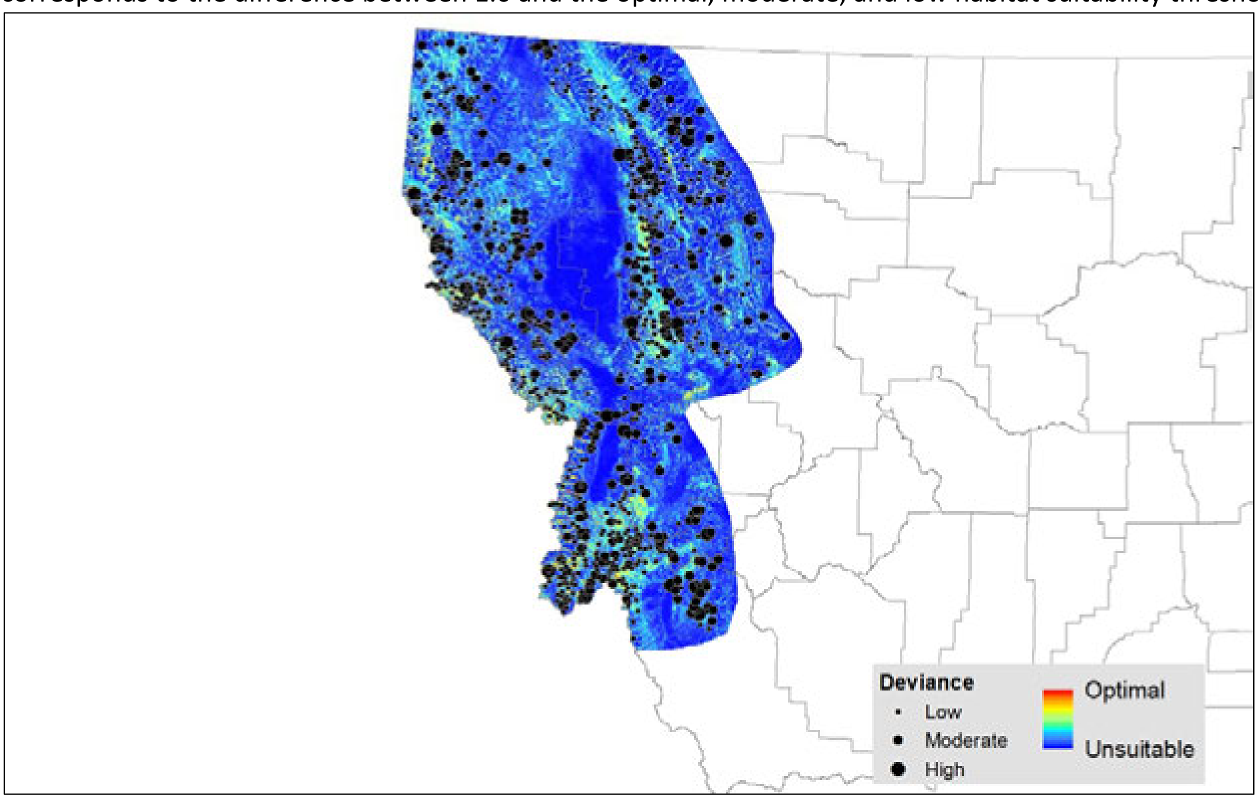


Figure 7. Continuous habitat suitability model output with all 2,324 observations (black) and survey locations that could have detected the species (gray).

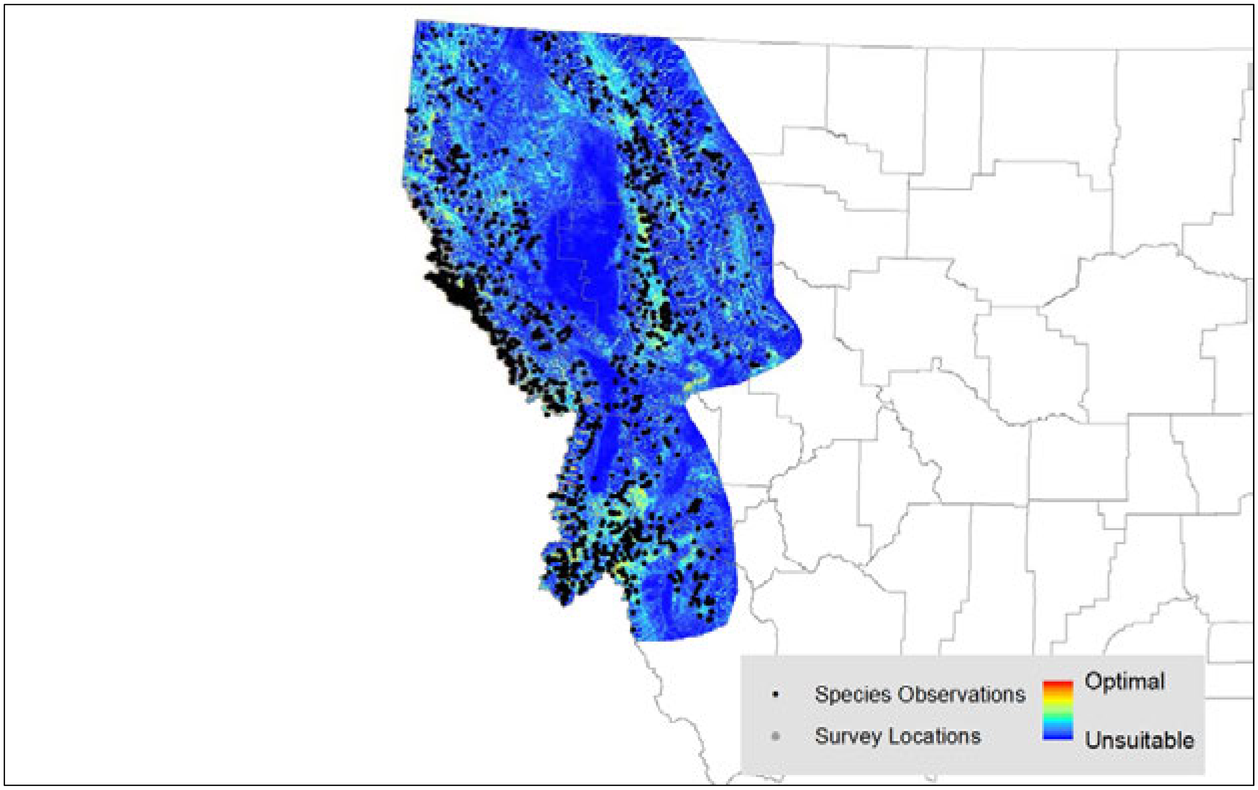


Figure 8. Model output classified into habitat suitability classes.

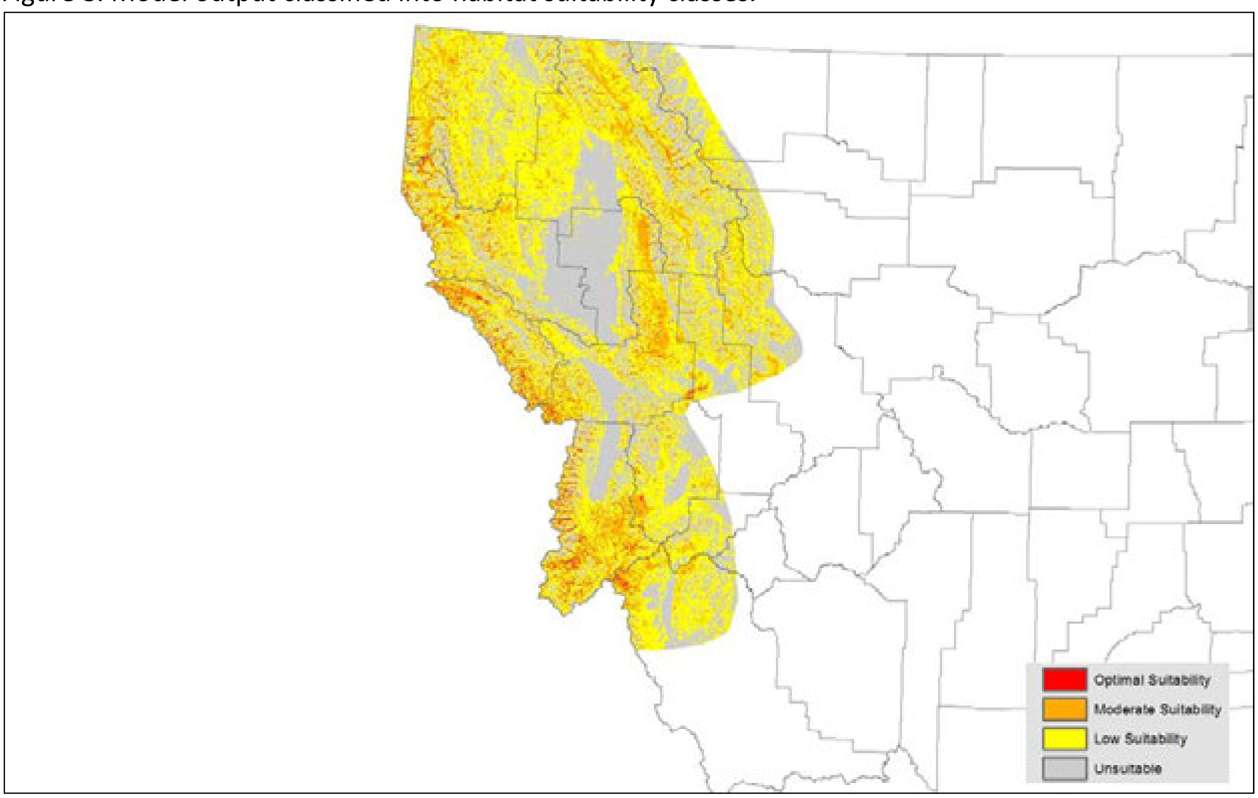
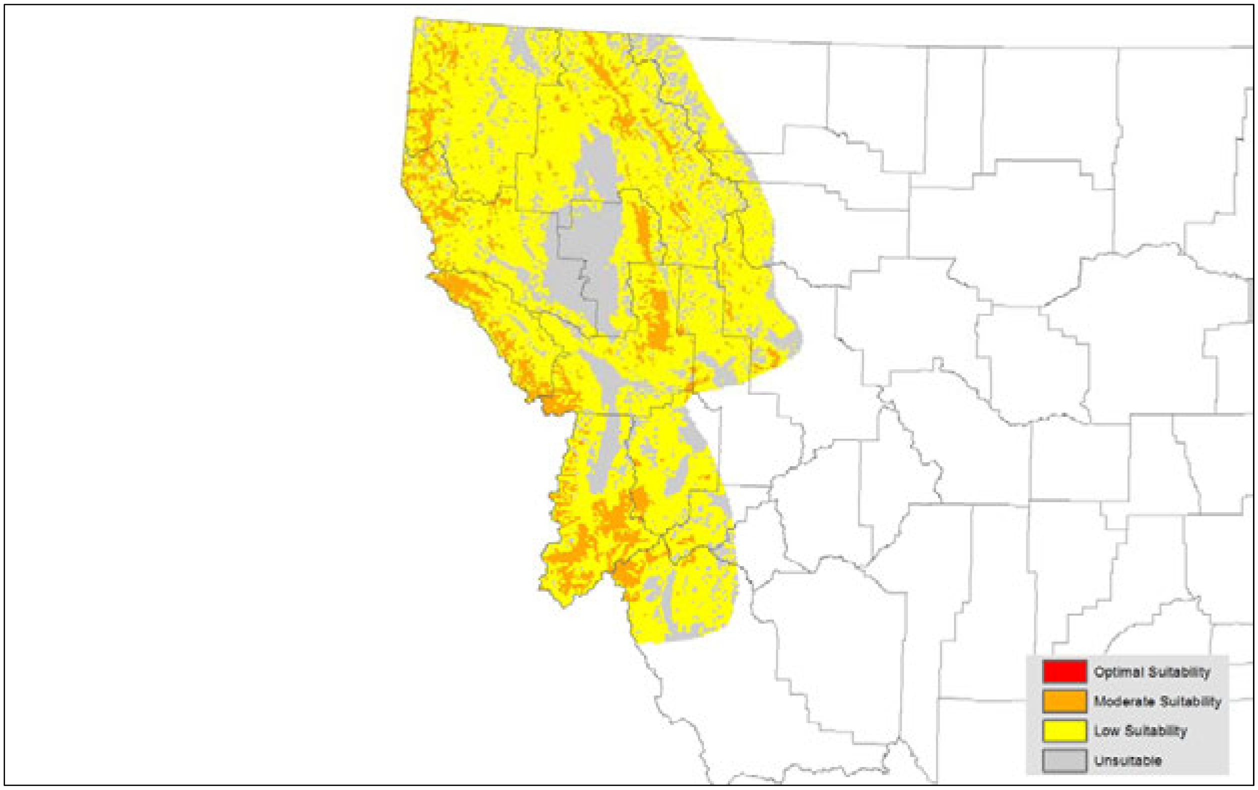


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Rocky Mountain Tailed Frog

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	182
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	128
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	102
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	70
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	35
Open Water	11	Common	14
Alpine-Montane Wet Meadow	9217	Common	11
Rocky Mountain Subalpine Deciduous Shrubland	5326	Common	8
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	2
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Rocky Mountain Lodgepole Pine Forest	4237	Occasional	62
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	7
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Occasional	7
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	3
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	2
Emergent Marsh	9222	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 822 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

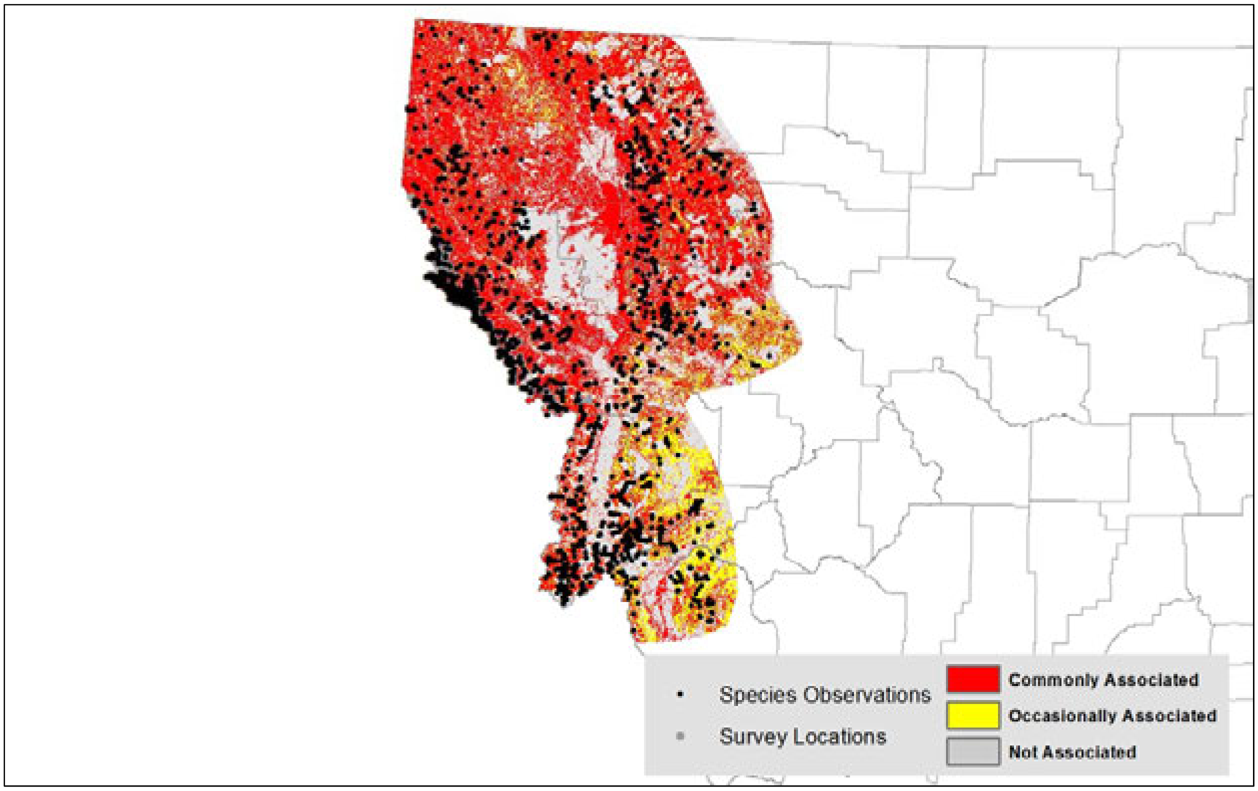
Measure	Value
Area of entire modeled range (percent of Montana)	70,513.9 km^2 (18.5%)
Area of Commonly and Occasionally Associated ES	44,863.0 km^2
Area of Commonly Associated ES	36,880.0 km^2
Area of Occasionally Associated ES	7,983.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	77.0%
Commonly Associated ES AVI[a]	67.2%
Occasionally Associated ES AVI[a]	9.8%

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

Figure 10. Deductive model output classified into habitat associations.



Western Toad (*Anaxyrus boreas*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S2 (Species of Concern)
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 3, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 3, 2017

Inductive Model Goal: To predict the distribution and relative suitability of summer breeding habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model appears to adequately reflect the distribution of Western Toad summer breeding habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics suggest a good model fit. The delineation of habitat suitability classes is well-supported by the data. However, note that because Western Toad is known to travel long distances from breeding sites, it is best to use this model output for identification of potential breeding sites and to use the deductive model output for broader landscape management needs.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with reasonably represent the amount of suitable habitat used by Western Toad adults and juveniles away from breeding sites across the species' known range in Montana.

Suggested Citation: Montana Natural Heritage Program. 2017. Western Toad (*Anaxyrus boreas*) predicted suitable habitat models created on October 03, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABB01030

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,543
Location Data Selection Rule 1	Records with <= 500 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,321
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	372
Season Modeled	Year-round
Number of Model Background Locations	22,416

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contslope	25.7%	conttmax	1.4%
contsumrad	18.8%	contddays	1.1%
catesys	14.1%	contelev	0.8%
catsoilord	9.5%	contnsasp	0.8%
contndvi	8.2%	contewasp	0.5%
catsoiltemp	6.8%	contwinrad	0.4%
contfrsted	4.5%	contprecip	0.3%
contwinpcp	3.4%	conttmin	0.2%
catgeol	1.8%	contvrm	0.1%
contstrmed	1.5%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.025
Moderate Logistic Threshold[b]	0.264
Optimal Logistic Threshold[c]	0.652
Area of entire modeled range (percent of Montana)	142,162.6 km^2 (37.4%)
Total area of predicted suitable habitat within modeled range	77,712.2 km^2
Area of predicted low suitability habitat within modeled range	57,831.2 km^2
Area of moderate suitability habitat within modeled range	17,252.7 km^2
Area of predicted optimal habitat within modeled range	2,628.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.

[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.

[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	96.0%
Moderate AVI[a]	77.4%
Optimal AVI[a]	35.6%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.985 ± 2.087
Training AUC[c]	0.909
Test AUC[d]	0.894

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.

[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 7.370, 2.662 and 0.857, respectively. Deviances for individual test locations are plotted in Figure 6.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

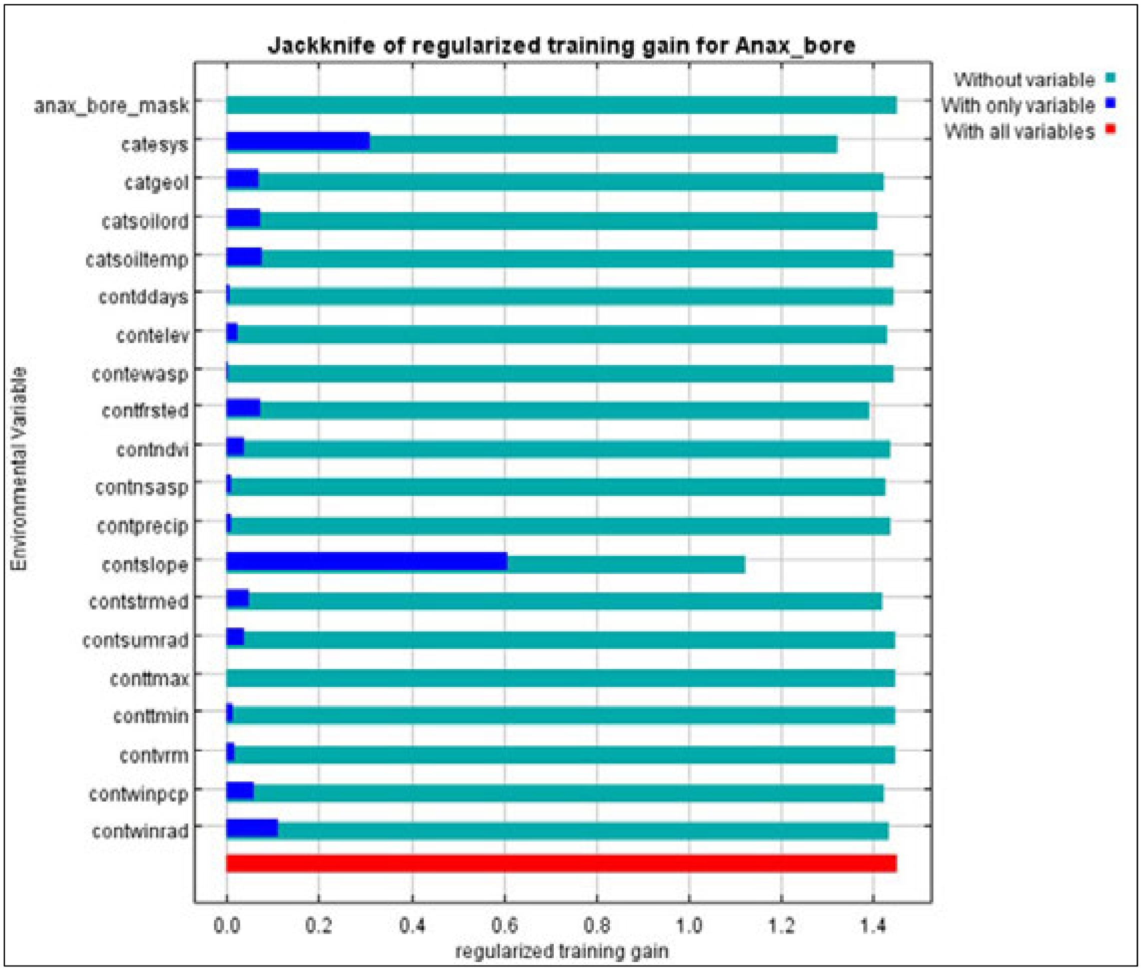


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

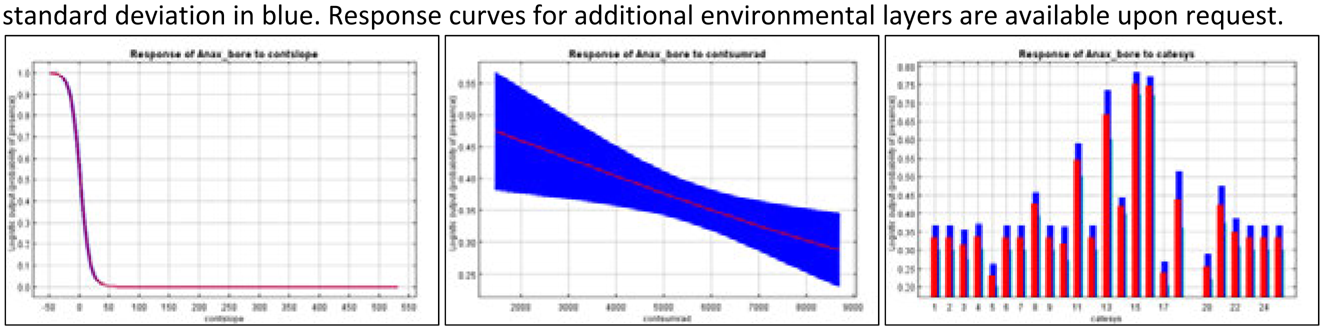


Figure 3. Continuous habitat suitability model output (logistic scale).

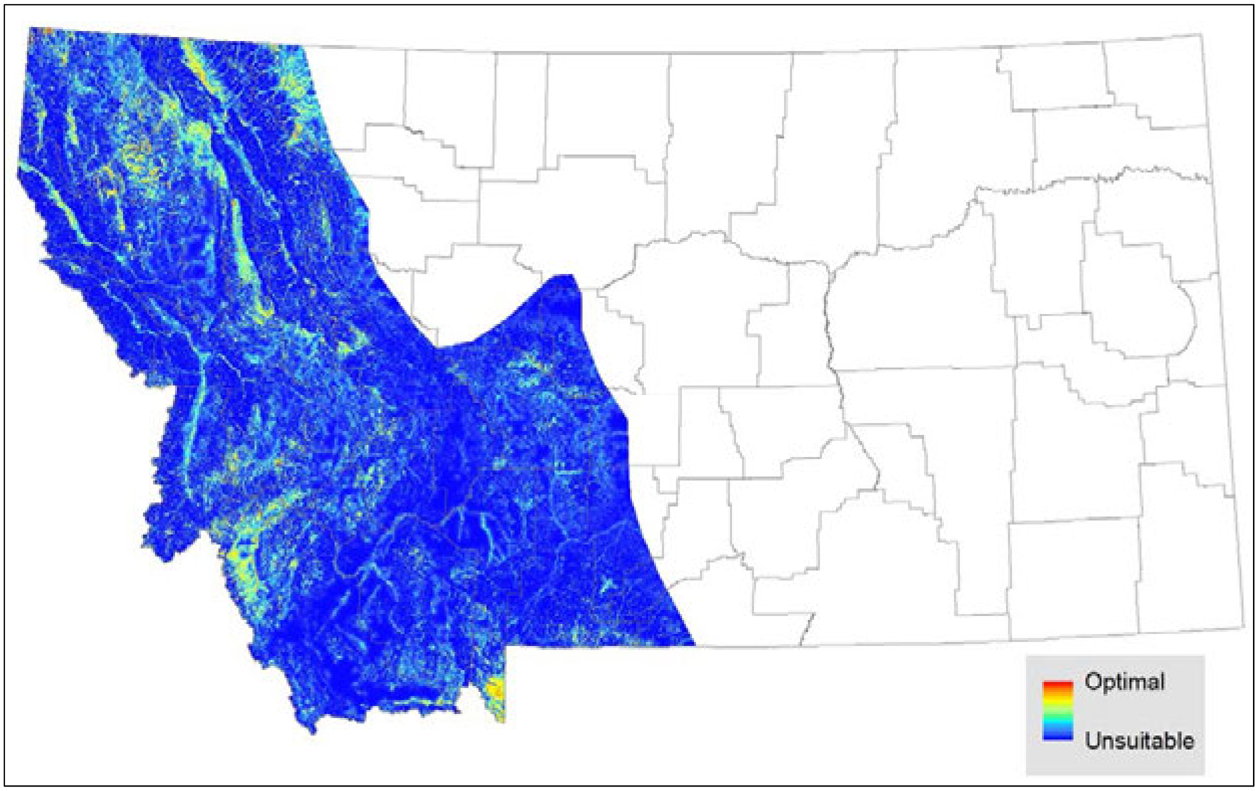


Figure 4. Standard deviation in the model output across the averaged models.

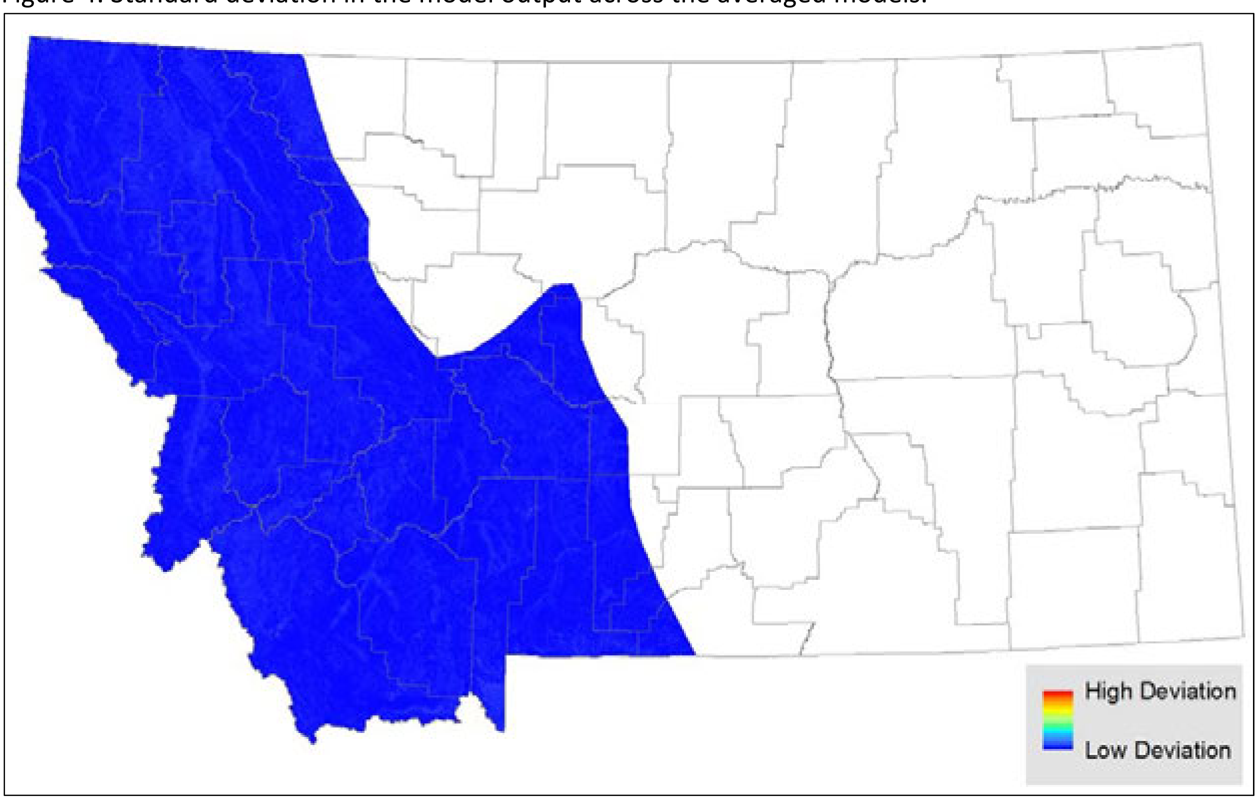


Figure 5. Continuous habitat suitability model output with the 372 observations used for modeling.

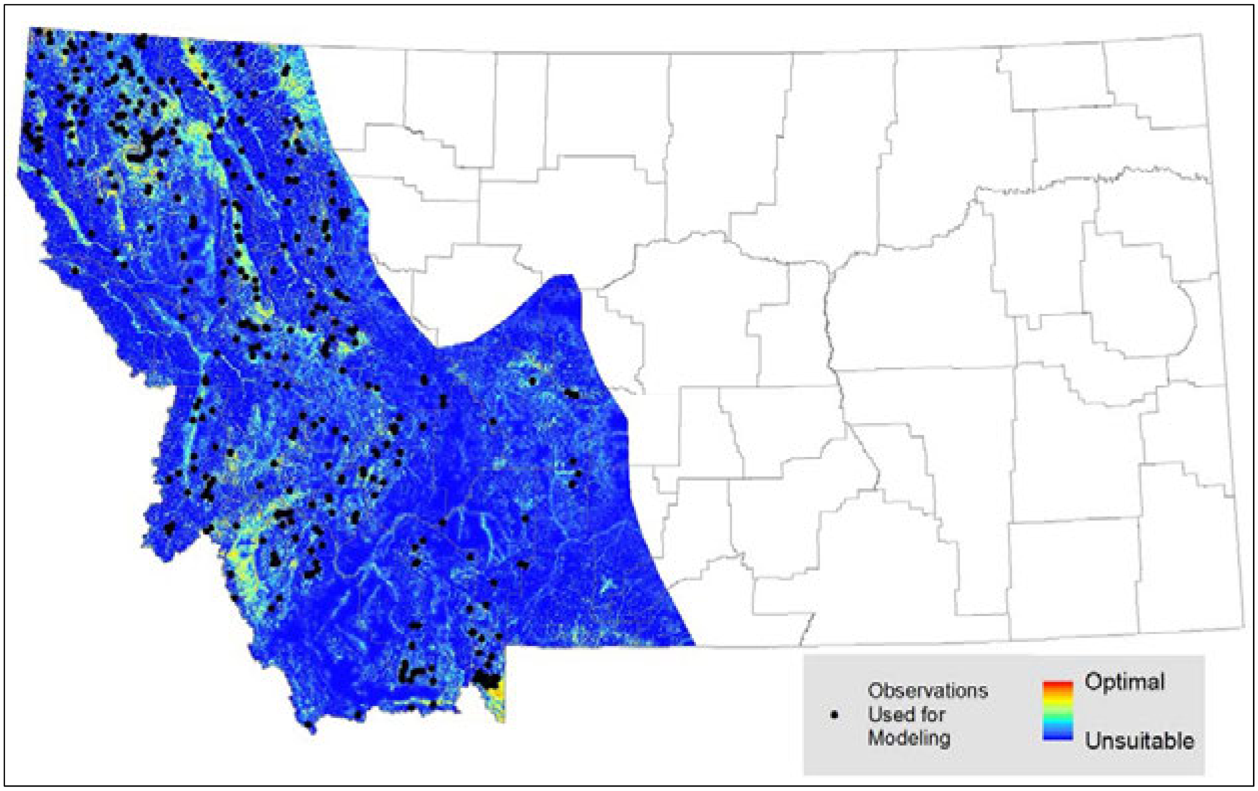


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

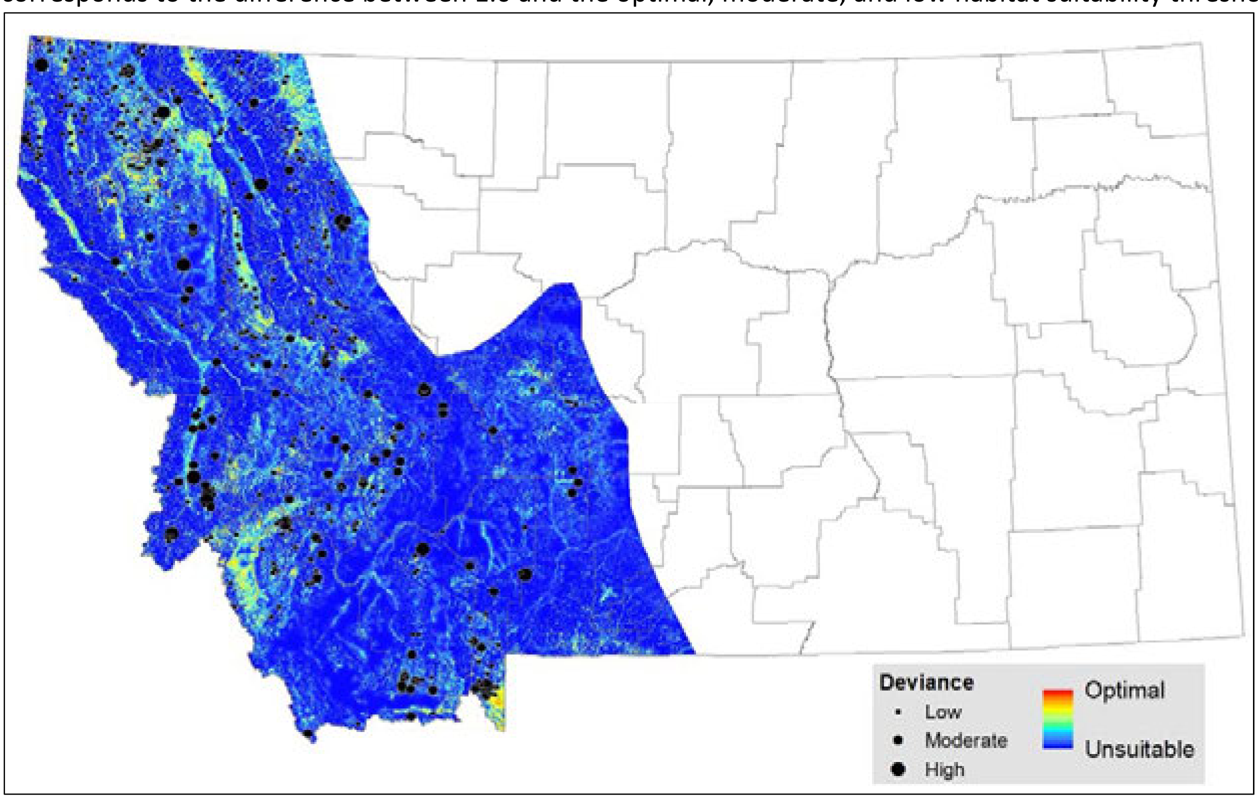


Figure 7. Continuous habitat suitability model output with all 2,543 observations (black) and survey locations that could have detected the species (gray).

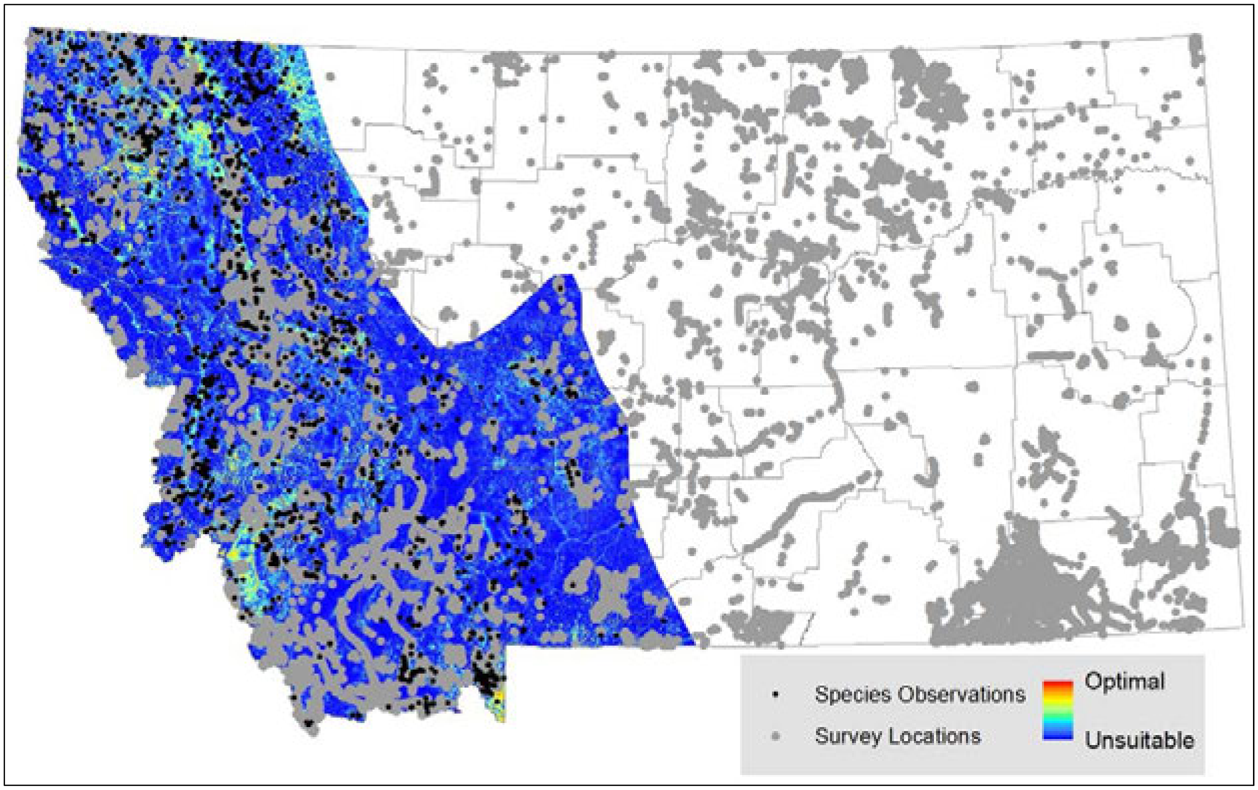


Figure 8. Model output classified into habitat suitability classes.

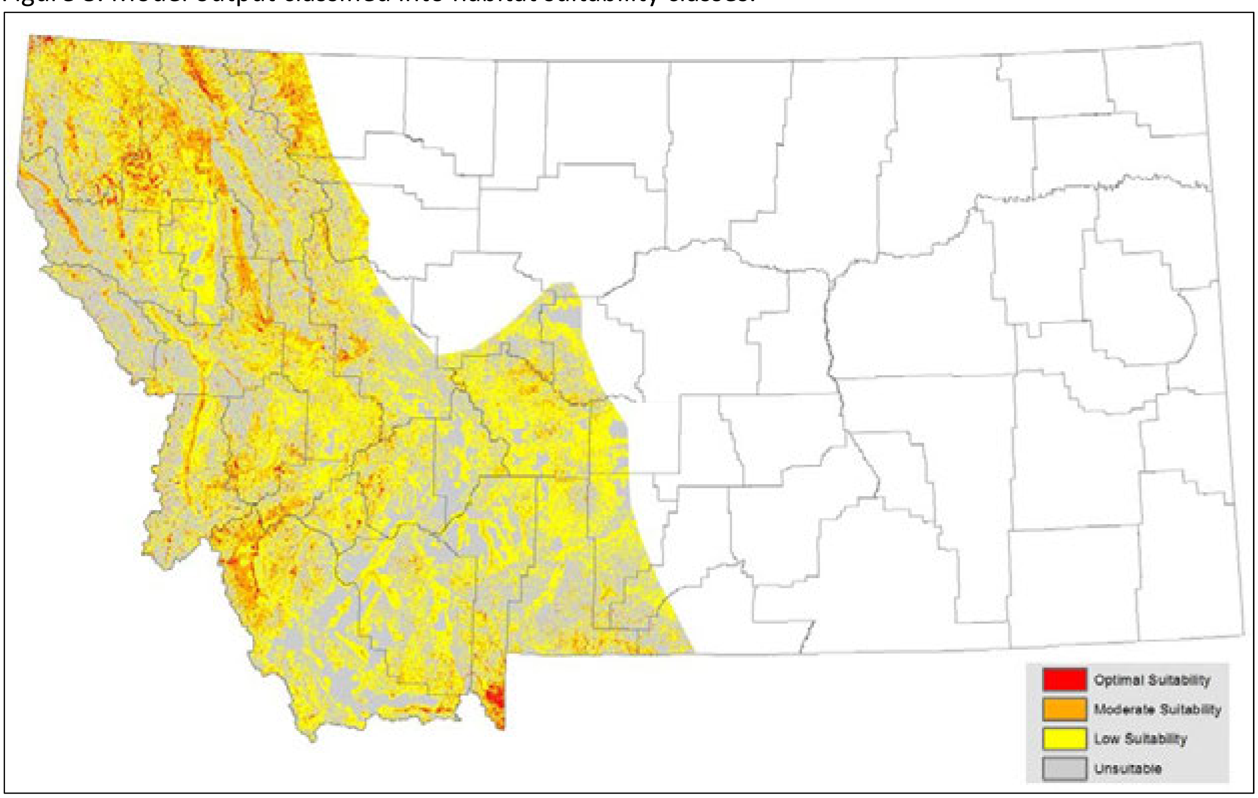
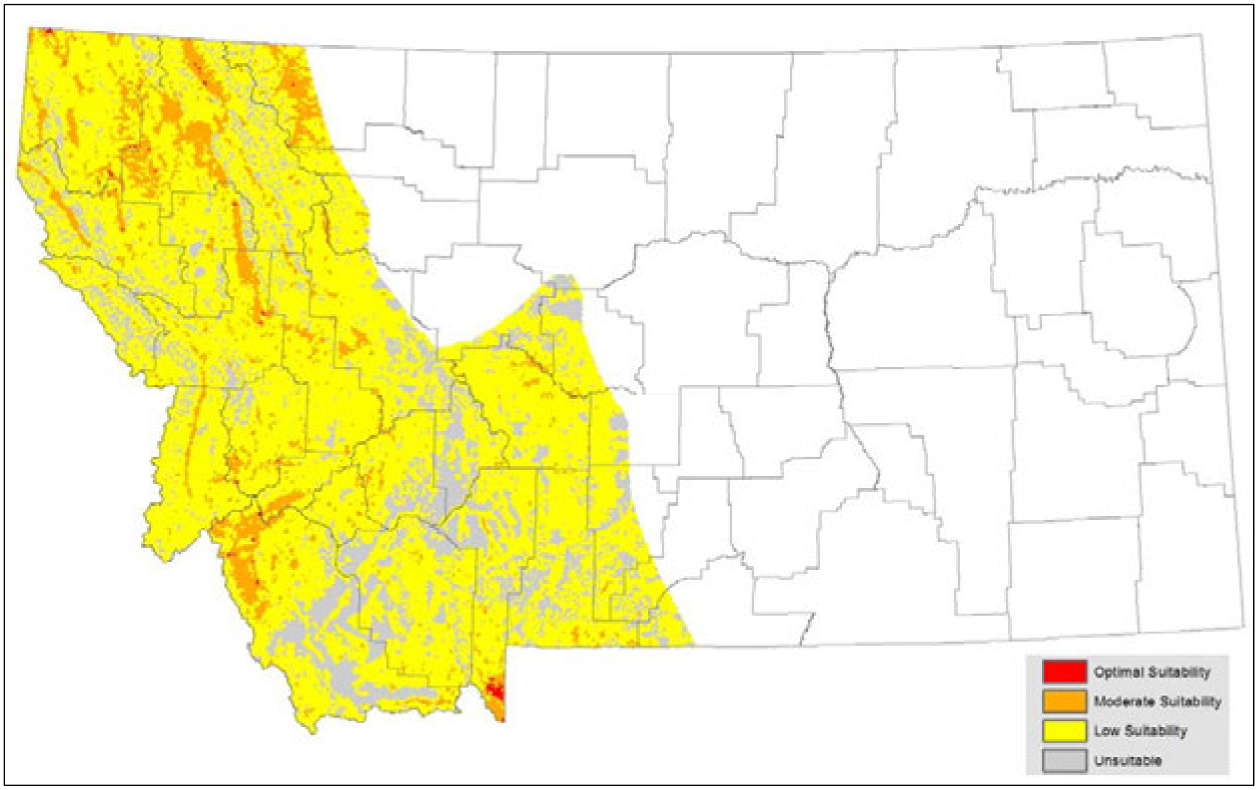


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Western Toad

Ecological System	Code	Association	Count[a]
Open Water	11	Common	40
Alpine-Montane Wet Meadow	9217	Common	39
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	38
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	29
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	27
Rocky Mountain Lodgepole Pine Forest	4237	Common	21
Montane Sagebrush Steppe	5455	Common	14
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	14
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	12
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	11
Recently burned forest	8501	Common	8
Insect-Killed Forest	8700	Common	8
Post-Fire Recovery	8505	Common	6
Harvested forest-tree regeneration	8601	Common	6
Rocky Mountain Subalpine Deciduous Shrubland	5326	Common	5
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	5
Aspen Forest and Woodland	4104	Common	3
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	3
Emergent Marsh	9222	Common	3
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	2
Aspen and Mixed Conifer Forest	4302	Common	2
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	2
Harvested forest-grass regeneration	8603	Common	2
Rocky Mountain Wooded Vernal Pool	9162	Common	1
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	1
Rocky Mountain Subalpine-Montane Fen	9234	Common	1
Quarries, Strip Mines and Gravel Pits	31	Common	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Common	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Common	0
Harvested forest-shrub regeneration	8602	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Occasional	31
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	6
Low Intensity Residential	22	Occasional	4
Developed, Open Space	21	Occasional	3
Pasture/Hay	81	Occasional	1
Mountain Mahogany Woodland and Shrubland	4303	Occasional	1
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Occasional	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Occasional	0

Table 5: Ecological Systems Associated with Western Toad

Ecological System	Code	Association	Count[a]
Recently burned shrubland	8503	Occasional	0
Burned Sagebrush	8504	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 372 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

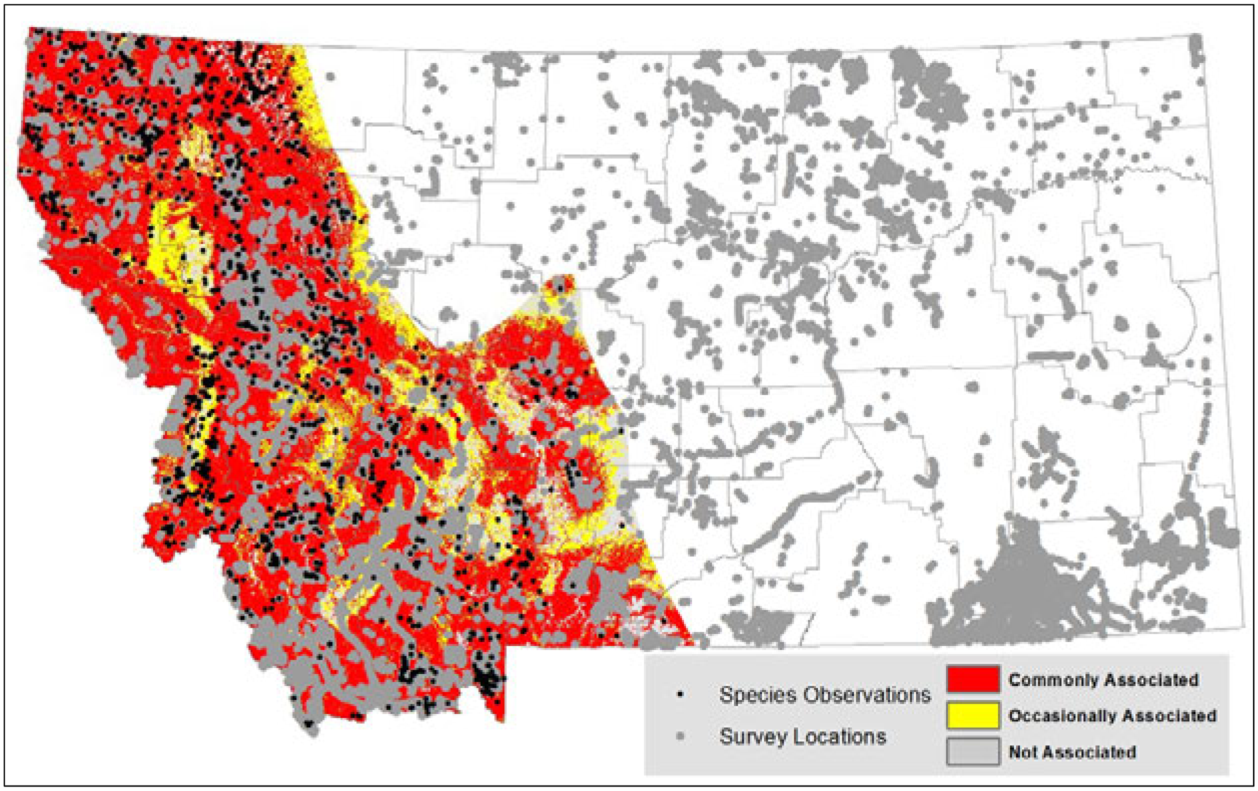
Measure	Value
Area of entire modeled range (percent of Montana)	142,162.6 km^2 (37.4%)
Area of Commonly and Occasionally Associated ES	124,408.0 km^2
Area of Commonly Associated ES	102,240.0 km^2
Area of Occasionally Associated ES	22,168.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	93.8%
Commonly Associated ES AVI[a]	81.5%
Occasionally Associated ES AVI[a]	12.4%

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

Figure 10. Deductive model output classified into habitat associations.



Boreal Chorus Frog (*Pseudacris maculata*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 3, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 3, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of representing the distribution of Boreal Chorus Frog general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate the model fit is good and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do a good job of representing the amount of suitable habitat for Boreal Chorus Frog across the species' known range in Montana, but should be used in conjunction with the inductive model output to identify areas of higher and lower suitability within those general systems.

Suggested Citation: Montana Natural Heritage Program. 2017. Boreal Chorus Frog (*Pseudacris maculata*) predicted suitable habitat models created on October 03, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABC05130

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	5,642
Location Data Selection Rule 1	Records with <= 500 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	4,735
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	2,140
Season Modeled	Year-round
Number of Model Background Locations	47,405

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	45.2%	contelev	1.1%
contslope	11.9%	contnsasp	0.8%
contsumrad	10.0%	contddays	0.6%
catsoiltemp	9.4%	contndvi	0.6%
catsoilord	7.8%	contewasp	0.4%
catgeol	5.7%	contfrsted	0.3%
conttmin	1.8%	contwinrad	0.1%
conttmax	1.5%	contprecip	0.1%
contwinpcp	1.5%	contvrm	0.0%
contstrmed	1.2%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.086
Moderate Logistic Threshold[b]	0.431
Optimal Logistic Threshold[c]	0.851
Area of entire modeled range (percent of Montana)	300,652.1 km^2 (79.0%)
Total area of predicted suitable habitat within modeled range	264,099.2 km^2
Area of predicted low suitability habitat within modeled range	179,099.5 km^2
Area of moderate suitability habitat within modeled range	84,020.9 km^2
Area of predicted optimal habitat within modeled range	978.8 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	99.3%
Moderate AVI[a]	67.8%
Optimal AVI[a]	4.5%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.516 ± 0.927
Training AUC[c]	0.778
Test AUC[d]	0.772

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.909, 1.684 and 0.323, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

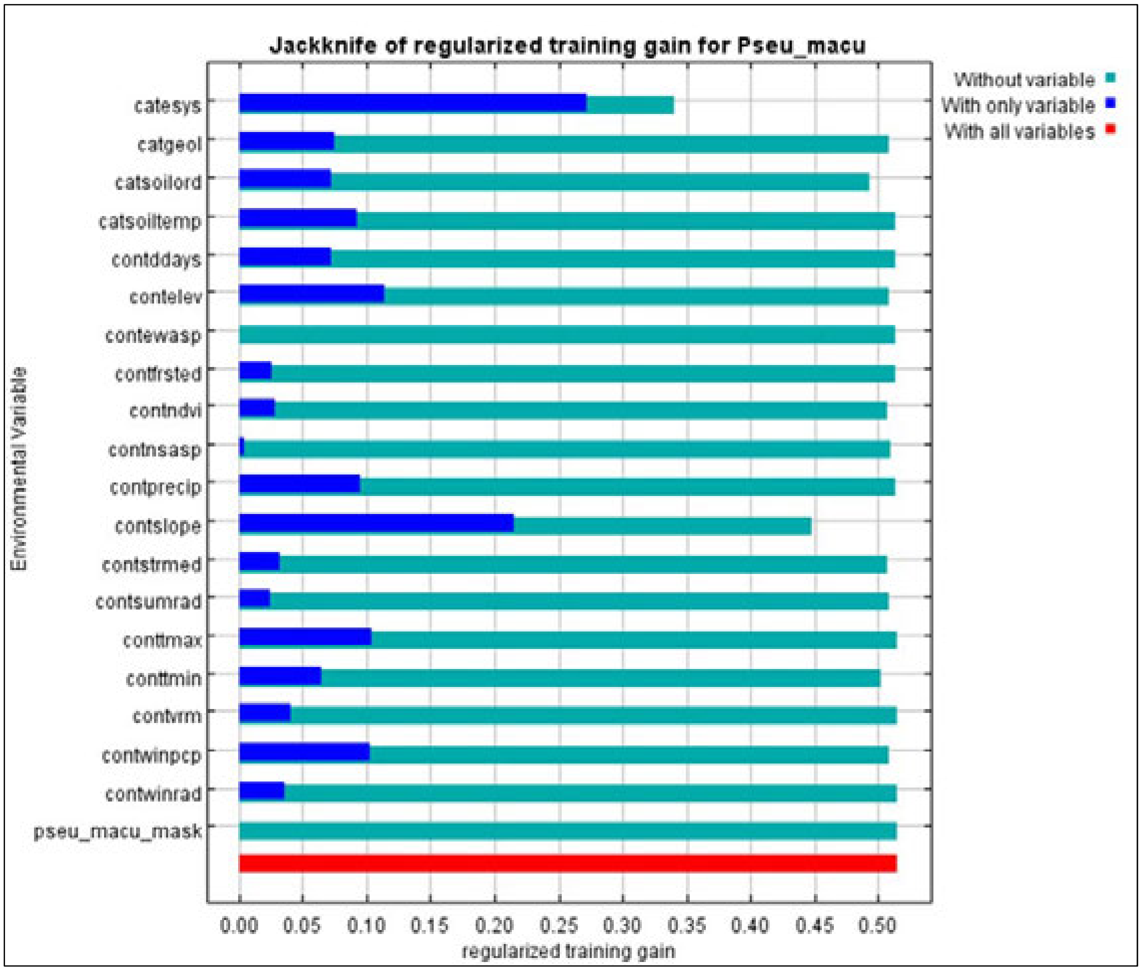


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

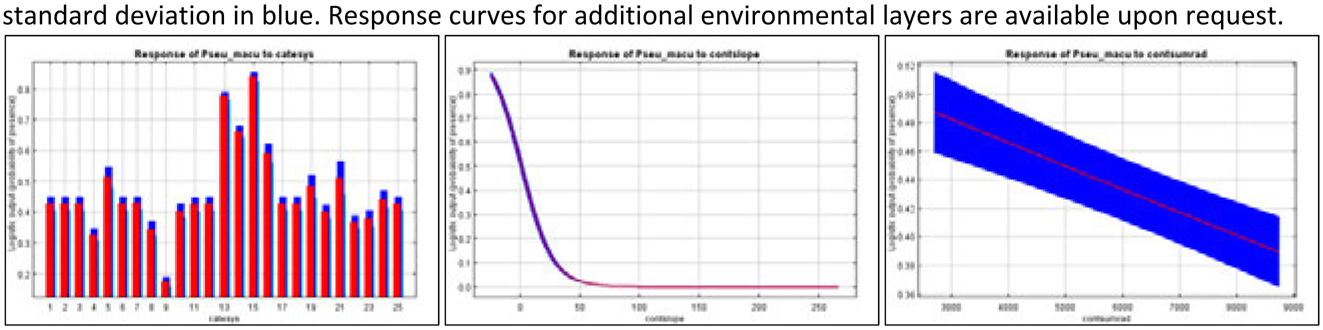


Figure 3. Continuous habitat suitability model output (logistic scale).

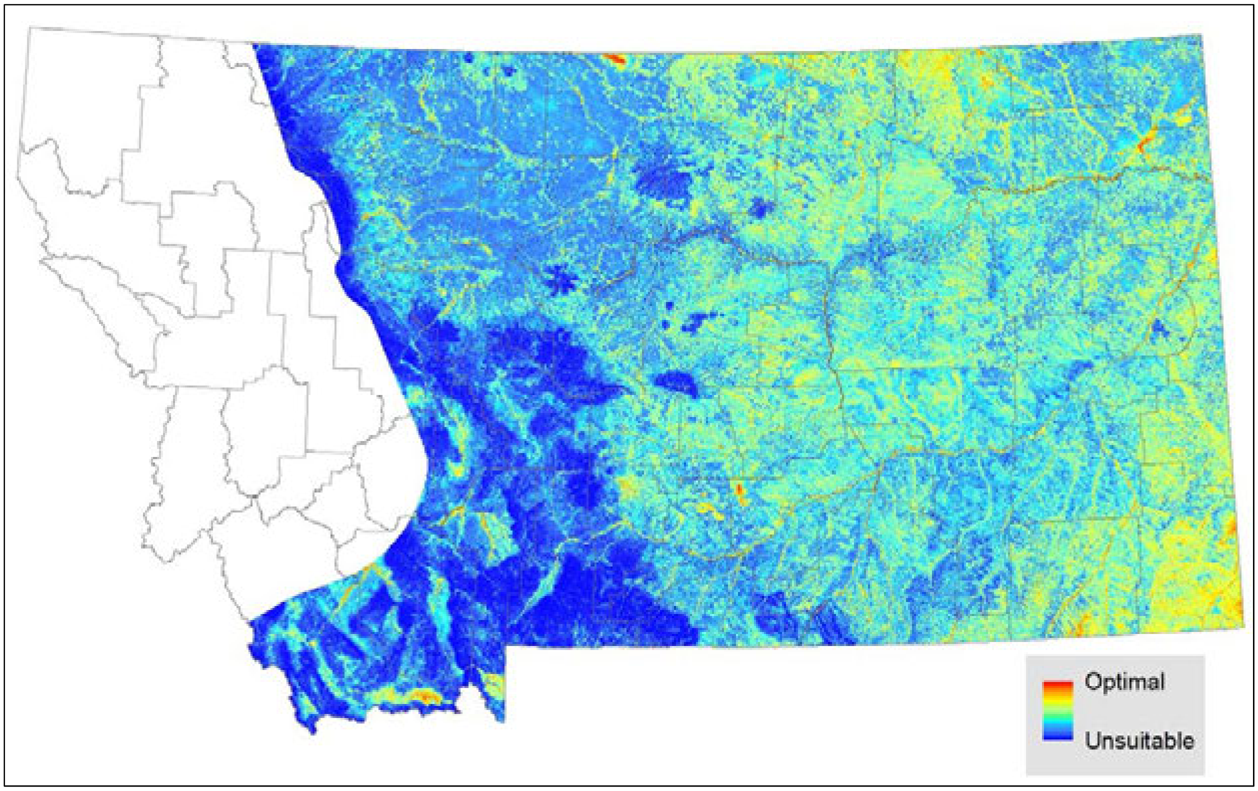


Figure 4. Standard deviation in the model output across the averaged models.

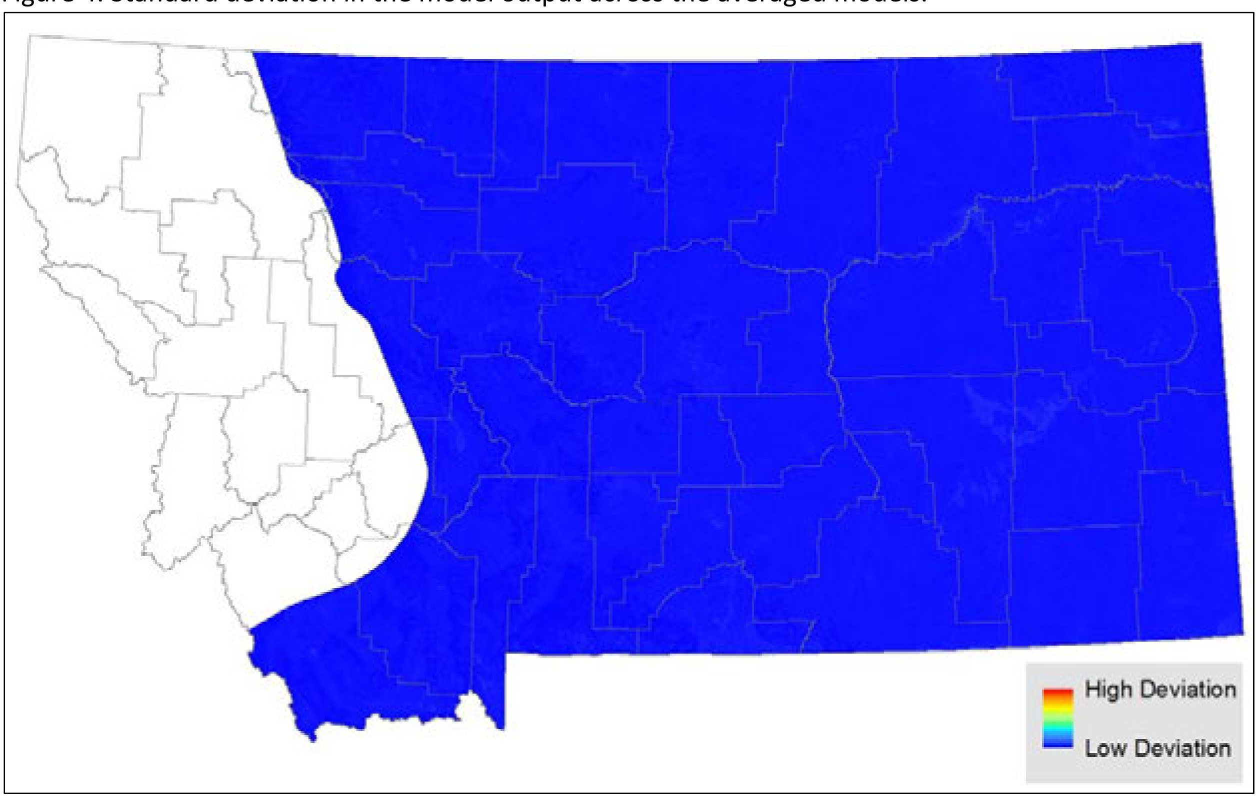


Figure 5. Continuous habitat suitability model output with the 2,140 observations used for modeling.

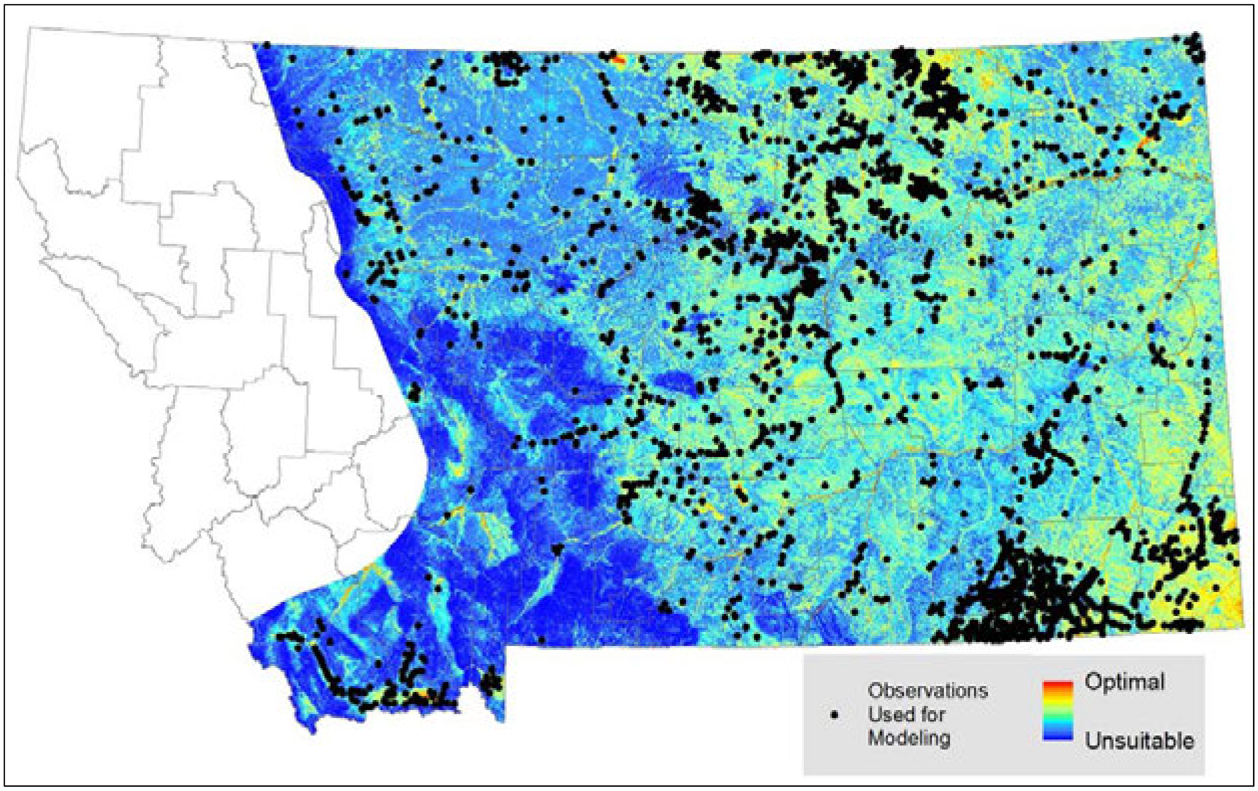


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

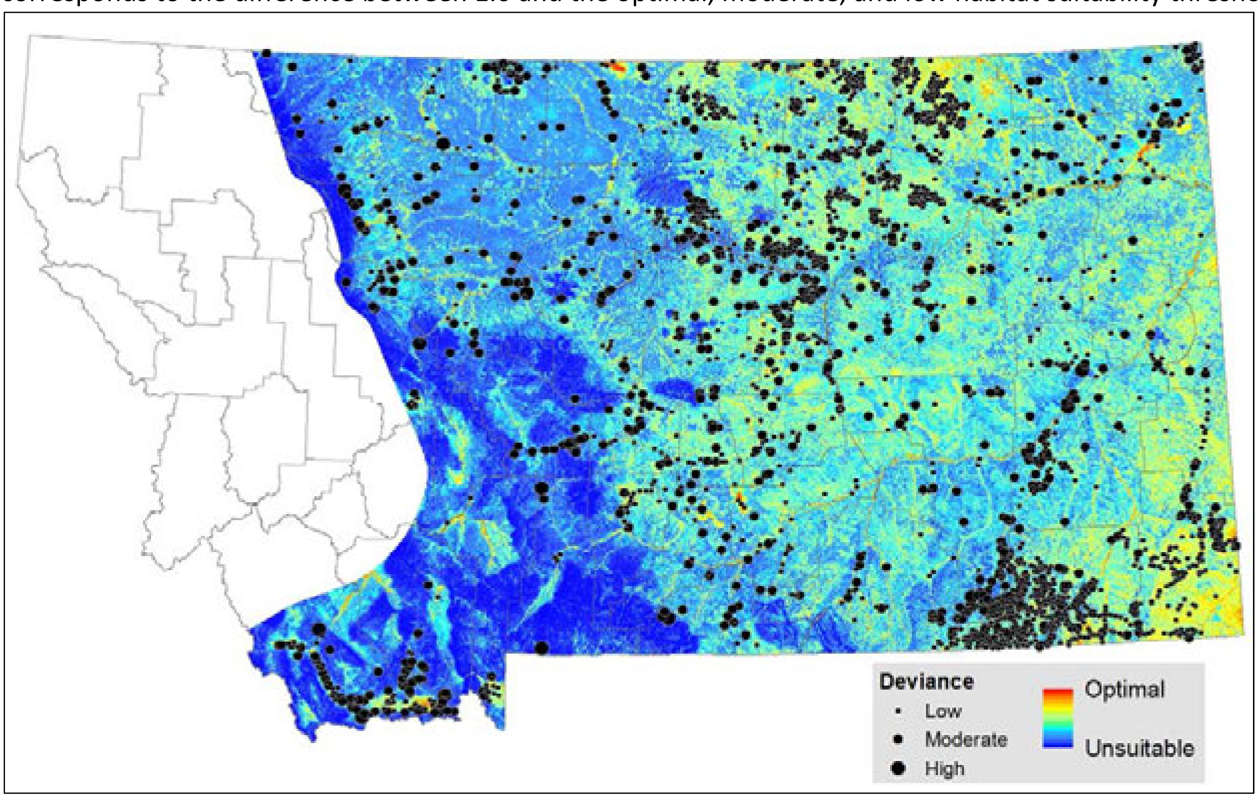


Figure 7. Continuous habitat suitability model output with all 5,642 observations (black) and survey locations that could have detected the species (gray).

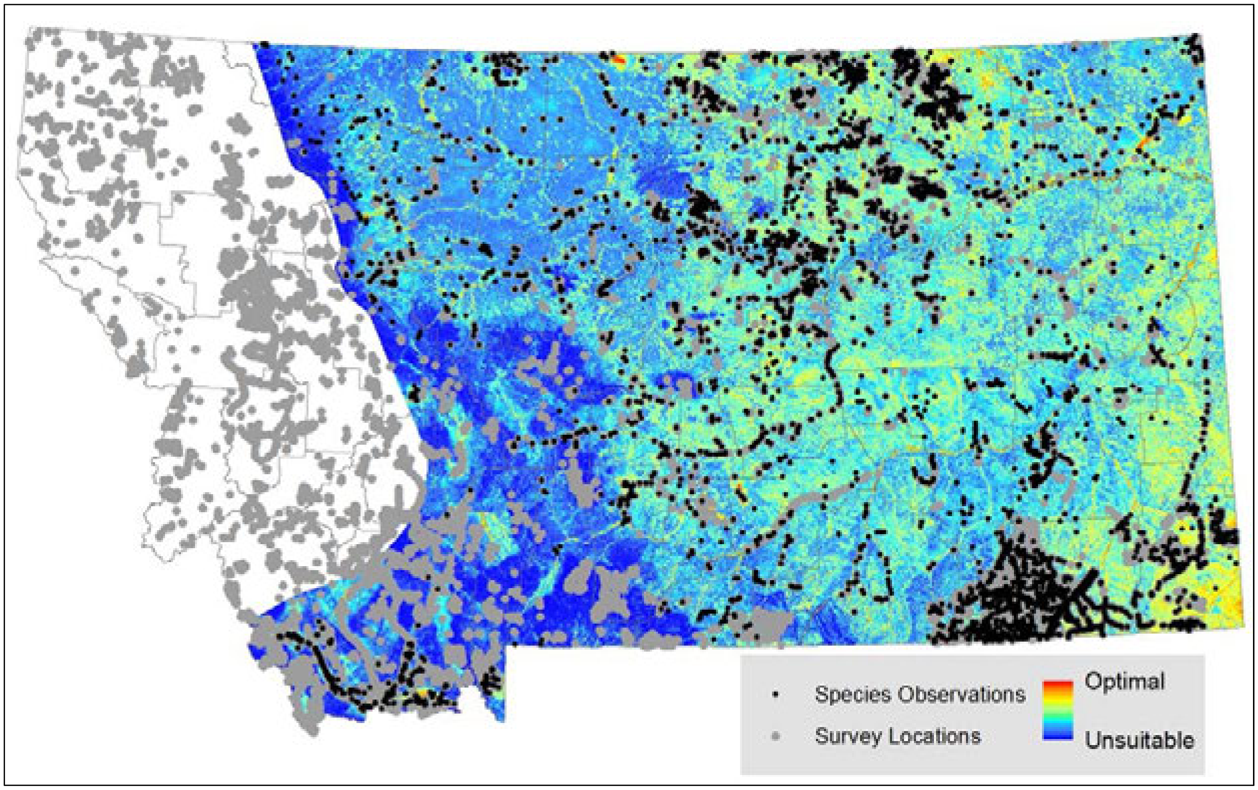


Figure 8. Model output classified into habitat suitability classes.

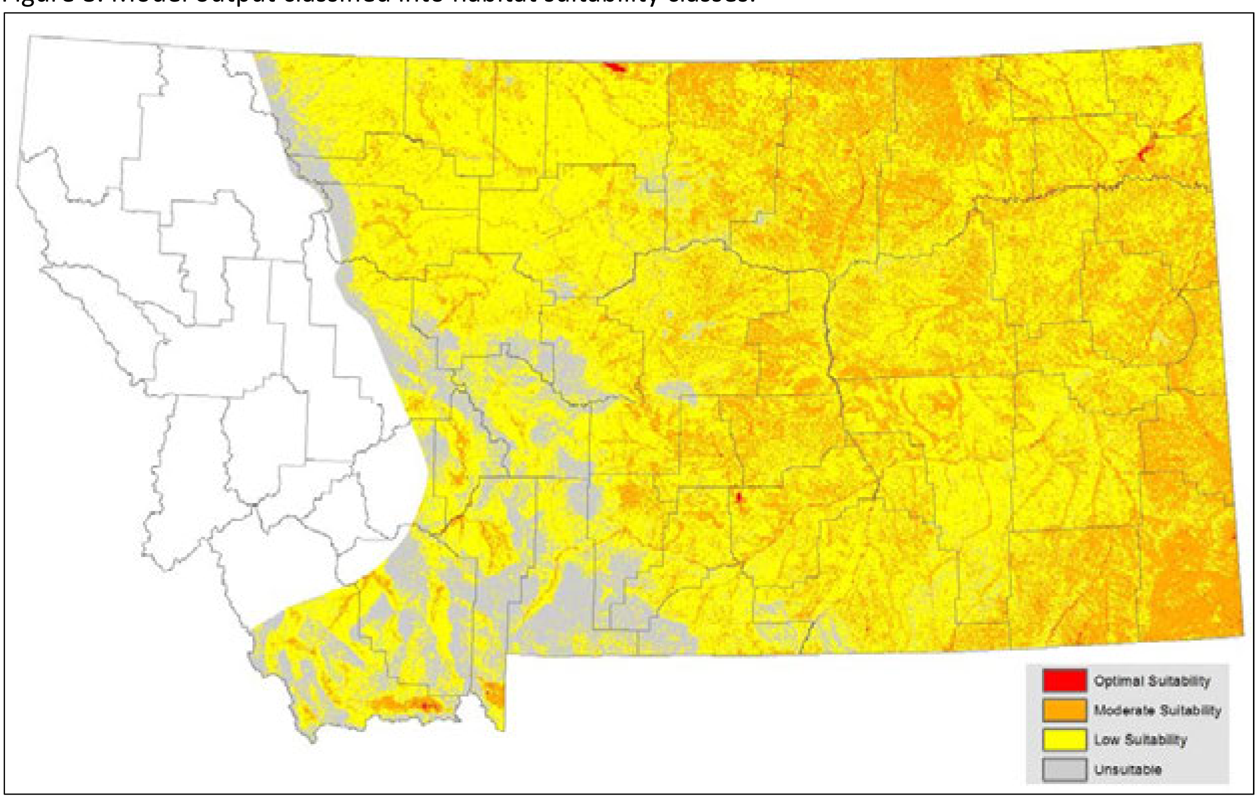
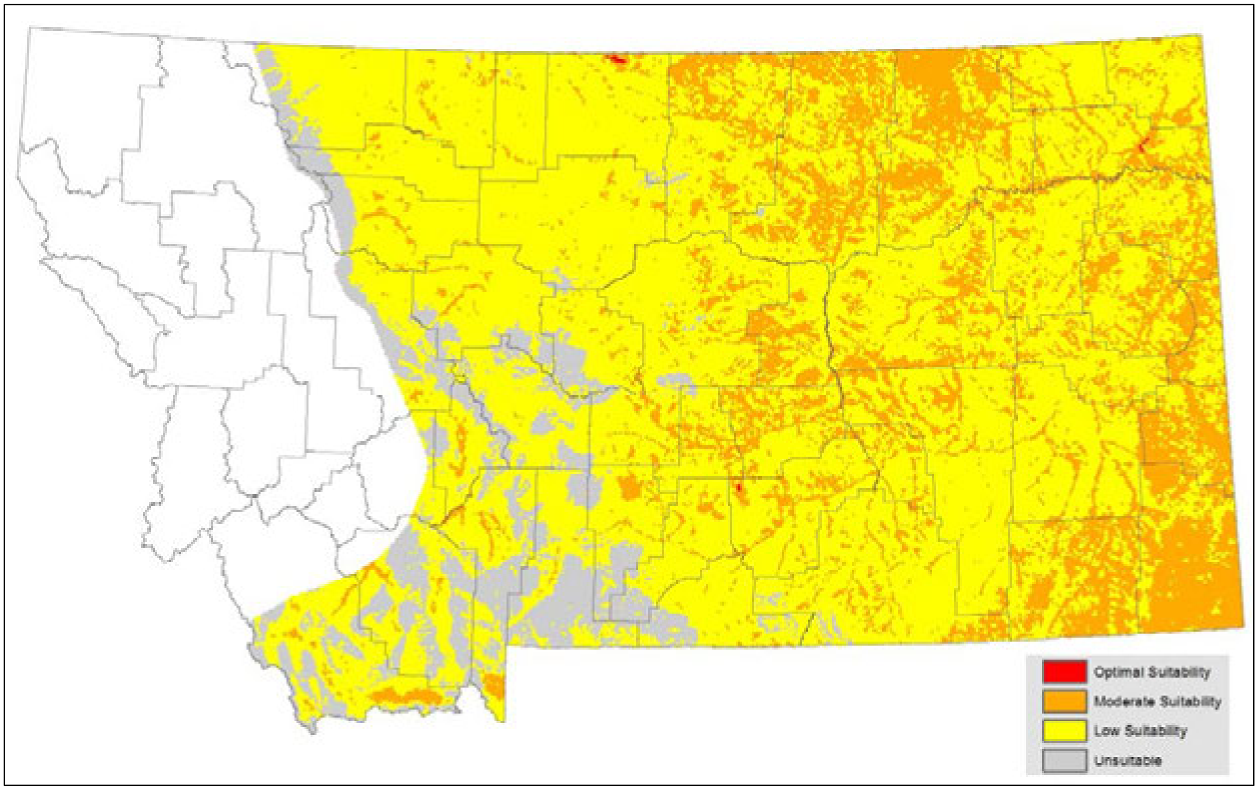


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Boreal Chorus Frog

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	561
Big Sagebrush Steppe	5454	Common	255
Great Plains Riparian	9326	Common	206
Open Water	11	Common	137
Great Plains Badlands	3114	Common	52
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Common	46
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	40
Great Plains Floodplain	9159	Common	40
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	31
Montane Sagebrush Steppe	5455	Common	27
Great Plains Saline Depression Wetland	9256	Common	26
Great Plains Sand Prairie	7121	Common	23
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	23
Recently burned grassland	8502	Common	22
Great Plains Prairie Pothole	9203	Common	20
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	19
Emergent Marsh	9222	Common	19
Greasewood Flat	9103	Common	18
Pasture/Hay	81	Common	16
Great Plains Wooded Draw and Ravine	4328	Common	15
Recently burned forest	8501	Common	15
Alpine-Montane Wet Meadow	9217	Common	15
Mat Saltbush Shrubland	5203	Common	12
Great Plains Shrubland	5262	Common	11
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	9
Post-Fire Recovery	8505	Common	9
Great Plains Closed Depressional Wetland	9252	Common	9
Developed, Open Space	21	Common	5
Great Plains Open Freshwater Depression Wetland	9218	Common	5
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Common	4
Cultivated Crops	82	Occasional	86
Low Intensity Residential	22	Occasional	8
Recently burned shrubland	8503	Occasional	8
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	4
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Occasional	3
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Occasional	2
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	2
High Intensity Residential	23	Occasional	1
Aspen Forest and Woodland	4104	Occasional	1
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Occasional	1

Table 5: Ecological Systems Associated with Boreal Chorus Frog

Ecological System	Code	Association	Count[a]
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Occasional	1
Rocky Mountain Lodgepole Pine Forest	4237	Occasional	1
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	1
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	1
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	1
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	1
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Mountain Mahogany Woodland and Shrubland	4303	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Alpine Turf	7117	Occasional	0
Rocky Mountain Wooded Vernal Pool	9162	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 2,140 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

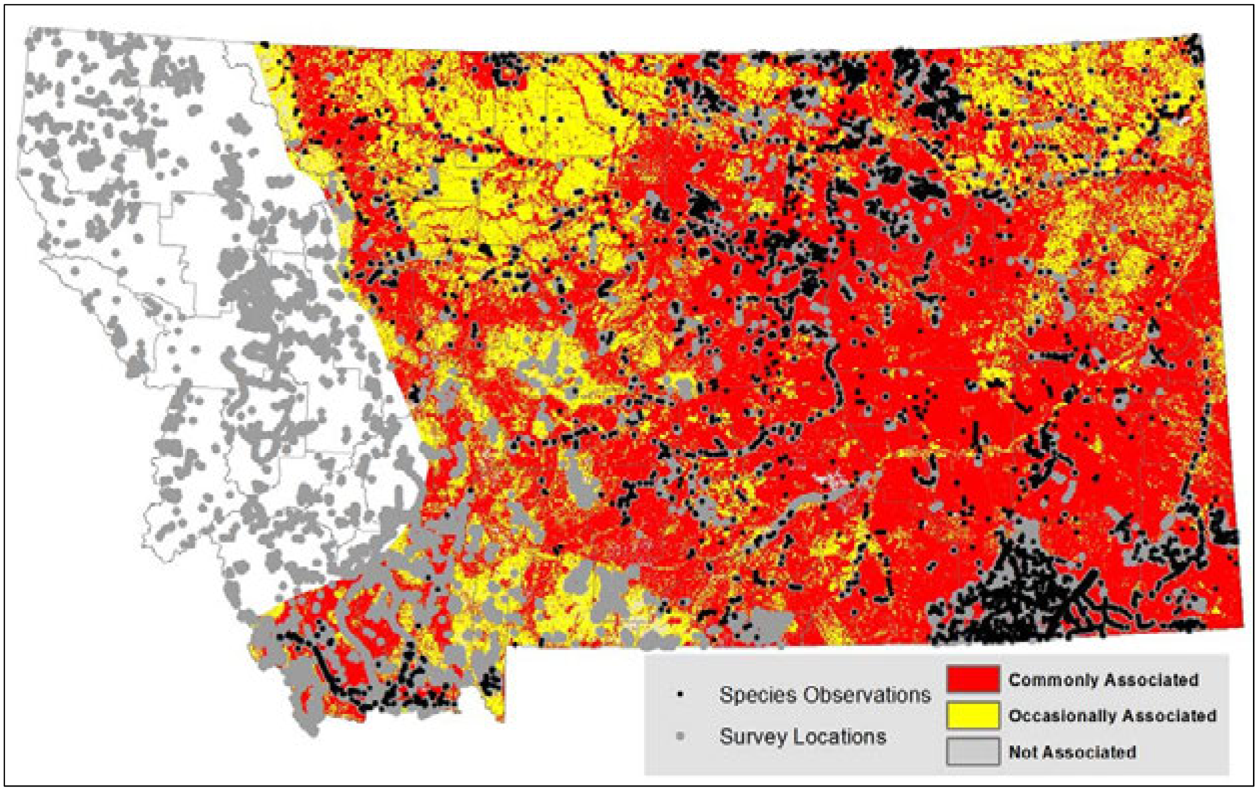
Measure	Value
Area of entire modeled range (percent of Montana)	300,652.1 km^2 (79.0%)
Area of Commonly and Occasionally Associated ES	291,087.0 km^2
Area of Commonly Associated ES	206,563.0 km^2
Area of Occasionally Associated ES	84,524.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	84.7%
Commonly Associated ES AVI[a]	79.0%
Occasionally Associated ES AVI[a]	5.7%

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

Figure 10. Deductive model output classified into habitat associations.



Plains Spadefoot (*Spea bombifrons*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3 (Species of Concern)
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 8, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 8, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Plains Spadefoot general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with somewhat overpredict the amount of suitable habitat for Plains Spadefoot across the species' known range in Montana so this product should be used in conjunction with the inductive model output for guiding management actions.

Suggested Citation: Montana Natural Heritage Program. 2017. Plains Spadefoot (*Spea bombifrons*) predicted suitable habitat models created on October 08, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABF02010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	820
Location Data Selection Rule 1	Records with <= 1200 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	678
Location Data Selection Rule 2	No overlap in locations within 3200 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	284
Season Modeled	Year-round
Number of Model Background Locations	47,221

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoilord	22.6%	contstrmed	1.2%
catesys	16.7%	conttmin	1.2%
conttmax	15.8%	contndvi	0.8%
catsoiltemp	15.7%	contfrsted	0.8%
contslope	6.6%	contewasp	0.6%
contsumrad	6.6%	contnsasp	0.5%
catgeol	5.1%	contwinrad	0.1%
contddays	3.1%	contvrm	0.0%
contelev	1.3%	contprecip	0.0%
contwinpcp	1.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.062
Moderate Logistic Threshold[b]	0.352
Optimal Logistic Threshold[c]	0.761
Area of entire modeled range (percent of Montana)	299,483.8 km^2 (78.7%)
Total area of predicted suitable habitat within modeled range	198,140.1 km^2
Area of predicted low suitability habitat within modeled range	131,623.7 km^2
Area of moderate suitability habitat within modeled range	63,119.8 km^2
Area of predicted optimal habitat within modeled range	3,396.6 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.

[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.

[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	96.1%
Moderate AVI[a]	71.8%
Optimal AVI[a]	20.4%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.692 ± 1.534
Training AUC[c]	0.864
Test AUC[d]	0.839

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.

[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 5.558, 2.088 and 0.545, respectively. Deviances for individual test locations are plotted in Figure 6.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

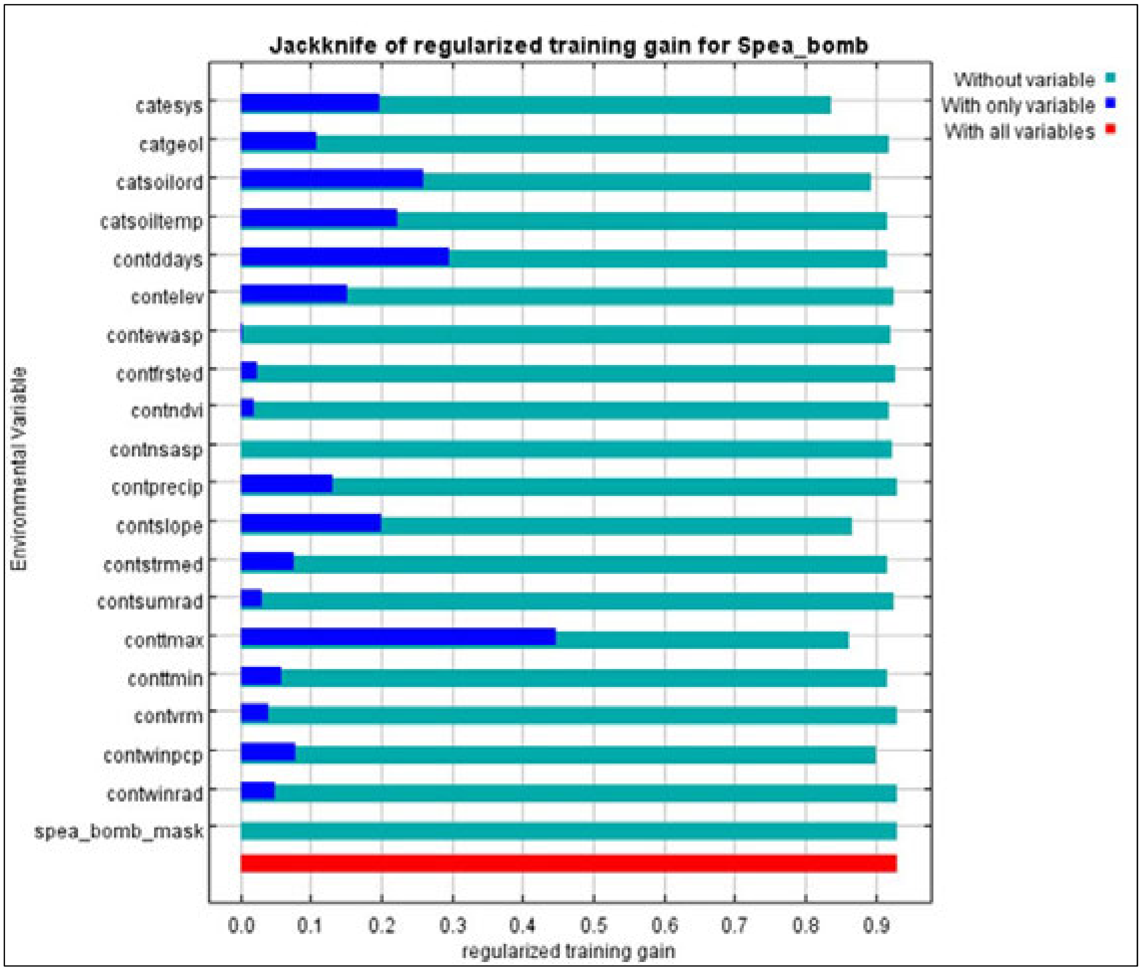
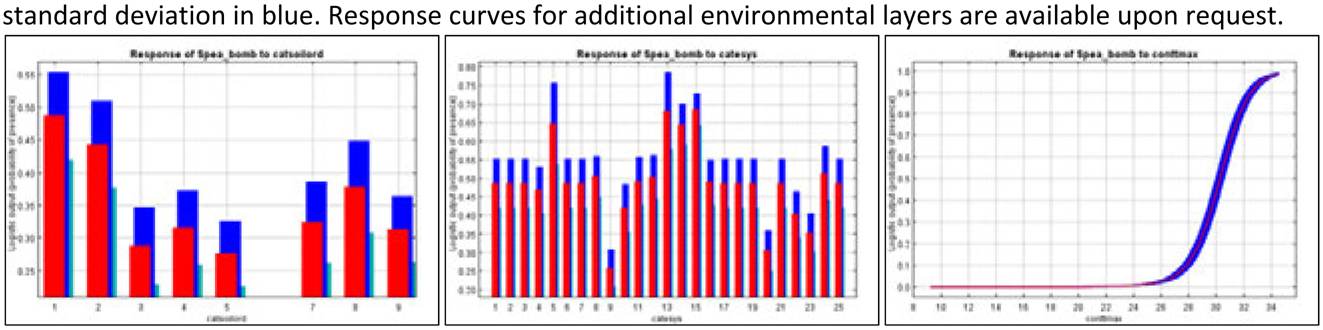


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

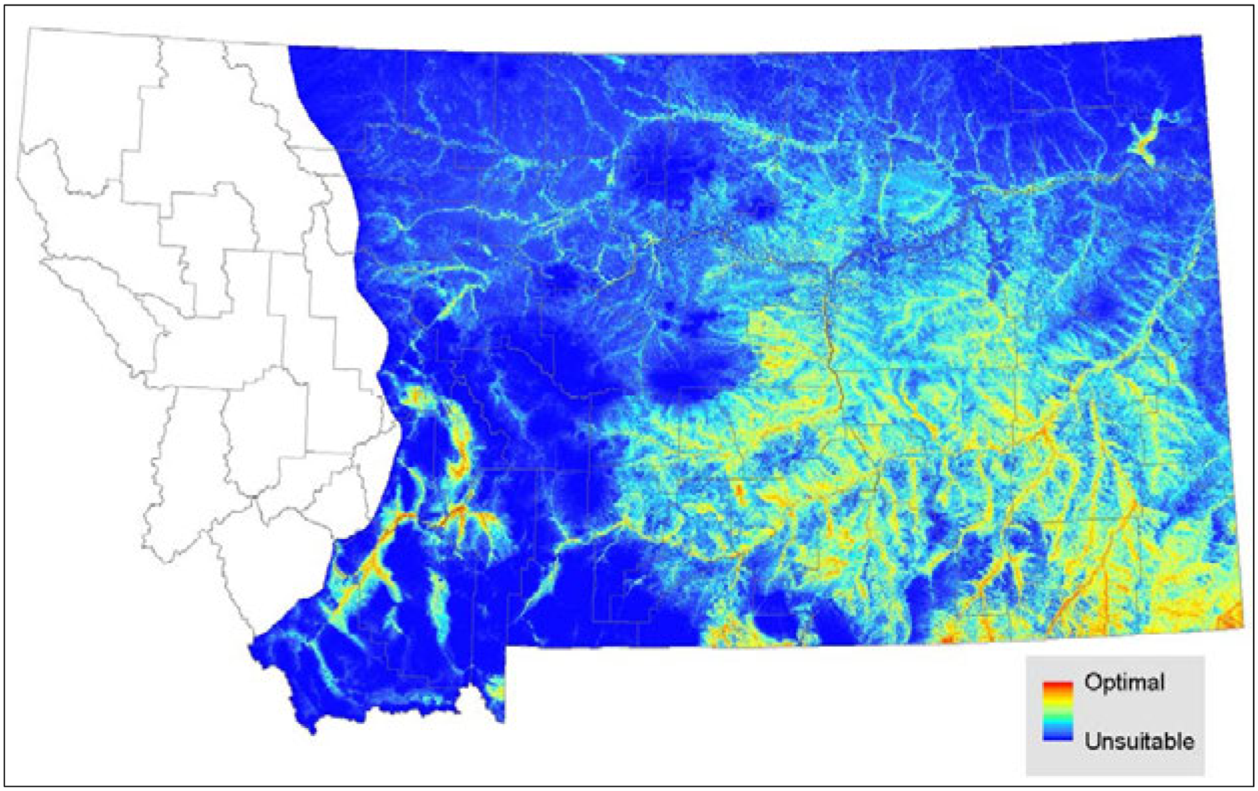


Figure 4. Standard deviation in the model output across the averaged models.

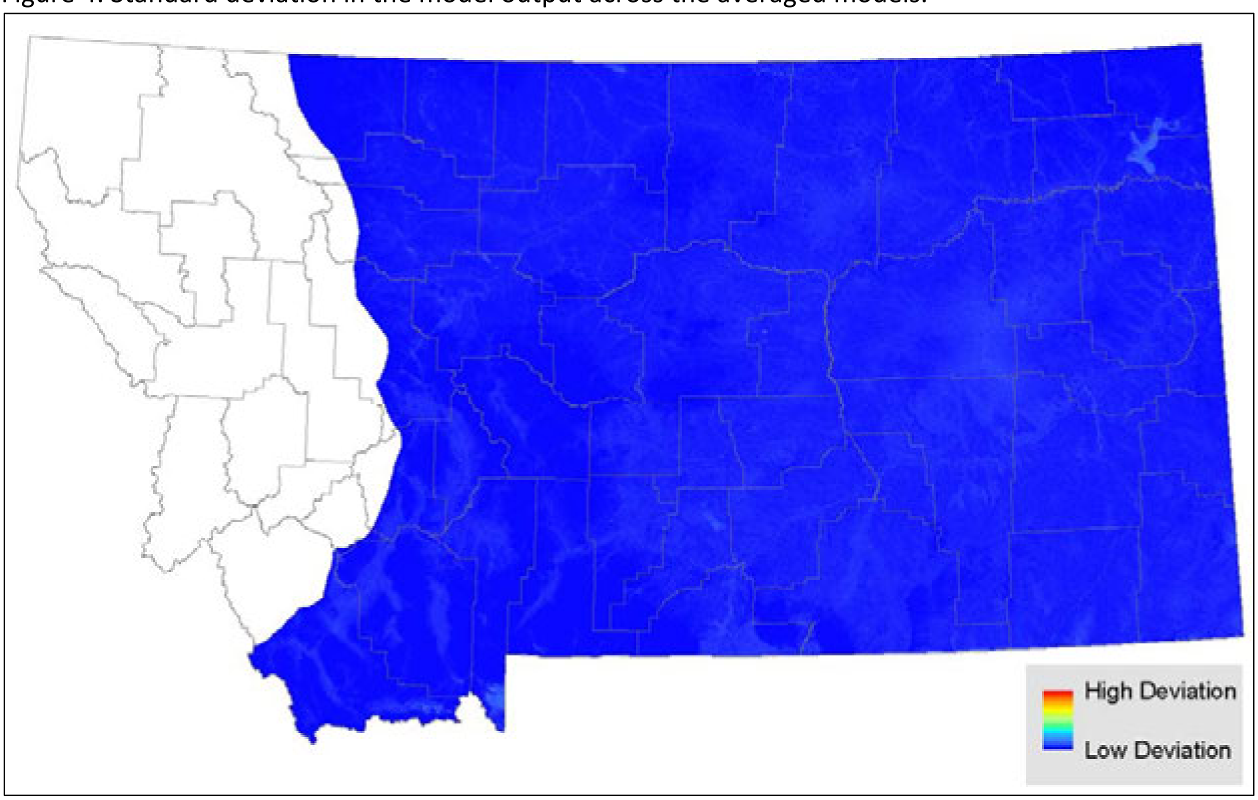


Figure 5. Continuous habitat suitability model output with the 284 observations used for modeling.

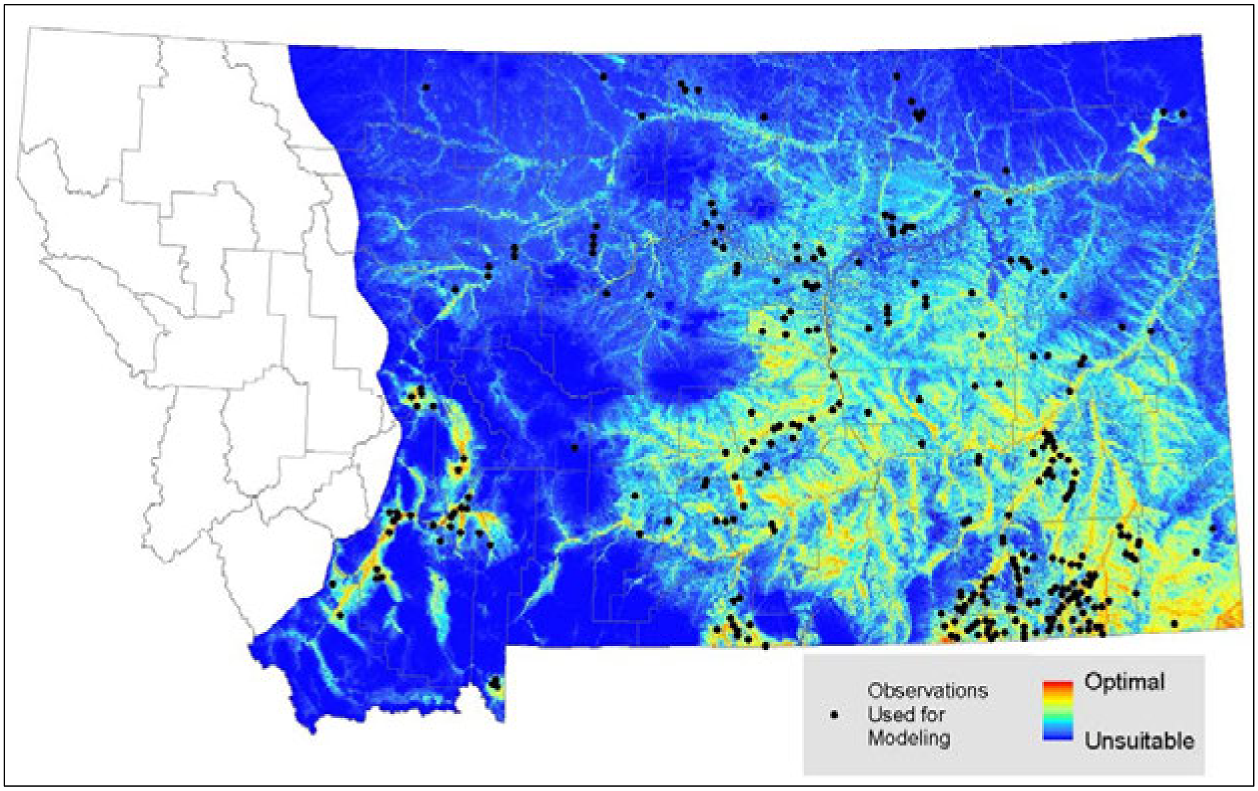


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

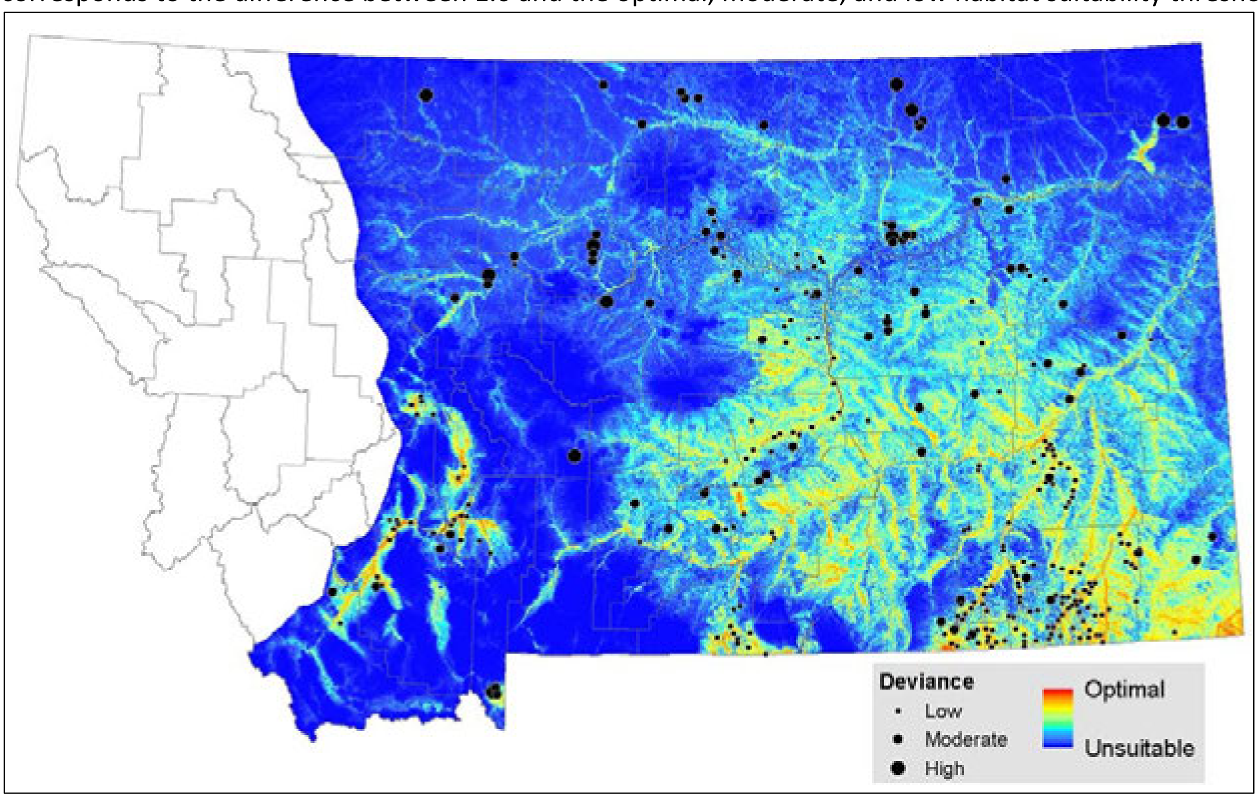


Figure 7. Continuous habitat suitability model output with all 820 observations (black) and survey locations that could have detected the species (gray).

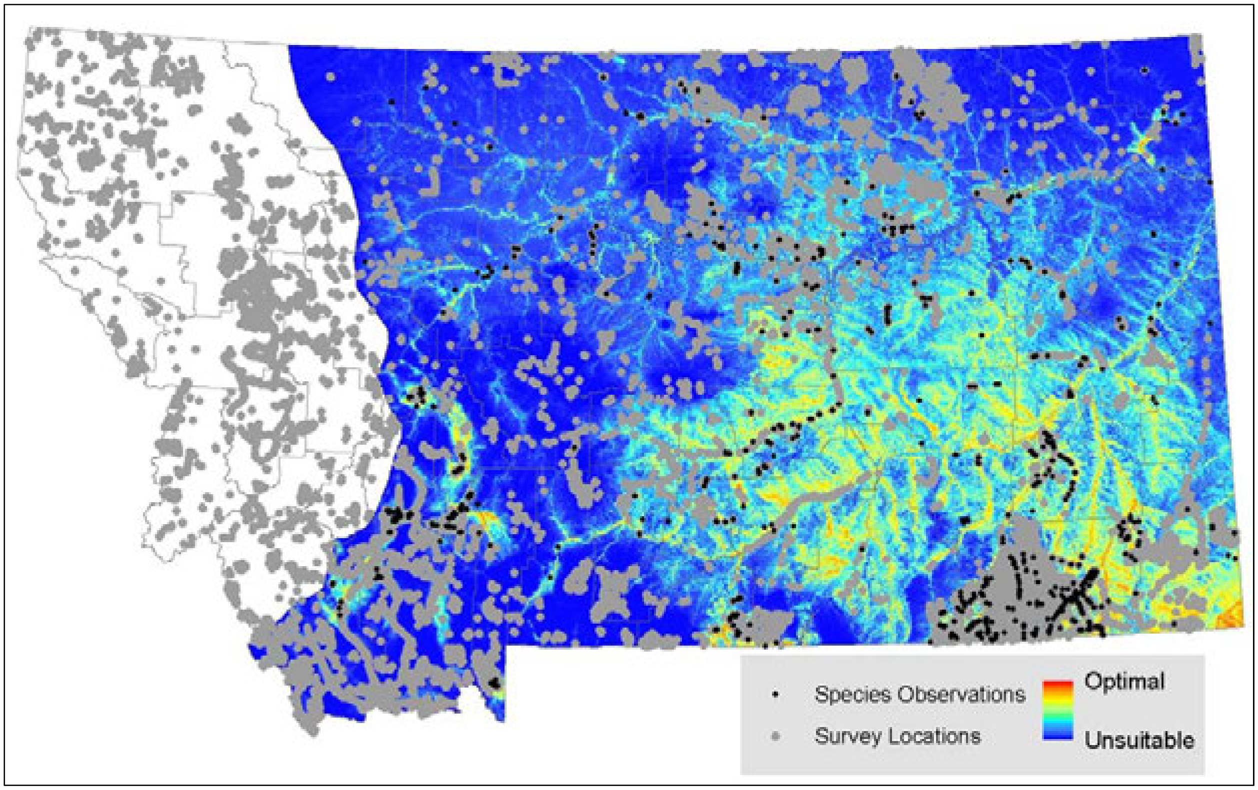


Figure 8. Model output classified into habitat suitability classes.

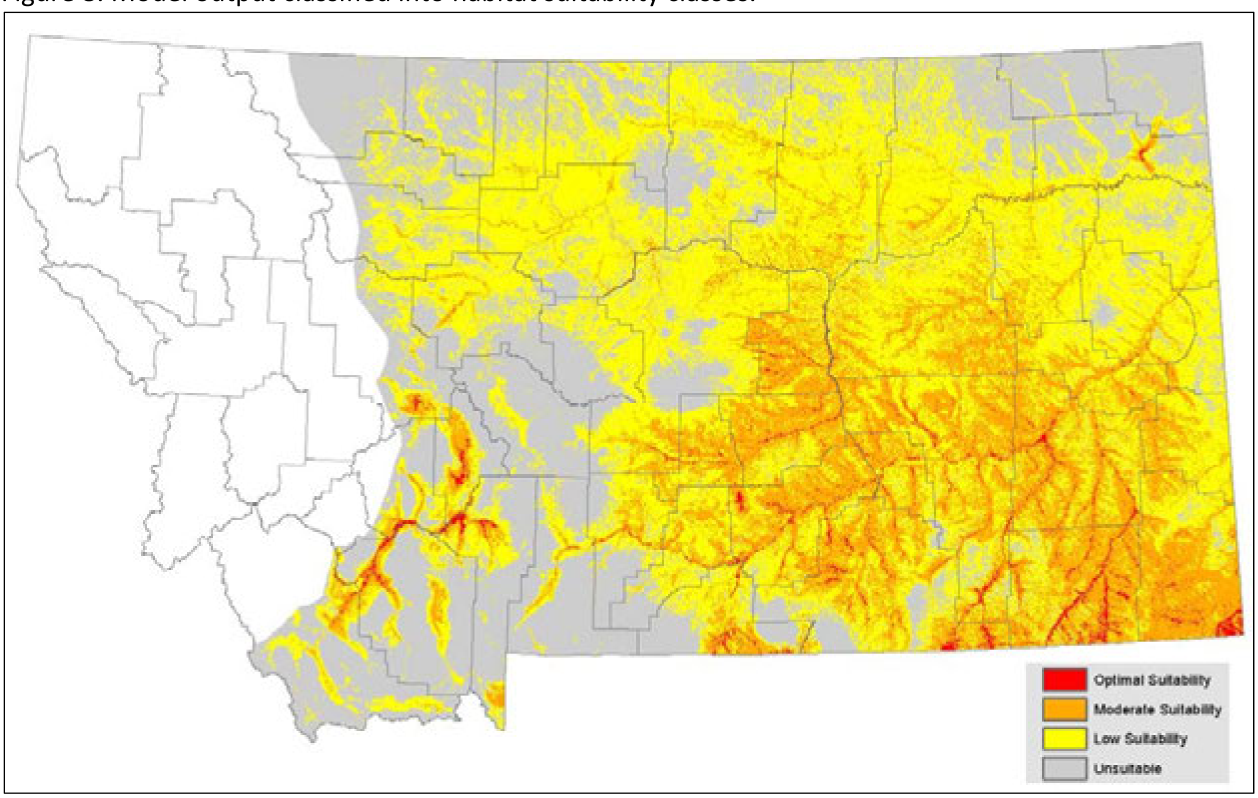
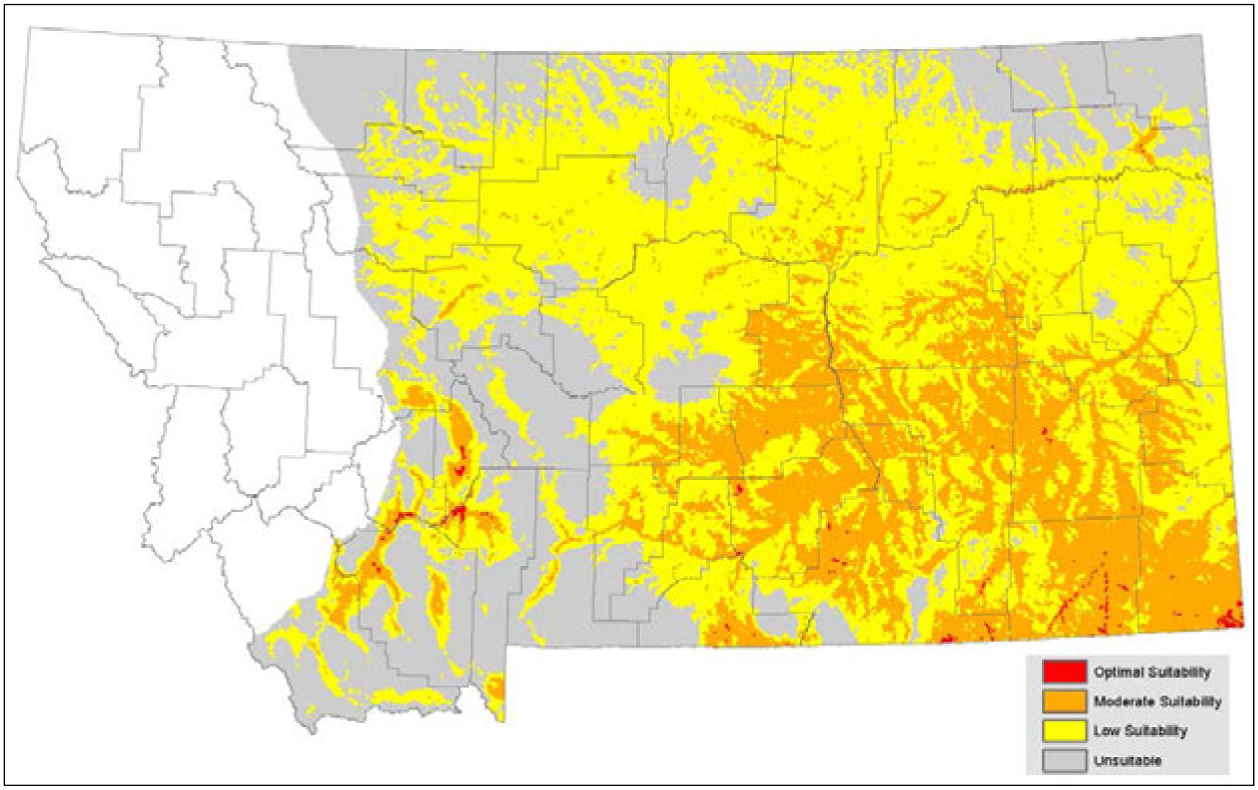


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Plains Spadefoot

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	70
Big Sagebrush Steppe	5454	Common	49
Great Plains Riparian	9326	Common	29
Great Plains Badlands	3114	Common	13
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	11
Open Water	11	Common	9
Great Plains Floodplain	9159	Common	7
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	4
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	4
Great Plains Sand Prairie	7121	Common	3
Recently burned grassland	8502	Common	2
Emergent Marsh	9222	Common	2
Great Plains Saline Depression Wetland	9256	Common	2
Mat Saltbush Shrubland	5203	Common	1
Montane Sagebrush Steppe	5455	Common	1
Recently burned shrubland	8503	Common	1
Burned Sagebrush	8504	Common	1
Greasewood Flat	9103	Common	1
Shale Badland	3139	Common	0
Active and Stabilized Dune	3160	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Great Plains Prairie Pothole	9203	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Pasture/Hay	81	Occasional	4
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Occasional	4
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	2
Recently burned forest	8501	Occasional	2
Developed, Open Space	21	Occasional	1
Low Intensity Residential	22	Occasional	1
Quarries, Strip Mines and Gravel Pits	31	Occasional	1
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	1
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	1
Great Plains Wooded Draw and Ravine	4328	Occasional	0
Great Plains Shrubland	5262	Occasional	0
Post-Fire Recovery	8505	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 284 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

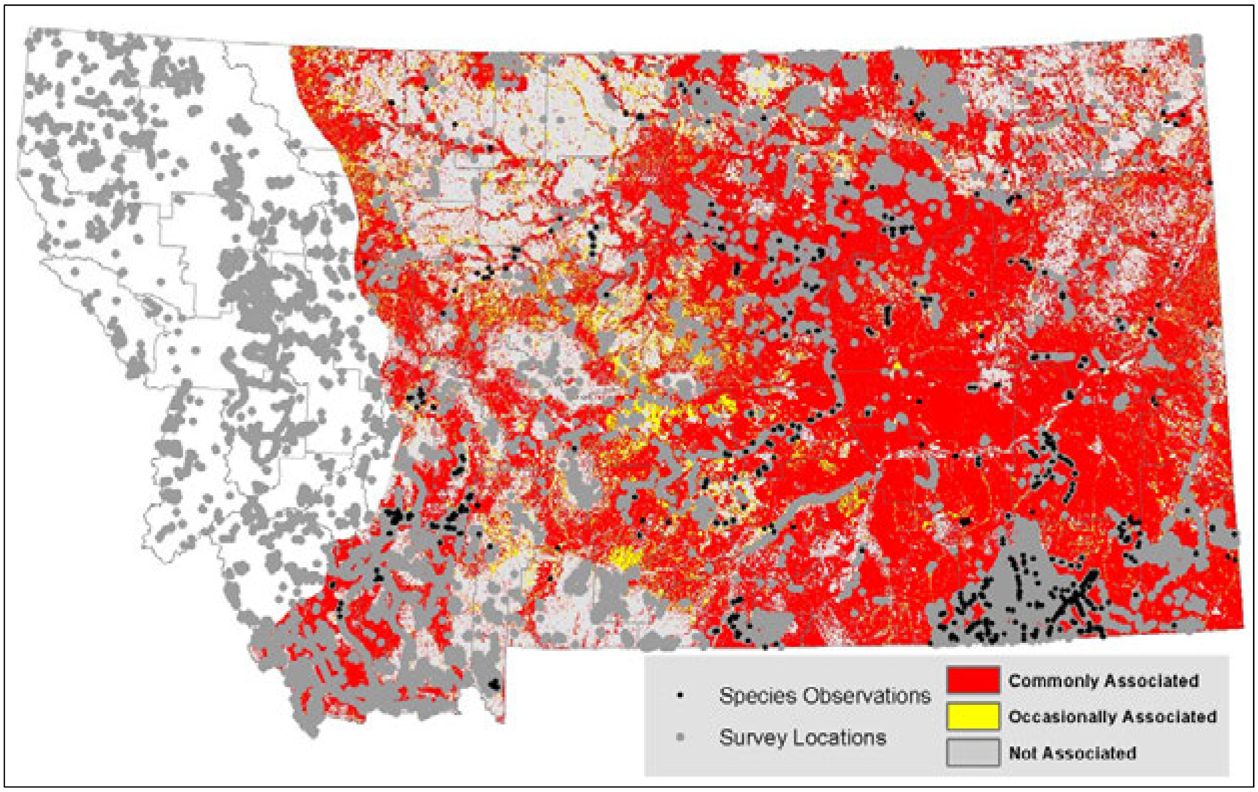
Measure	**Value**
Area of entire modeled range (percent of Montana)	299,483.8 km^2 (78.7%)
Area of Commonly and Occasionally Associated ES	205,759.0 km^2
Area of Commonly Associated ES	186,093.0 km^2
Area of Occasionally Associated ES	19,666.0 km^2

Table 7: Evaluation Metrics

Metric	**Value**
Commonly and Occasionally Associated ES AVI[a]	79.2%
Commonly Associated ES AVI[a]	73.9%
Occasionally Associated ES AVI[a]	5.3%

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

Figure 10. Deductive model output classified into habitat associations.



American Bullfrog (*Lithobates catesbeianus*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: SNA
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 5, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 6, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the entire state of Montana.
Inductive Model Performance: The model appears to adequately reflect what we know about the current distribution of American Bullfrog year-round habitat suitability at larger spatial scales. Areas that are predicted by the model where the species is currently absent seem plausible, especially for moderate and optimal suitability classes. Evaluation metrics suggest a good model fit. However, the delineation of habitat suitability classes is a somewhat hindered by sample size.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the entire state of Montana.
Deductive Model Performance: Ecological systems that American Bullfrog is commonly and occasionally associated with over predict the amount of potentially suitable habitat available to the species. The inductive model is much more informative for survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. American Bullfrog (*Lithobates catesbeianus*) predicted suitable habitat models created on October 05, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABH01070

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	450
Location Data Selection Rule 1	Records with <= 1600 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	424
Location Data Selection Rule 2	No overlap in locations within 400 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	63
Season Modeled	Entire state, Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	24.7%	contndvi	1.0%
contddays	20.2%	contslope	0.5%
catgeol	18.8%	contwinrad	0.4%
catsoilord	15.0%	contprecip	0.3%
contwinpcp	4.4%	contelev	0.2%
catsoiltemp	4.1%	contsumrad	0.2%
conttmin	3.0%	contnsasp	0.1%
conttmax	2.9%	contewasp	0.0%
contfrsted	2.1%	contvrm	0.0%
contstrmed	2.0%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.003
Moderate Logistic Threshold[b]	0.091
Optimal Logistic Threshold[c]	0.230
Area of entire modeled range (percent of Montana)	380,529.02 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	33,372.8 km^2
Area of predicted low suitability habitat within modeled range	29,450.3 km^2
Area of moderate suitability habitat within modeled range	2,274.7 km^2
Area of predicted optimal habitat within modeled range	1,647.8 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.4%
Moderate AVI[a]	77.8%
Optimal AVI[a]	71.4%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.733 ± 3.813
Training AUC[c]	0.994
Test AUC[d]	0.989

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 11.686, 4.794 and 2.942, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

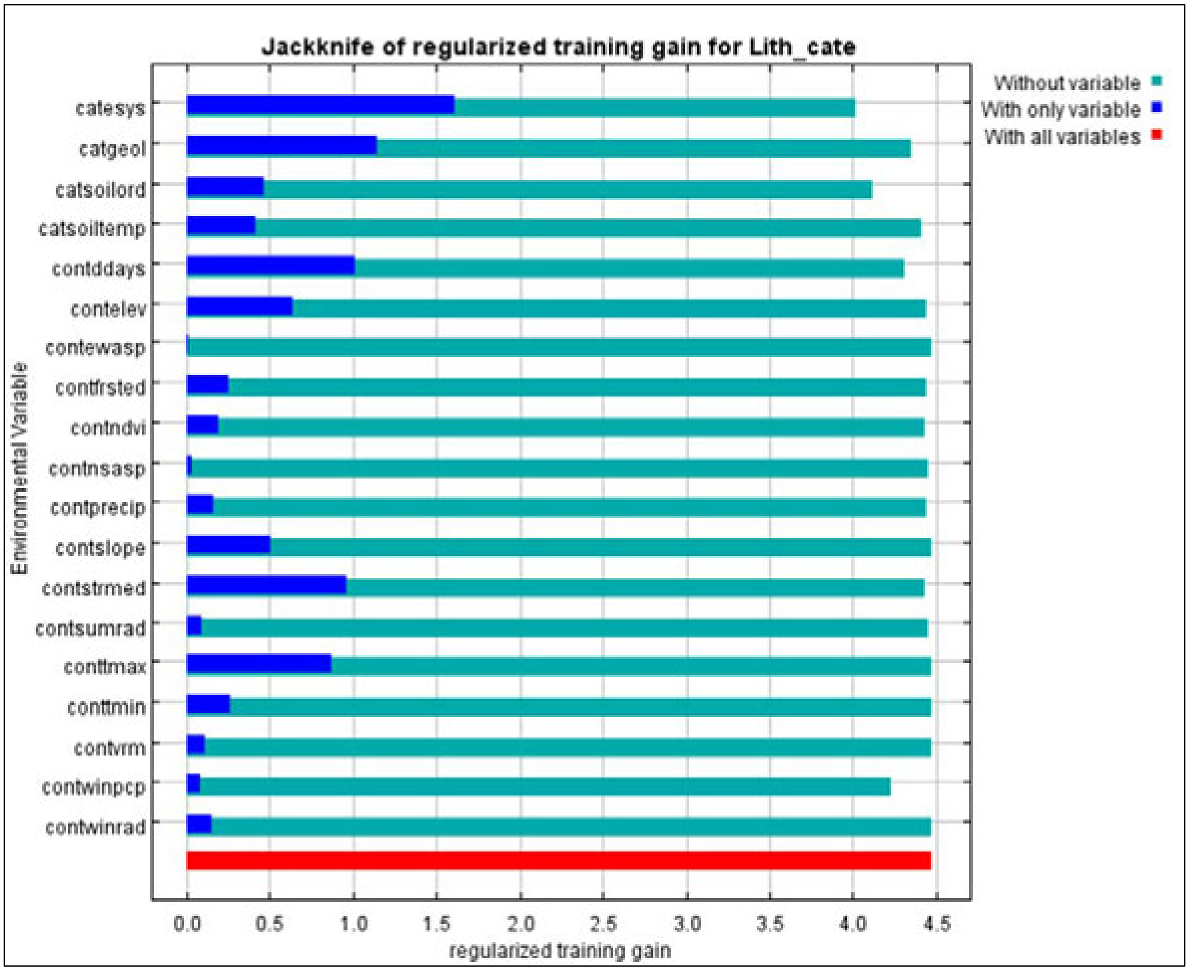
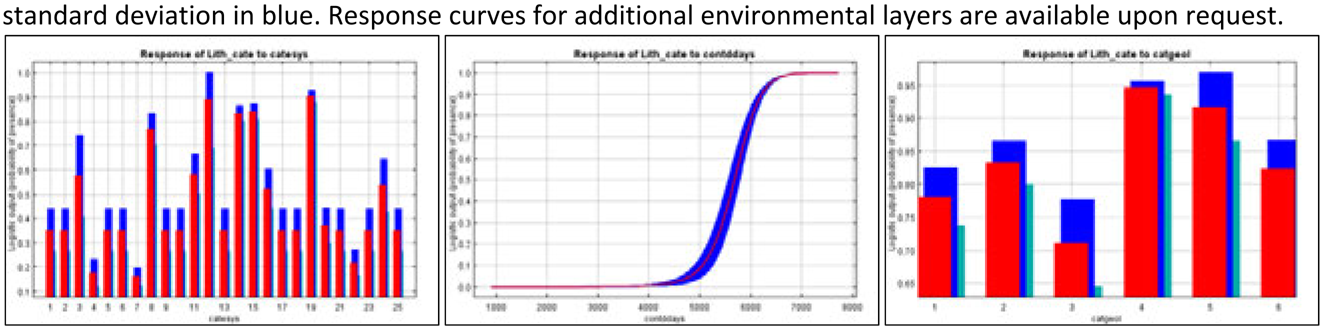


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

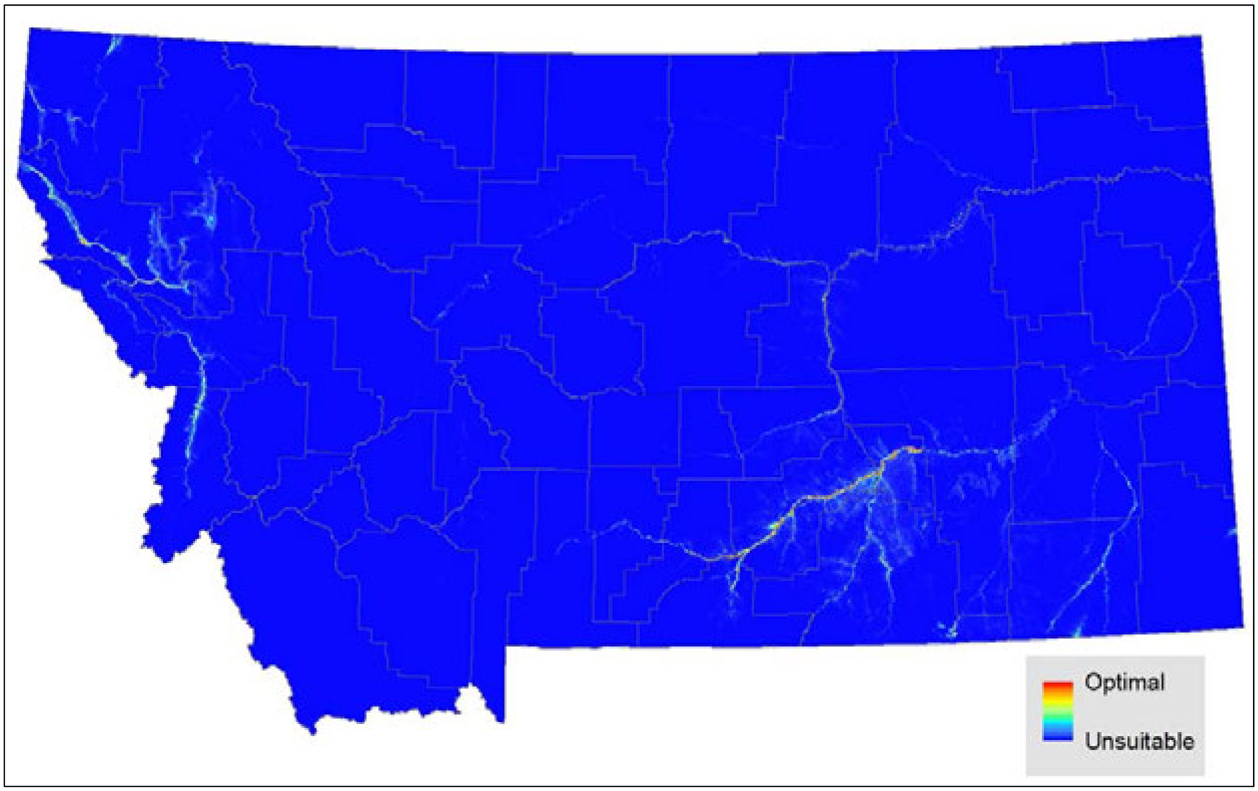


Figure 4. Standard deviation in the model output across the averaged models.

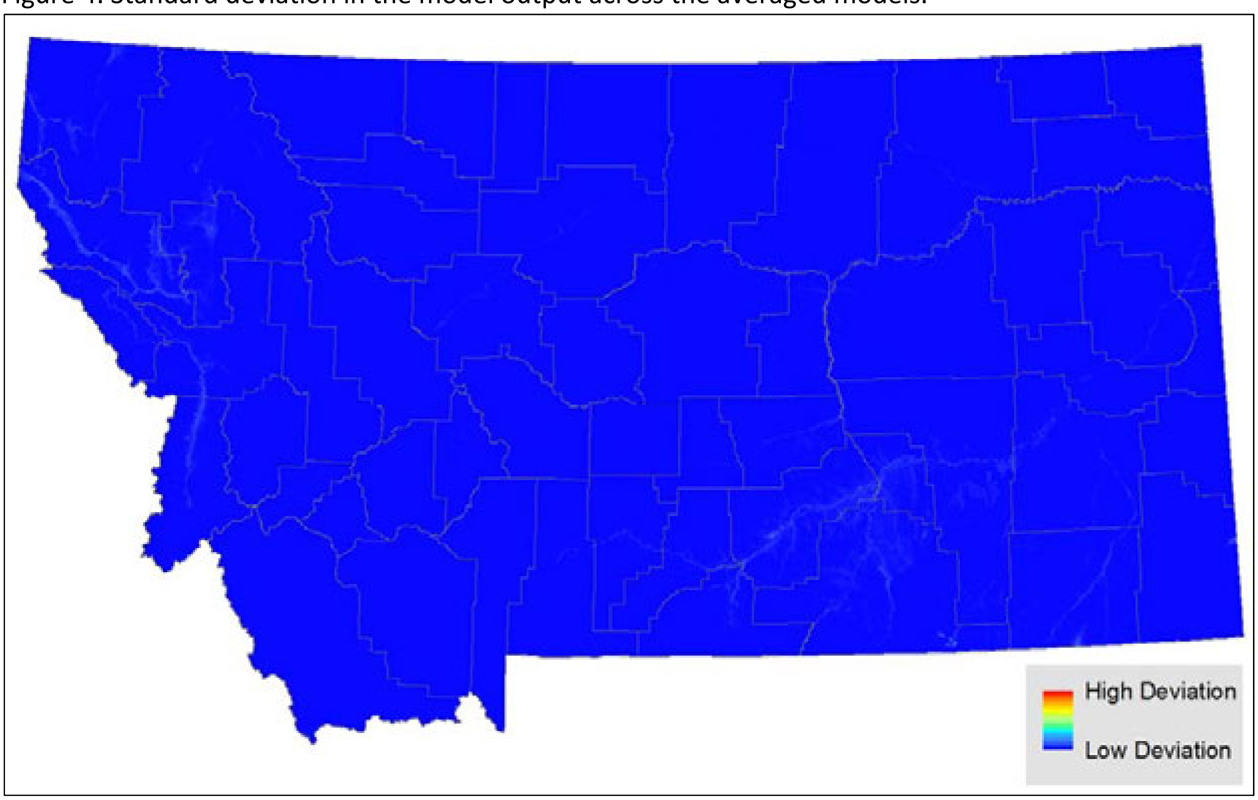


Figure 5. Continuous habitat suitability model output with the 63 observations used for modeling.

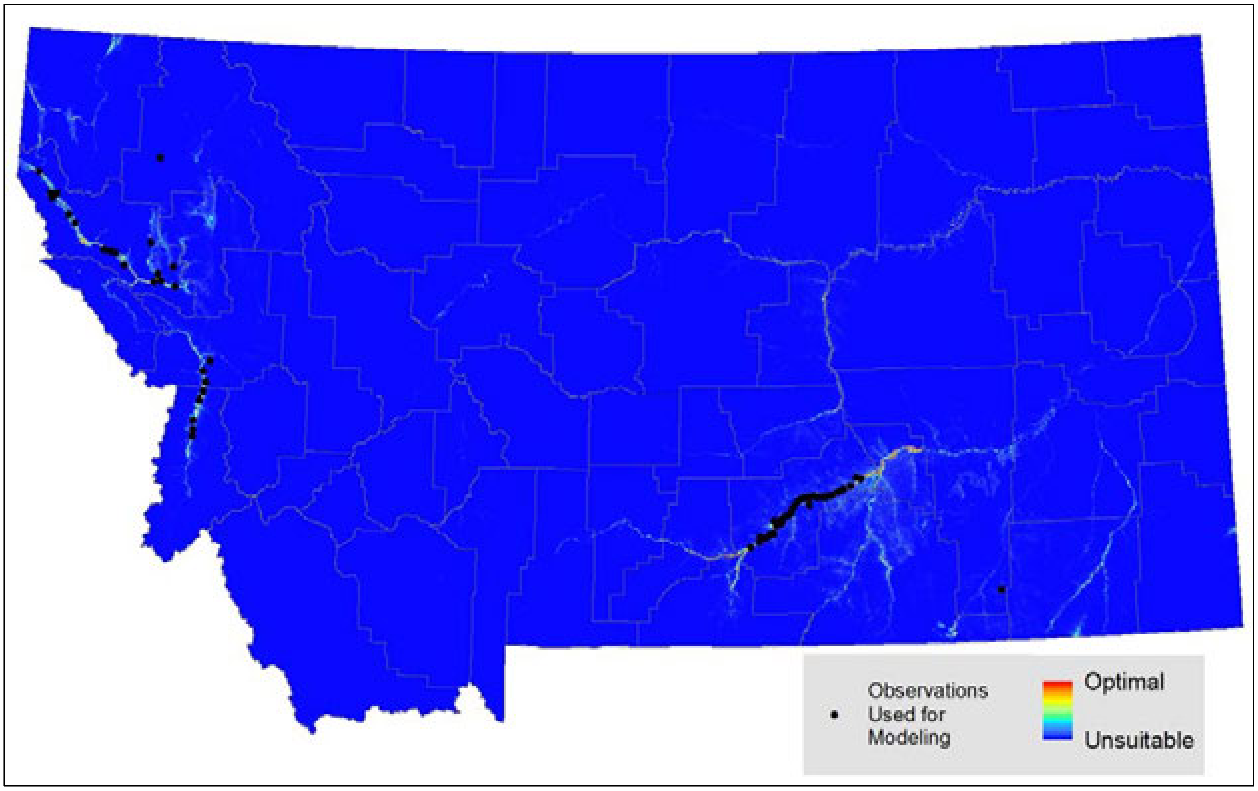


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

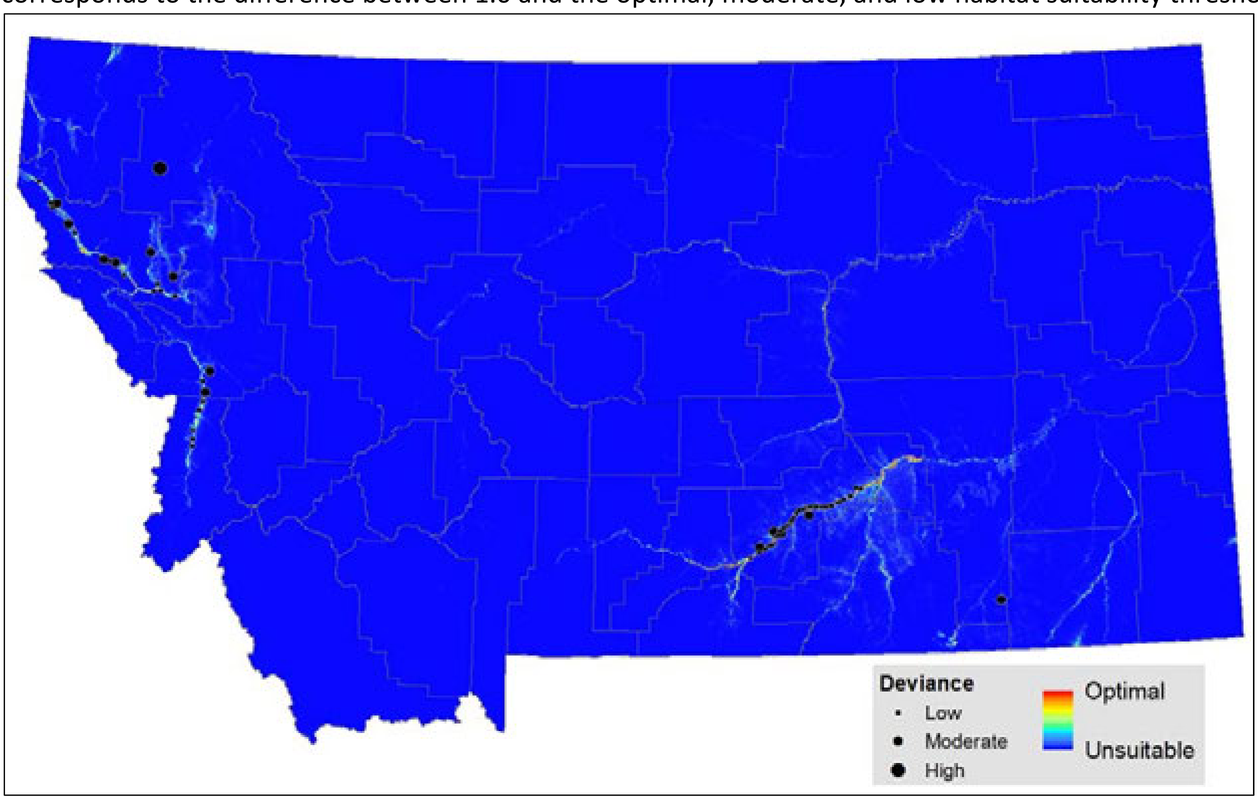


Figure 7. Continuous habitat suitability model output with all 450 observations (black) and survey locations that could have detected the species (gray).

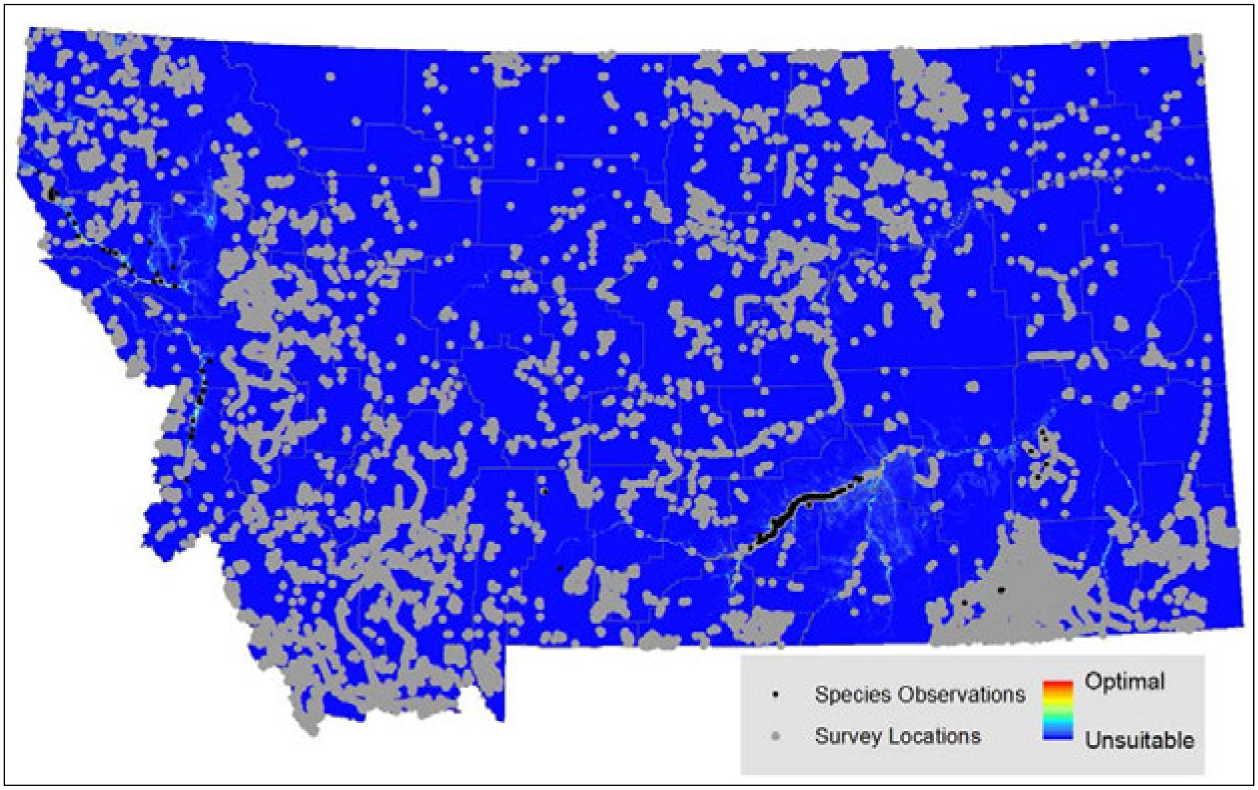


Figure 8. Model output classified into habitat suitability classes.

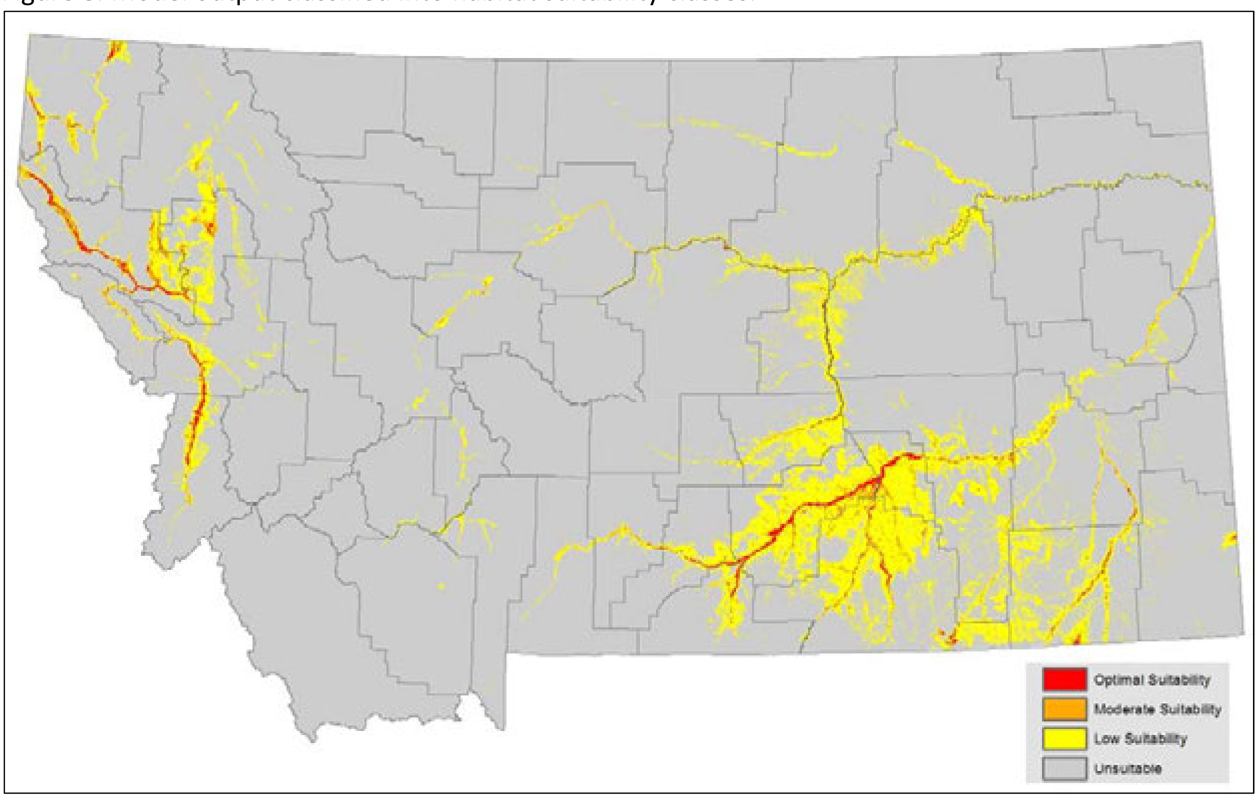
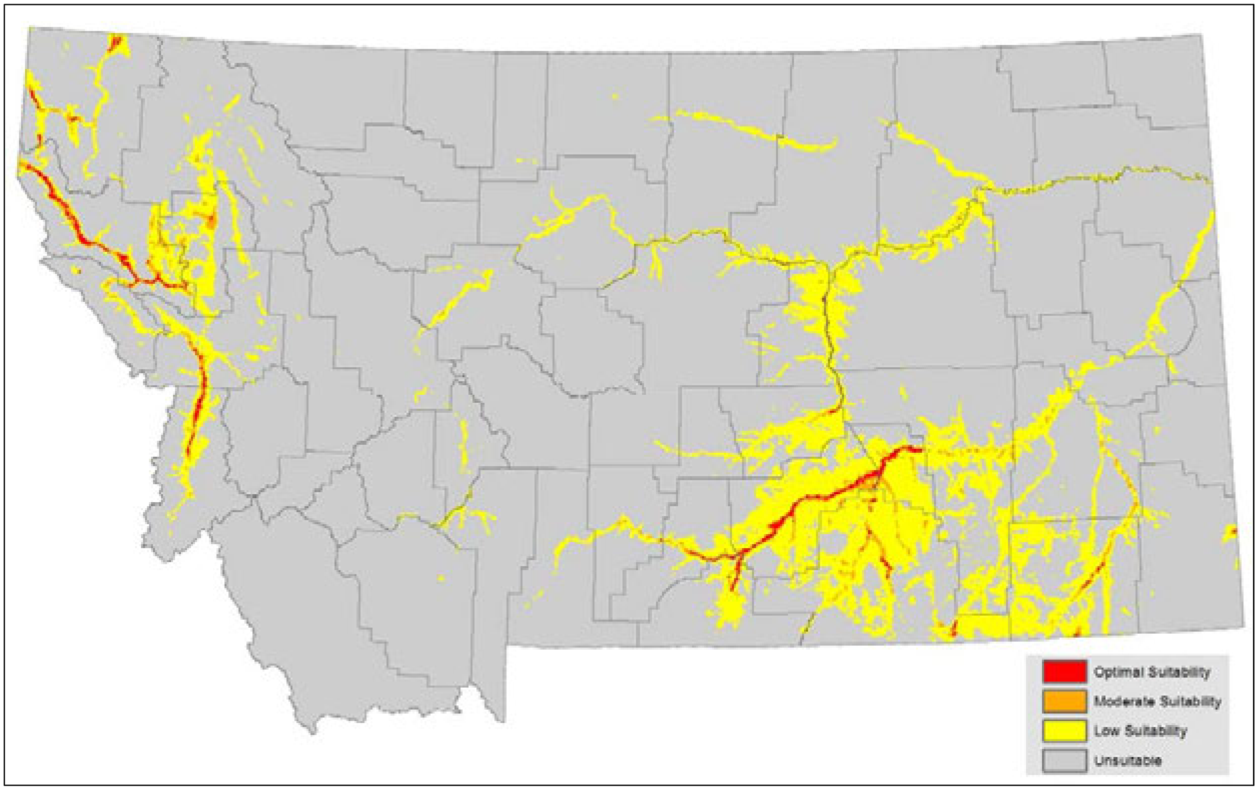


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with American Bullfrog

Ecological System	Code	Association	Count[a]
Open Water	11	Common	21
Great Plains Floodplain	9159	Common	13
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	7
Introduced Riparian and Wetland Vegetation	8406	Common	4
Great Plains Riparian	9326	Common	2
Emergent Marsh	9222	Common	0
Alpine-Montane Wet Meadow	9217	Occasional	2

[a] A count of the observation records intersecting each ecological system, based on the 63 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

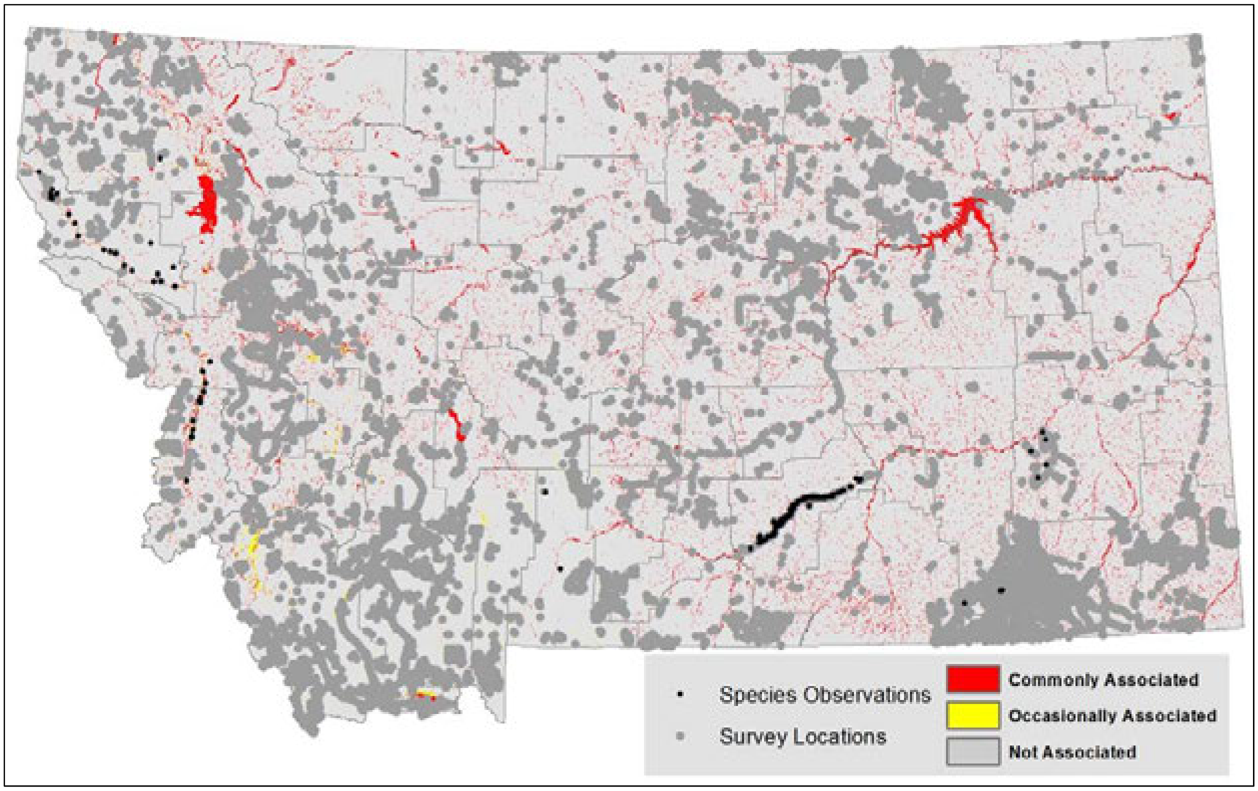
Measure	Value
Area of entire modeled range (percent of Montana)	380,529.02 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	15,673.0 km^2
Area of Commonly Associated ES	10,336.0 km^2
Area of Occasionally Associated ES	1,252.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	77.8%
Commonly Associated ES AVI[a]	34.9%
Occasionally Associated ES AVI[a]	3.2%

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

Figure 10. Deductive model output classified into habitat associations.



Northern Leopard Frog (*Lithobates pipiens*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S1,S4 (Species of Concern)
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 5, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 6, 2017

Inductive Model Goal: To predict the distribution and relative suitability of year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model adequately reflects the distribution of Northern Leopard Frog year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with somewhat under represent the amount of suitable habitat across the species' known range in Montana because some wetlands and riparian types are poorly represented in the current land cover layer. However, these systems do represent the core habitats the species is dependent on and many observations for the species are made within a short distance of these habitats.

Suggested Citation: Montana Natural Heritage Program. 2017. Northern Leopard Frog (*Lithobates pipiens*) predicted suitable habitat models created on October 05, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABH01170

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,484
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	599
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	391
Season Modeled	Entire state, Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	33.7%	conttmax	2.1%
catsoiltemp	26.5%	contewasp	2.0%
contddays	5.6%	contnsasp	1.9%
contstrmed	4.6%	contfrsted	1.7%
catsoilord	4.4%	contelev	1.7%
catgeol	4.1%	contsumrad	1.7%
conttmin	3.5%	contndvi	0.4%
contwinpcp	3.4%	contprecip	0.3%
contslope	2.4%	contwinrad	0.0%

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.051
Moderate Logistic Threshold[b]	0.300
Optimal Logistic Threshold[c]	0.688
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	197,457.8 km^2
Area of predicted low suitability habitat within modeled range	133,353.8 km^2
Area of moderate suitability habitat within modeled range	57,960.8 km^2
Area of predicted optimal habitat within modeled range	6,143.2 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	97.7%
Moderate AVI[a]	74.9%
Optimal AVI[a]	29.7%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.772 ± 1.577
Training AUC[c]	0.906
Test AUC[d]	0.888

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.956, 2.409 and 0.747, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

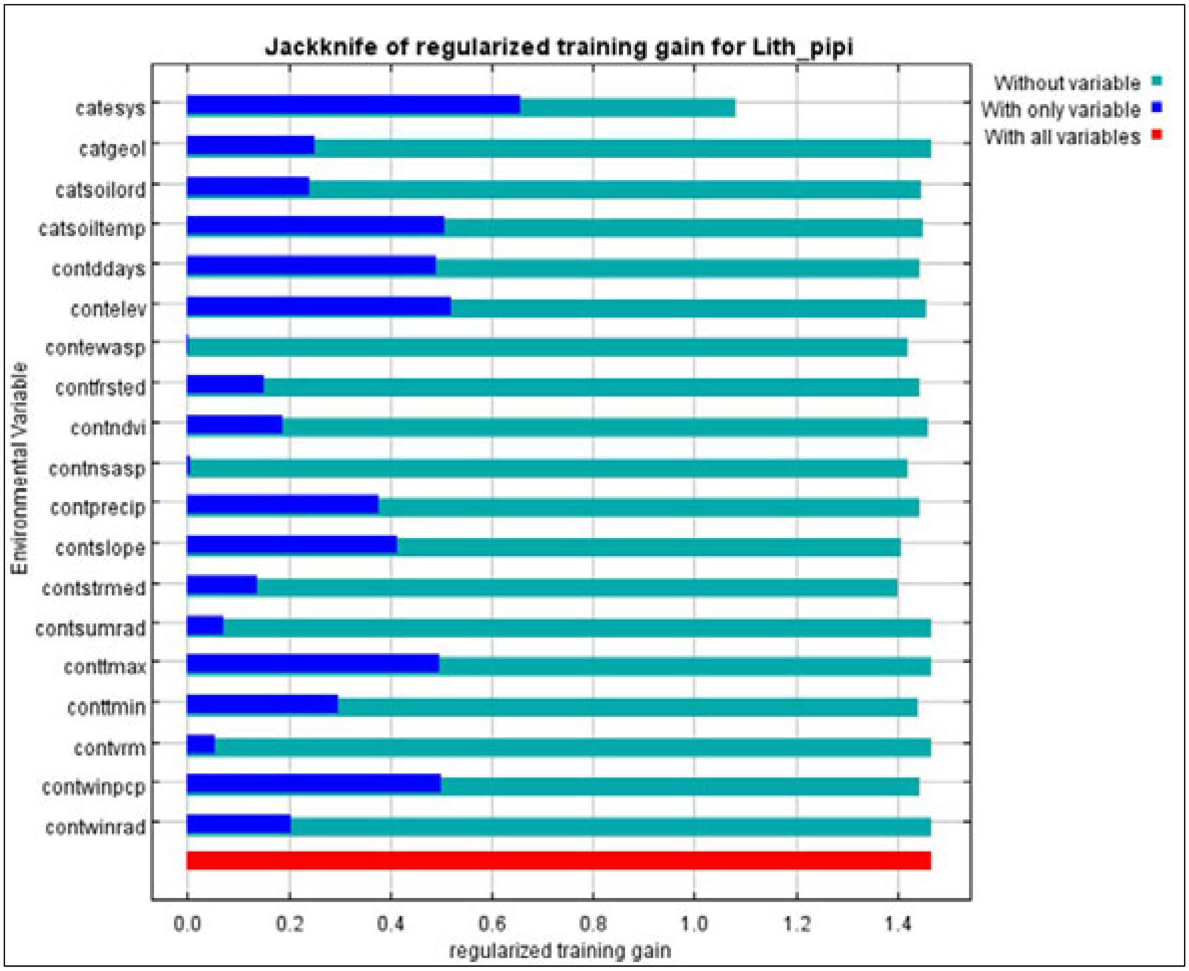
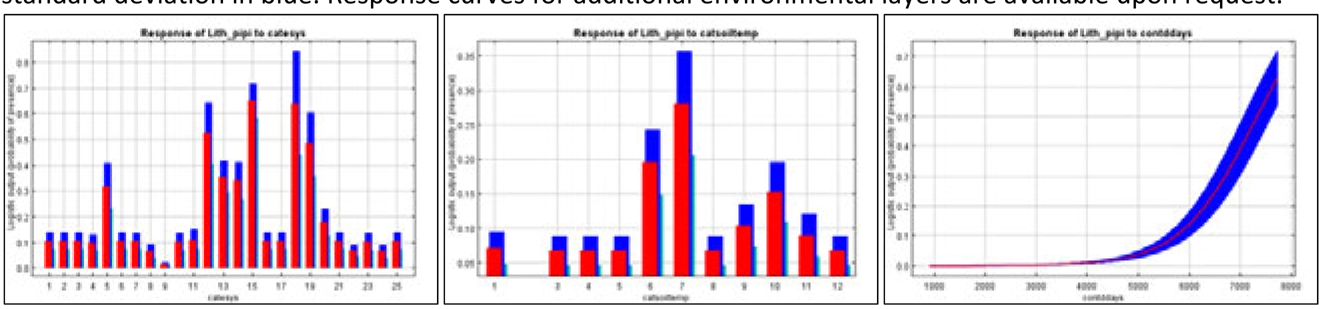


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

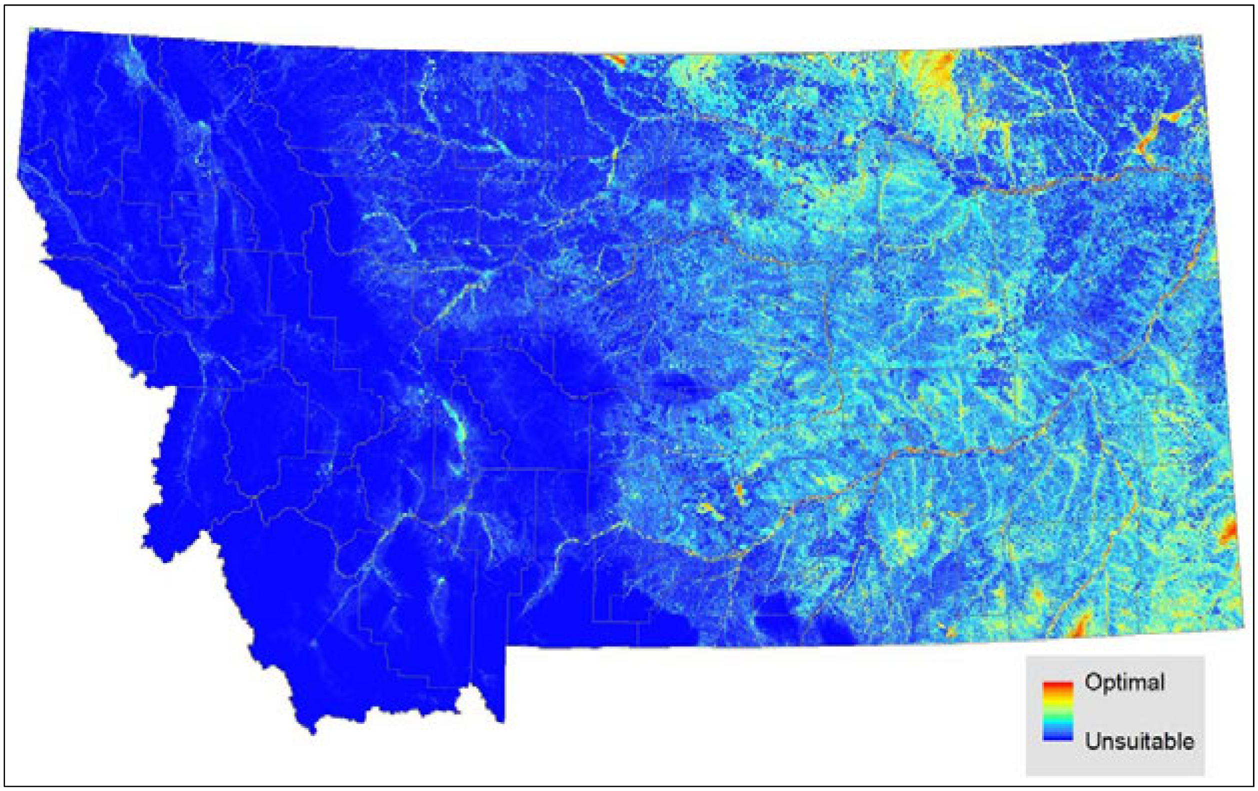


Figure 4. Standard deviation in the model output across the averaged models.

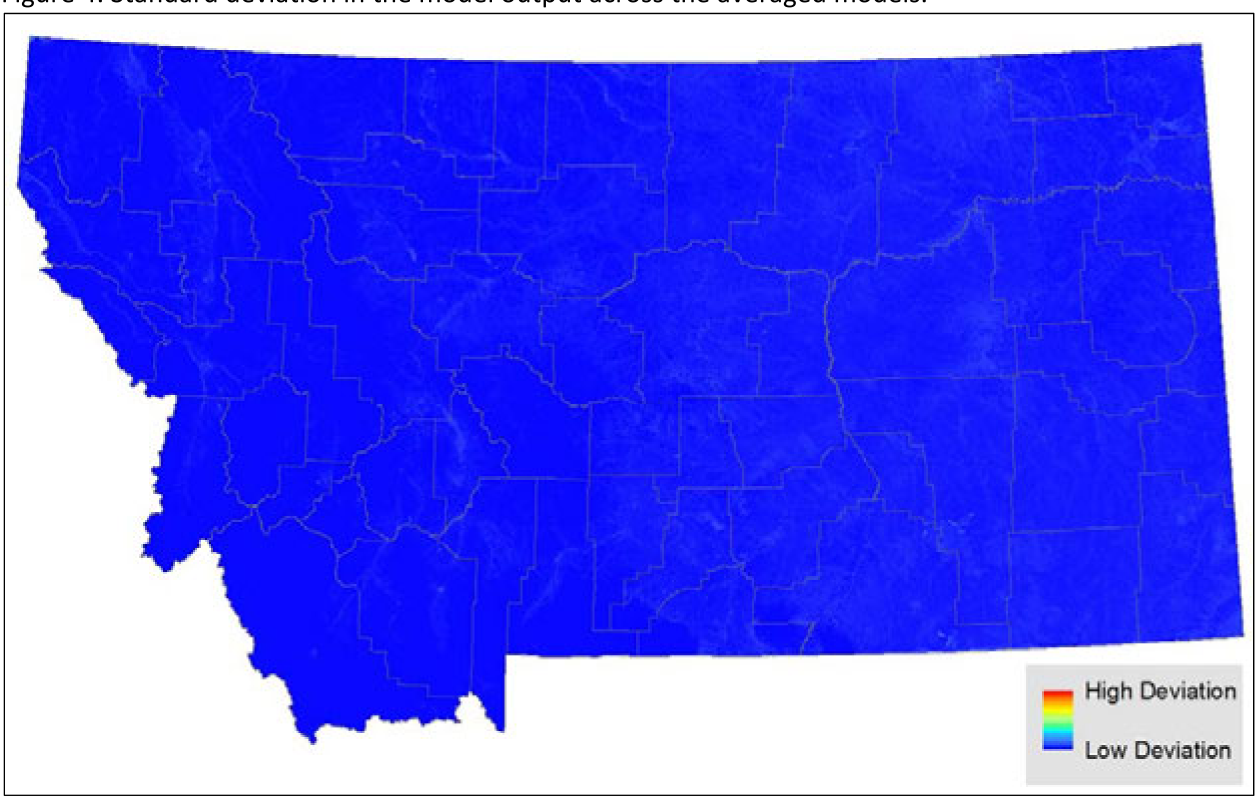


Figure 5. Continuous habitat suitability model output with the 391 observations used for modeling.

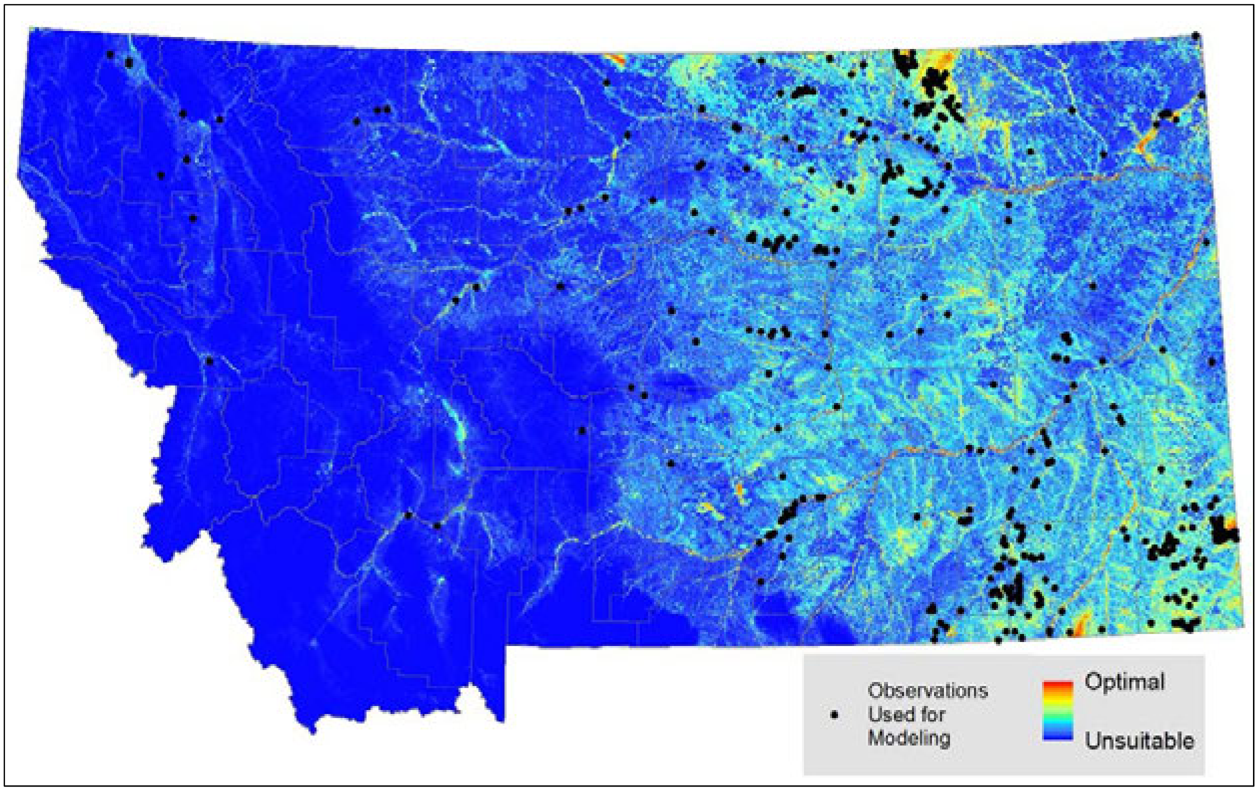


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

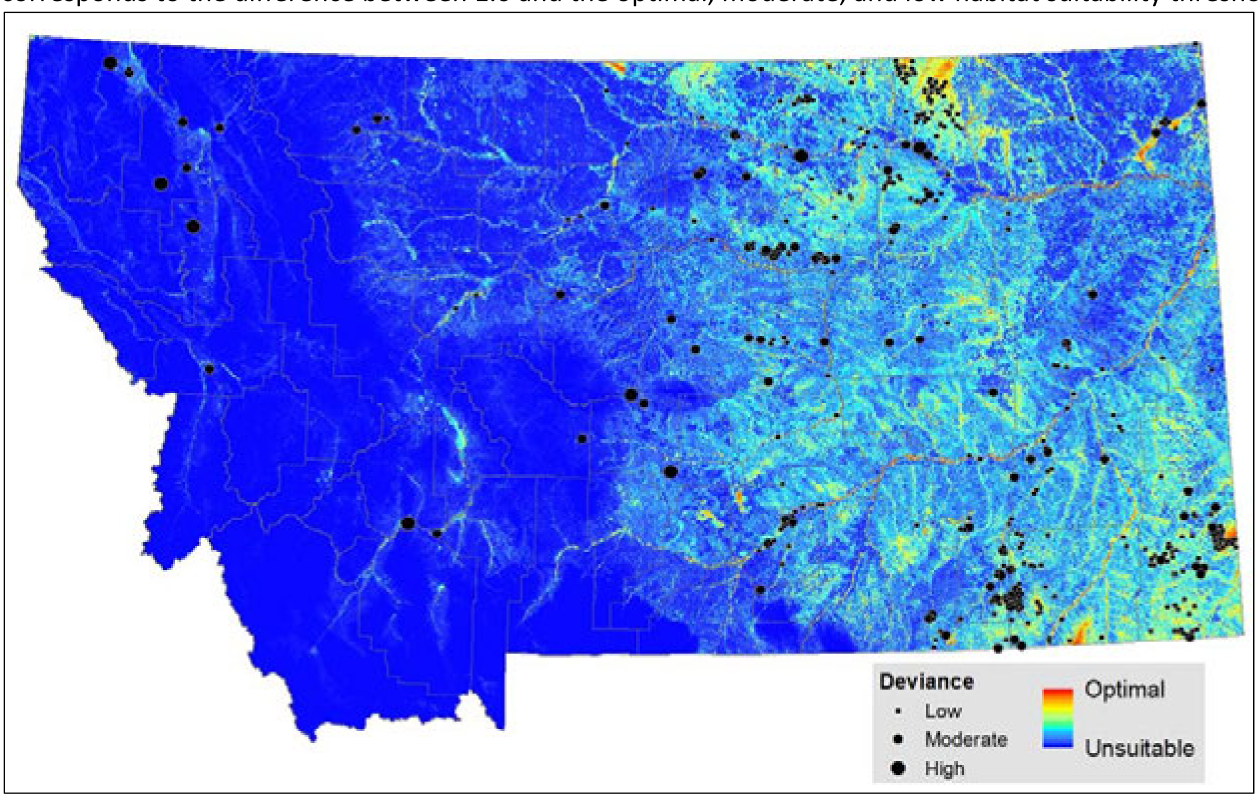


Figure 7. Continuous habitat suitability model output with all 2,484 observations (black) and survey locations that could have detected the species (gray).

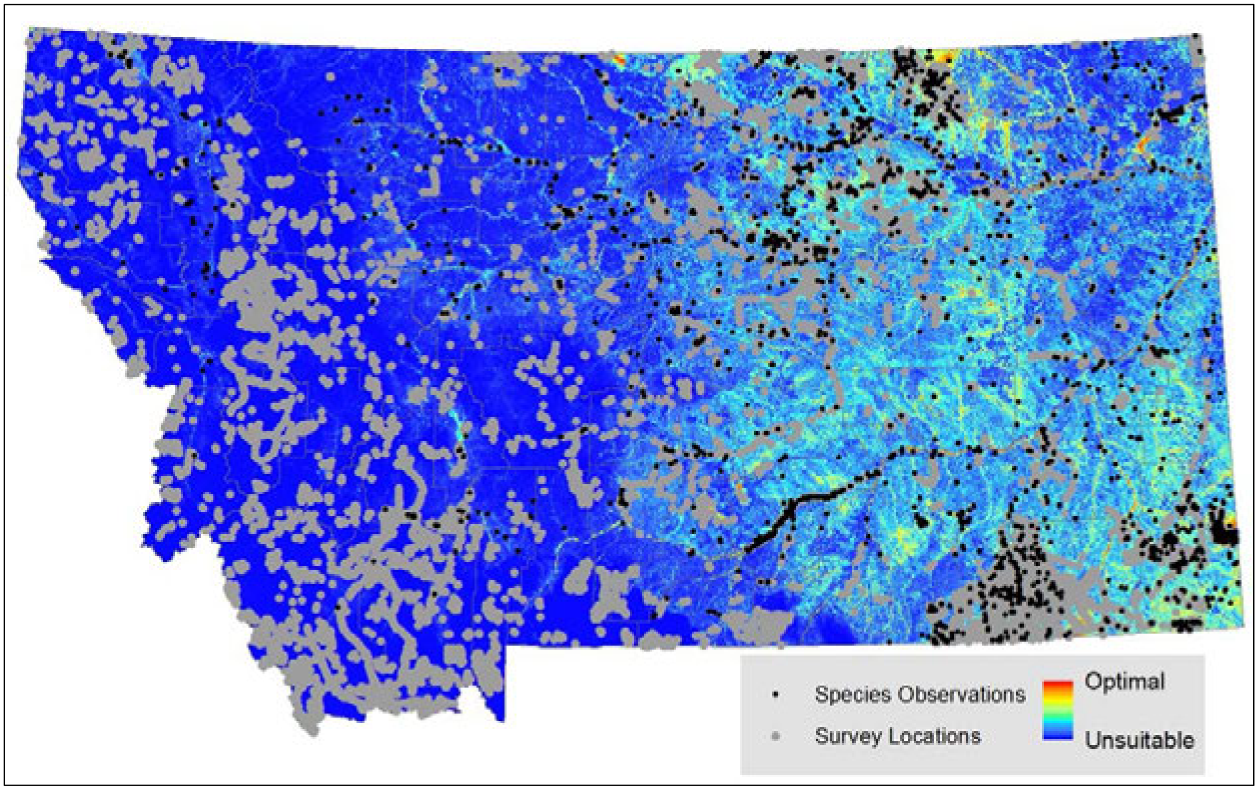


Figure 8. Model output classified into habitat suitability classes.

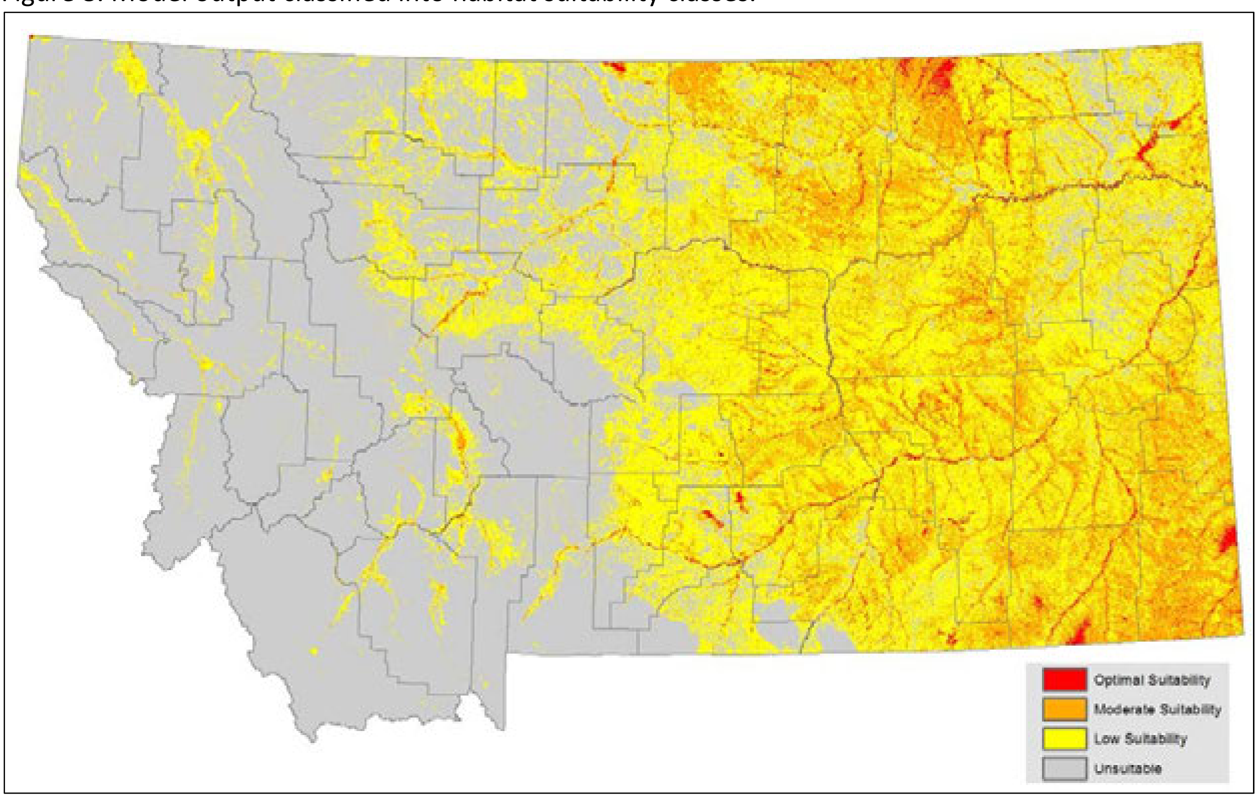
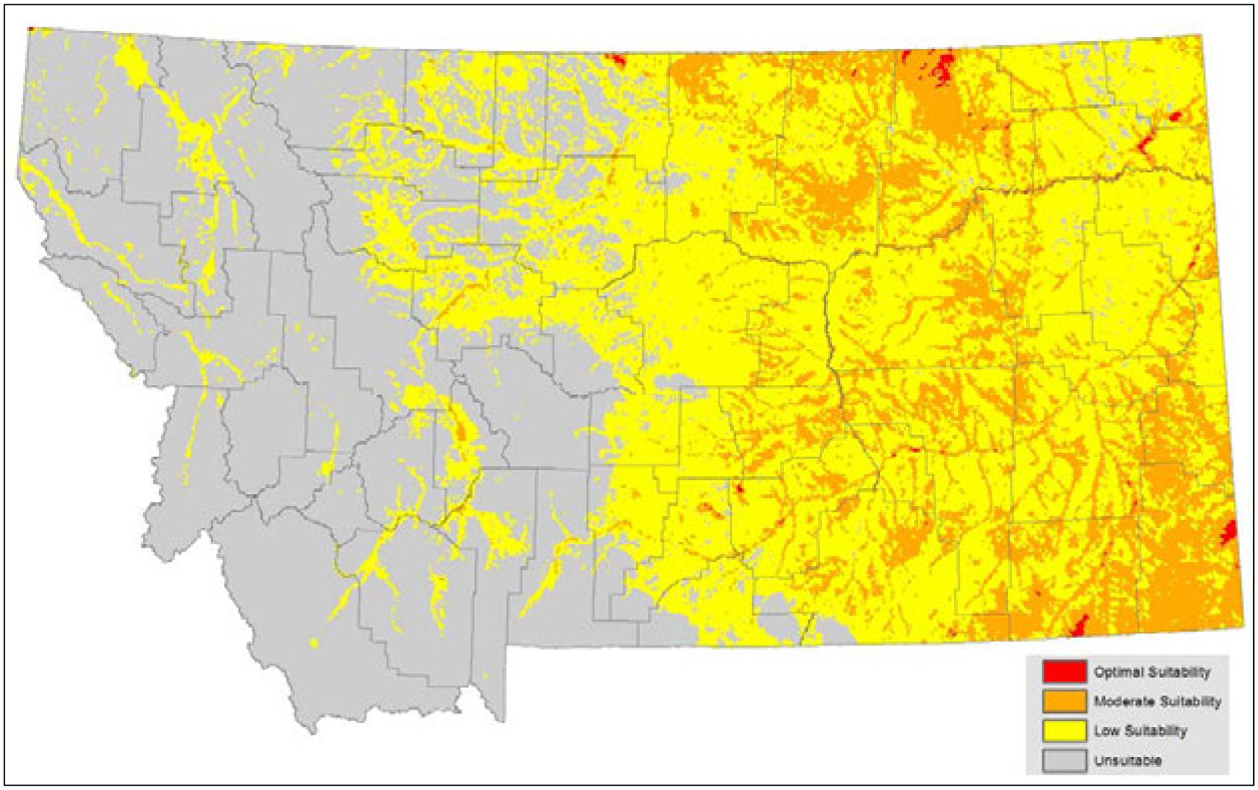


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Northern Leopard Frog

Ecological System	Code	Association	Count[a]
Open Water	11	Common	64
Great Plains Riparian	9326	Common	64
Great Plains Floodplain	9159	Common	14
Emergent Marsh	9222	Common	11
Great Plains Saline Depression Wetland	9256	Common	4
Great Plains Closed Depressional Wetland	9252	Common	2
Great Plains Prairie Pothole	9203	Common	1
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Wooded Draw and Ravine	4328	Occasional	8
Greasewood Flat	9103	Occasional	5
Pasture/Hay	81	Occasional	4
Quarries, Strip Mines and Gravel Pits	31	Occasional	3
Introduced Riparian and Wetland Vegetation	8406	Occasional	2
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	2
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Occasional	2
Rocky Mountain Wooded Vernal Pool	9162	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Occasional	0
Alpine-Montane Wet Meadow	9217	Occasional	0
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 391 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

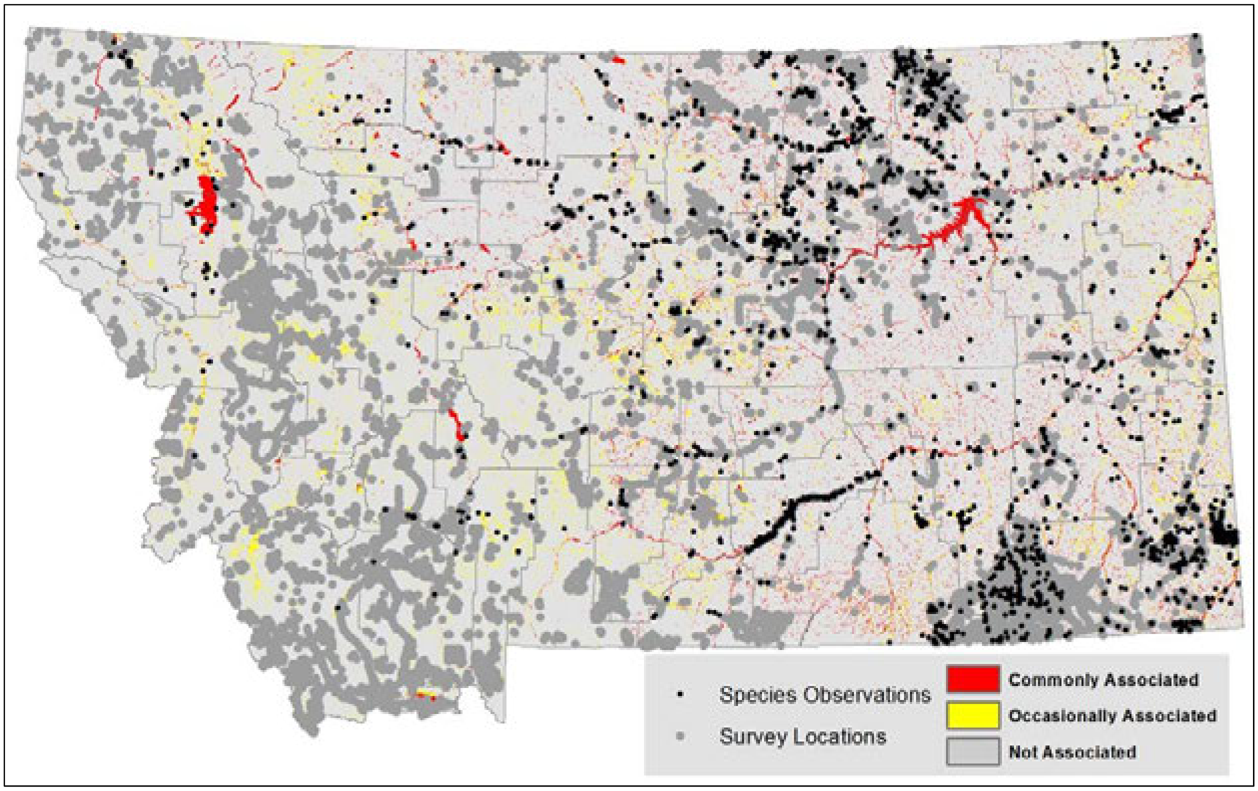
Measure	Value
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	26,424.0 km^2
Area of Commonly Associated ES	12,509.0 km^2
Area of Occasionally Associated ES	13,915.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	47.6%
Commonly Associated ES AVI[a]	40.9%
Occasionally Associated ES AVI[a]	6.7%

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

Figure 10. Deductive model output classified into habitat associations.



Columbia Spotted Frog (*Rana luteiventris*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 4, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 4, 2017

Inductive Model Goal: To predict the distribution and relative suitability of breeding habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Columbia Spotted Frog breeding habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with somewhat under represent the amount of suitable habitat across the species' known range in Montana because some wetlands and riparian types are poorly represented in the current land cover layer. However, these systems do represent the core aquatic habitats the species is dependent on and many observations for the species are made within a short distance of these habitats.

Suggested Citation: Montana Natural Heritage Program. 2017. Columbia Spotted Frog (*Rana luteiventris*) predicted suitable habitat models created on October 04, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AAABH01290

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	6,720
Location Data Selection Rule 1	Records with <= 900 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	2,962
Location Data Selection Rule 2	No overlap in locations within 1600 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	1,049
Season Modeled	Year-round
Number of Model Background Locations	23,688

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contslope	20.4%	contelev	1.2%
contndvi	16.6%	contddays	0.9%
catesys	15.3%	contstrmed	0.9%
catsoiltemp	11.7%	contnsasp	0.8%
catsoilord	8.1%	conttmin	0.5%
contwinpcp	7.2%	contprecip	0.5%
contsumrad	6.8%	contwinrad	0.5%
contfrsted	3.8%	contewasp	0.3%
catgeol	3.3%	contvrm	0.0%
conttmax	1.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.045
Moderate Logistic Threshold[b]	0.289
Optimal Logistic Threshold[c]	0.685
Area of entire modeled range (percent of Montana)	150,229.8 km^2 (39.5%)
Total area of predicted suitable habitat within modeled range	78,452.4 km^2
Area of predicted low suitability habitat within modeled range	55,005.2 km^2
Area of moderate suitability habitat within modeled range	20,735.3 km^2
Area of predicted optimal habitat within modeled range	2,711.9 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	95.2%
Moderate AVI[a]	75.6%
Optimal AVI[a]	31.5%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.925 ± 2.103
Training AUC[c]	0.885
Test AUC[d]	0.878

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 6.216, 2.483 and 0.758, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

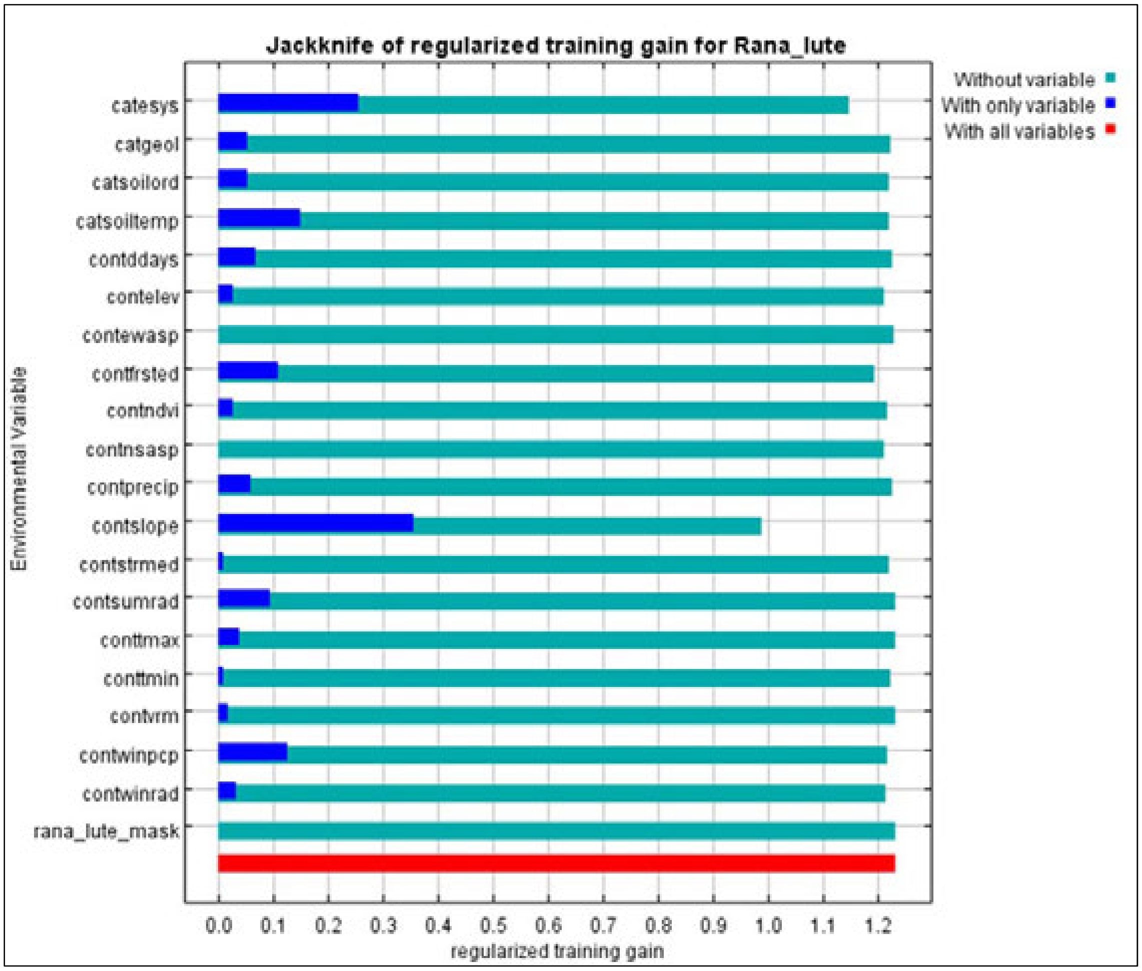


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.

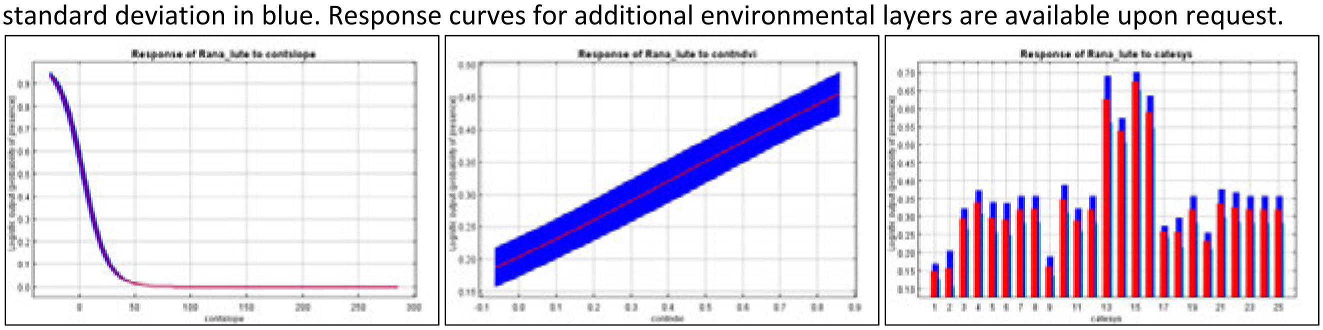


Figure 3. Continuous habitat suitability model output (logistic scale).

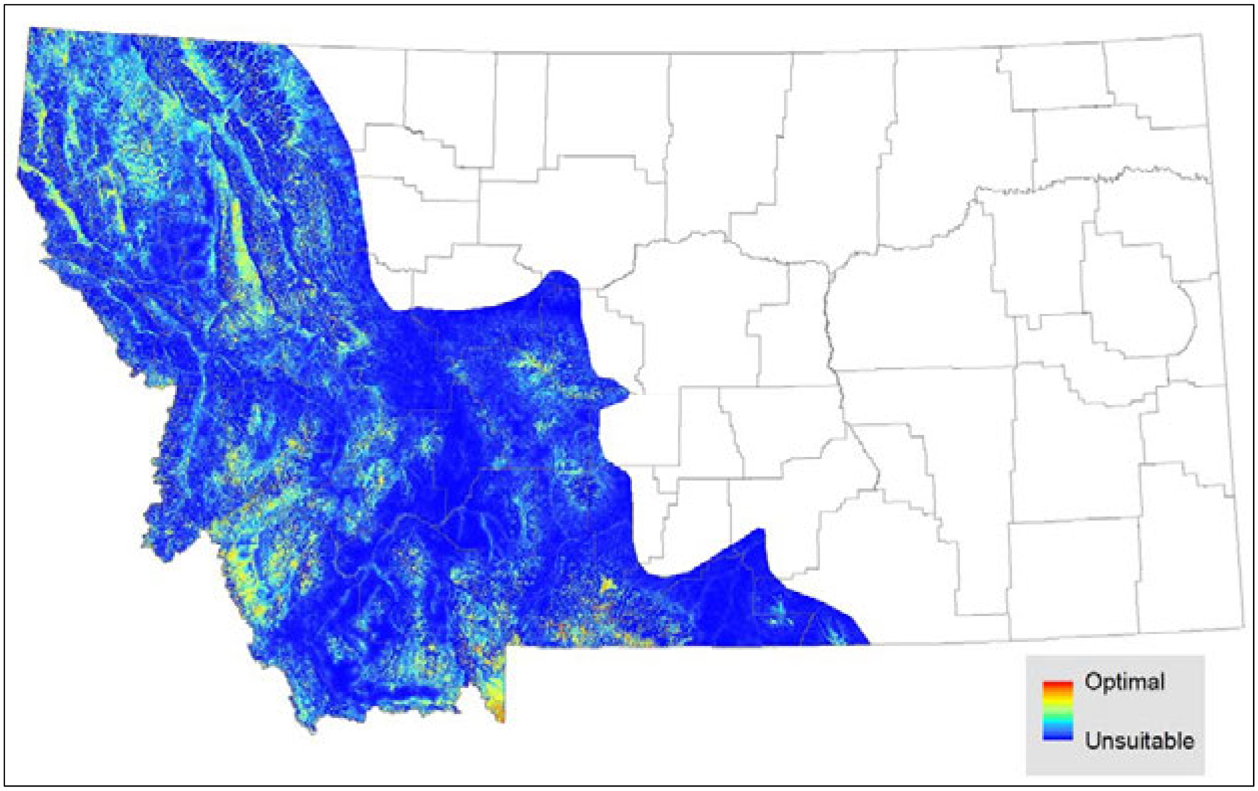


Figure 4. Standard deviation in the model output across the averaged models.

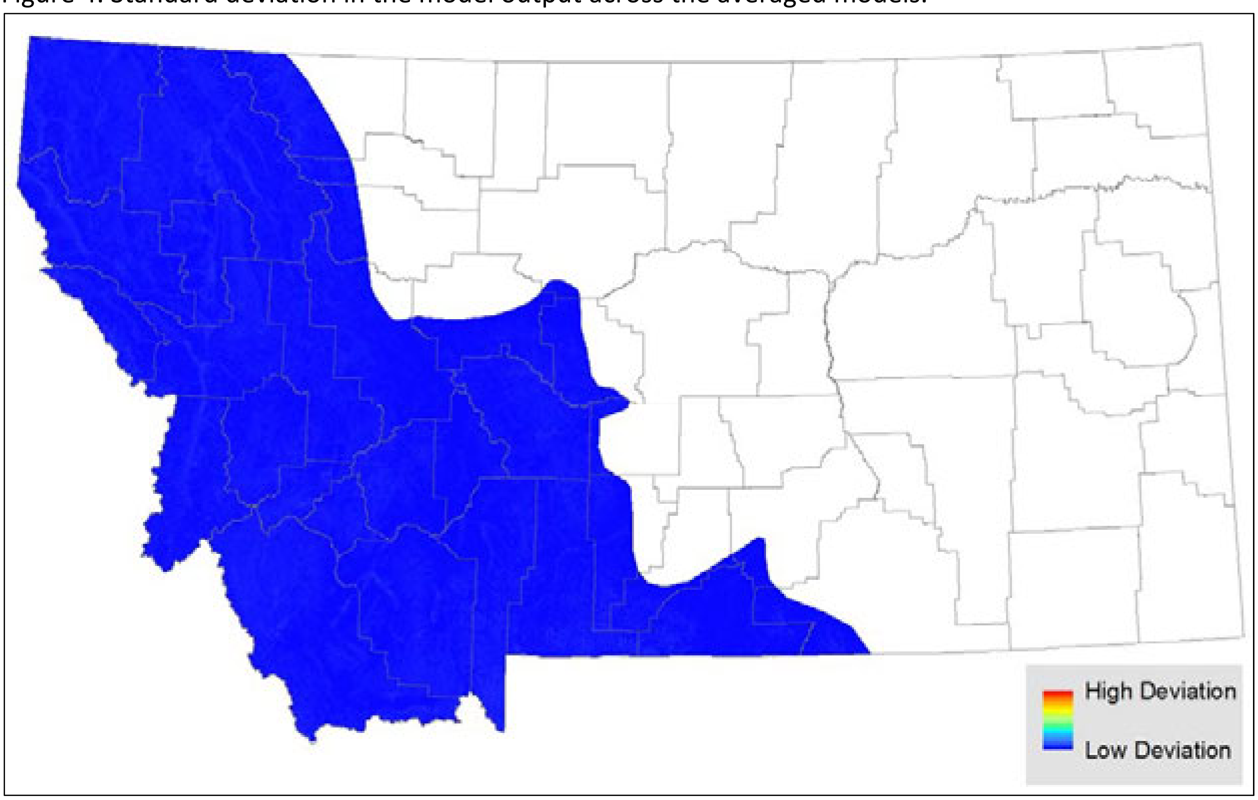


Figure 5. Continuous habitat suitability model output with the 1,049 observations used for modeling.

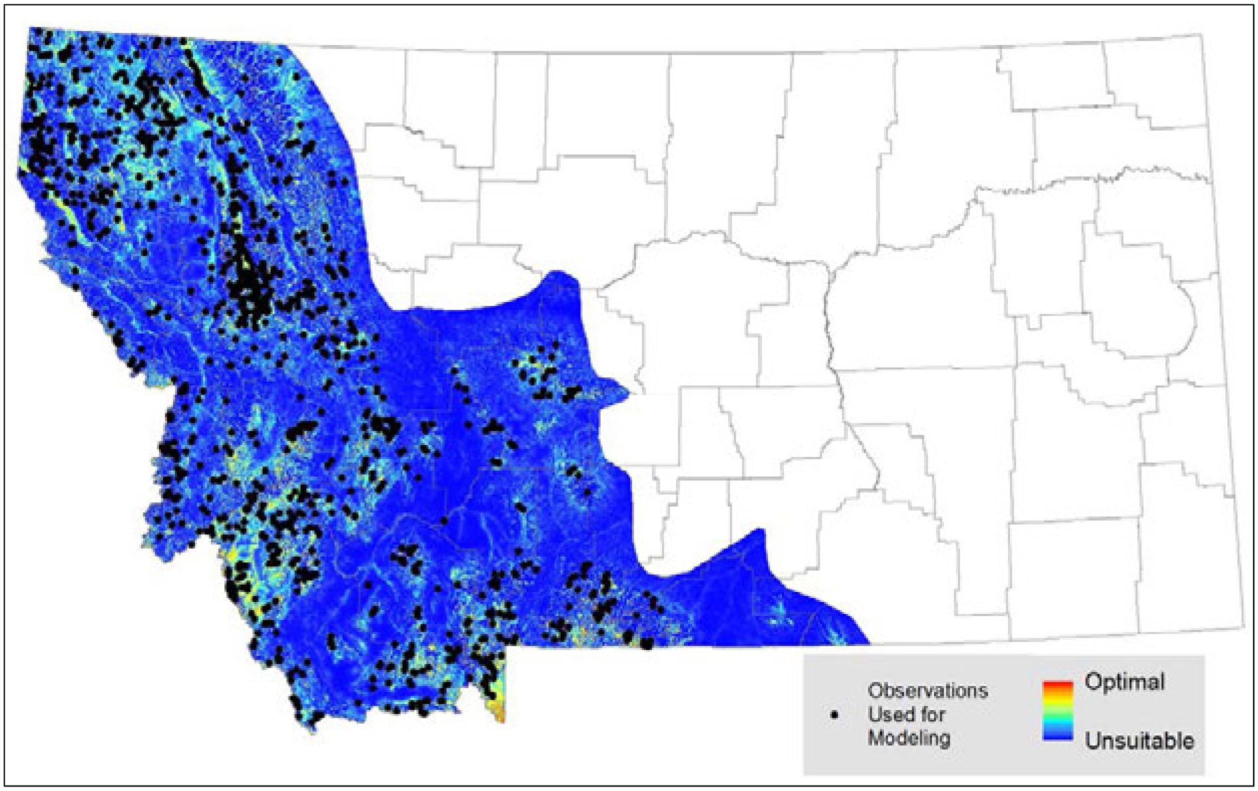


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

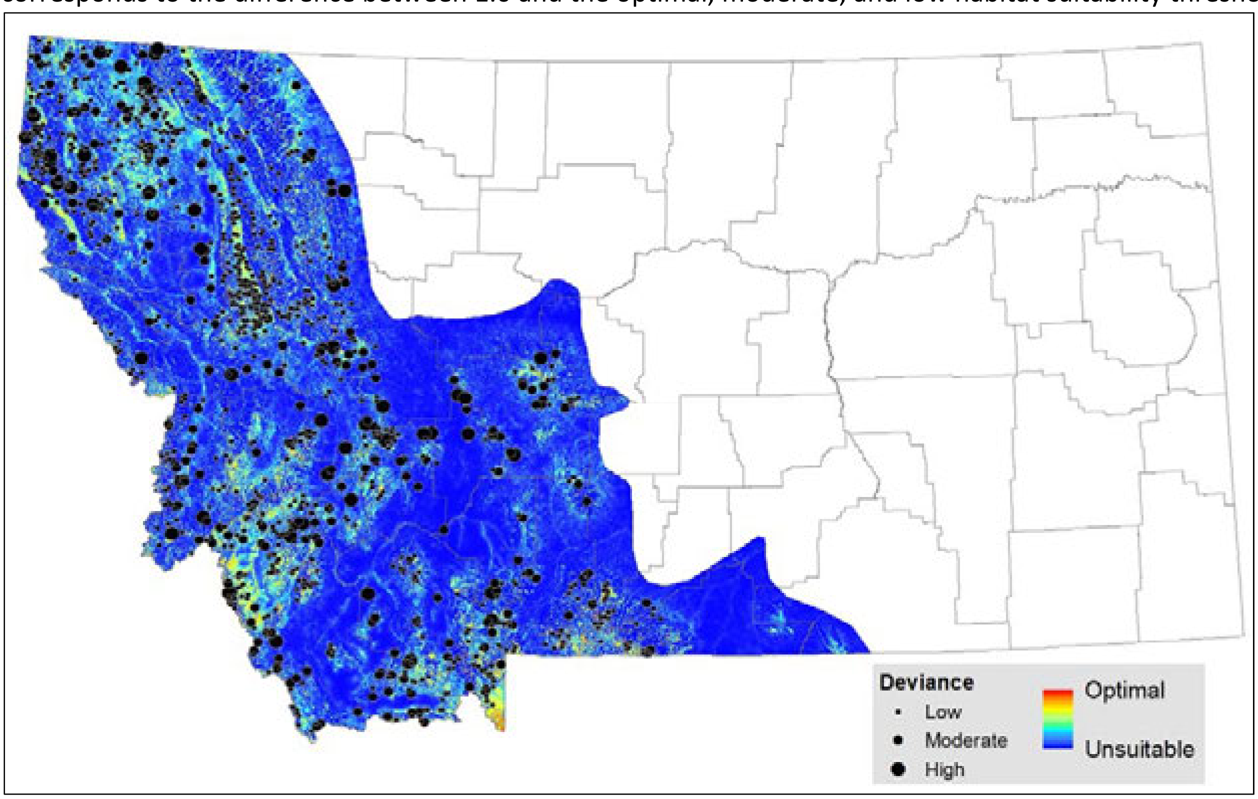


Figure 7. Continuous habitat suitability model output with all 6,720 observations (black) and survey locations that could have detected the species (gray).

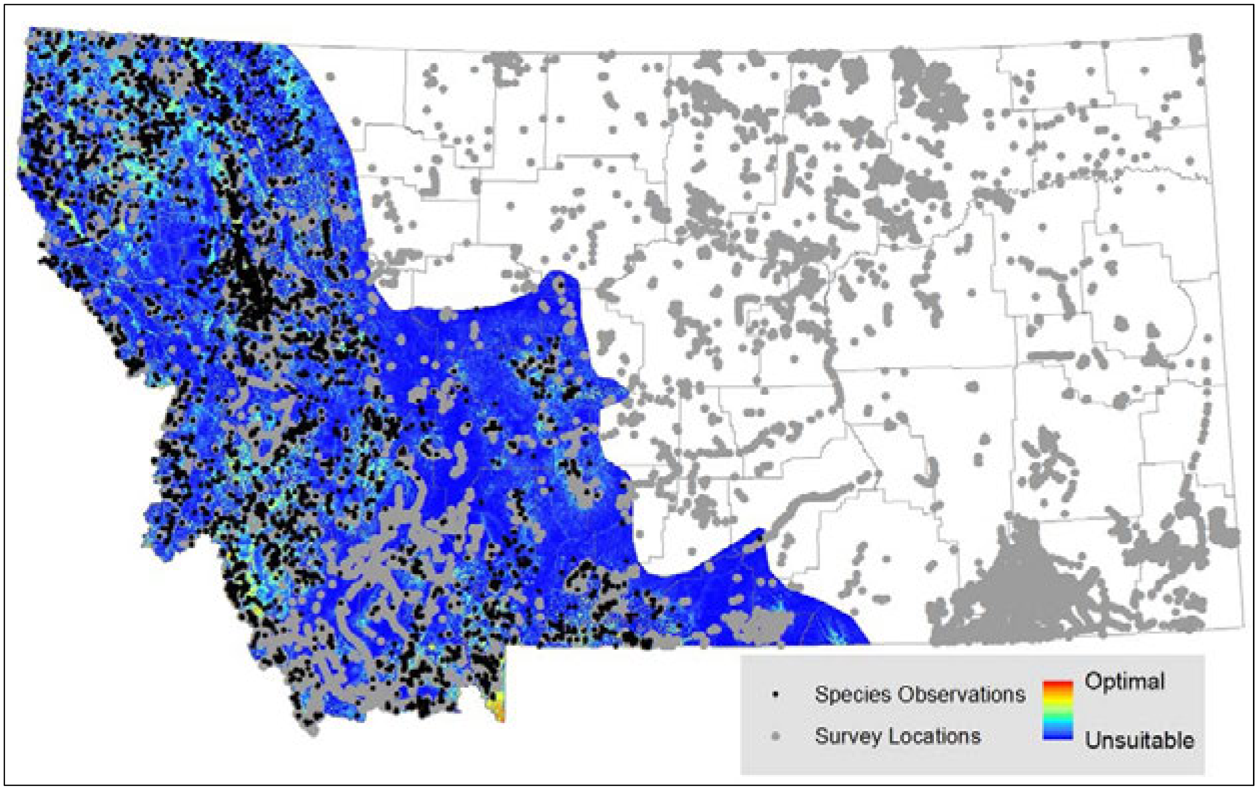


Figure 8. Model output classified into habitat suitability classes.

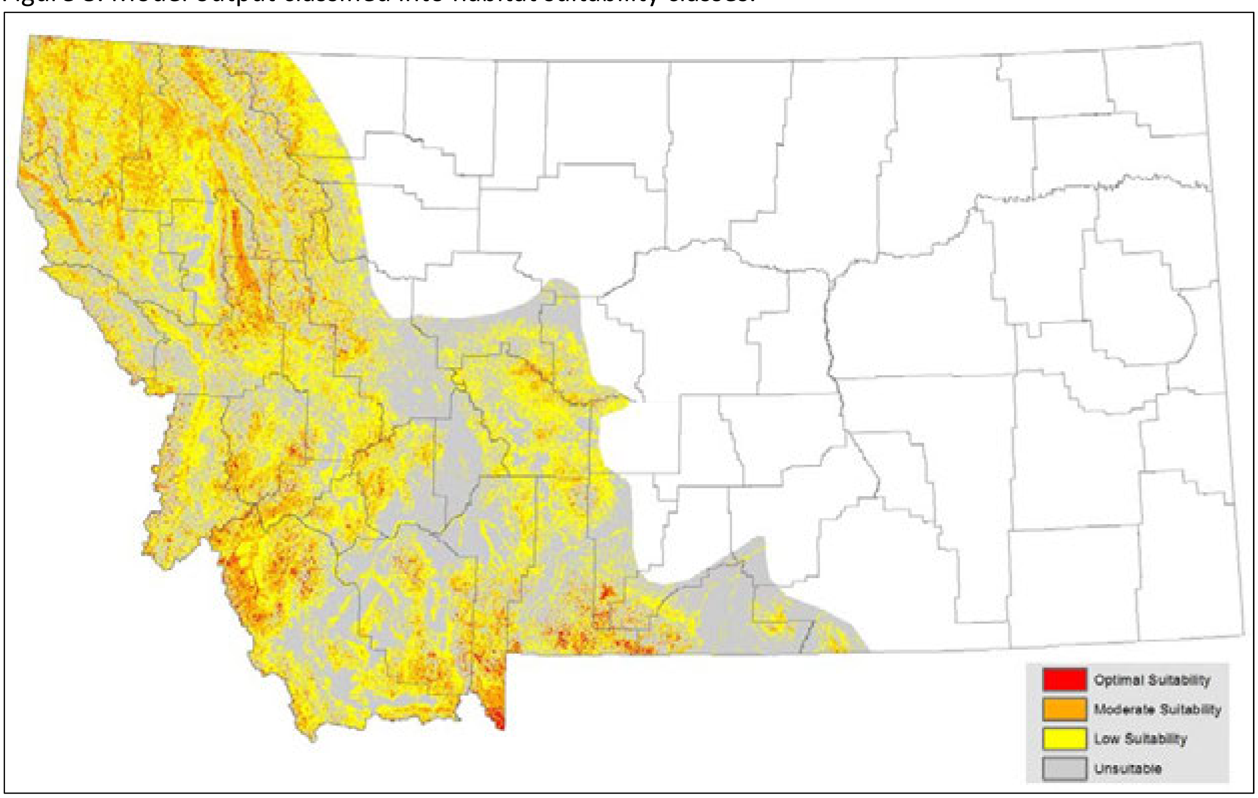
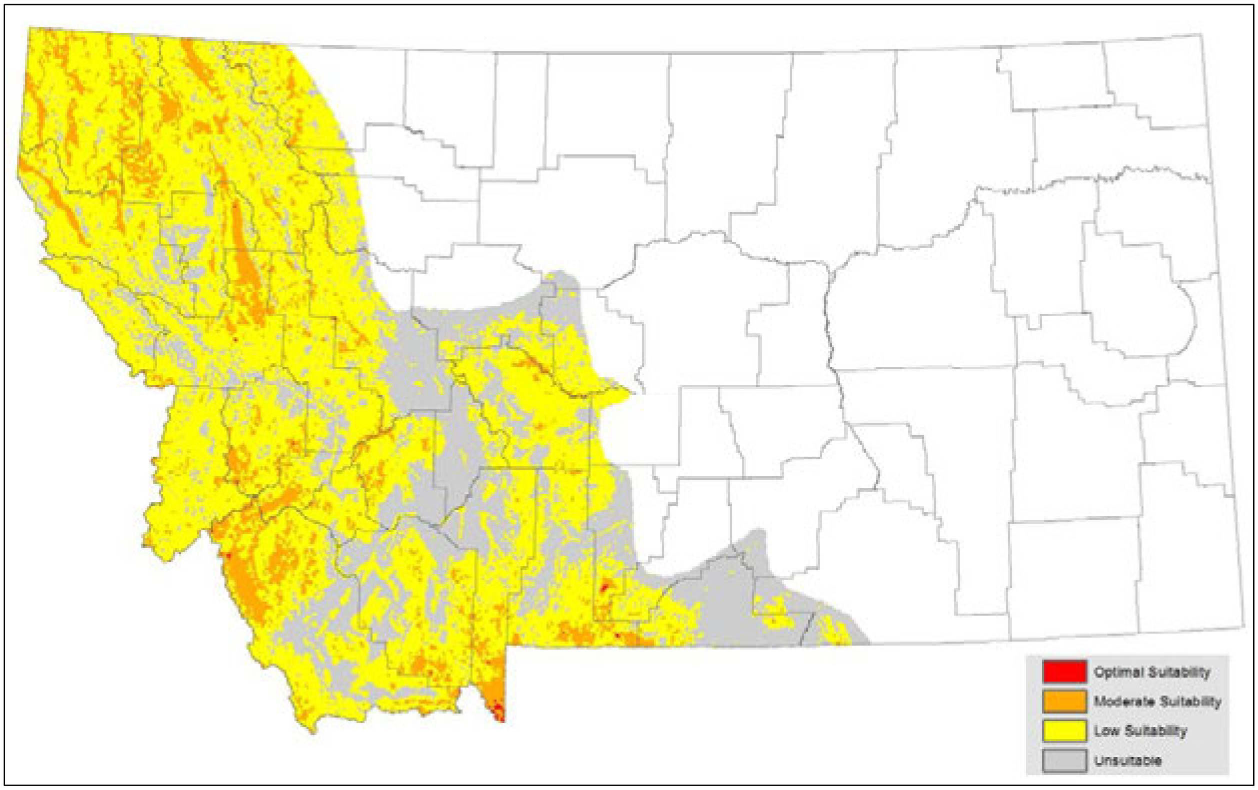


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Columbia Spotted Frog

Ecological System	Code	Association	Count[a]
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	122
Open Water	11	Common	74
Alpine-Montane Wet Meadow	9217	Common	69
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	24
Emergent Marsh	9222	Common	9
Rocky Mountain Subalpine-Montane Fen	9234	Common	6
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	4
Rocky Mountain Conifer Swamp	9111	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	33
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	20
Great Plains Floodplain	9159	Occasional	0
Great Plains Riparian	9326	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 1,049 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

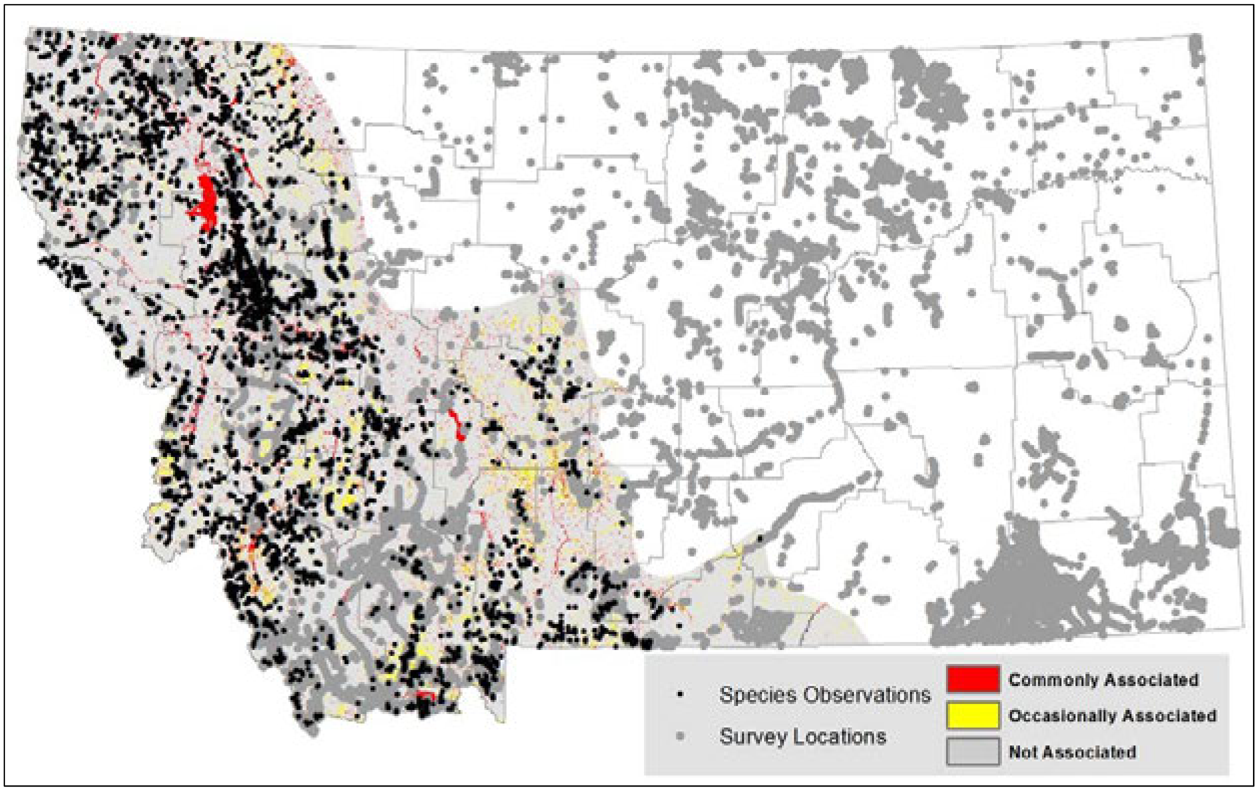
Measure	Value
Area of entire modeled range (percent of Montana)	150,229.8 km^2 (39.5%)
Area of Commonly and Occasionally Associated ES	13,304.0 km^2
Area of Commonly Associated ES	6,987.0 km^2
Area of Occasionally Associated ES	6,317.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	34.5%
Commonly Associated ES AVI[a]	29.5%
Occasionally Associated ES AVI[a]	5.0%

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

Figure 10. Deductive model output classified into habitat associations.



Snapping Turtle (*Chelydra serpentina*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3 (Species of Concern)
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 7, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 7, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Snapping Turtle general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics generally indicate good model fit. The high standard deviation in the model output associated with the riparian areas likely results from a small portion of the data coming from more isolated upland settings. The delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do a reasonably good job of representing the amount of suitable habitat for Snapping Turtle within its native range and overestimate suitable habitat in the introduced range. Low AVI evaluations are a result of the fact that a large portion of observations for this species are made on roads which are not suitable habitat.

Suggested Citation: Montana Natural Heritage Program. 2017. Snapping Turtle (*Chelydra serpentina*) predicted suitable habitat models created on October 07, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARAAB01010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	146
Location Data Selection Rule 1	Records with <= 1600 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	119
Location Data Selection Rule 2	No overlap in locations within 800 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	78
Season Modeled	Entire state, Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
conttmax	43.8%	contnsasp	1.0%
catesys	24.4%	contprecip	0.8%
contstrmed	10.2%	conttmin	0.8%
catsoiltemp	6.2%	contwinpcp	0.2%
catgeol	4.5%	contwinrad	0.0%
catsoilord	3.8%	contfrsted	0.0%
contslope	1.7%	contddays	0.0%
contndvi	1.3%	contewasp	0.0%
contelev	1.1%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.013
Moderate Logistic Threshold[b]	0.118
Optimal Logistic Threshold[c]	0.478
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	107,478.7 km^2
Area of predicted low suitability habitat within modeled range	80,718.2 km^2
Area of moderate suitability habitat within modeled range	22,011.6 km^2
Area of predicted optimal habitat within modeled range	4,748.8 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	92.3%
Moderate AVI[a]	78.2%
Optimal AVI[a]	56.4%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.637 ± 3.358
Training AUC[c]	0.964
Test AUC[d]	0.940

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 8.686, 4.278 and 1.478, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

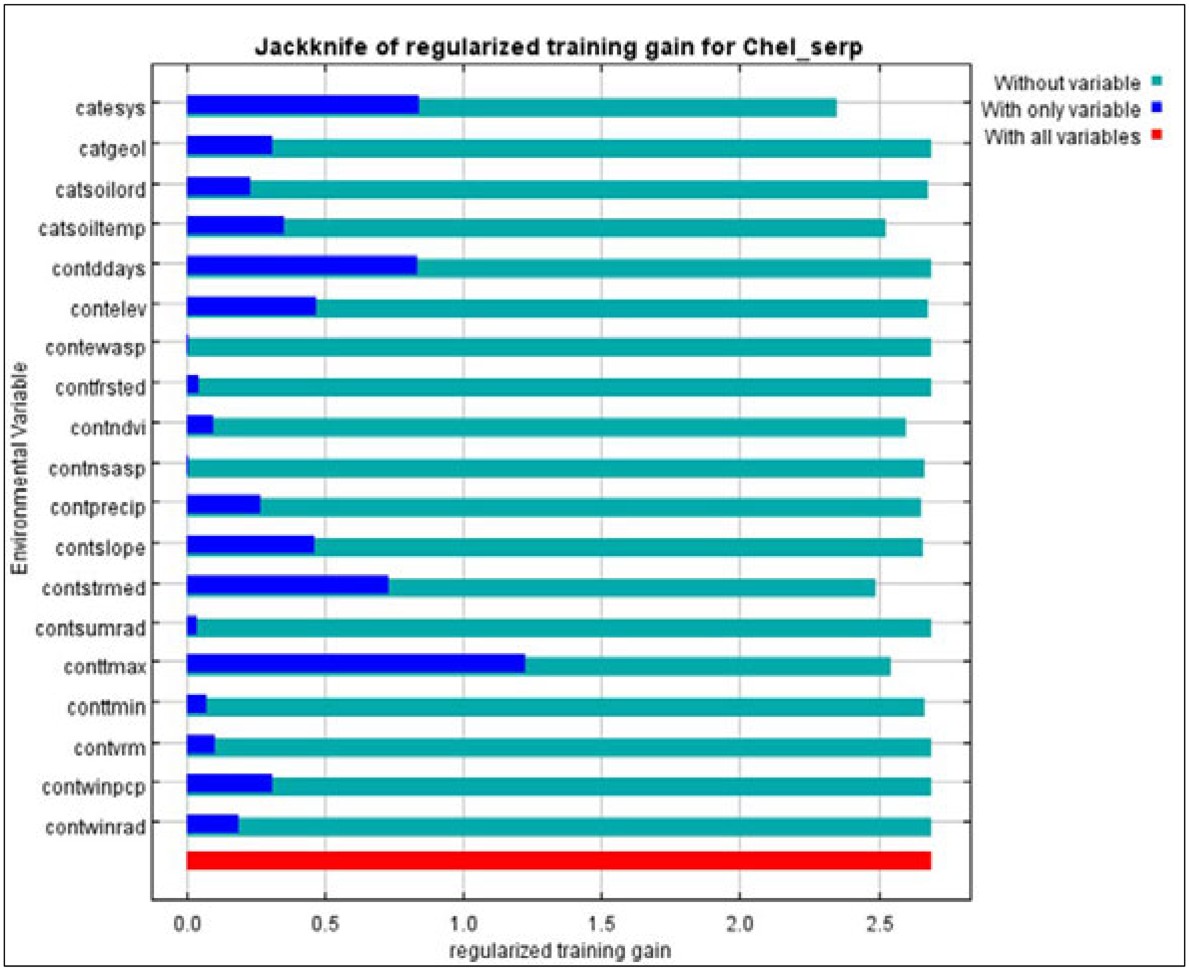
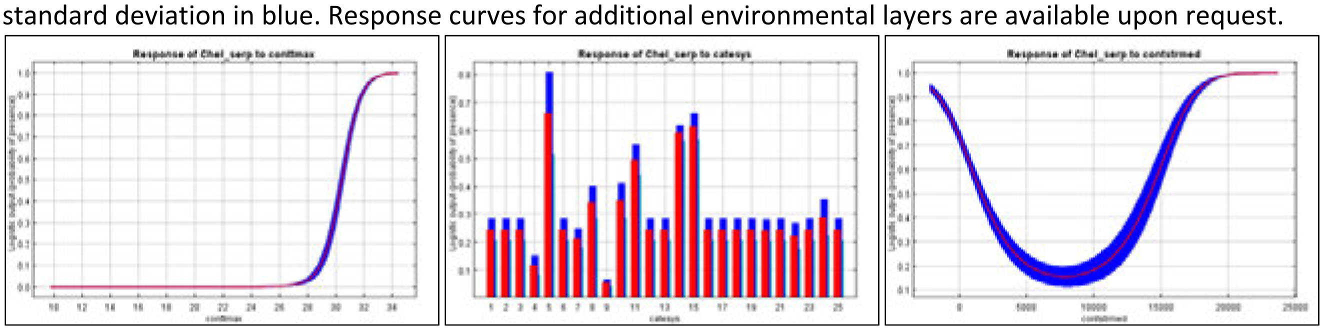


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

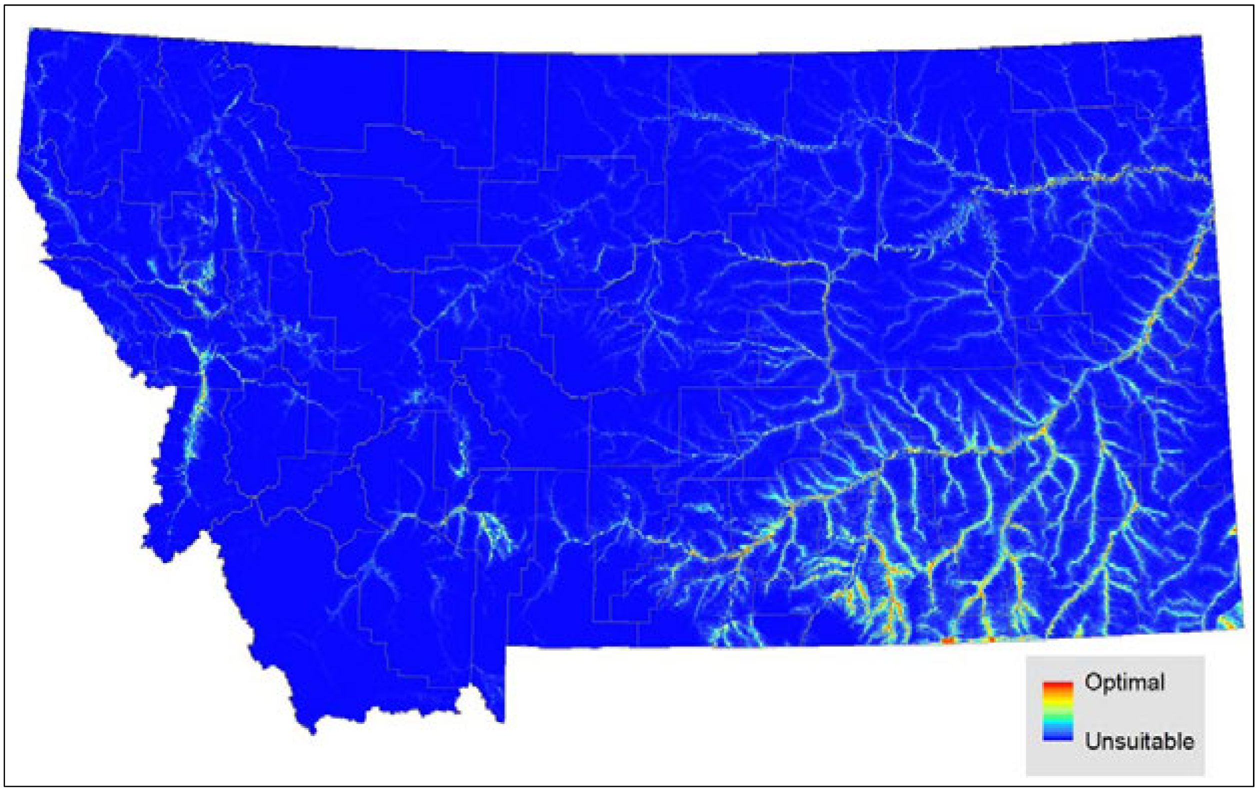


Figure 4. Standard deviation in the model output across the averaged models.

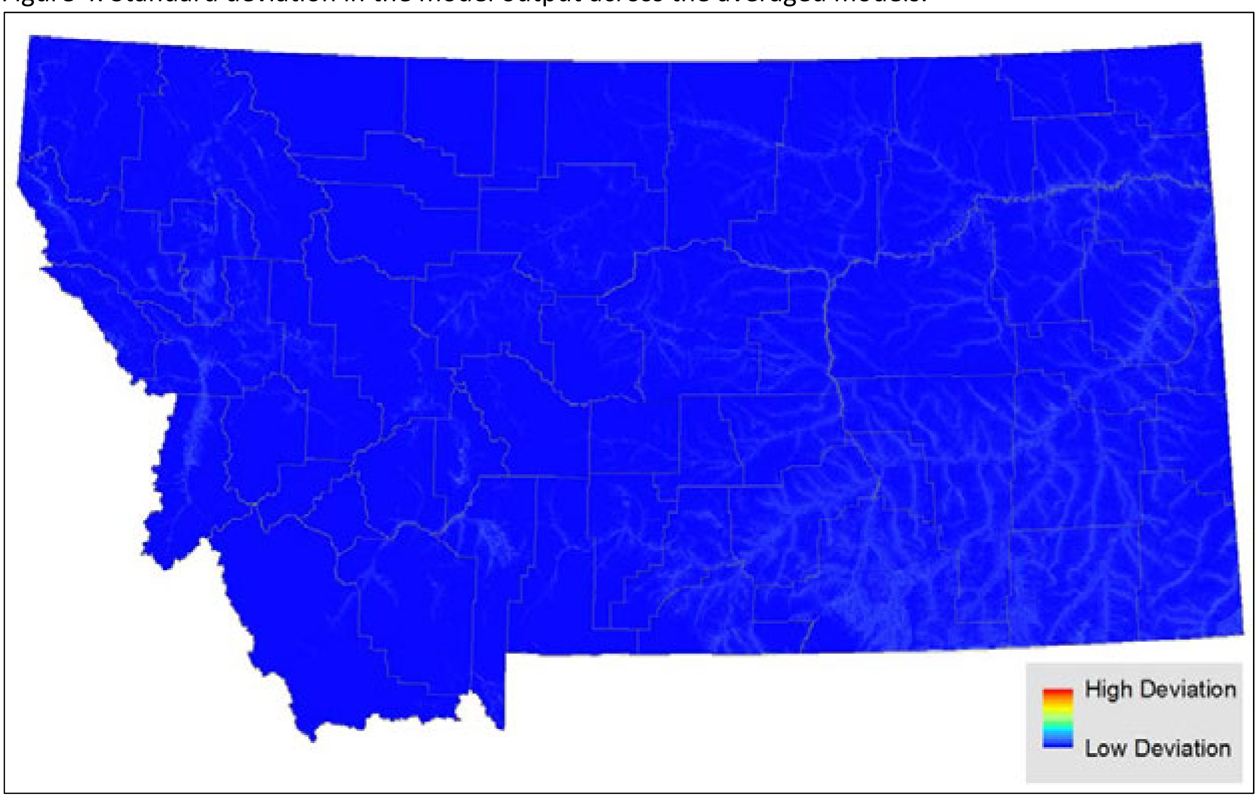


Figure 5. Continuous habitat suitability model output with the 78 observations used for modeling.

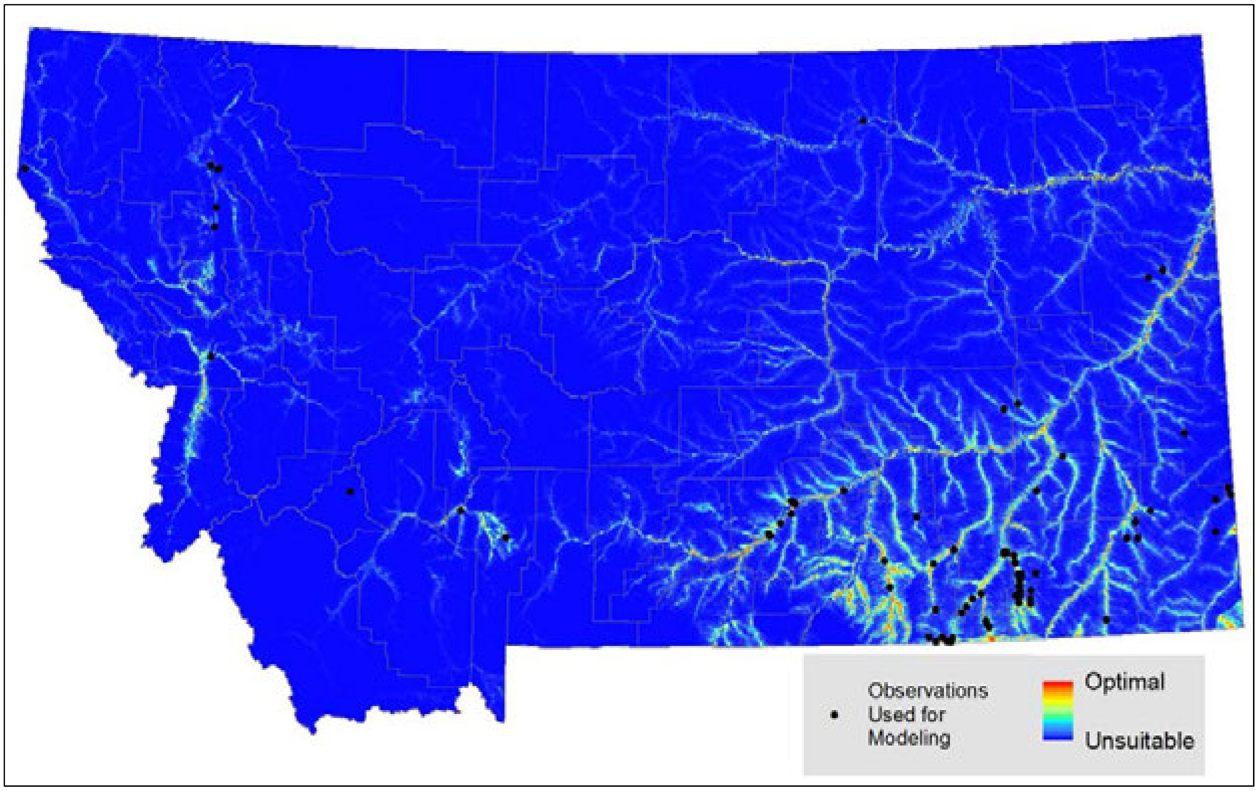


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

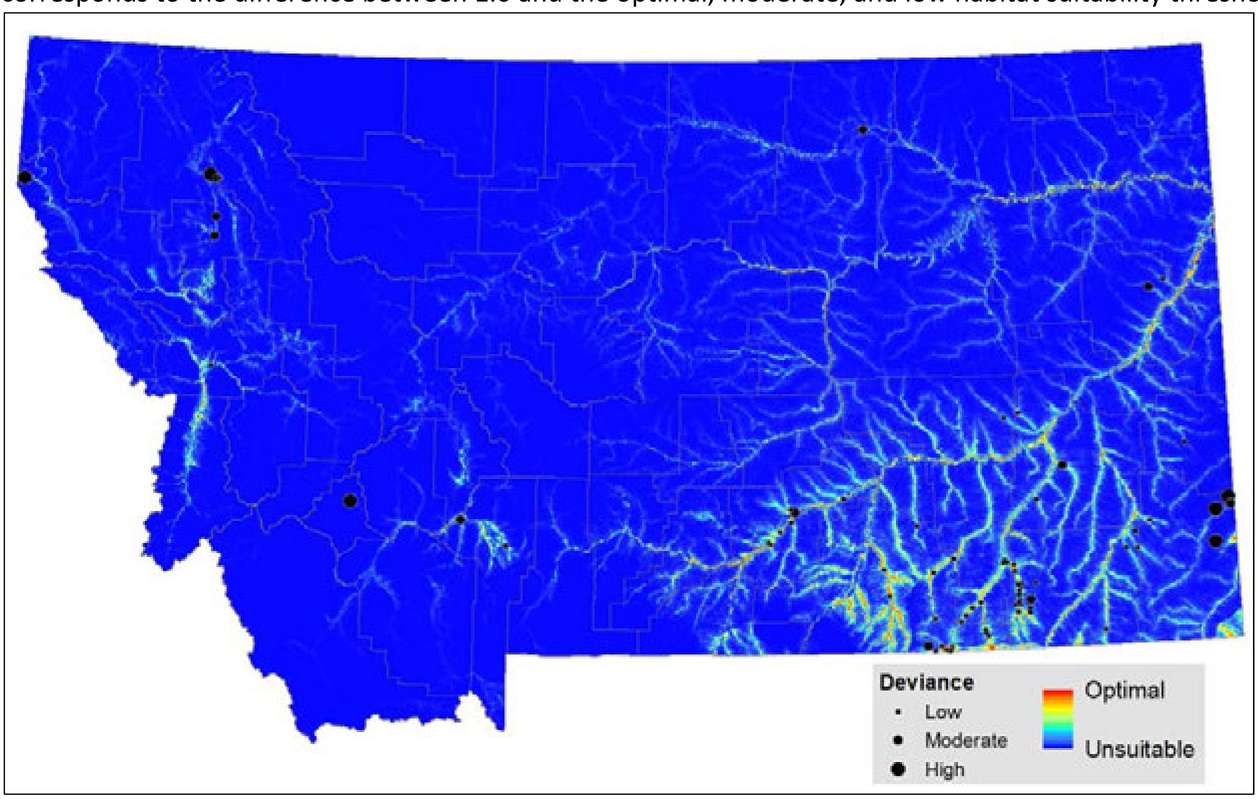


Figure 7. Continuous habitat suitability model output with all 146 observations (black) and survey locations that could have detected the species (gray).

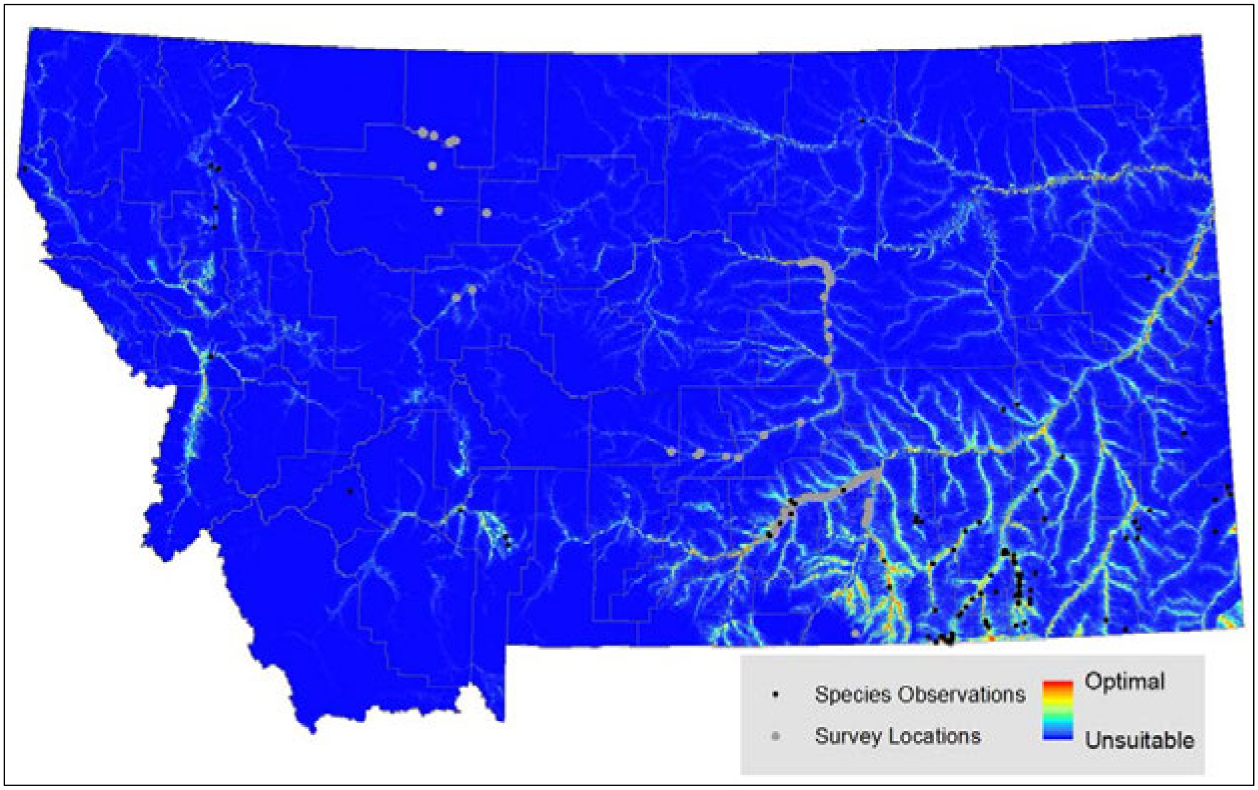


Figure 8. Model output classified into habitat suitability classes.

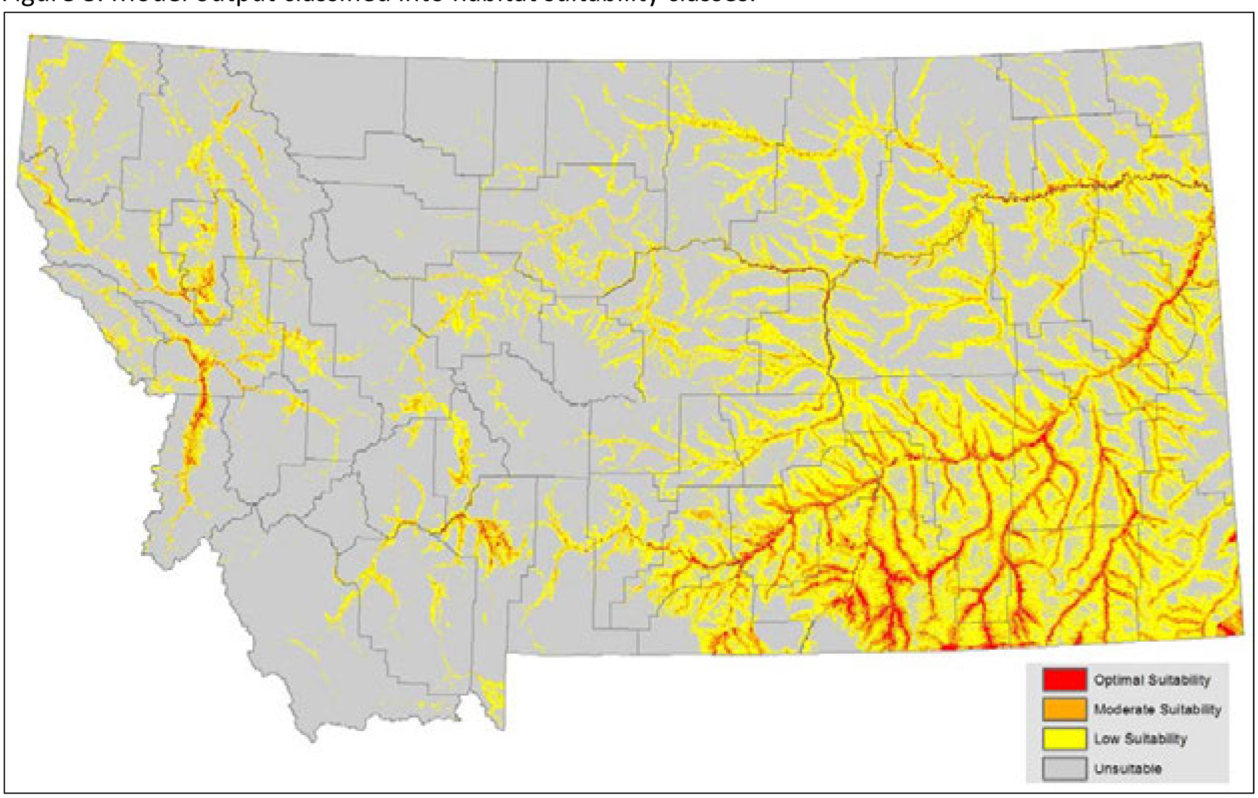
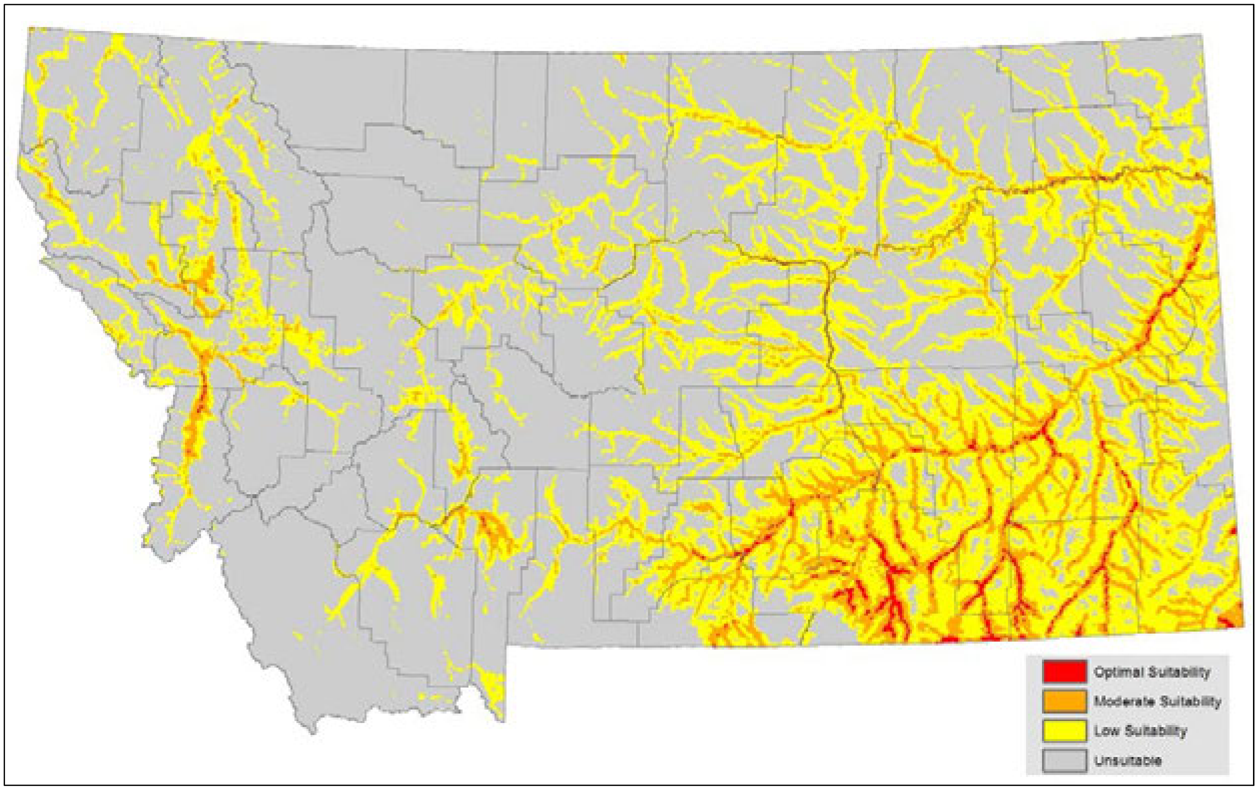


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Snapping Turtle

Ecological System	Code	Association	Count[a]
Great Plains Riparian	9326	Common	16
Open Water	11	Common	11
Great Plains Floodplain	9159	Common	3
Emergent Marsh	9222	Common	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	3
Great Plains Open Freshwater Depression Wetland	9218	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 78 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

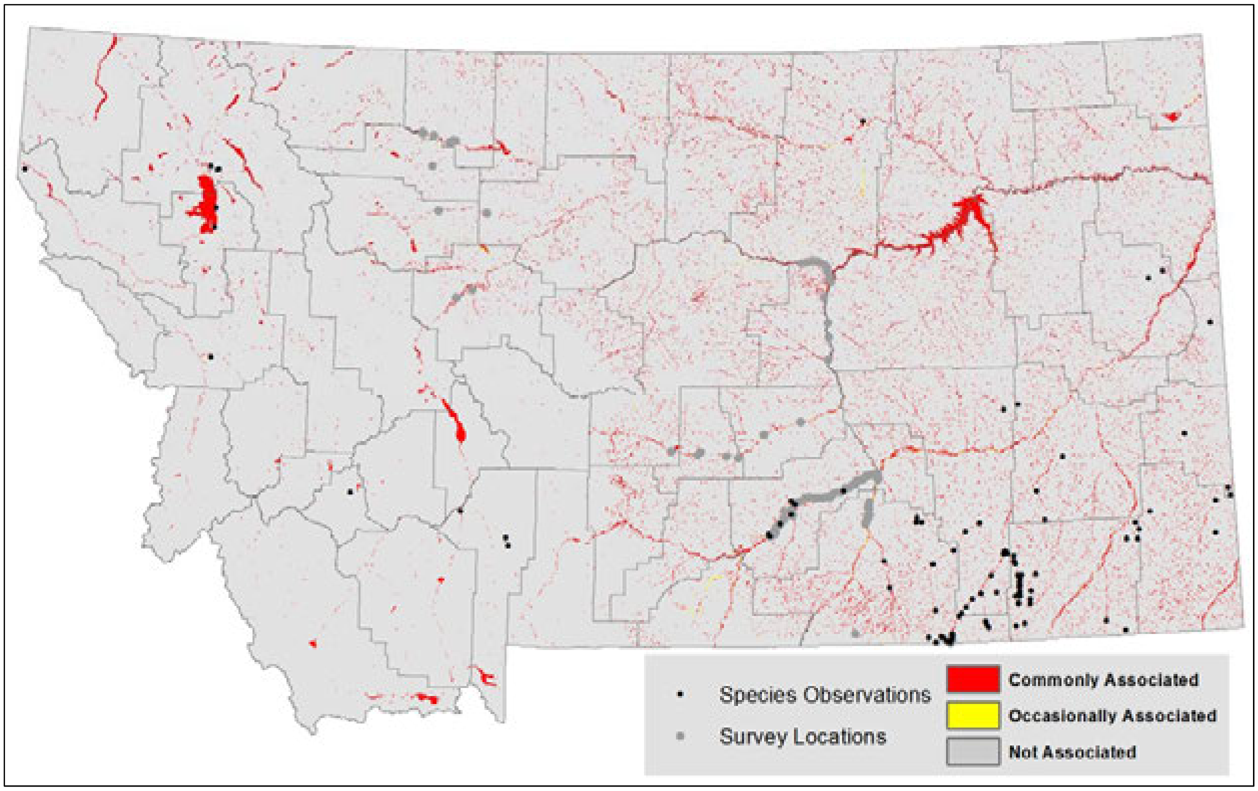
Measure	Value
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	11,883.0 km^2
Area of Commonly Associated ES	11,600.0 km^2
Area of Occasionally Associated ES	282.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	42.3%
Commonly Associated ES AVI[a]	38.5%
Occasionally Associated ES AVI[a]	3.9%

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

Figure 10. Deductive model output classified into habitat associations.



Painted Turtle (*Chrysemys picta*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 5, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Painted Turtle general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with somewhat under represent the amount of suitable habitat across the species' known range in Montana because some wetlands and riparian types are poorly represented in the current land cover layer. However, these systems do represent the core aquatic habitats the species is dependent on and many observations for the species are made within a short distance of these habitats.

Suggested Citation: Montana Natural Heritage Program. 2017. Painted Turtle (*Chrysemys picta*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARAAD01010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,057
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,872
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	942
Season Modeled	Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	35.4%	contstrmed	2.5%
catsoiltemp	19.0%	contndvi	2.1%
catgeol	11.3%	contewasp	1.0%
contelev	5.9%	conttmin	0.9%
catsoilord	5.2%	contnsasp	0.8%
contslope	4.5%	contfrsted	0.7%
contddays	4.0%	contwinpcp	0.7%
conttmax	3.1%	contwinrad	0.1%
contsumrad	2.8%	contprecip	0.0%

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.089
Moderate Logistic Threshold[b]	0.372
Optimal Logistic Threshold[c]	0.746
Area of entire modeled range (percent of Montana)	363,952.15 km^2 (95.7%)
Total area of predicted suitable habitat within modeled range	232,921.9 km^2
Area of predicted low suitability habitat within modeled range	159,382.0 km^2
Area of moderate suitability habitat within modeled range	68,322.0 km^2
Area of predicted optimal habitat within modeled range	5,217.9 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	97.9%
Moderate AVI[a]	74.4%
Optimal AVI[a]	21.3%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.534 ± 1.184
Training AUC[c]	0.870
Test AUC[d]	0.862

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.832, 1.979 and 0.587, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

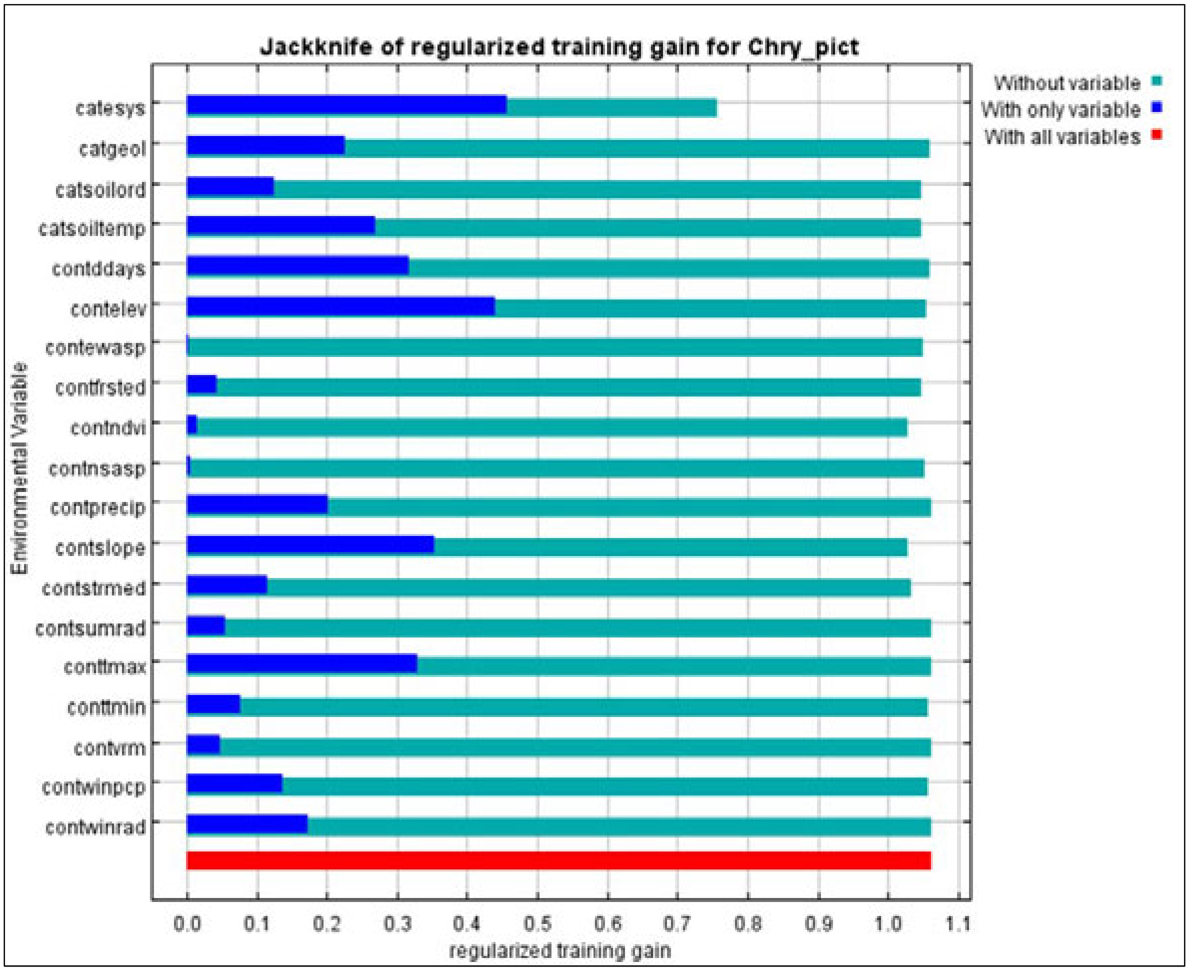
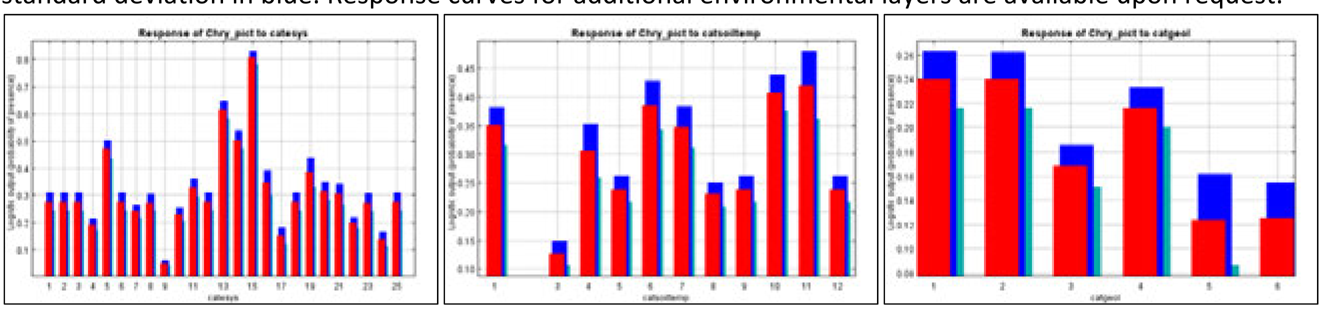


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

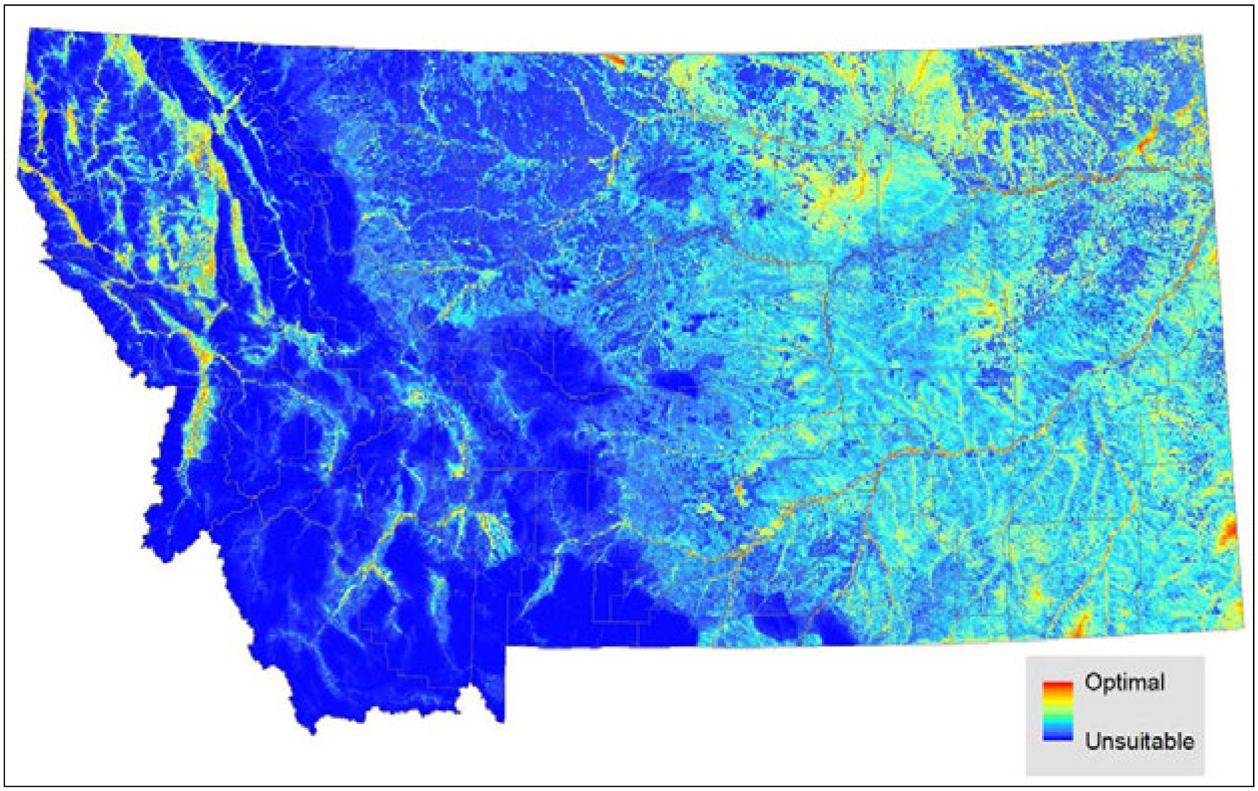


Figure 4. Standard deviation in the model output across the averaged models.

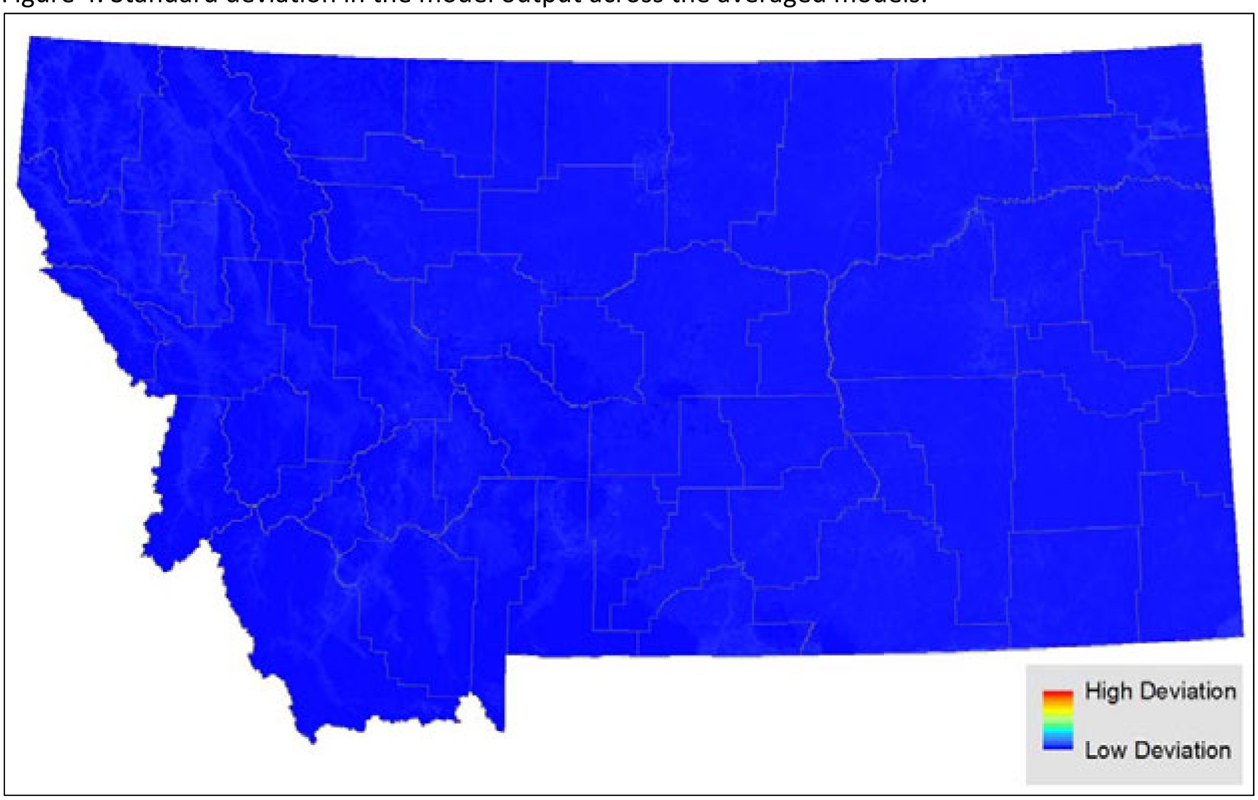


Figure 5. Continuous habitat suitability model output with the 942 observations used for modeling.

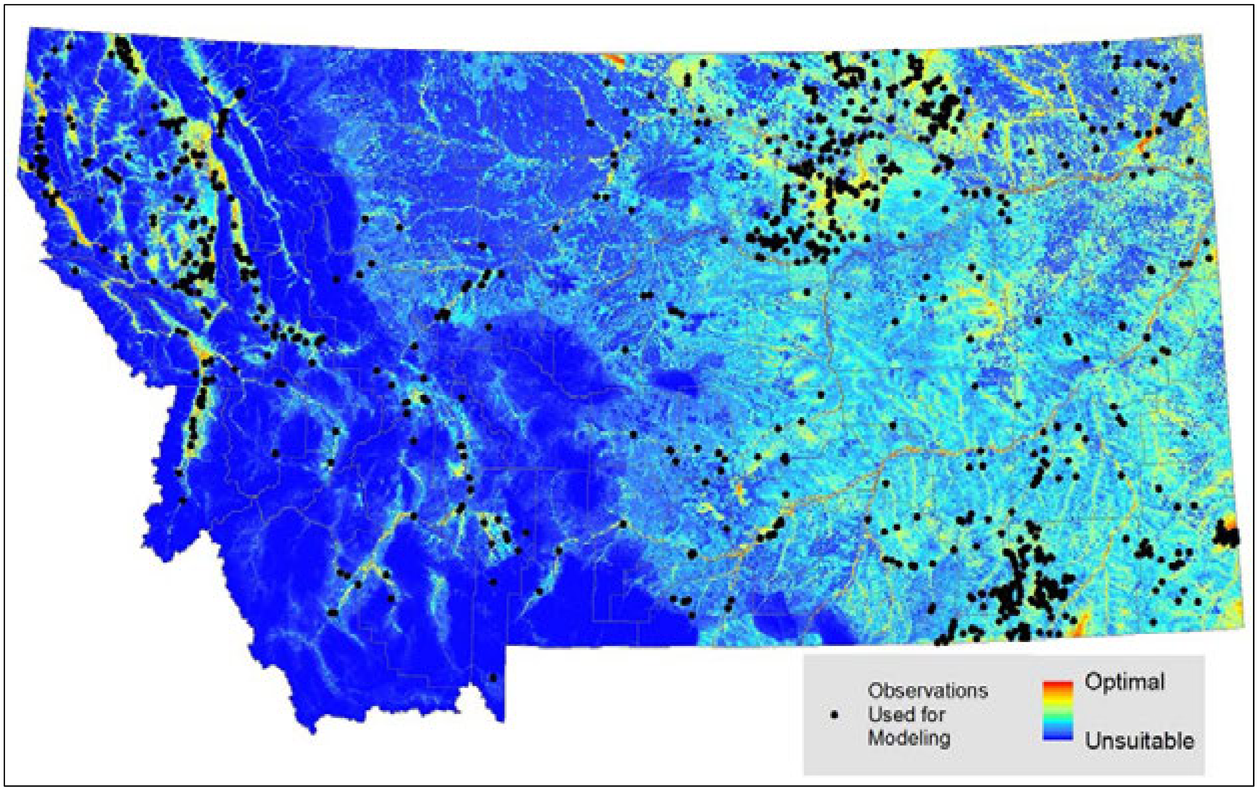


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

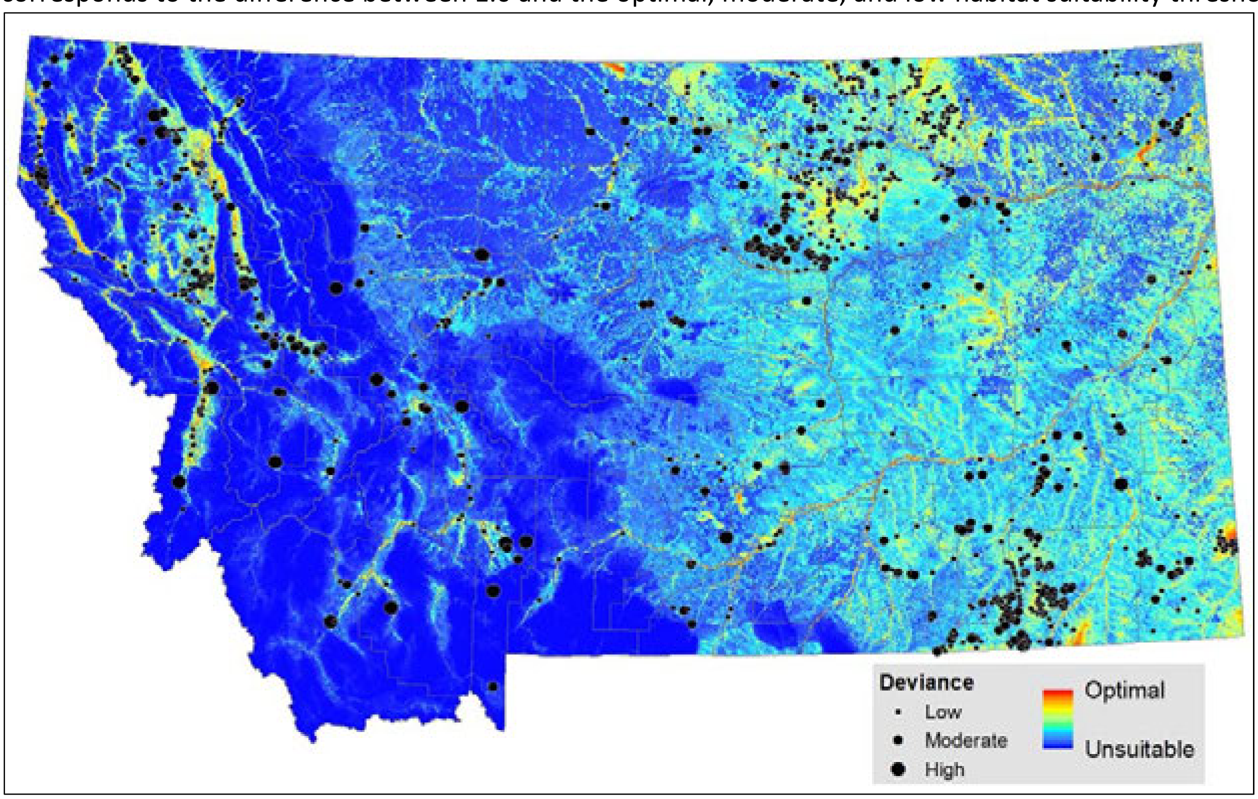


Figure 7. Continuous habitat suitability model output with all 2,057 observations (black) and survey locations that could have detected the species (gray).

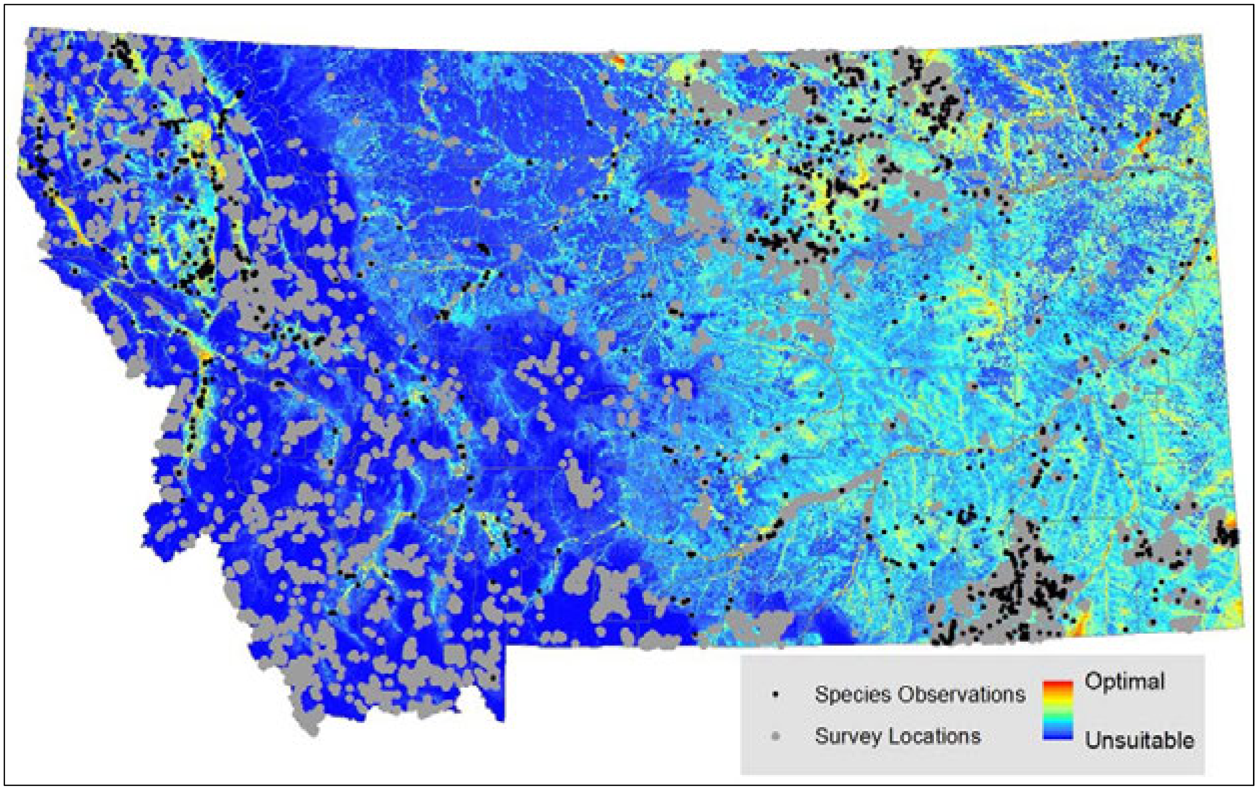


Figure 8. Model output classified into habitat suitability classes.

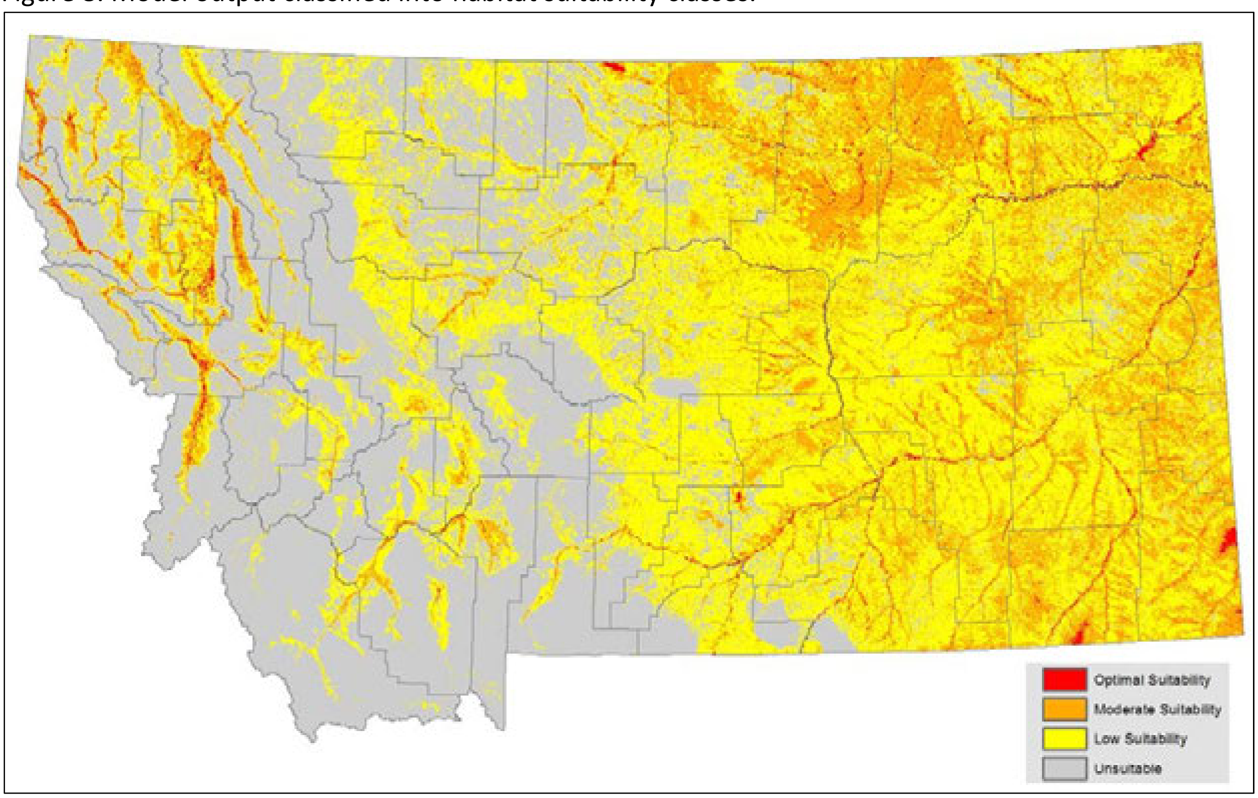
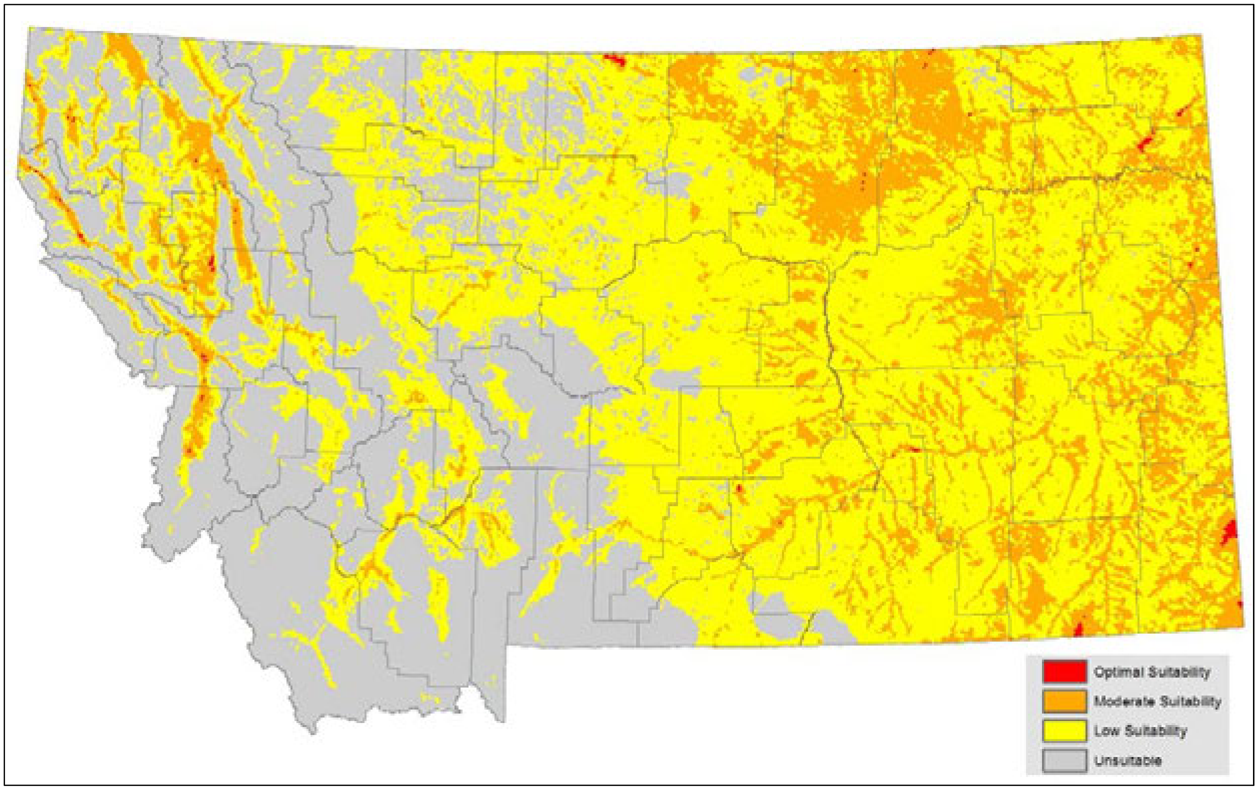


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Painted Turtle

Ecological System	Code	Association	Count[a]
Open Water	11	Common	141
Great Plains Riparian	9326	Common	83
Emergent Marsh	9222	Common	24
Great Plains Floodplain	9159	Common	18
Great Plains Prairie Pothole	9203	Common	8
Great Plains Closed Depressional Wetland	9252	Common	3
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	30
Alpine-Montane Wet Meadow	9217	Occasional	13
Great Plains Wooded Draw and Ravine	4328	Occasional	11
Great Plains Saline Depression Wetland	9256	Occasional	8
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Occasional	7
Quarries, Strip Mines and Gravel Pits	31	Occasional	2
Rocky Mountain Conifer Swamp	9111	Occasional	0
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 942 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

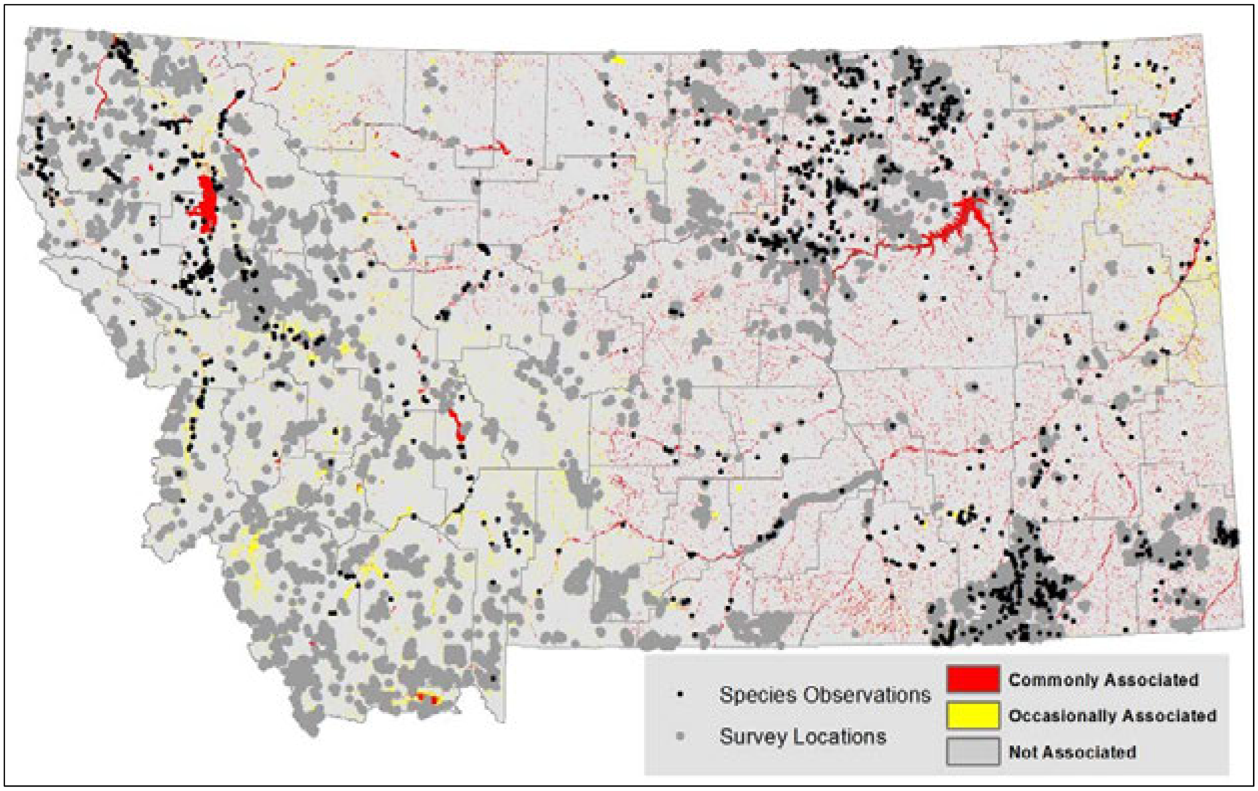
Measure	Value
Area of entire modeled range (percent of Montana)	363,952.15 km^2 (95.7%)
Area of Commonly and Occasionally Associated ES	20,162.0 km^2
Area of Commonly Associated ES	12,048.0 km^2
Area of Occasionally Associated ES	8,113.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	36.9%
Commonly Associated ES AVI[a]	29.4%
Occasionally Associated ES AVI[a]	7.5%

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

Figure 10. Deductive model output classified into habitat associations.



Greater Short-horned Lizard (*Phrynosoma hernandesi*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3 (Species of Concern)
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 9, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 9, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting what we know about the distribution of Greater Short-horned Lizard general year-round habitat suitability at larger spatial scales across the species' known range as well as highlighting areas the species may be present in outside of the currently documented range. Blocky appearance of output in some areas reflects the importance of soil order in the model. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is reasonably well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of suitable habitat for the species' known range in Montana and this output should be used in conjunction with the inductive model output in survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Greater Short-horned Lizard (*Phrynosoma hernandesi*) predicted suitable habitat models created on October 9, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARACF12080

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,709
Location Data Selection Rule 1	Records with <= 1200 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,601
Location Data Selection Rule 2	No overlap in locations within 800 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	195
Season Modeled	Entire state, Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoilord	30.2%	conttmin	1.5%
catesys	12.1%	contelev	1.4%
catgeol	10.1%	contewasp	1.3%
contwinpcp	8.9%	contnsasp	1.1%
catsoiltemp	7.7%	contstrmed	1.0%
contddays	7.0%	contvrm	0.6%
conttmax	6.6%	contslope	0.6%
contndvi	4.2%	contprecip	0.2%
contsumrad	3.3%	contwinrad	0.0%
contfrsted	2.0%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.096
Moderate Logistic Threshold[b]	0.363
Optimal Logistic Threshold[c]	0.738
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	180,078.5 km^2
Area of predicted low suitability habitat within modeled range	94,696.5 km^2
Area of moderate suitability habitat within modeled range	82,547.9 km^2
Area of predicted optimal habitat within modeled range	2,834.1 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	97.4%
Moderate AVI[a]	79.0%
Optimal AVI[a]	11.8%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.677 ± 1.406
Training AUC[c]	0.890
Test AUC[d]	0.856

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.693, 2.026 and 0.609, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

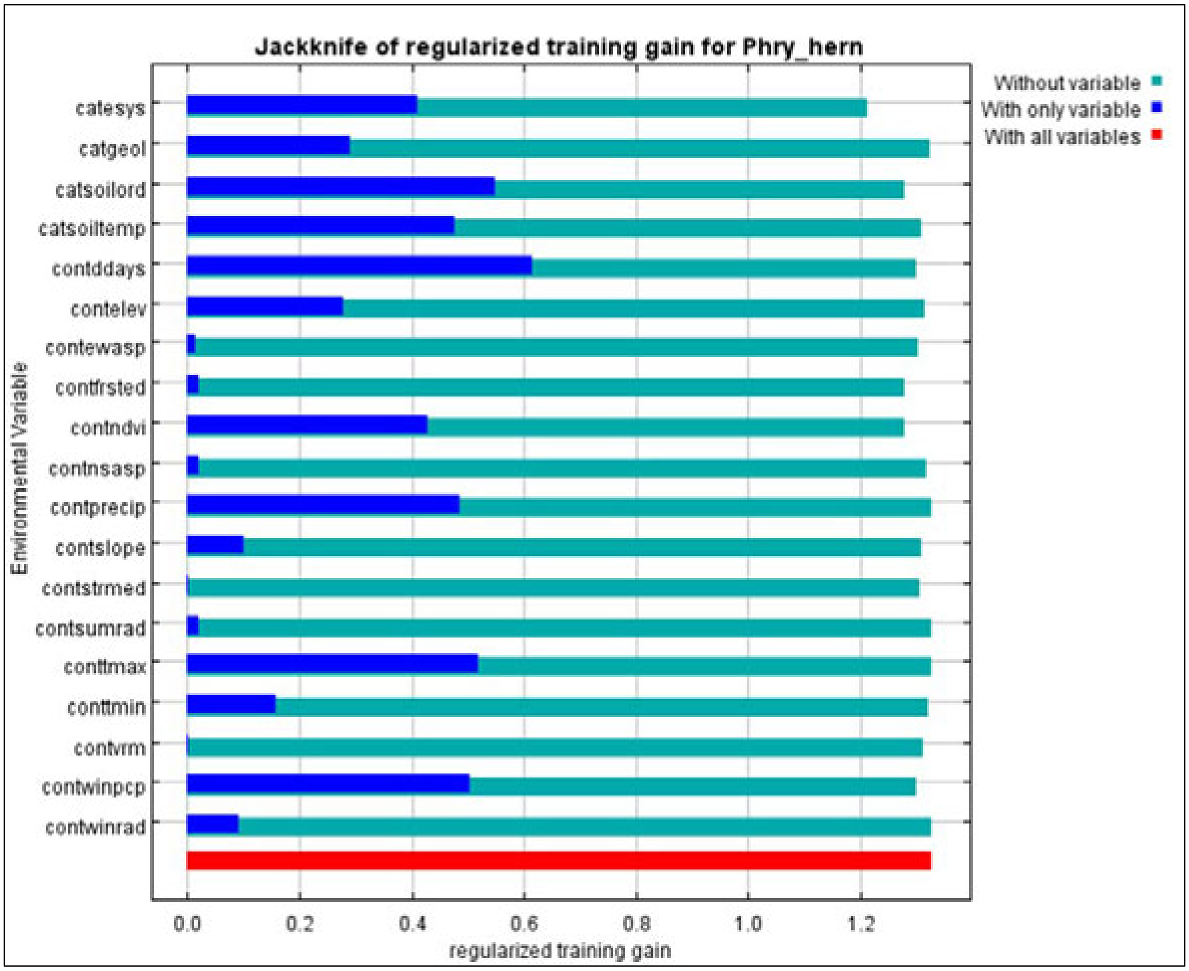
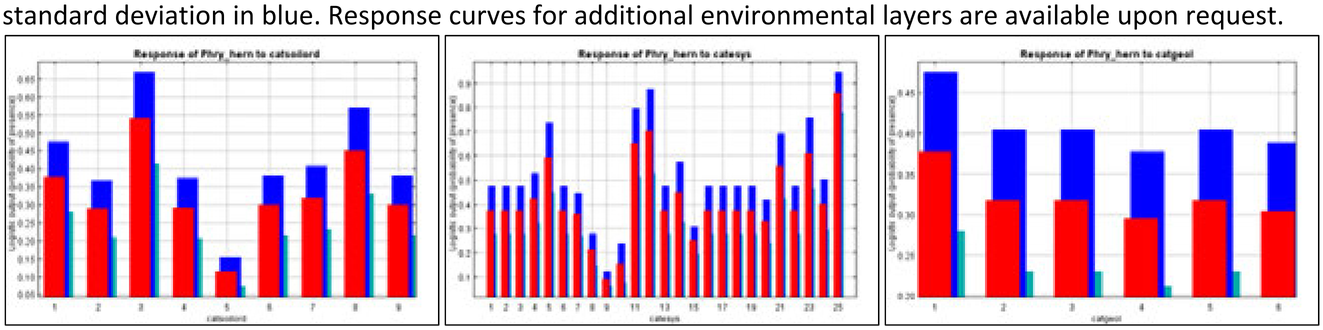


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

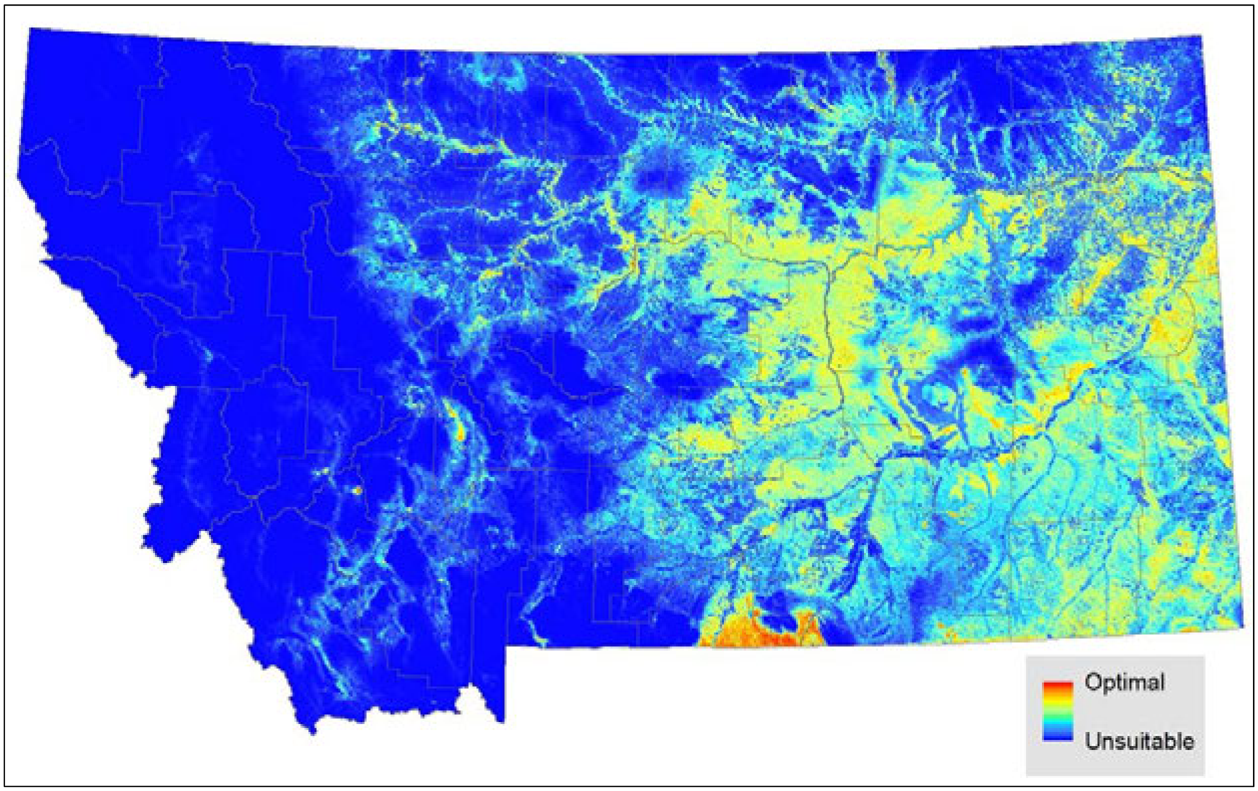


Figure 4. Standard deviation in the model output across the averaged models.

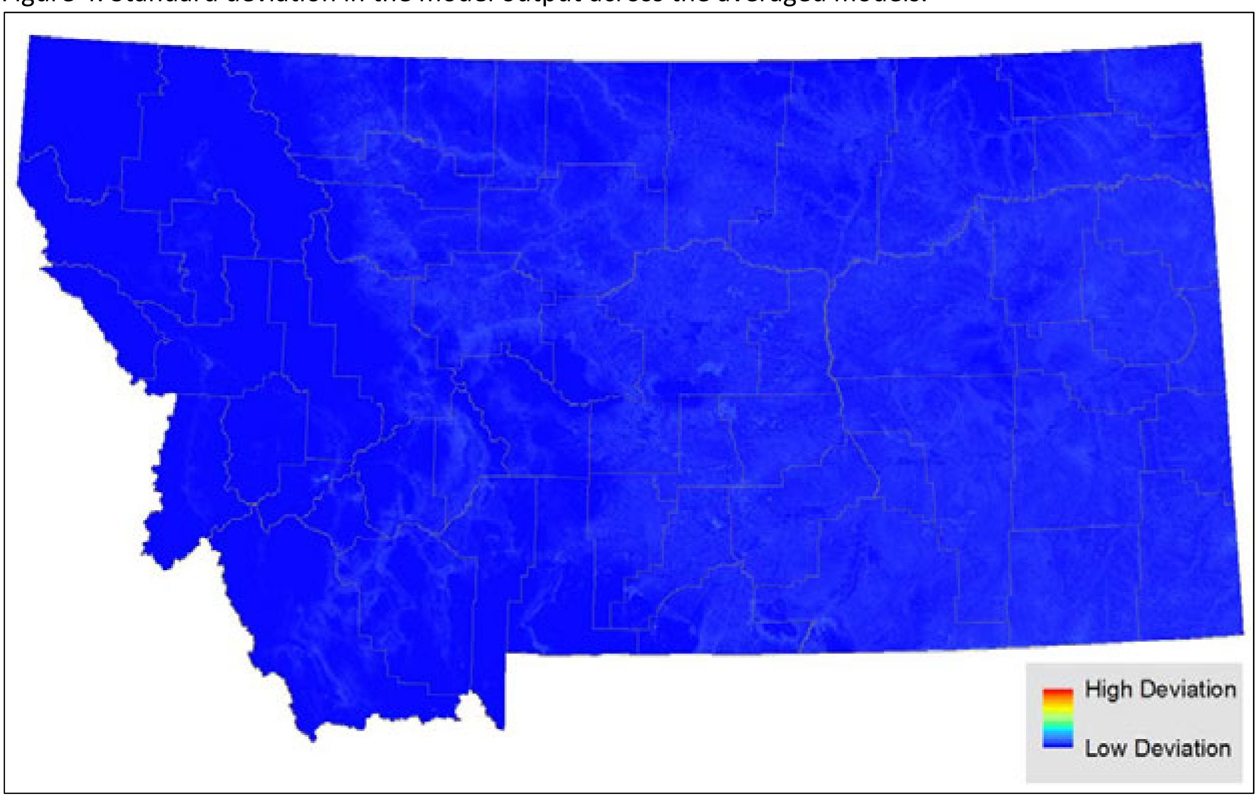


Figure 5. Continuous habitat suitability model output with the 195 observations used for modeling.

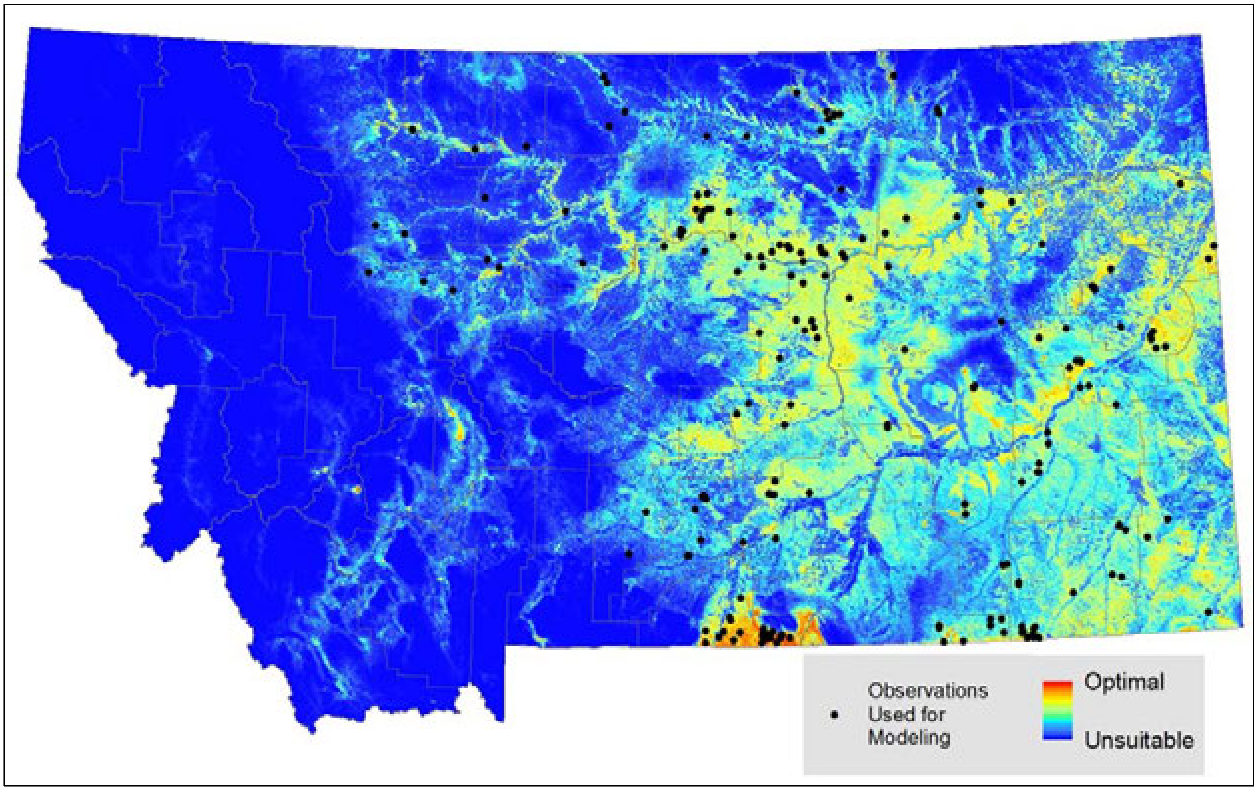


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

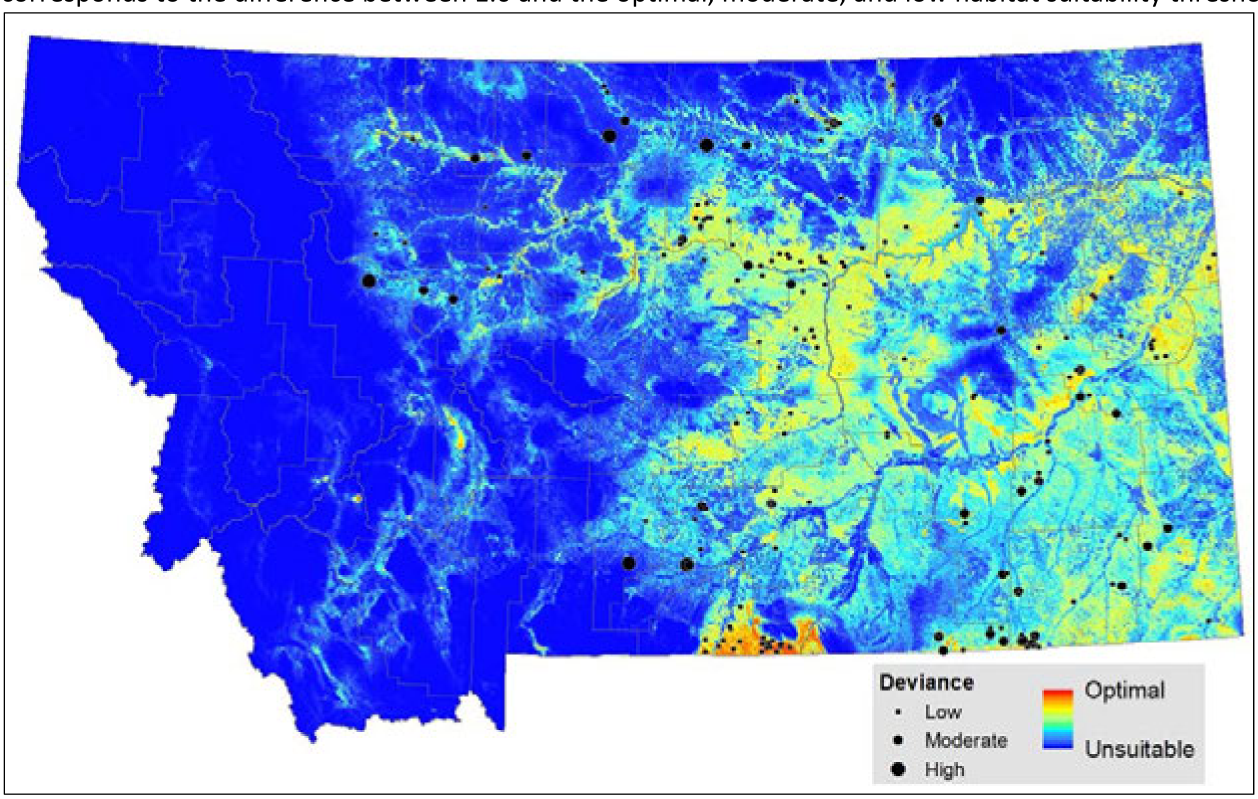


Figure 7. Continuous habitat suitability model output with all 1,709 observations (black) and survey locations that could have detected the species (gray).

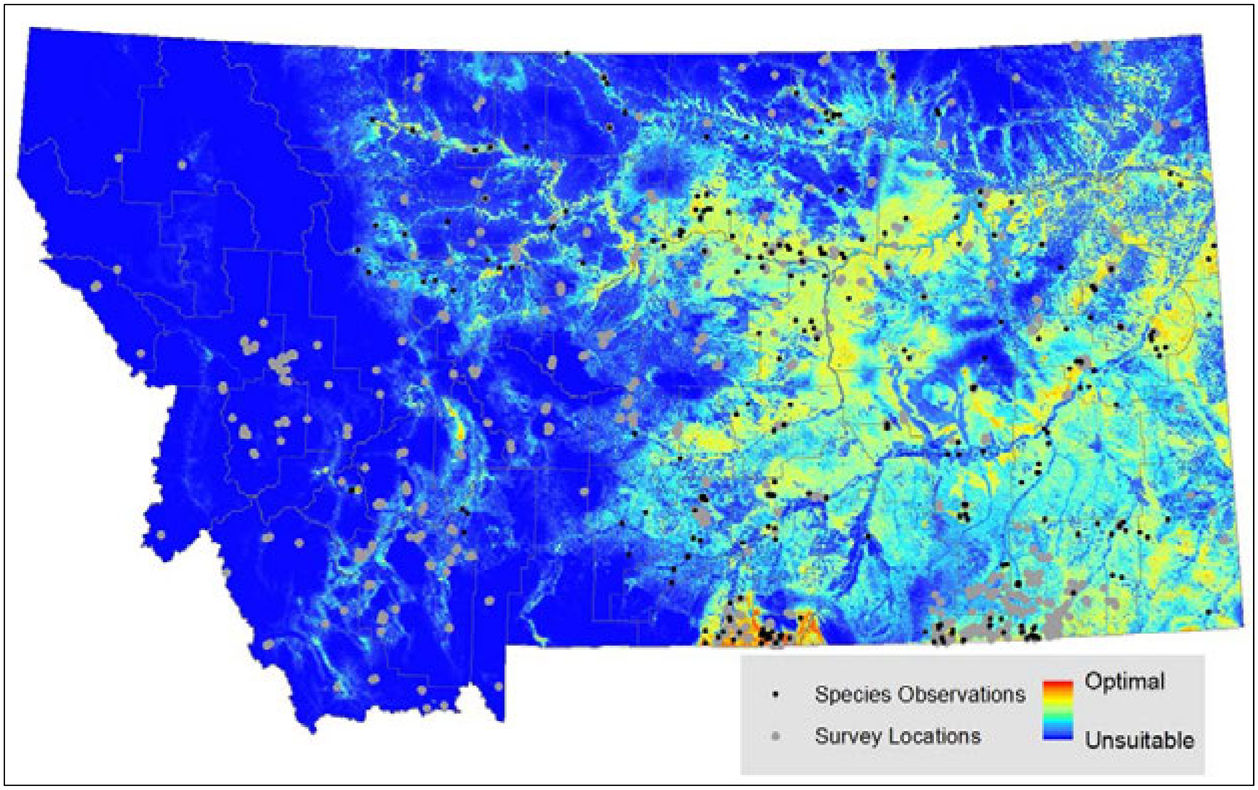


Figure 8. Model output classified into habitat suitability classes.

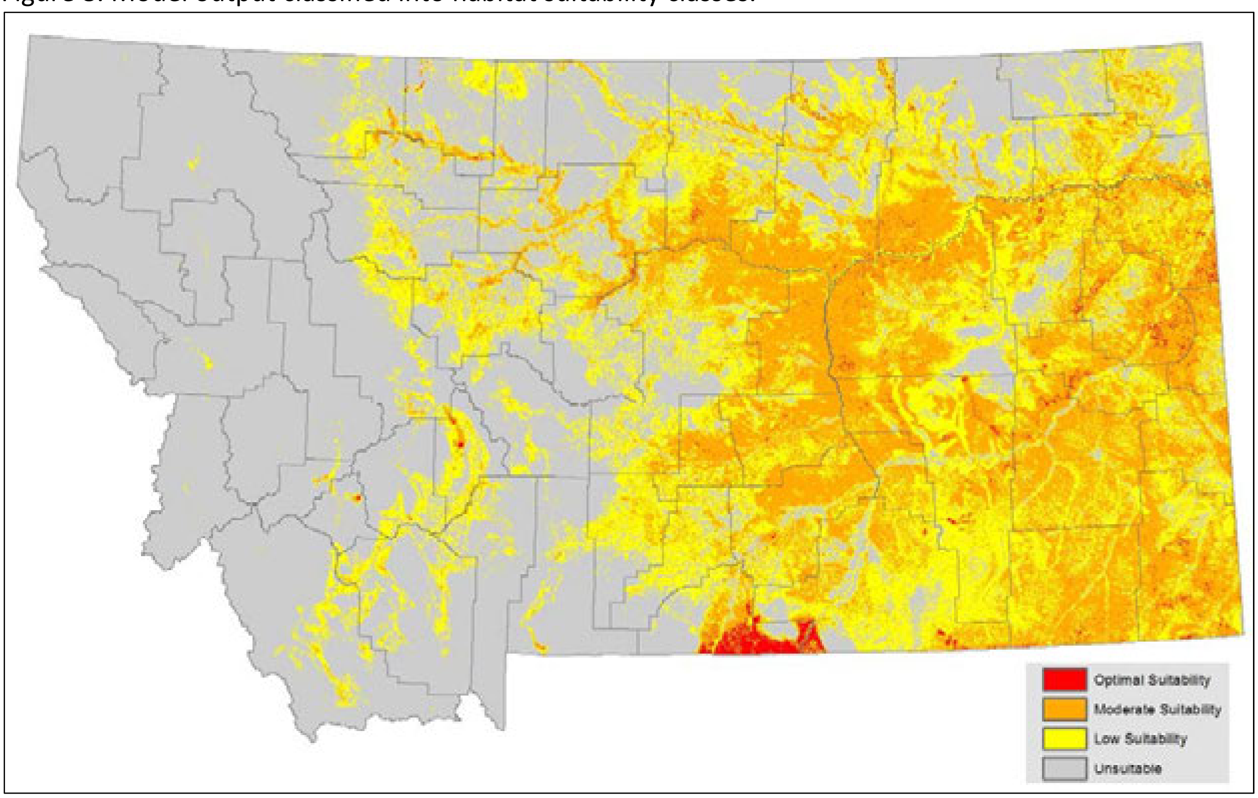
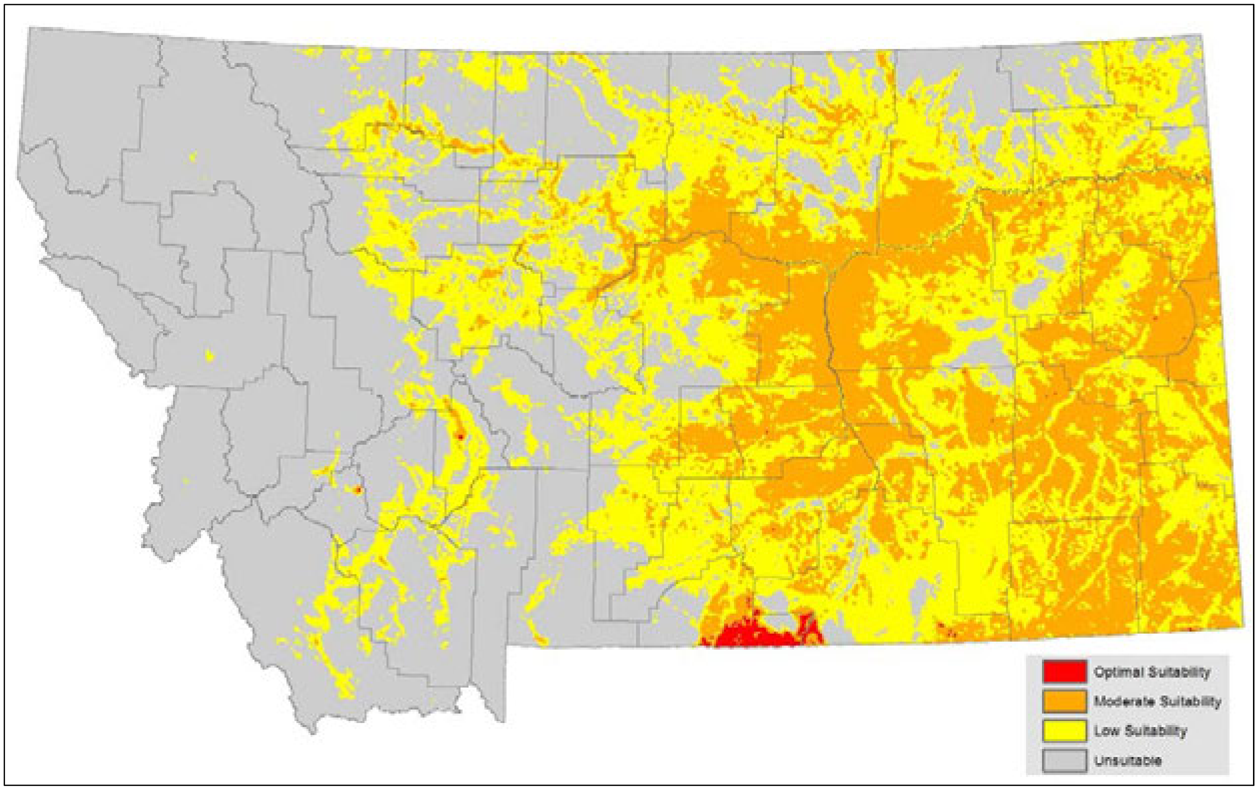


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagons at a scale of 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Greater Short-horned Lizard

Ecological System	Code	Association	Count[a]
Big Sagebrush Steppe	5454	Common	58
Great Plains Mixedgrass Prairie	7114	Common	44
Great Plains Badlands	3114	Common	14
Great Plains Sand Prairie	7121	Common	12
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	10
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	6
Mat Saltbush Shrubland	5203	Common	5
Recently burned grassland	8502	Common	4
Great Plains Riparian	9326	Common	4
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	2
Wyoming Basin Cliff and Canyon	3173	Common	1
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	1
Burned Sagebrush	8504	Common	1
Post-Fire Recovery	8505	Common	1
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Recently burned shrubland	8503	Common	0
Shale Badland	3139	Occasional	2
Great Plains Shrubland	5262	Occasional	2
Great Plains Cliff and Outcrop	3142	Occasional	0
Montane Sagebrush Steppe	5455	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 195 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

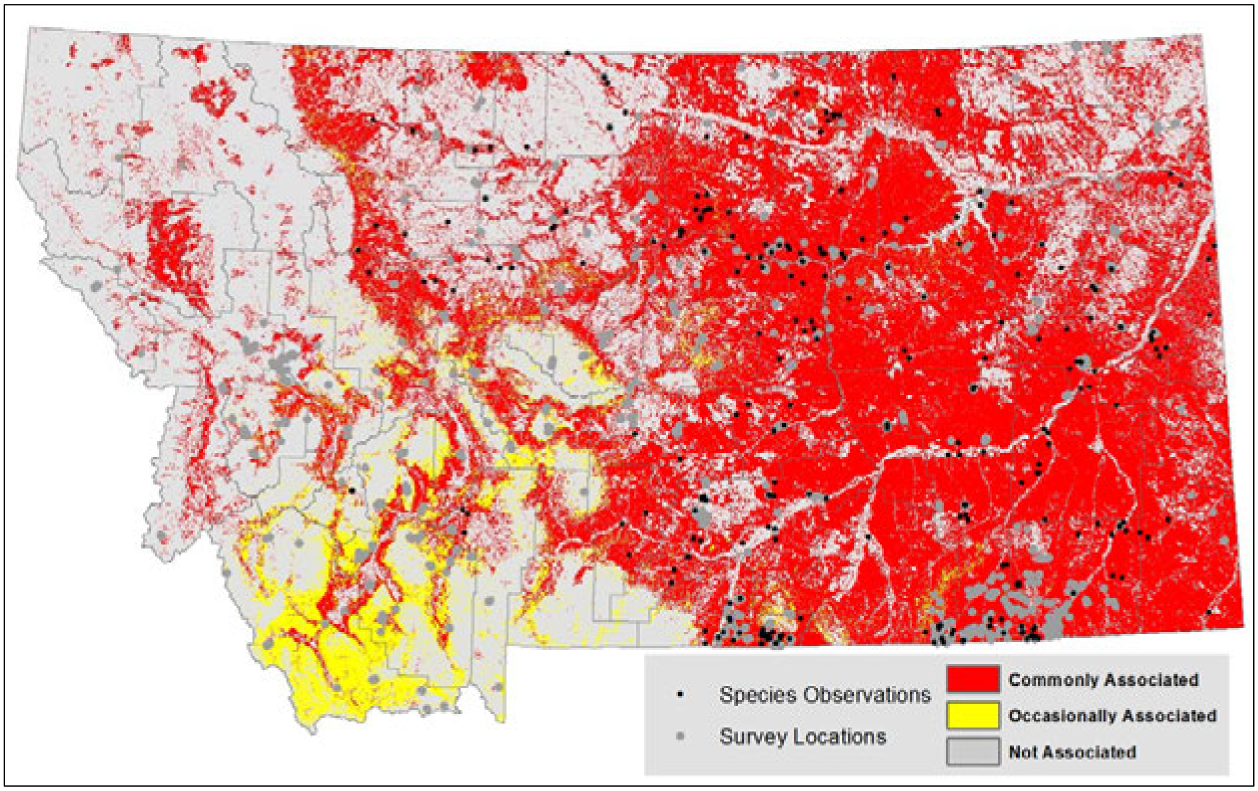
Measure	Value
Area of entire modeled range (percent of Montana)	380,529.0 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	195,447.0 km^2
Area of Commonly Associated ES	177,069.0 km^2
Area of Occasionally Associated ES	18,377.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	85.6%
Commonly Associated ES AVI[a]	83.6%
Occasionally Associated ES AVI[a]	2.0%

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

Figure 10. Deductive model output classified into habitat associations.



Northern Rubber Boa (*Charina bottae*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017
Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Northern Rubber Boa general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with over represent the amount of suitable habitat for Northern Rubber Boa across the species' known range in Montana and this output should be used in conjunction with inductive model output for survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Northern Rubber Boa (*Charina bottae*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADA01010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	277
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	206
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	165
Season Modeled	Year-round
Number of Model Background Locations	25,370

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contwinpcp	12.9%	contstrmed	3.7%
contddays	12.8%	contvrm	2.4%
contwinrad	11.6%	contslope	2.3%
catgeol	9.6%	conttmax	2.2%
contnsasp	8.5%	contfrsted	2.0%
catsoiltemp	7.0%	catsoilord	2.0%
conttmin	5.6%	contewasp	1.4%
contelev	5.5%	contprecip	1.0%
catesys	4.7%	contsumrad	0.9%
contndvi	3.9%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.041
Moderate Logistic Threshold[b]	0.212
Optimal Logistic Threshold[c]	0.629
Area of entire modeled range (percent of Montana)	160,898.12 km^2 (42.3%)
Total area of predicted suitable habitat within modeled range	73,827.8 km^2
Area of predicted low suitability habitat within modeled range	52,618.4 km^2
Area of moderate suitability habitat within modeled range	18,739.4 km^2
Area of predicted optimal habitat within modeled range	2,470.0 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.

[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.

[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	91.5%
Moderate AVI[a]	72.1%
Optimal AVI[a]	35.1%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.511 ± 2.891
Training AUC[c]	0.926
Test AUC[d]	0.876

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.

[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 6.408, 3.103 and 0.926, respectively. Deviances for individual test locations are plotted in Figure 6.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

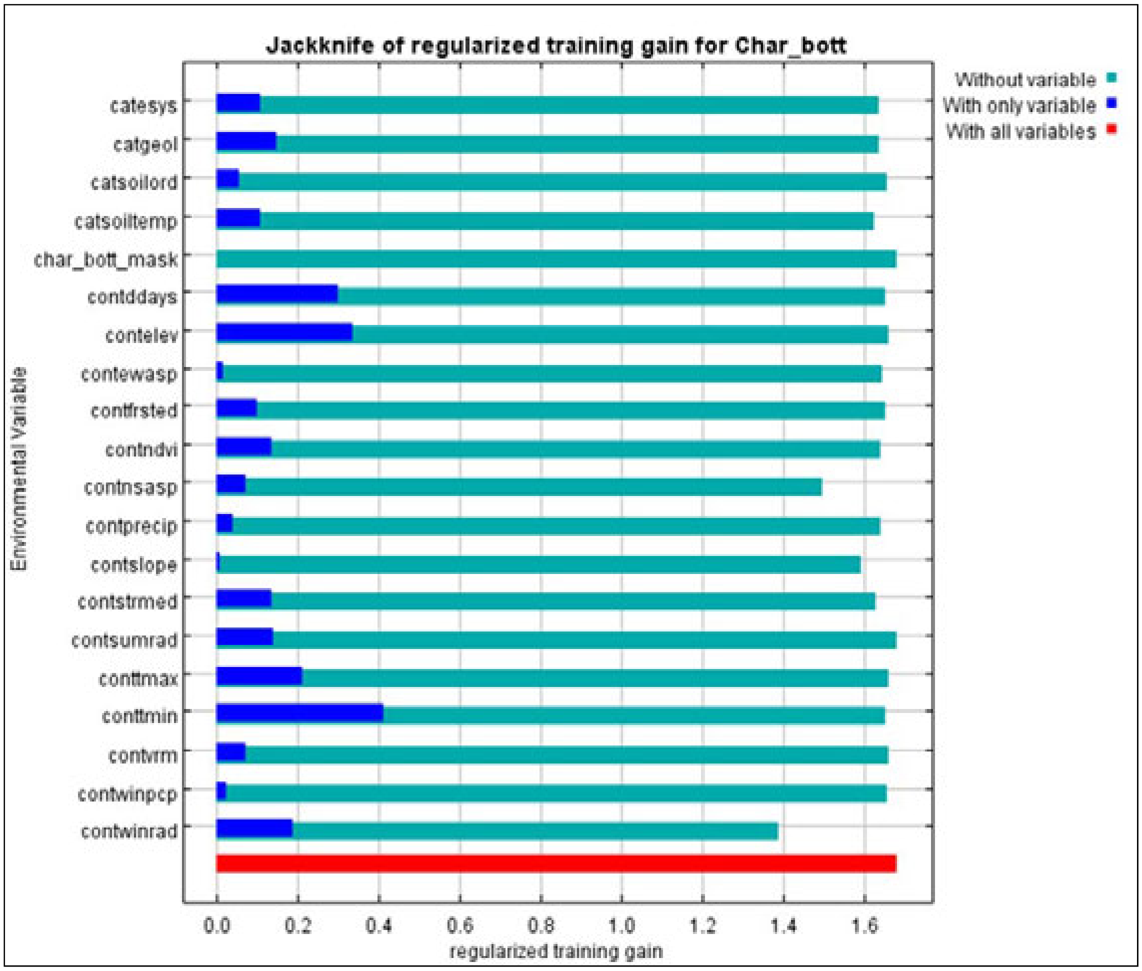
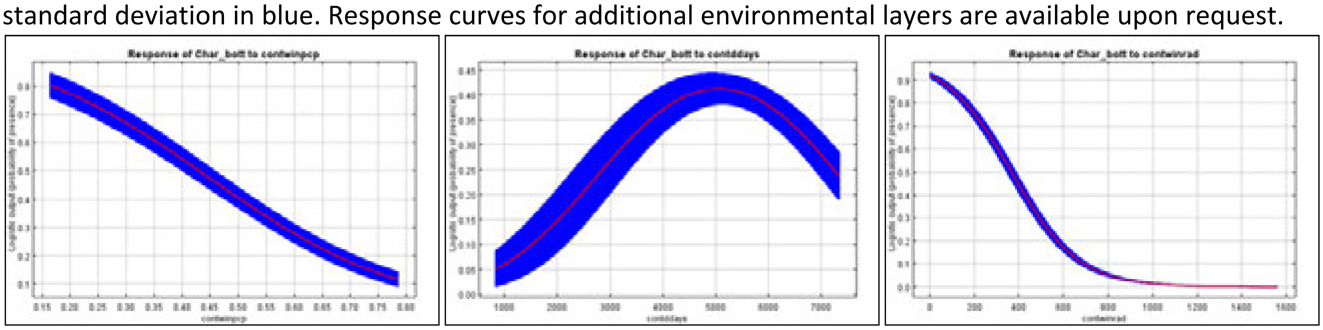


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

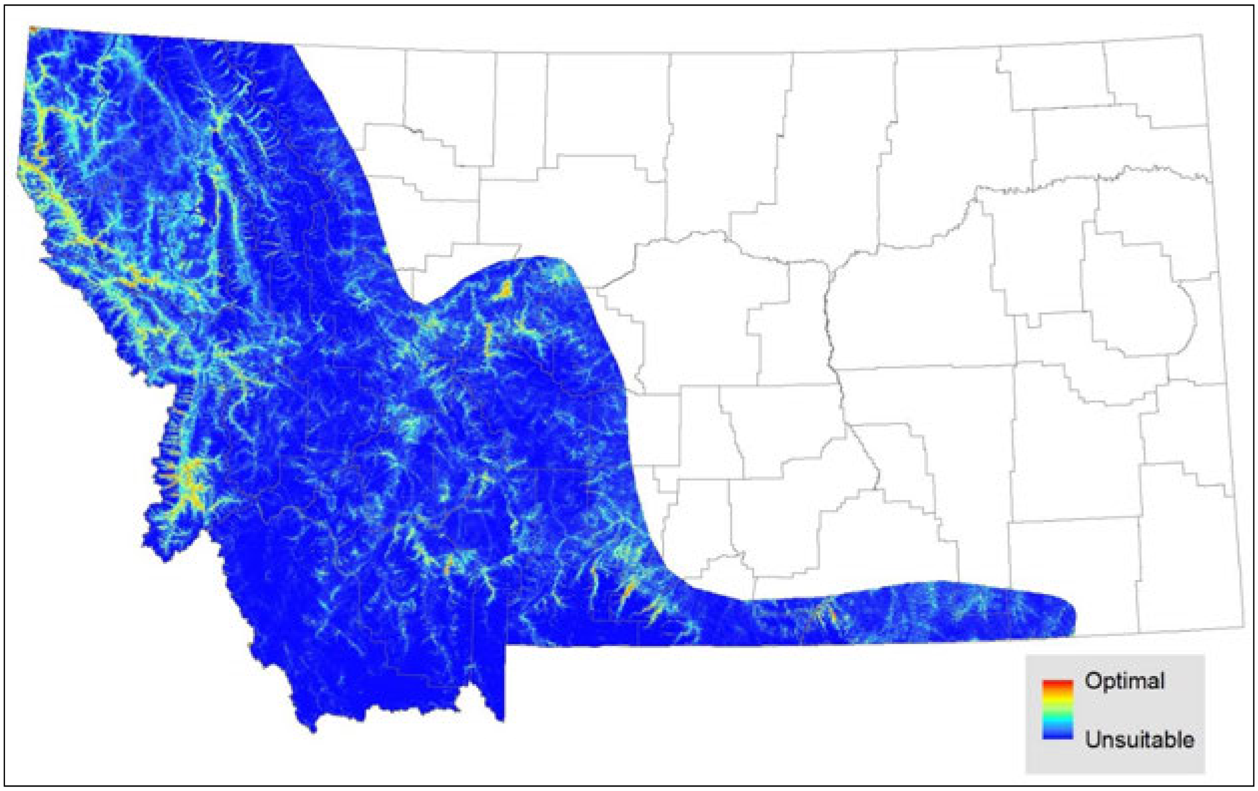


Figure 4. Standard deviation in the model output across the averaged models.

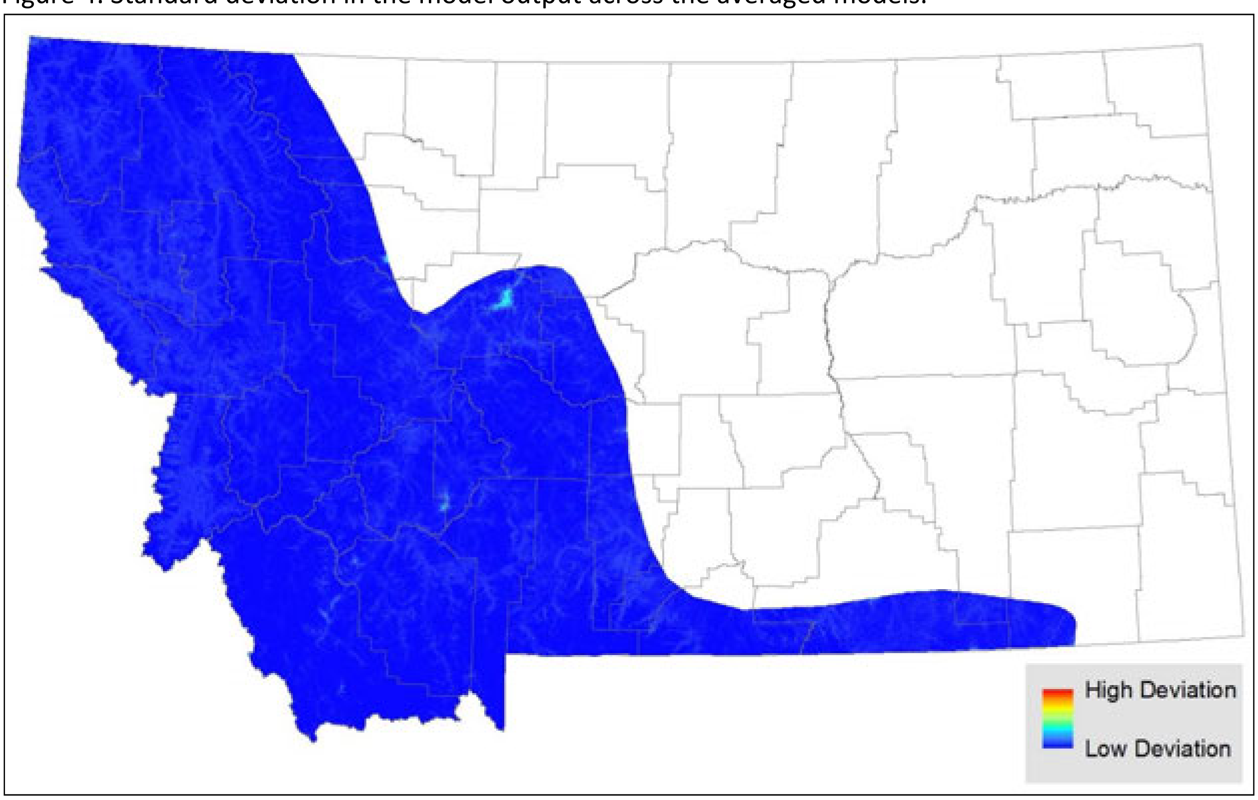


Figure 5. Continuous habitat suitability model output with the 165 observations used for modeling.

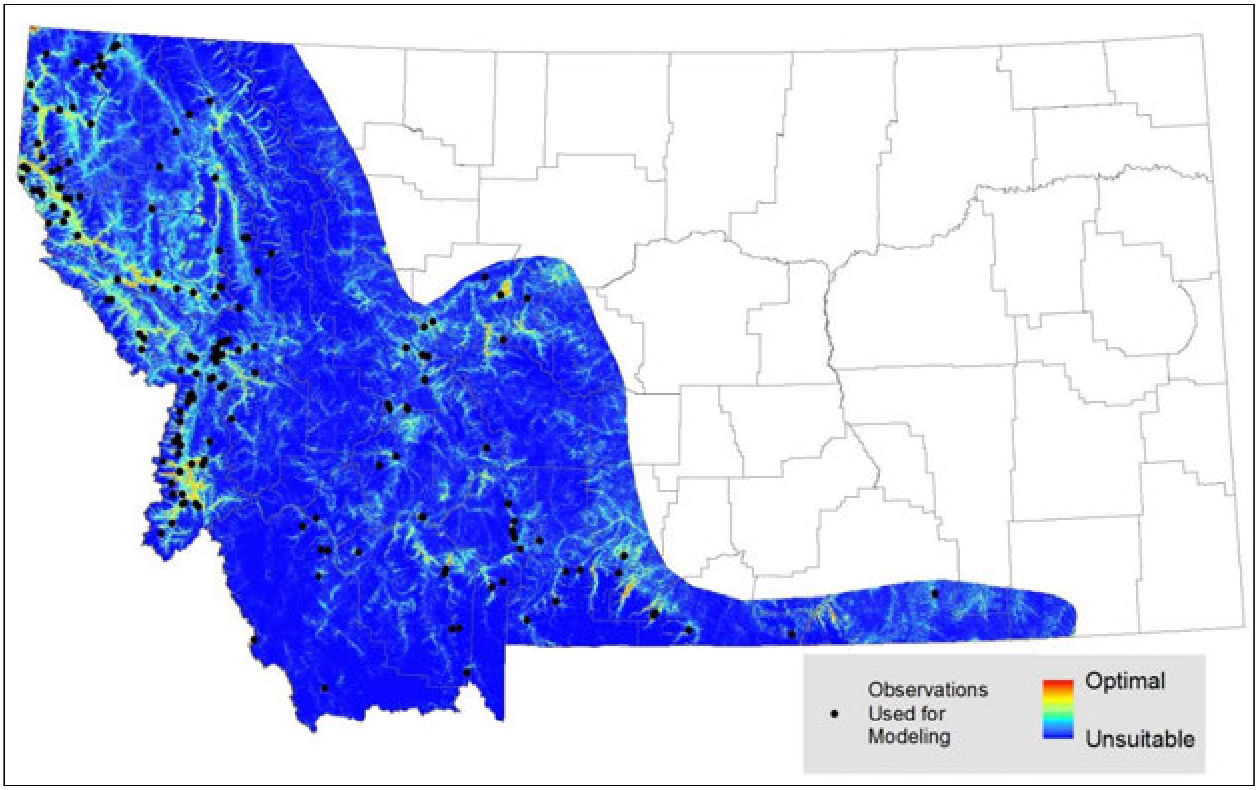


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

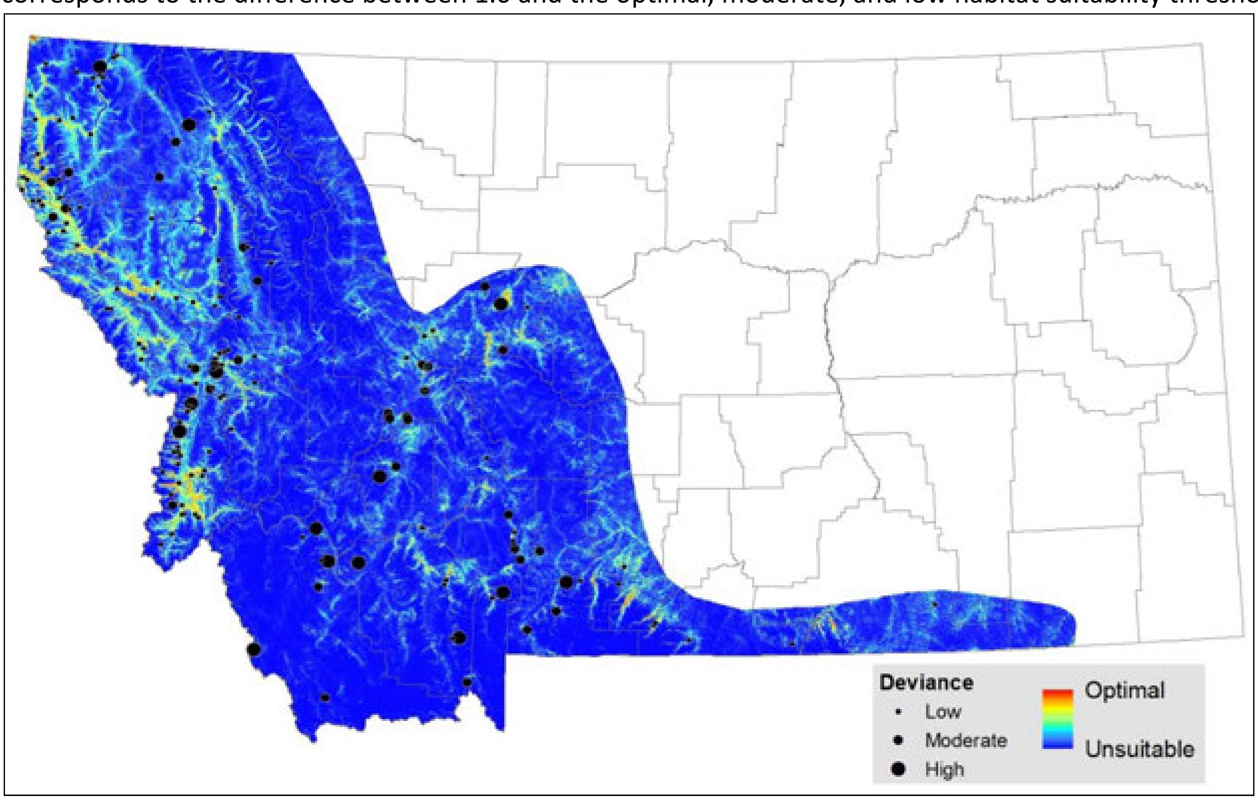


Figure 7. Continuous habitat suitability model output with all 277 observations (black) and survey locations that could have detected the species (gray).

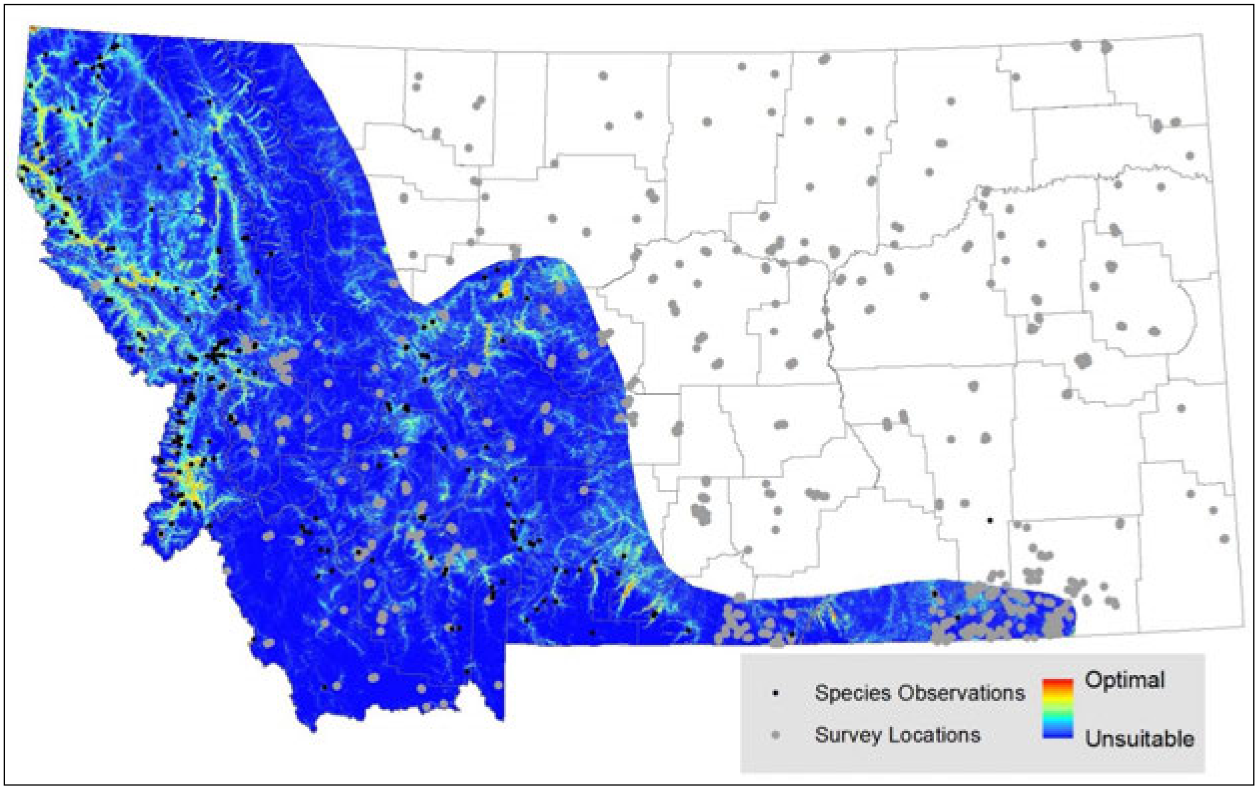


Figure 8. Model output classified into habitat suitability classes.

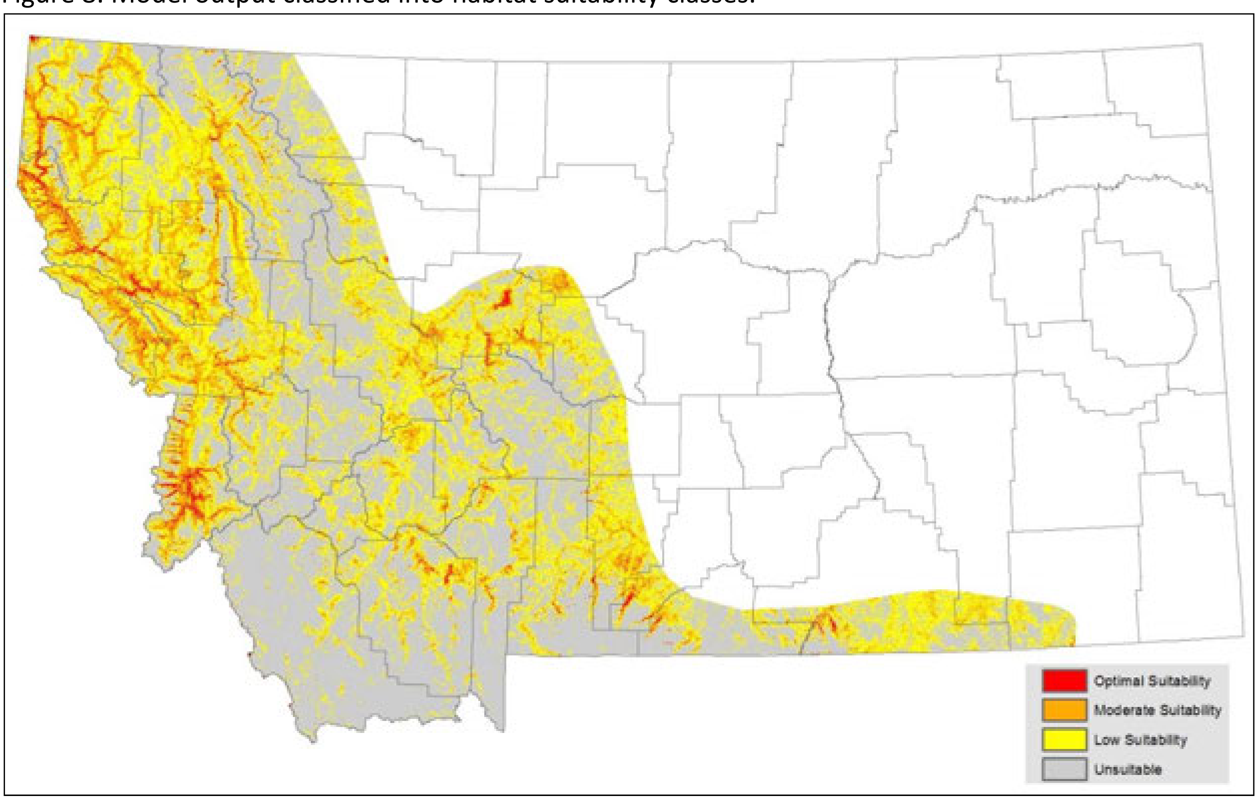
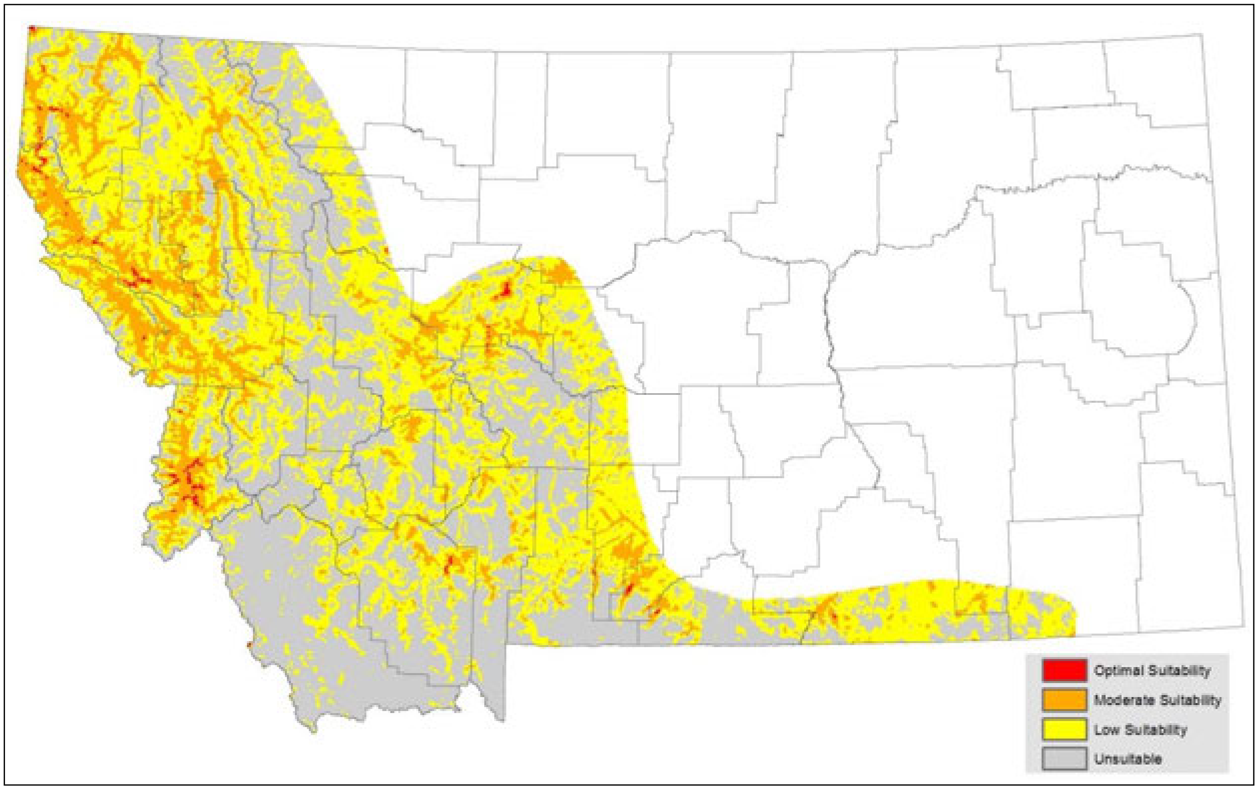


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Northern Rubber Boa

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	26
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	21
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	12
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	11
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	11
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	10
Rocky Mountain Lodgepole Pine Forest	4237	Common	6
Recently burned forest	8501	Common	6
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	3
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	2
Harvested forest-tree regeneration	8601	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	0
Great Plains Riparian	9326	Common	0
Post-Fire Recovery	8505	Occasional	7
Developed, Open Space	21	Occasional	4
Big Sagebrush Steppe	5454	Occasional	2
Insect-Killed Forest	8700	Occasional	2
Low Intensity Residential	22	Occasional	1
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	1
Montane Sagebrush Steppe	5455	Occasional	1
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	1
Great Plains Cliff and Outcrop	3142	Occasional	0
Aspen Forest and Woodland	4104	Occasional	0
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Occasional	0
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Great Plains Wooded Draw and Ravine	4328	Occasional	0
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	0
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Occasional	0
Harvested forest-shrub regeneration	8602	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 165 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

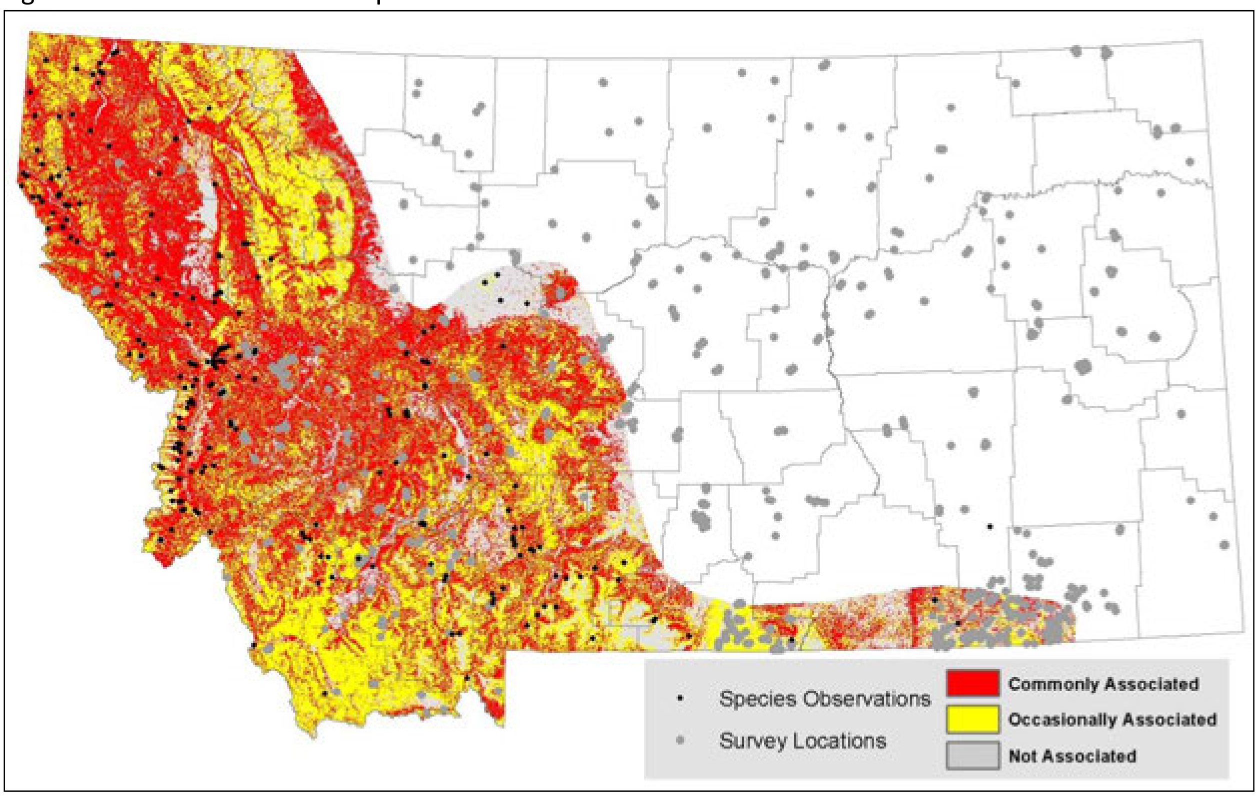
Measure	Value
Area of entire modeled range (percent of Montana)	160,898.12 km^2 (42.3%)
Area of Commonly and Occasionally Associated ES	128,148.0 km^2
Area of Commonly Associated ES	72,920.0 km^2
Area of Occasionally Associated ES	55,228.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	77.6%
Commonly Associated ES AVI[a]	66.1%
Occasionally Associated ES AVI[a]	11.5%

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

Figure 10. Deductive model output classified into habitat associations.



North American Racer (*Coluber constrictor*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S5
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: September 29, 2017
Evaluator: Bryce Maxell
Evaluation Date: September 29, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of North American Racer general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with adequately represent the amount of suitable habitat for North American Racer across the species' known range in Montana, but should be used in conjunction with inductive model output.

Suggested Citation: Montana Natural Heritage Program. 2017. North American Racer (*Coluber constrictor*) predicted suitable habitat models created on September 29, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADB07010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,103
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	905
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	661
Season Modeled	Year-round
Number of Model Background Locations	56,783

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoiltemp	25.4%	contelev	1.8%
conttmax	16.9%	contwinrad	1.2%
contddays	14.5%	contnsasp	1.1%
catesys	12.2%	contndvi	1.1%
catgeol	6.3%	conttmin	1.0%
catsoilord	5.7%	contewasp	0.4%
contstrmed	5.4%	contvrm	0.1%
contwinpcp	3.2%	contprecip	0.0%
contsumrad	1.9%	contslope	0.0%
contfrsted	1.9%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.115
Moderate Logistic Threshold[b]	0.424
Optimal Logistic Threshold[c]	0.818
Area of entire modeled range (percent of Montana)	360,123.3 km^2 (94.6%)
Total area of predicted suitable habitat within modeled range	247,244.8 km^2
Area of predicted low suitability habitat within modeled range	143,584.6 km^2
Area of moderate suitability habitat within modeled range	102,820.7 km^2
Area of predicted optimal habitat within modeled range	839.5 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.

[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.

[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.0%
Moderate AVI[a]	69.9%
Optimal AVI[a]	1.8%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.509 ± 1.008
Training AUC[c]	0.814
Test AUC[d]	0.794

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.

[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 4.331, 1.717 and 0.402, respectively. Deviances for individual test locations are plotted in Figure 6.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

[c] 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.

[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

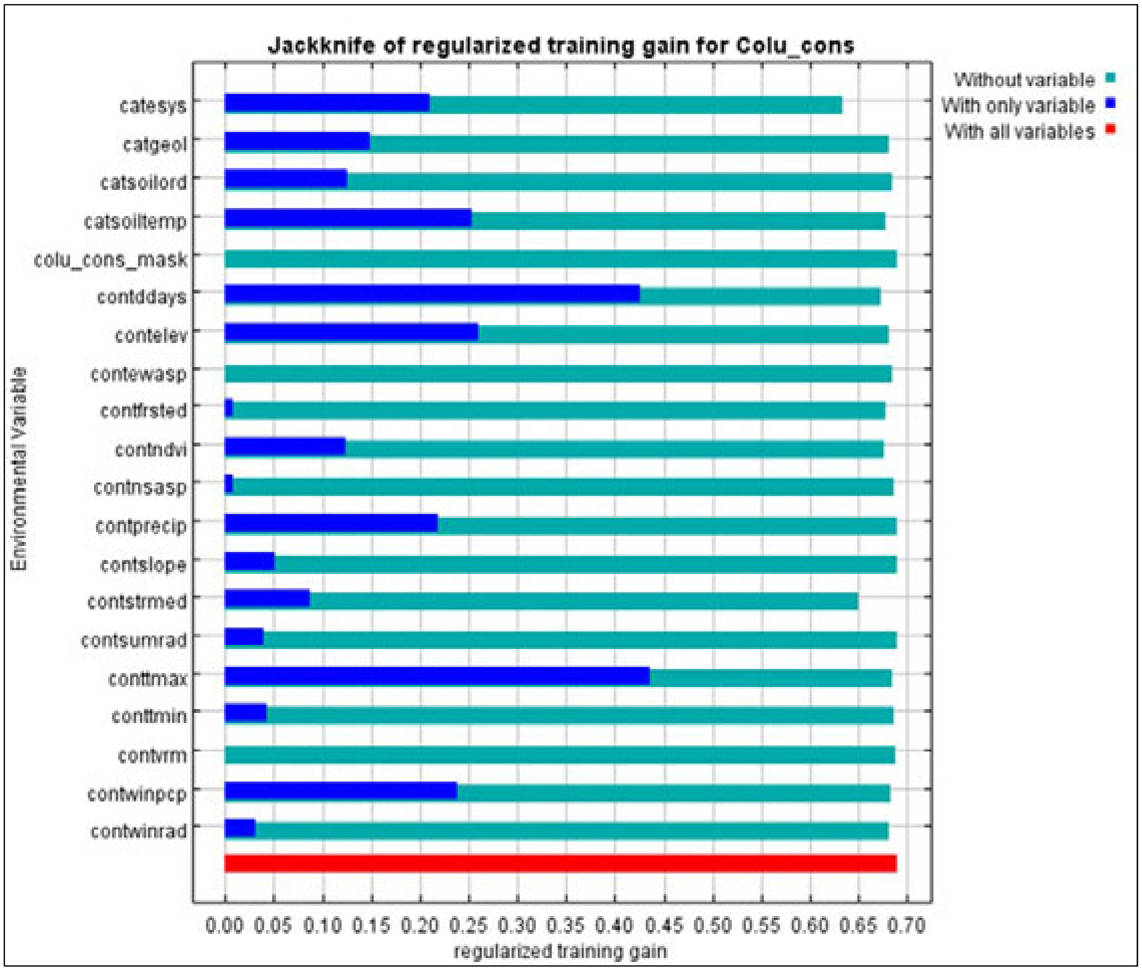
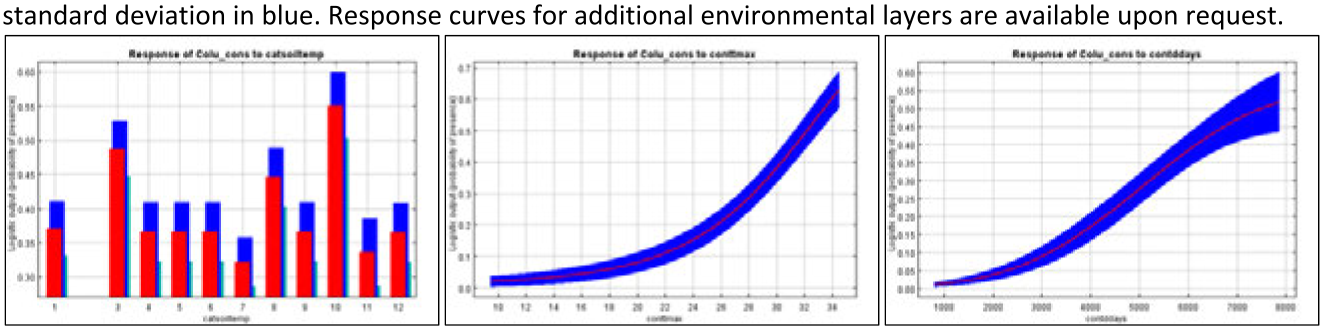


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

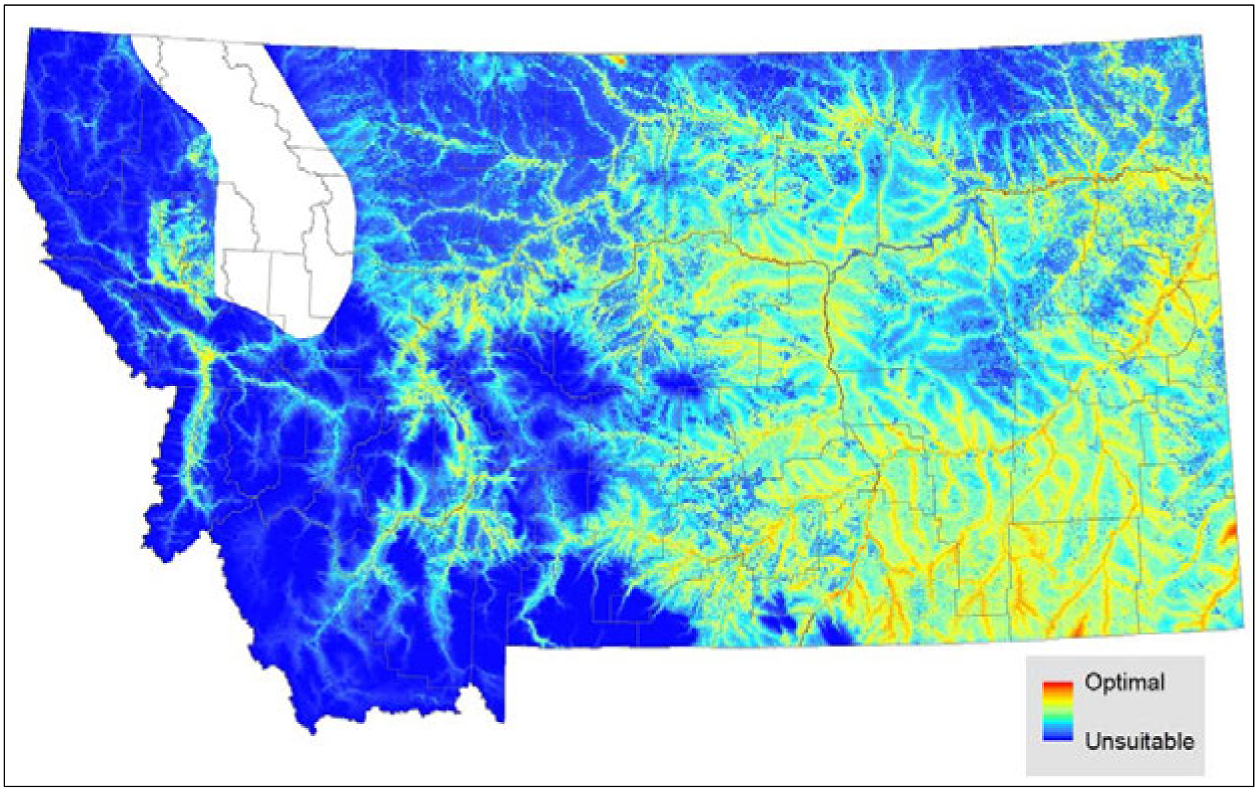


Figure 4. Standard deviation in the model output across the averaged models.

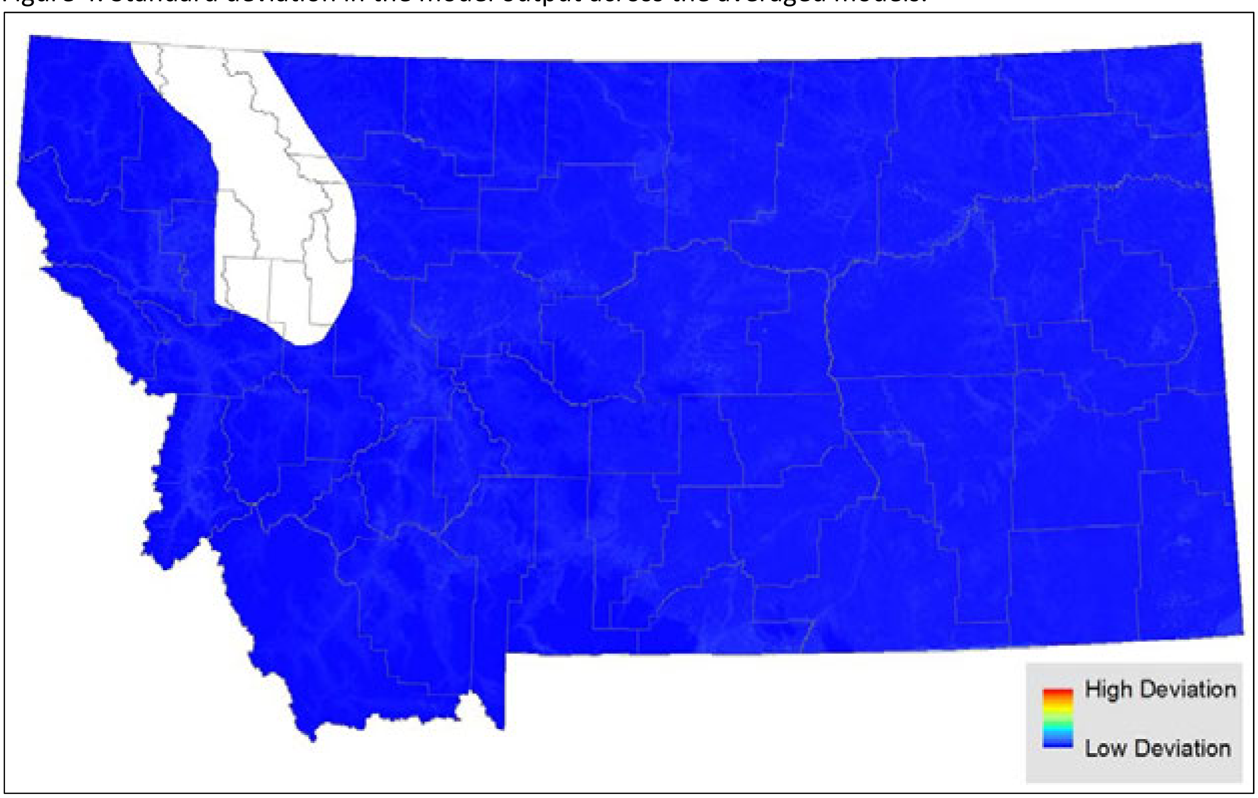


Figure 5. Continuous habitat suitability model output with the 661 observations used for modeling.

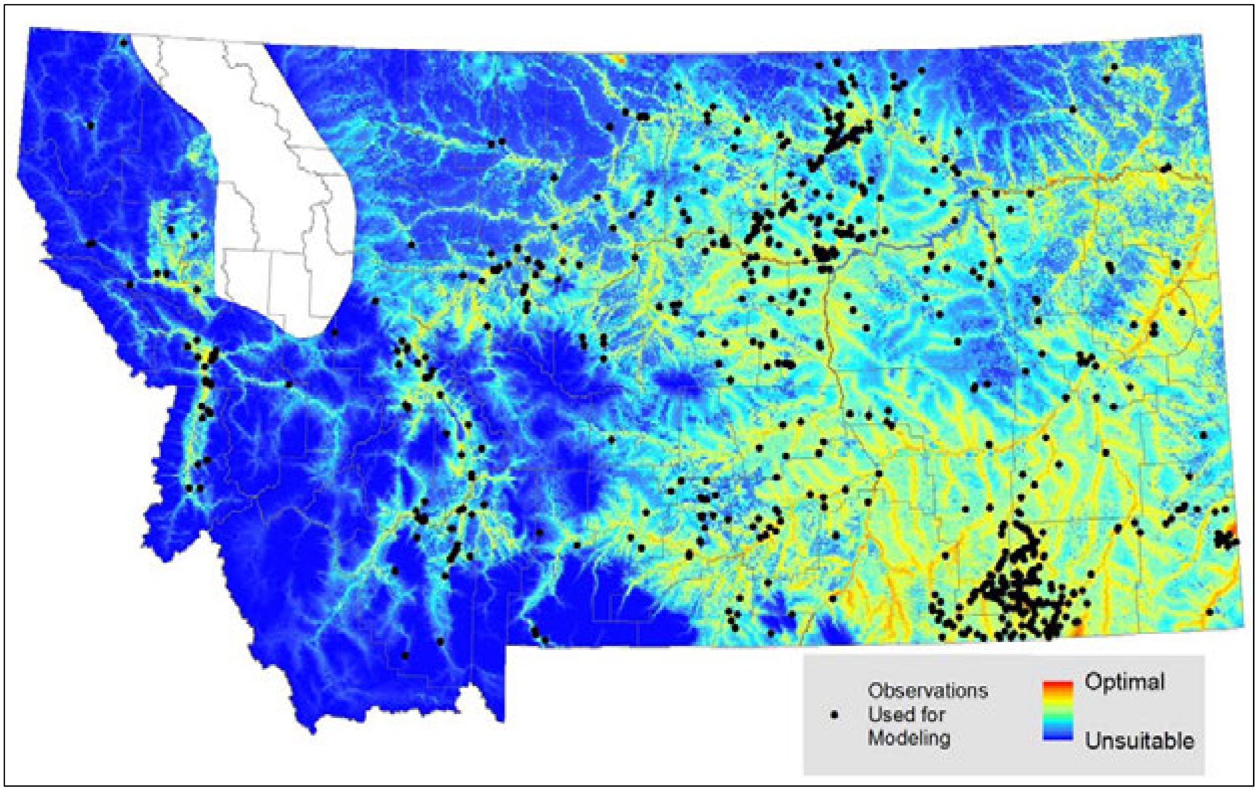


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

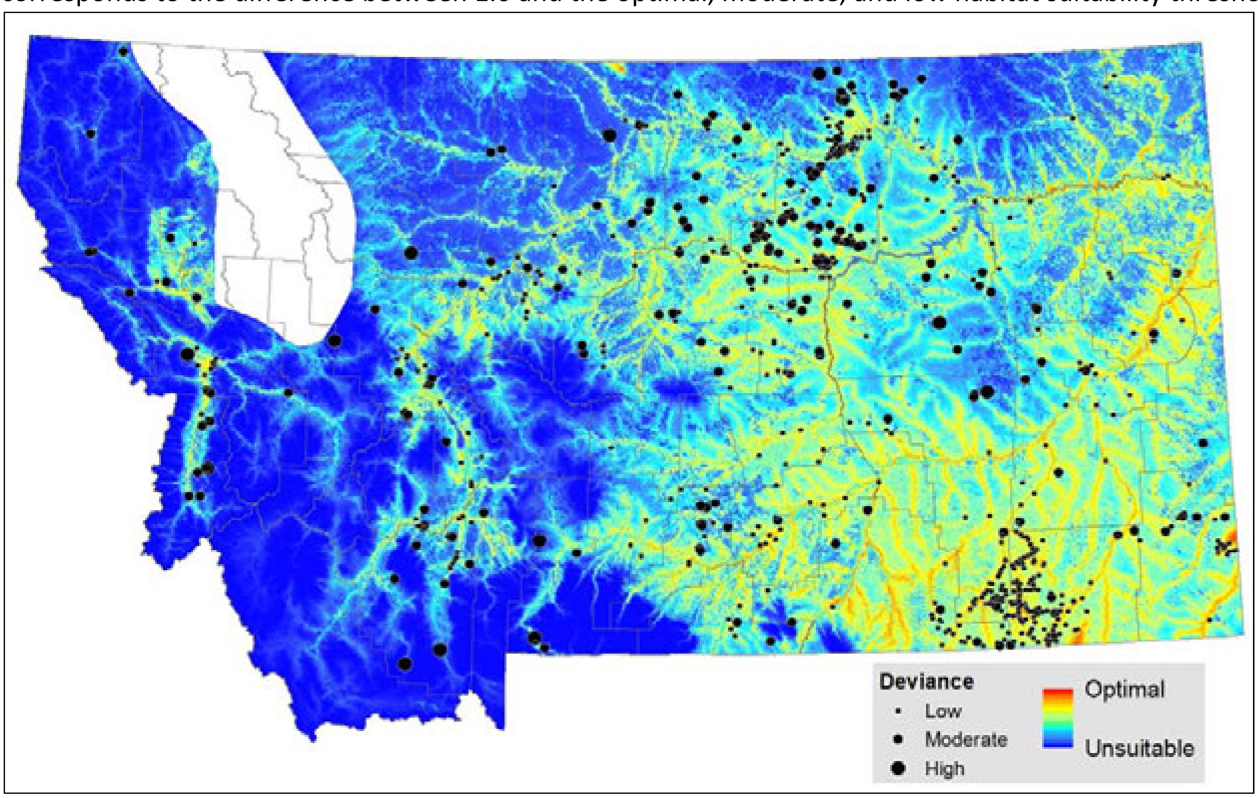


Figure 7. Continuous habitat suitability model output with all 1,103 observations (black) and survey locations that could have detected the species (gray).

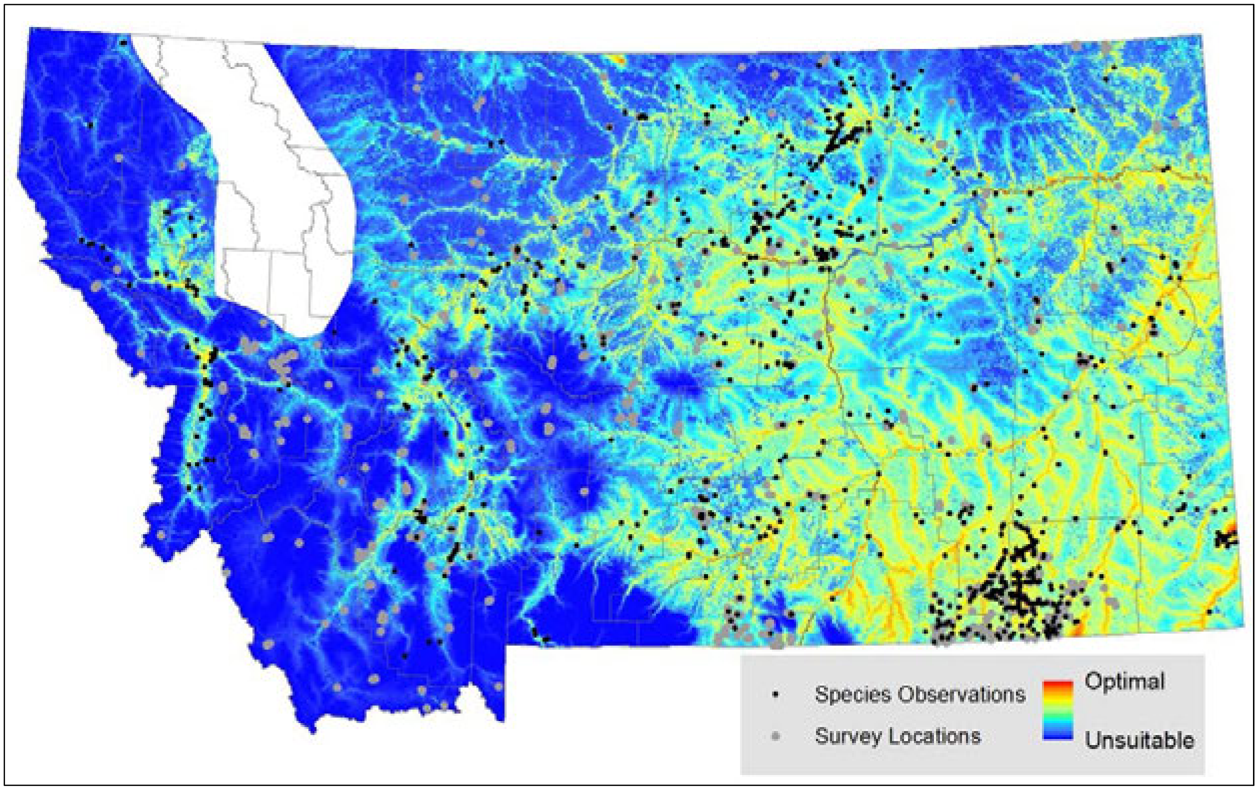


Figure 8. Model output classified into habitat suitability classes.

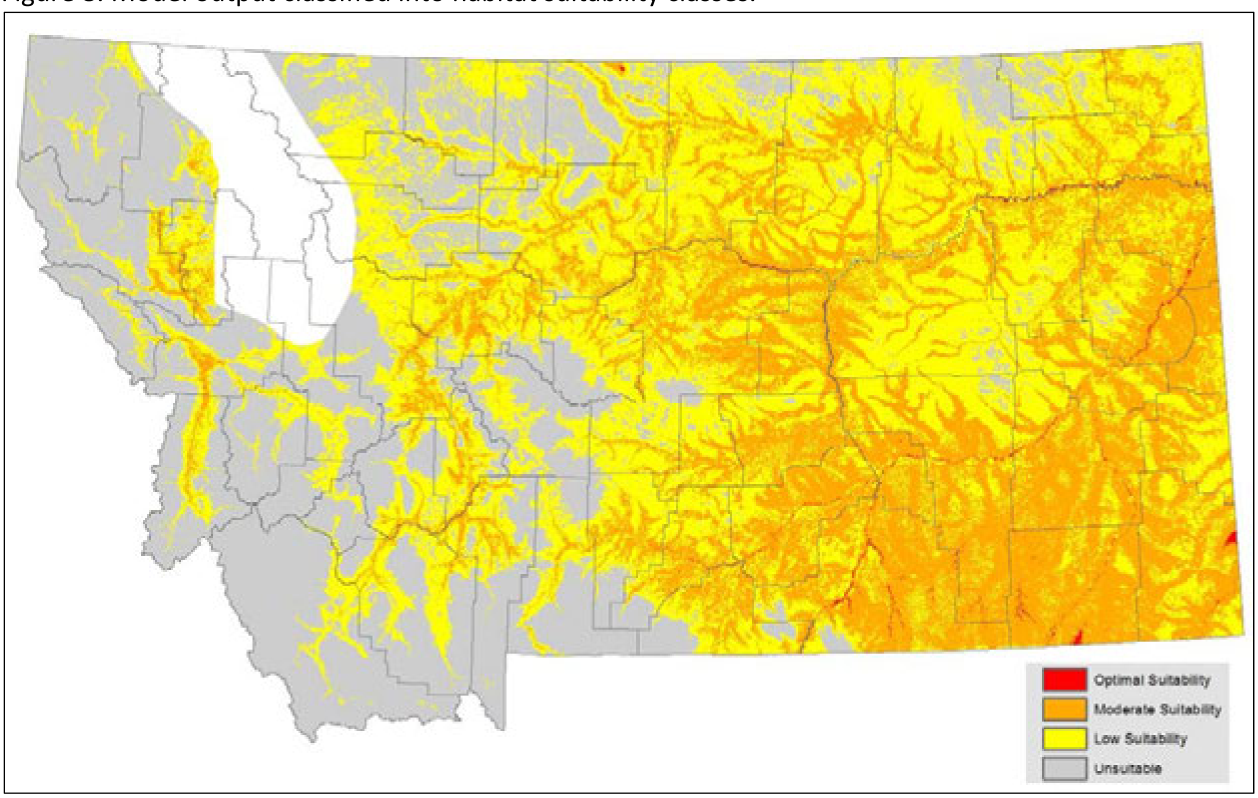
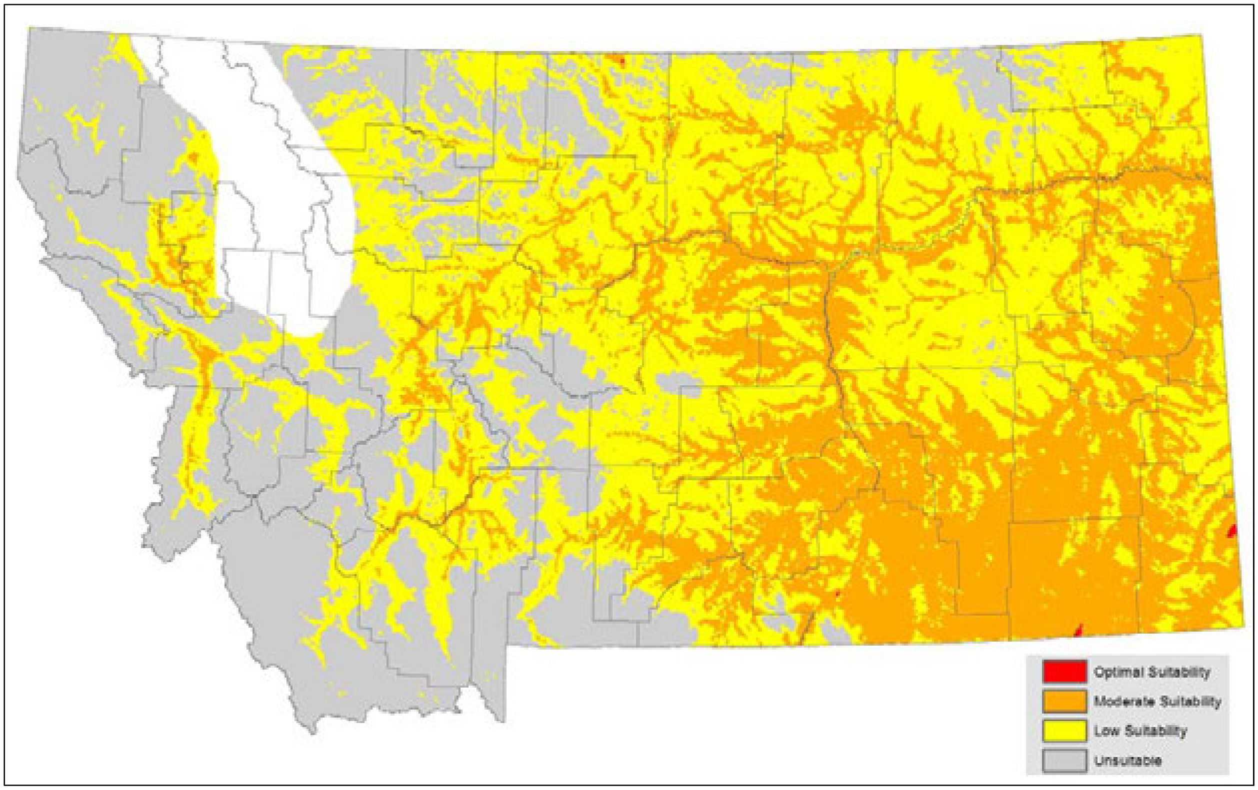


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with North American Racer

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	145
Big Sagebrush Steppe	5454	Common	86
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	31
Great Plains Badlands	3114	Common	21
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	17
Great Plains Sand Prairie	7121	Common	16
Great Plains Riparian	9326	Common	14
Montane Sagebrush Steppe	5455	Common	11
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Common	11
Great Plains Floodplain	9159	Common	11
Recently burned forest	8501	Common	7
Recently burned grassland	8502	Common	6
Recently burned shrubland	8503	Common	6
Great Plains Shrubland	5262	Common	5
Greasewood Flat	9103	Common	5
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	4
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	4
Burned Sagebrush	8504	Common	4
Mat Saltbush Shrubland	5203	Common	3
Great Plains Wooded Draw and Ravine	4328	Common	2
Shale Badland	3139	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Low Sagebrush Shrubland	5209	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Low Intensity Residential	22	Occasional	6
Pasture/Hay	81	Occasional	6
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	6
Post-Fire Recovery	8505	Occasional	5
Developed, Open Space	21	Occasional	2
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	2
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	1
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	1
Active and Stabilized Dune	3160	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 661 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

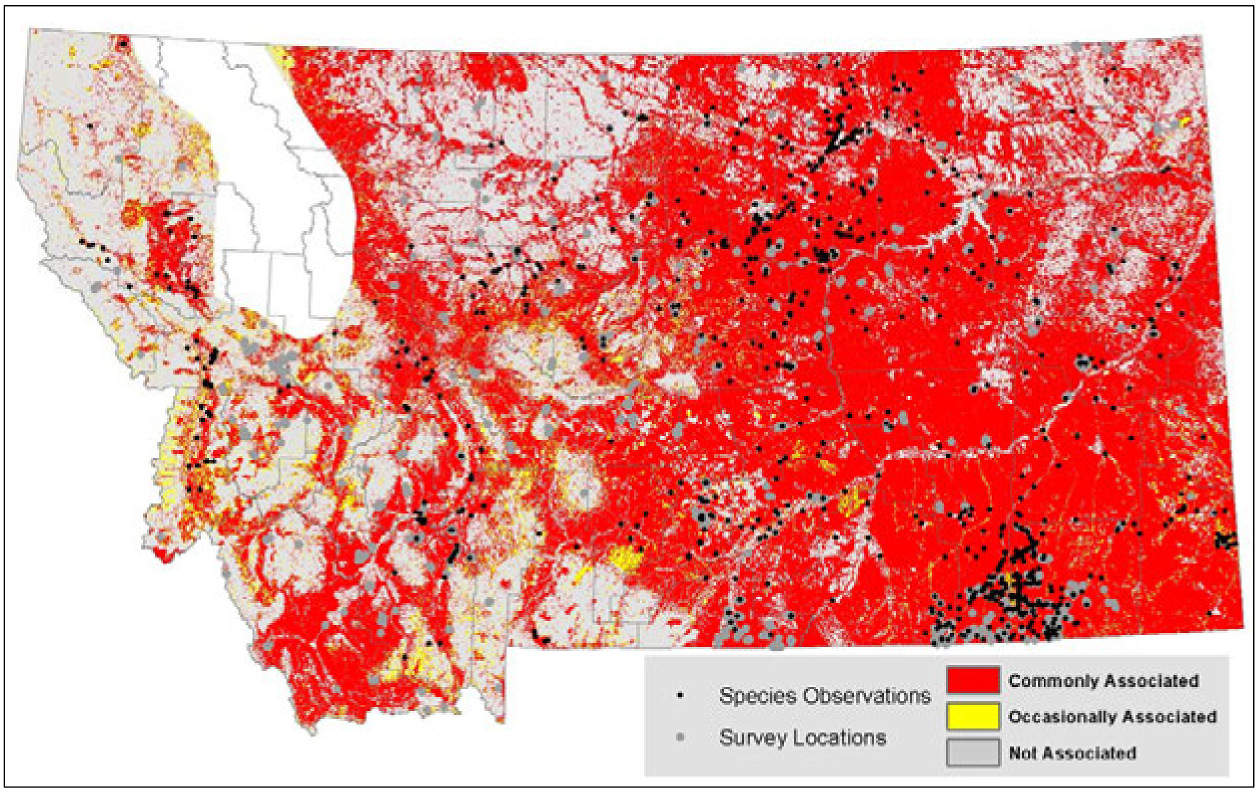
Measure	Value
Area of entire modeled range (percent of Montana)	360,123.3 km^2 (94.6%)
Area of Commonly and Occasionally Associated ES	227,352.0 km^2
Area of Commonly Associated ES	211,875.0 km^2
Area of Occasionally Associated ES	15,478.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	66.4%
Commonly Associated ES AVI[a]	62.9%
Occasionally Associated ES AVI[a]	3.5%

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

Figure 10. Deductive model output classified into habitat associations.



Western Milksnake (*Lampropeltis gentilis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S2 (Species of Concern)
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Western Milksnake general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with likely dramatically overpredict the amount of suitable habitat for Western Milksnake across the species' known range in Montana. The inductive model is preferable for making survey and management decisions about the species.

Suggested Citation: Montana Natural Heritage Program. 2017. Western Milksnake (*Lampropeltis gentilis*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADB1905B

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	147
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	120
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	82
Season Modeled	Year-round
Number of Model Background Locations	31,569

Inductive Model Results

Table 3: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
contfrsted	20.7%	contnsasp	2.8%
conttmax	15.8%	catsoiltemp	1.6%
catesys	14.7%	contvrm	1.0%
contwinpcp	8.5%	contelev	0.7%
contddays	8.1%	contwinrad	0.4%
contstrmed	7.1%	contprecip	0.2%
conttmin	5.9%	contslope	0.1%
contewasp	4.3%	contndvi	0.0%
catgeol	4.1%	contsumrad	0.0%
catsoilord	4.0%		

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

Table 4: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.062
Moderate Logistic Threshold[b]	0.252
Optimal Logistic Threshold[c]	0.680
Area of entire modeled range (percent of Montana)	200,214.81 km^2 (52.6%)
Total area of predicted suitable habitat within modeled range	80,050.1 km^2
Area of predicted low suitability habitat within modeled range	46,673.6 km^2
Area of moderate suitability habitat within modeled range	30,259.7 km^2
Area of predicted optimal habitat within modeled range	3,116.8 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 5: Evaluation Metrics

Metric	Value
Low AVI[a]	95.0%
Moderate AVI[a]	76.2%
Optimal AVI[a]	28.8%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	2.011 ± 1.656
Training AUC[c]	0.917
Test AUC[d]	0.888

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.558, 2.758 and 0.771, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

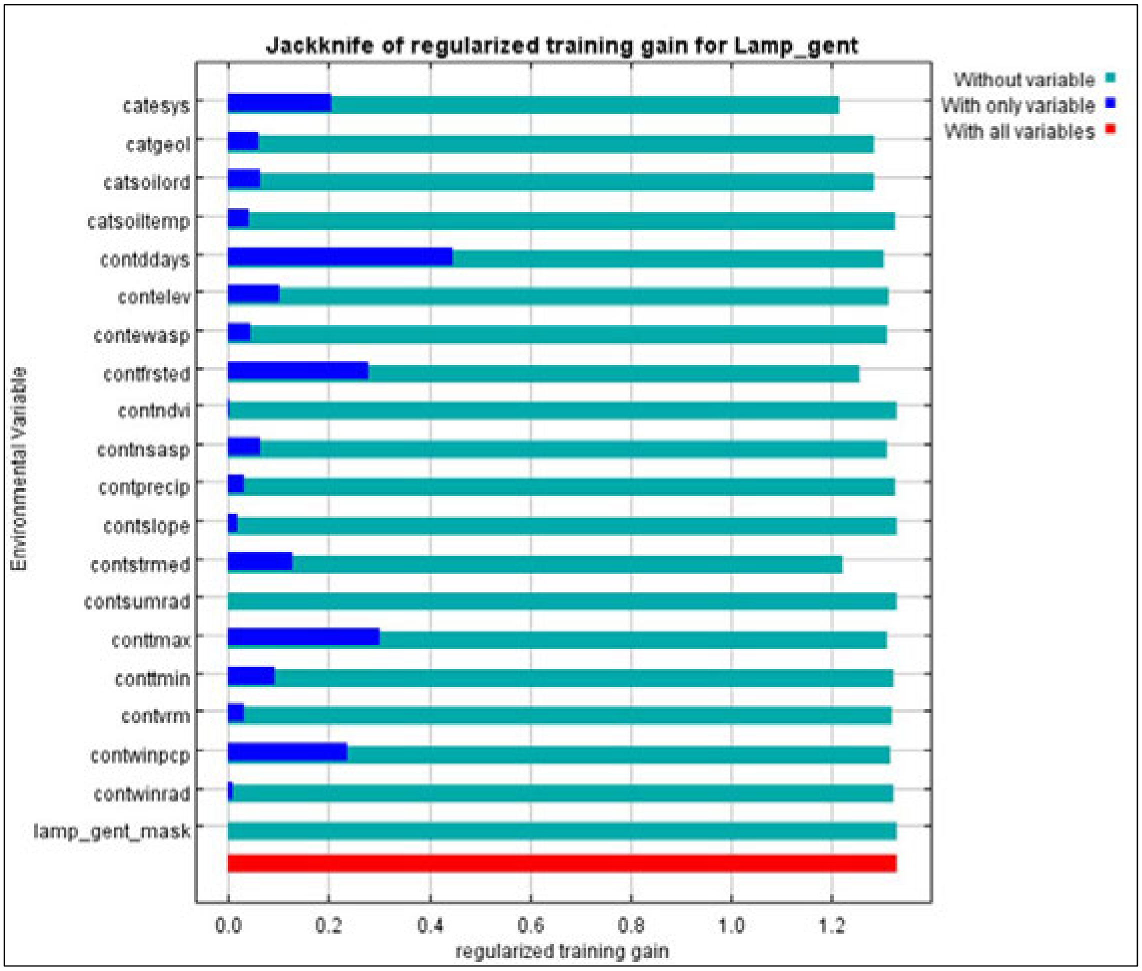
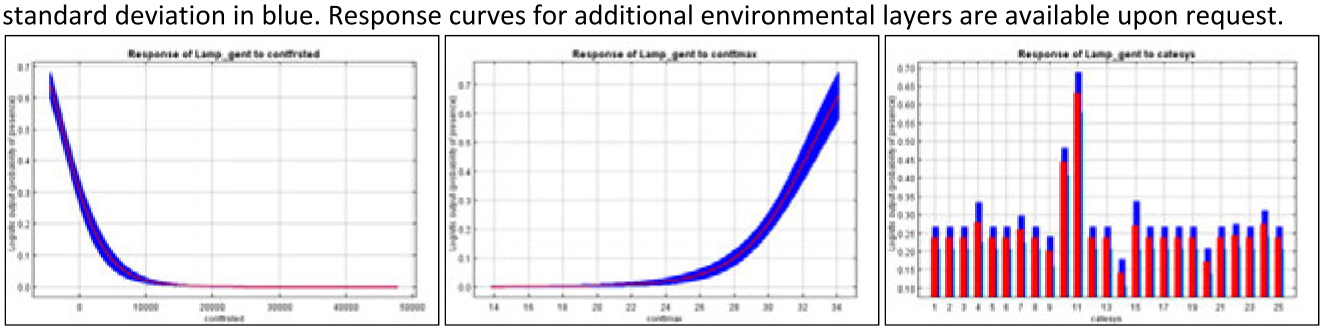


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

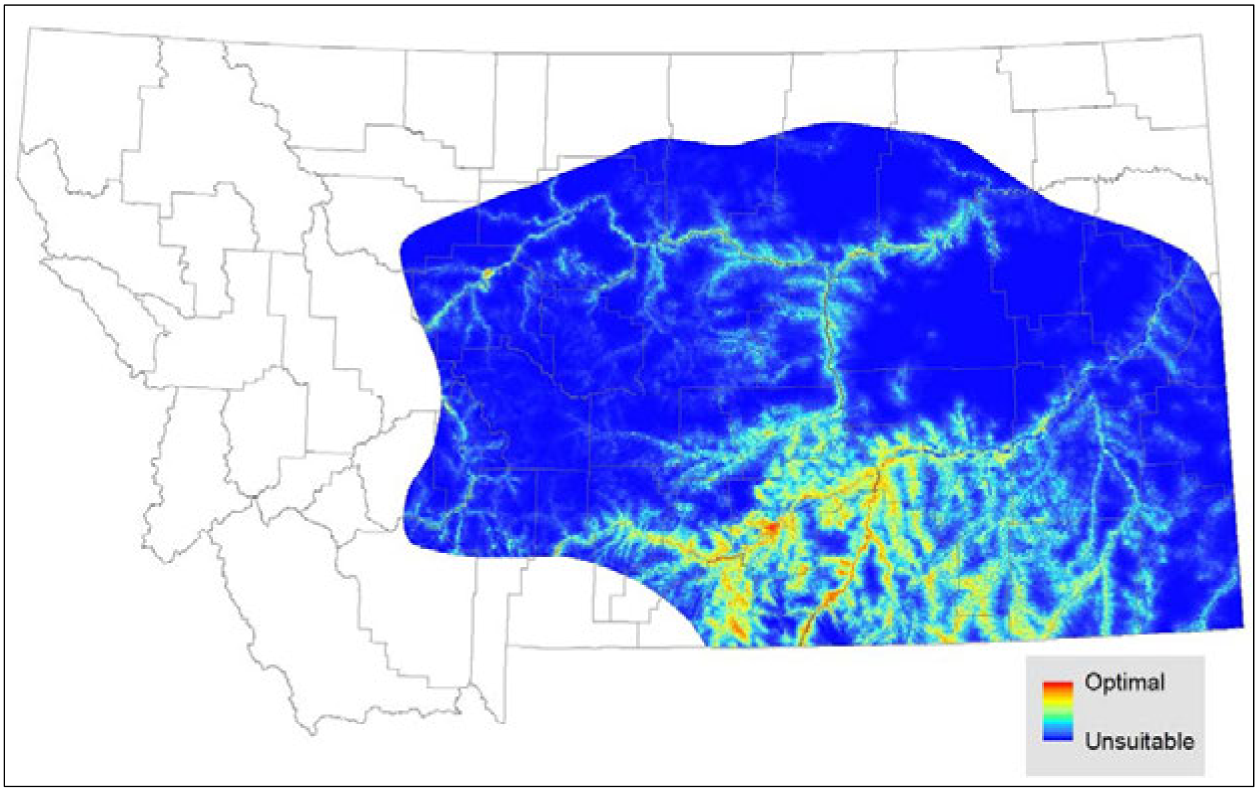


Figure 4. Standard deviation in the model output across the averaged models.

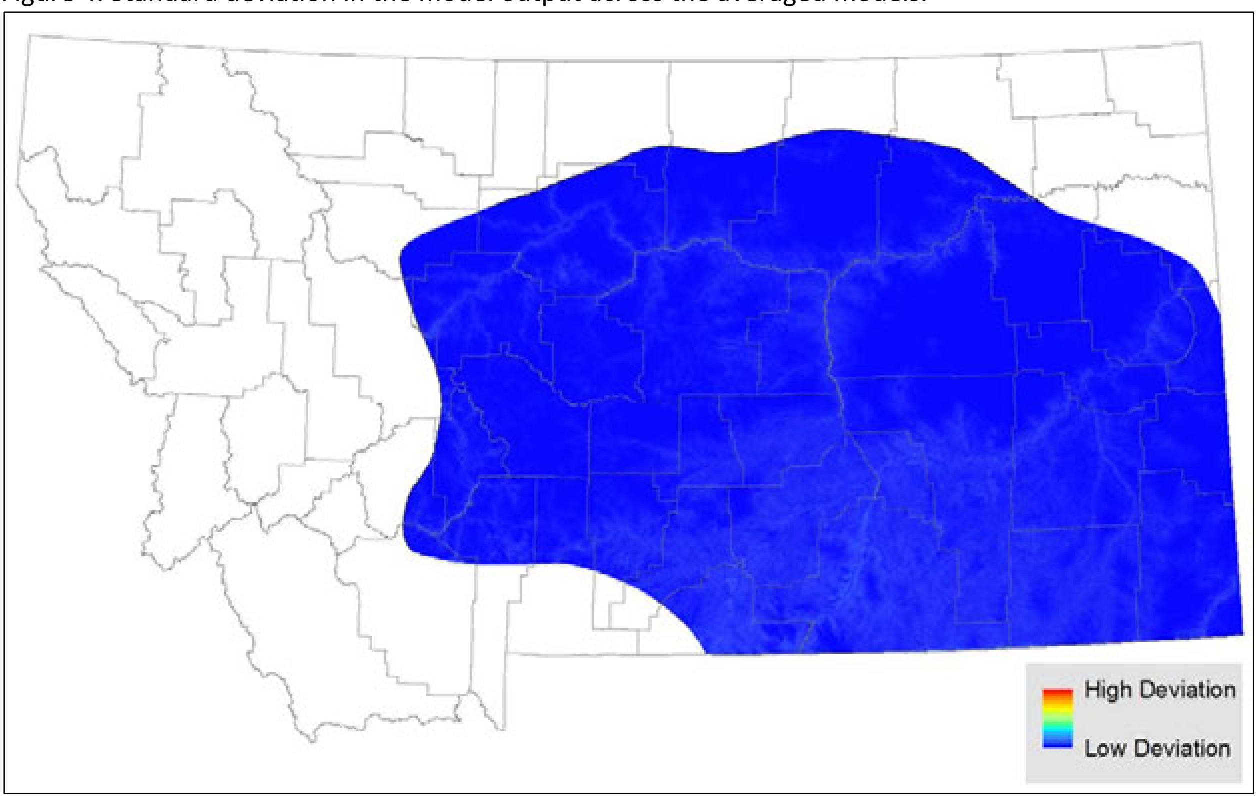


Figure 5. Continuous habitat suitability model output with the 82 observations used for modeling.

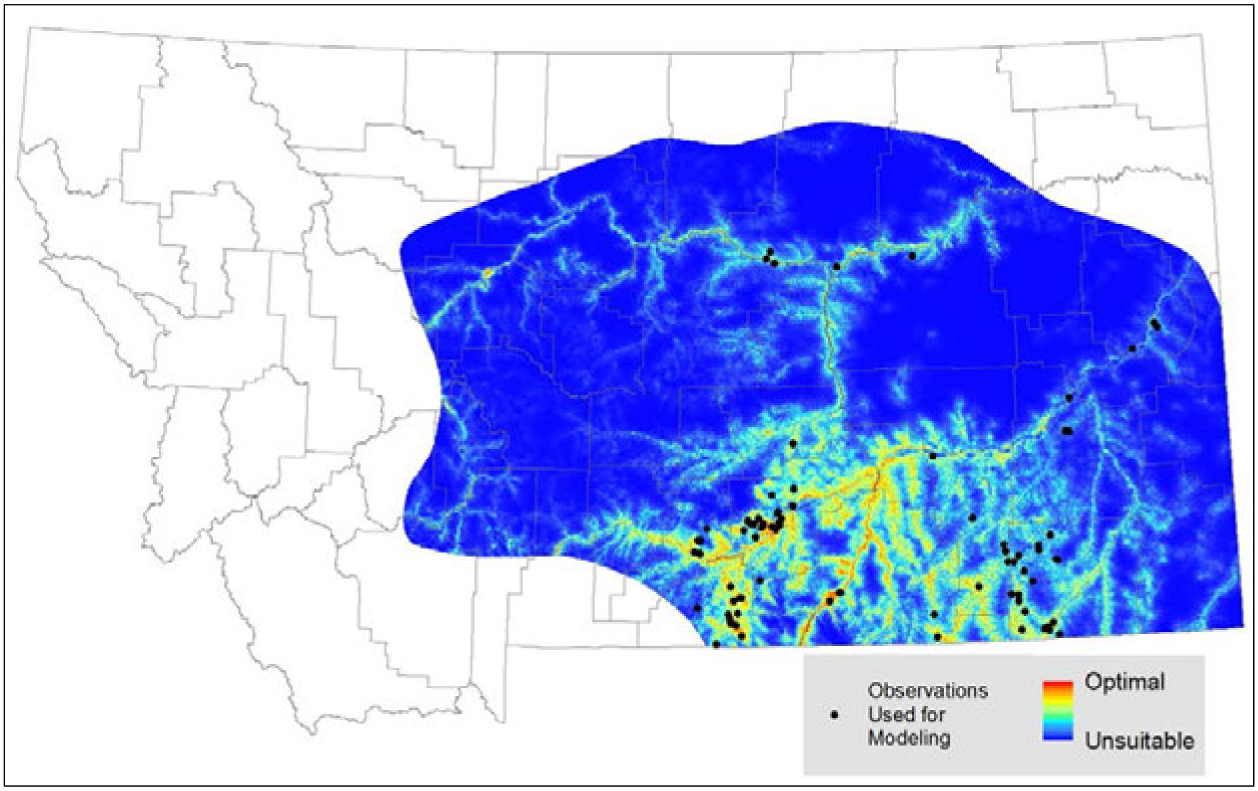


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

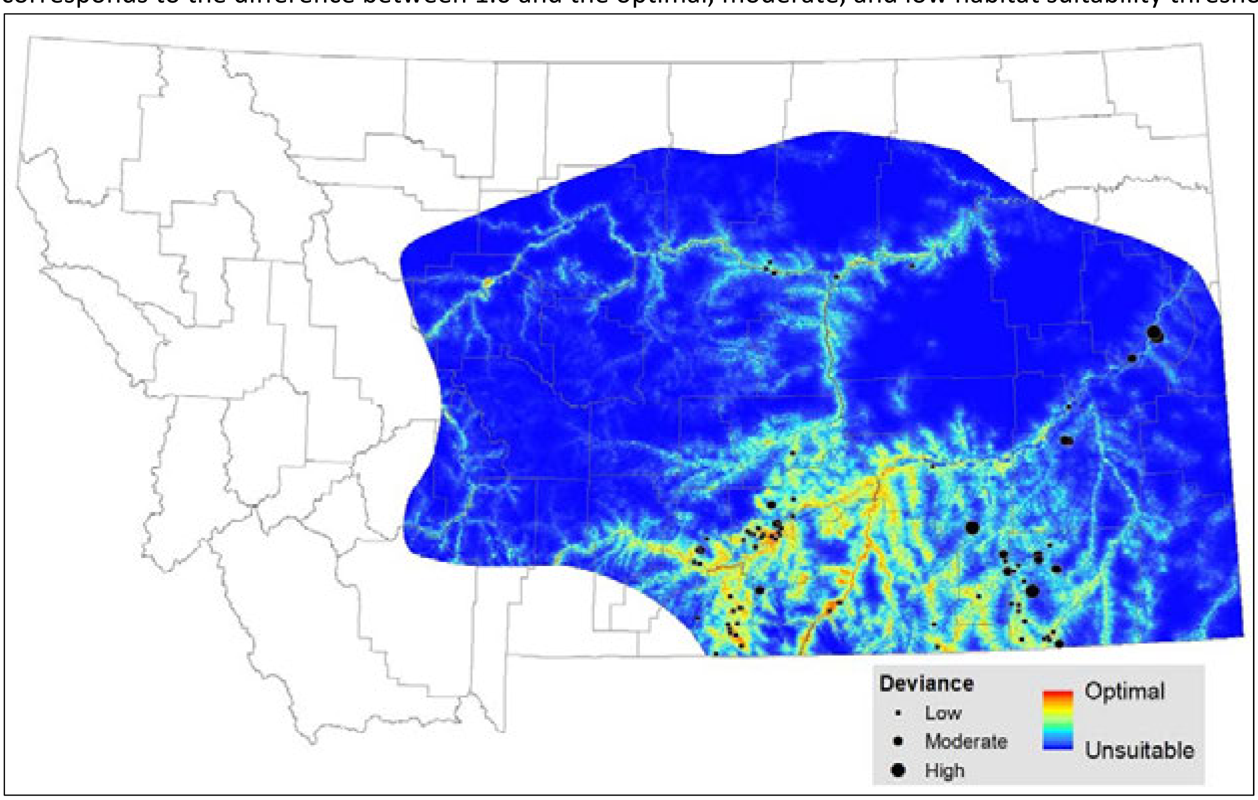


Figure 7. Continuous habitat suitability model output with all 147 observations (black) and survey locations that could have detected the species (gray).

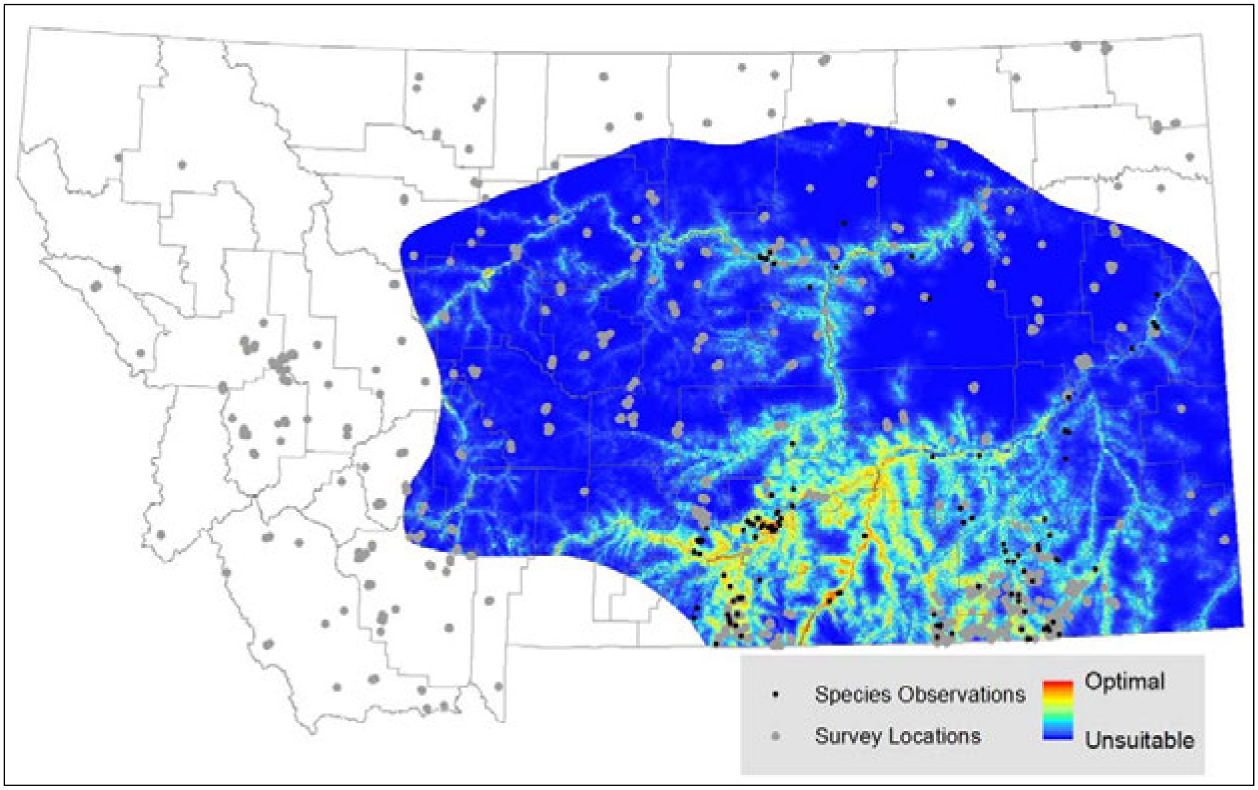


Figure 8. Model output classified into habitat suitability classes.

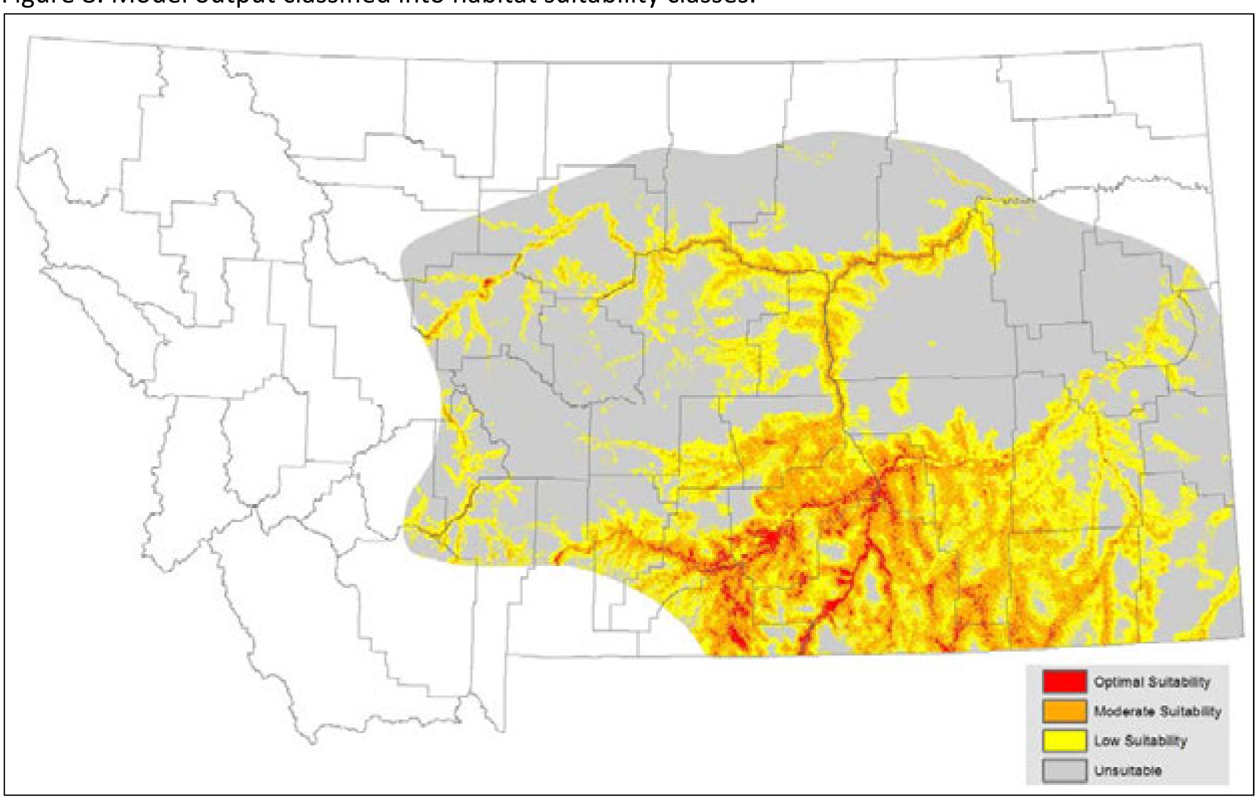
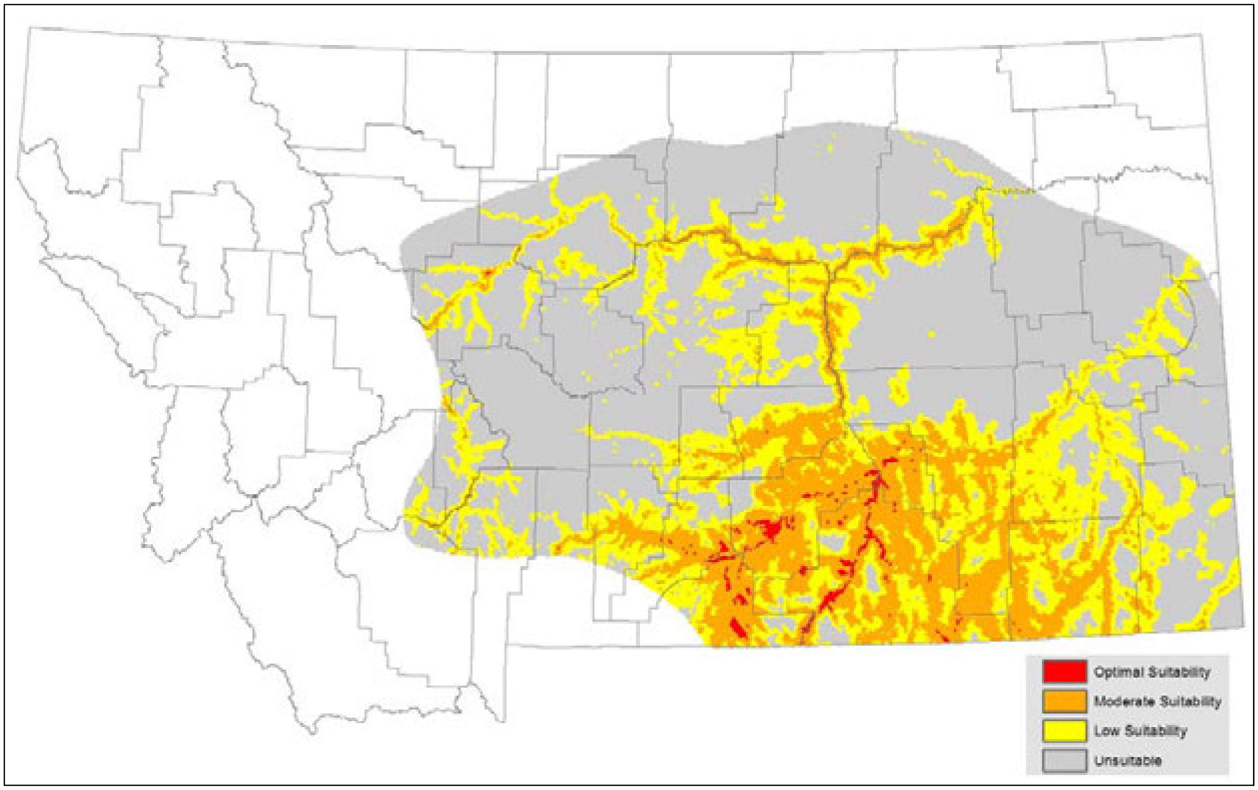


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Western Milksnake

Ecological System	Code	Association	Count[a]
Big Sagebrush Steppe	5454	Common	16
Great Plains Mixedgrass Prairie	7114	Common	16
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	8
Great Plains Sand Prairie	7121	Common	3
Great Plains Floodplain	9159	Common	3
Great Plains Badlands	3114	Common	2
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	2
Recently burned forest	8501	Common	2
Shale Badland	3139	Common	1
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	1
Recently burned grassland	8502	Common	1
Great Plains Riparian	9326	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Great Plains Wooded Draw and Ravine	4328	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	0
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	0
Recently burned shrubland	8503	Common	0
Post-Fire Recovery	8505	Common	0
Greasewood Flat	9103	Common	0
Low Intensity Residential	22	Occasional	5
Developed, Open Space	21	Occasional	2
Montane Sagebrush Steppe	5455	Occasional	1
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	1
Burned Sagebrush	8504	Occasional	1
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Occasional	0
Big Sagebrush Shrubland	5257	Occasional	0
Great Plains Shrubland	5262	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 82 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

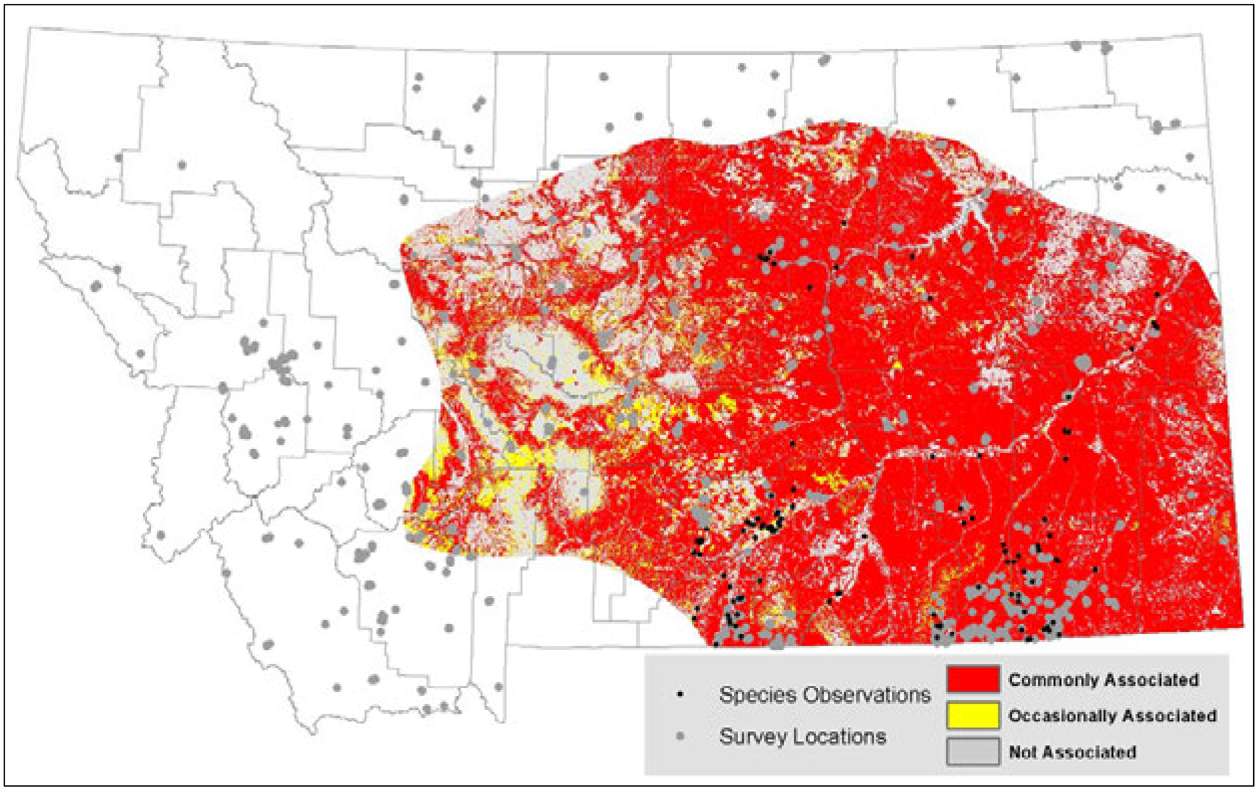
Measure	Value
Area of entire modeled range (percent of Montana)	200,214.81 km^2 (52.6%)
Area of Commonly and Occasionally Associated ES	150,145.0 km^2
Area of Commonly Associated ES	138,398.0 km^2
Area of Occasionally Associated ES	11,746.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	80.5%
Commonly Associated ES AVI[a]	68.3%
Occasionally Associated ES AVI[a]	12.2%

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

Figure 10. Deductive model output classified into habitat associations.



Gophersnake (*Pituophis catenifer*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S5
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Gophersnake general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit. With the exception of the optimal habitat suitability class cutoff, the delineation of habitat suitability classes is well supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do an adequate job of representing the amount of suitable habitat across the species' known range in Montana. Low AVI evaluations are a result of the fact that a large portion of observations for this species are made on roads which are not suitable habitat.

Suggested Citation: Montana Natural Heritage Program. 2017. Gophersnake (*Pituophis catenifer*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADB26020

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,388
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,147
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	806
Season Modeled	Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoiltemp	35.2%	contnsasp	1.5%
conttmax	14.7%	contsumrad	1.3%
catesys	11.6%	contwinrad	1.0%
contddays	7.3%	conttmin	0.8%
catgeol	6.8%	contndvi	0.5%
contelev	6.2%	contewasp	0.3%
contstrmed	5.4%	contprecip	0.2%
contwinpcp	2.9%	contslope	0.0%
catsoilord	2.3%	contvrm	0.0%
contfrsted	1.8%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.124
Moderate Logistic Threshold[b]	0.419
Optimal Logistic Threshold[c]	0.807
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	244,236.5 km^2
Area of predicted low suitability habitat within modeled range	159,998.6 km^2
Area of moderate suitability habitat within modeled range	82,227.6 km^2
Area of predicted optimal habitat within modeled range	2,010.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.5%
Moderate AVI[a]	68.9%
Optimal AVI[a]	3.0%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.528 ± 1.159
Training AUC[c]	0.837
Test AUC[d]	0.824

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.177, 1.740 and 0.428, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

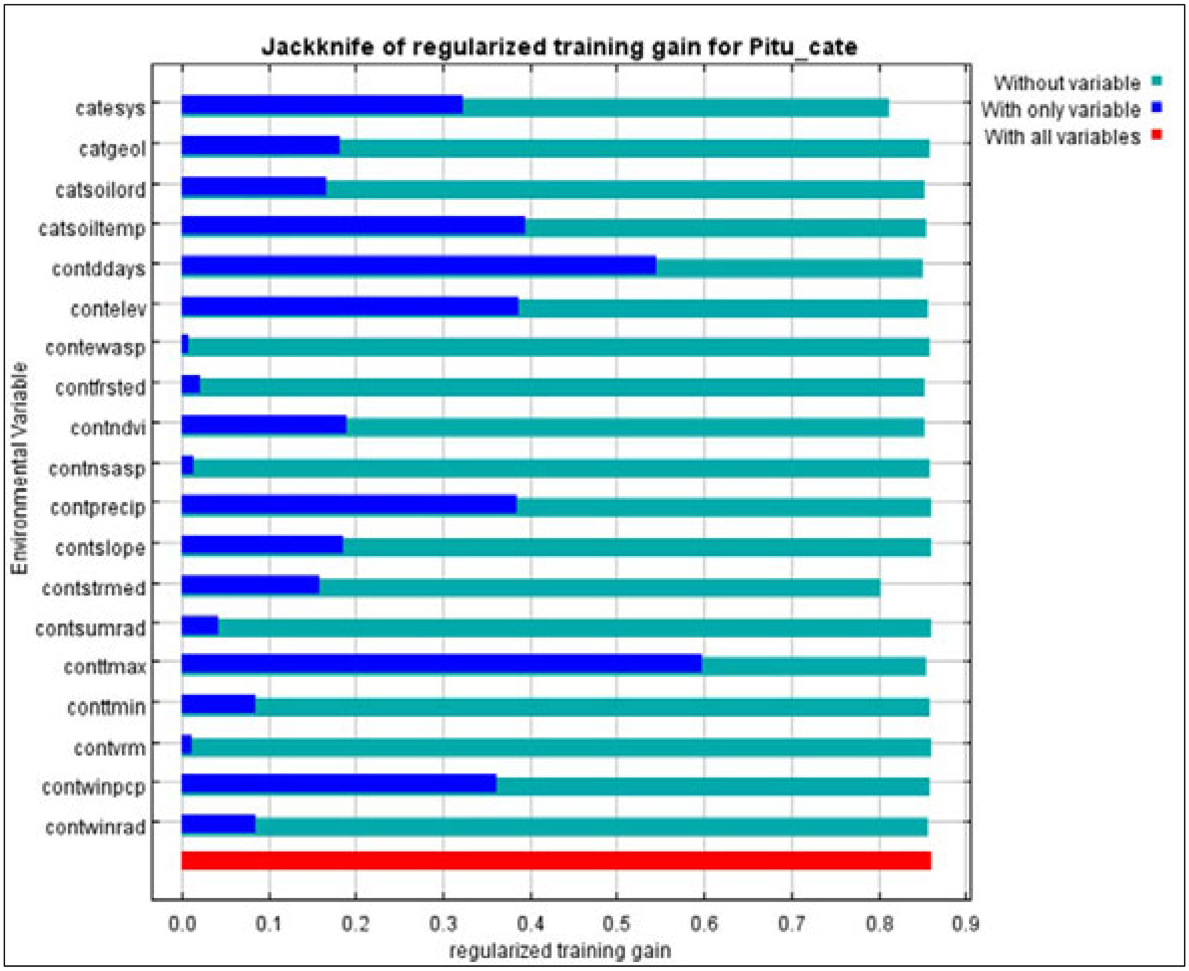
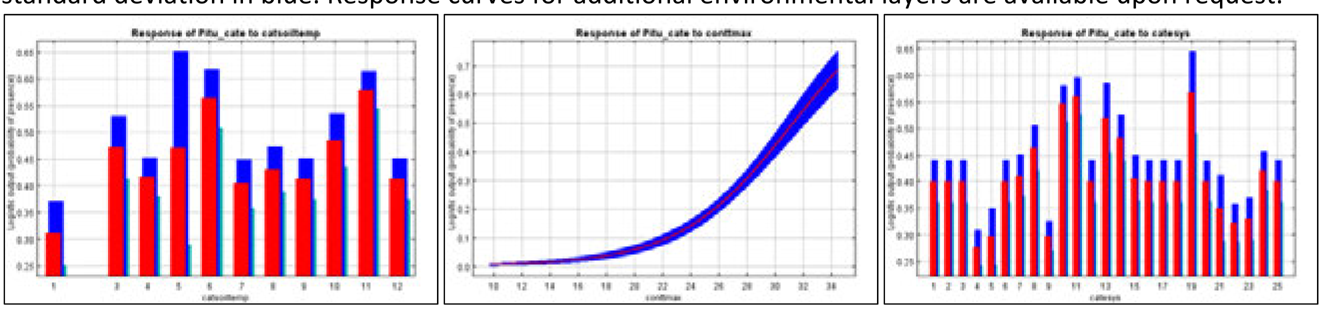


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

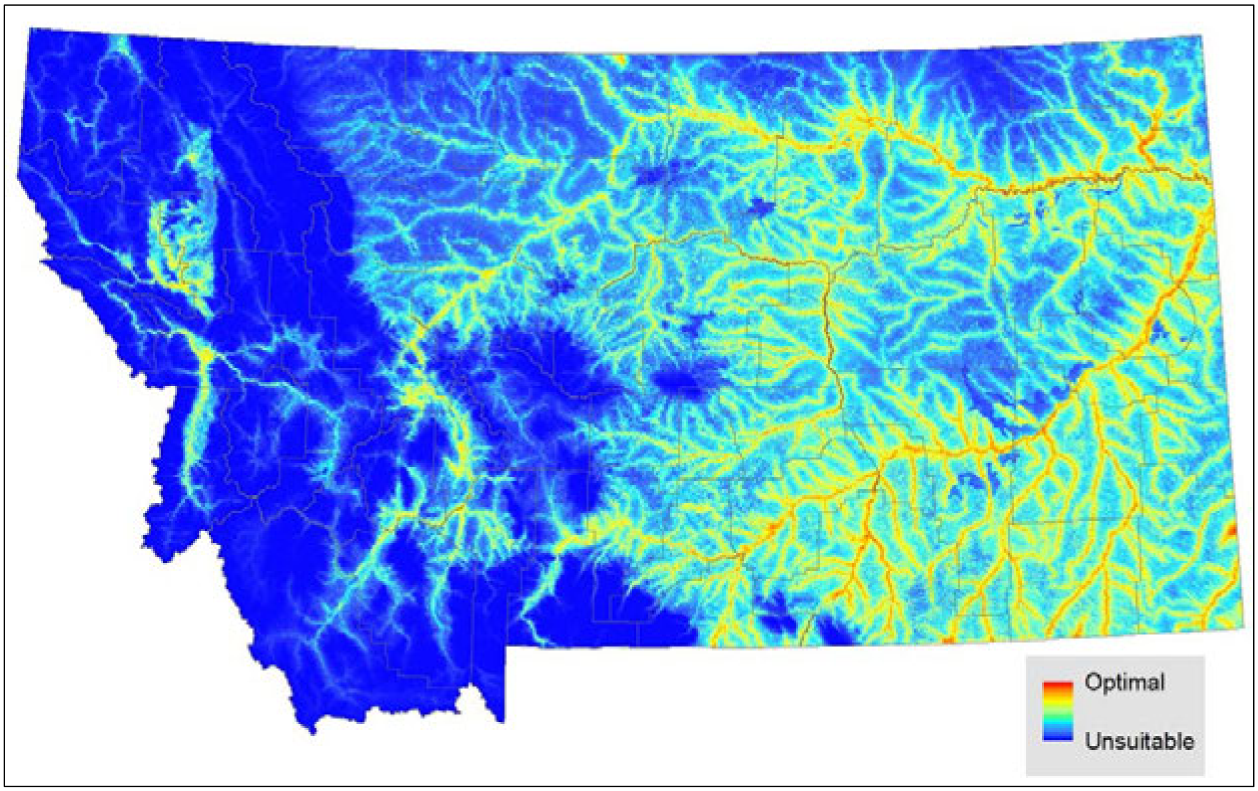


Figure 4. Standard deviation in the model output across the averaged models.

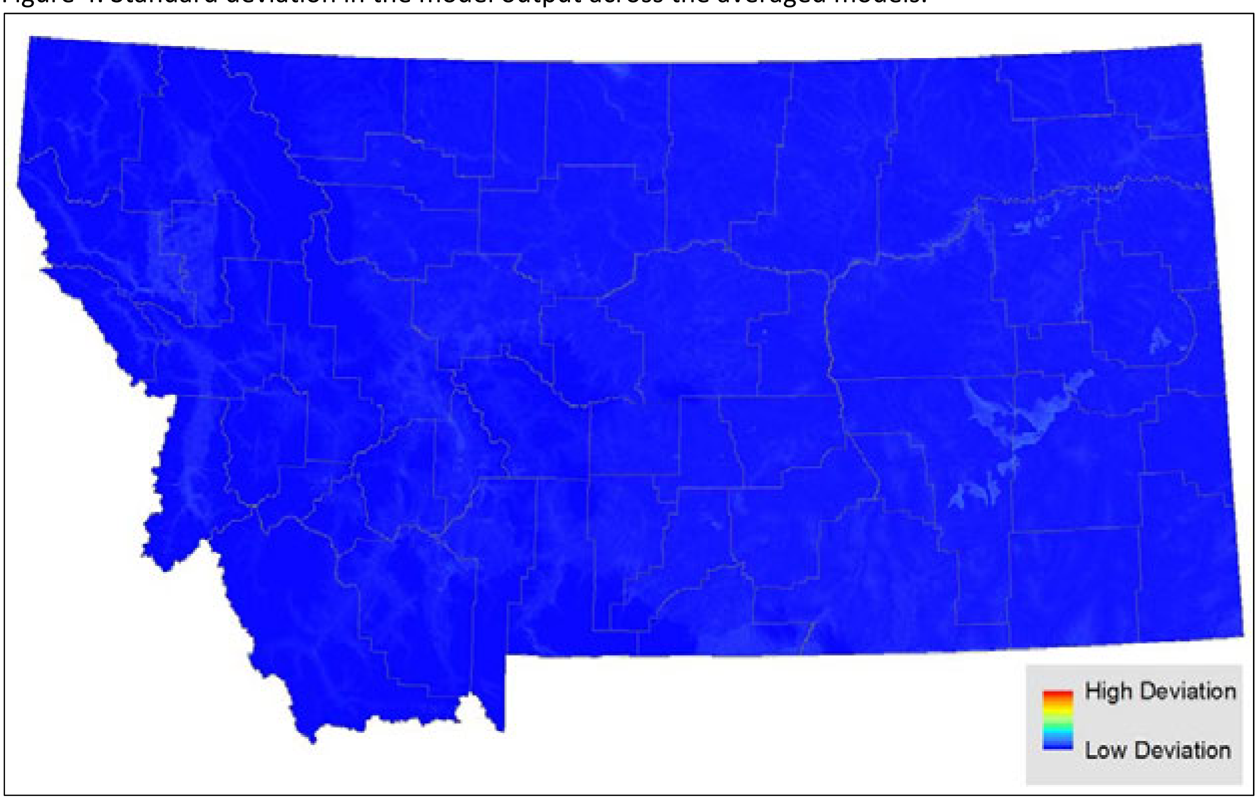


Figure 5. Continuous habitat suitability model output with the 806 observations used for modeling.

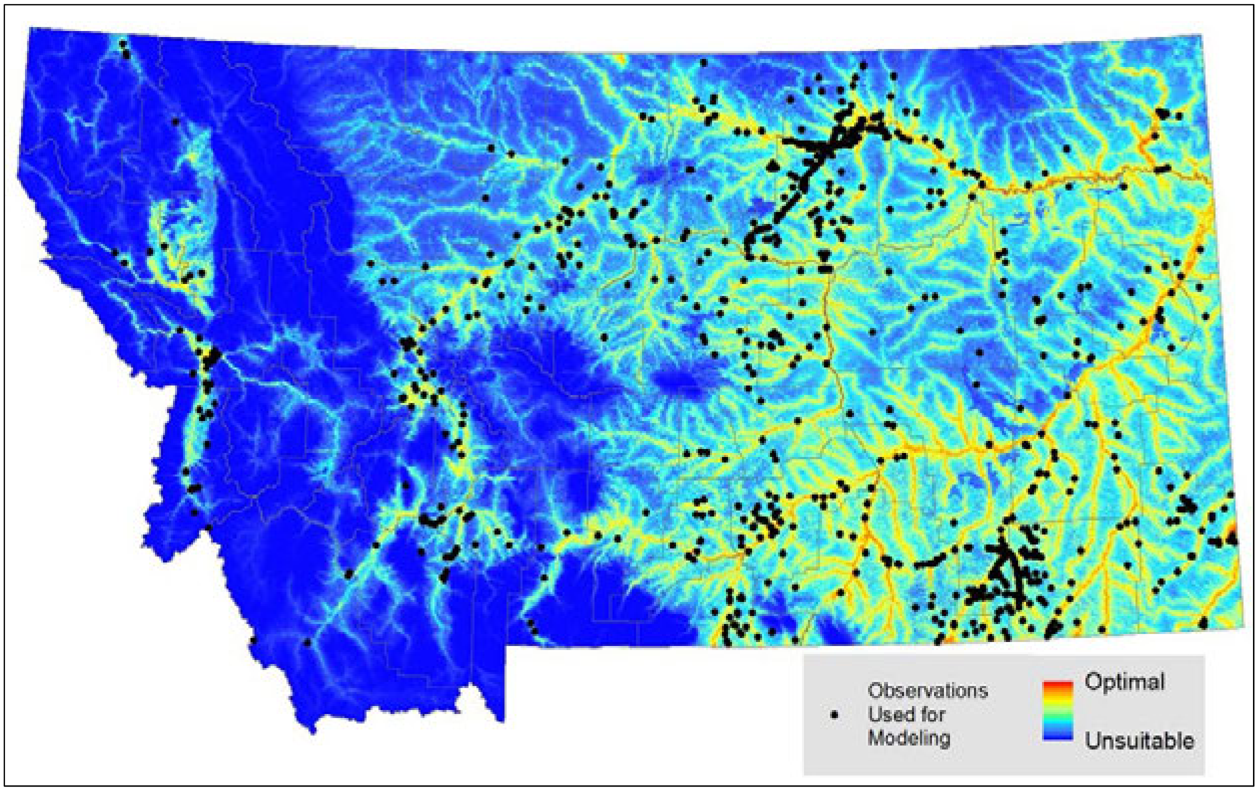


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

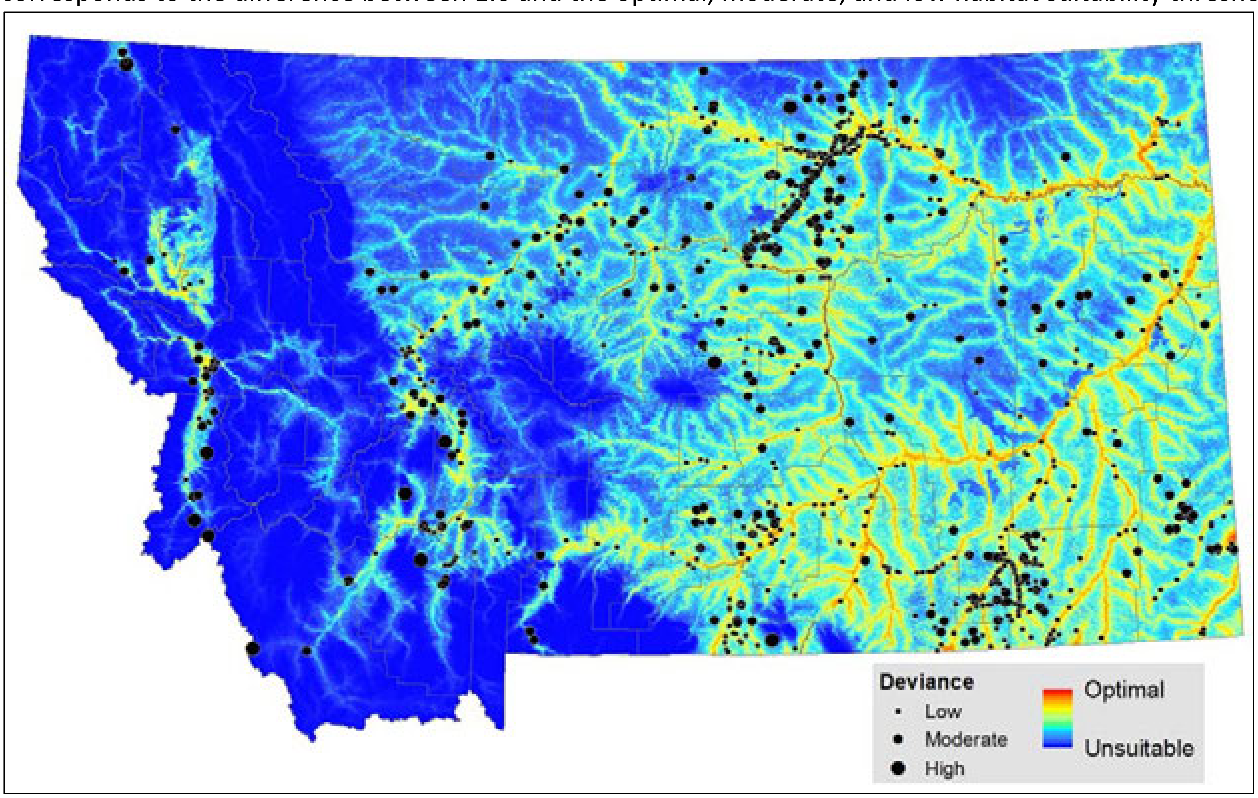


Figure 7. Continuous habitat suitability model output with all 1,388 observations (black) and survey locations that could have detected the species (gray).

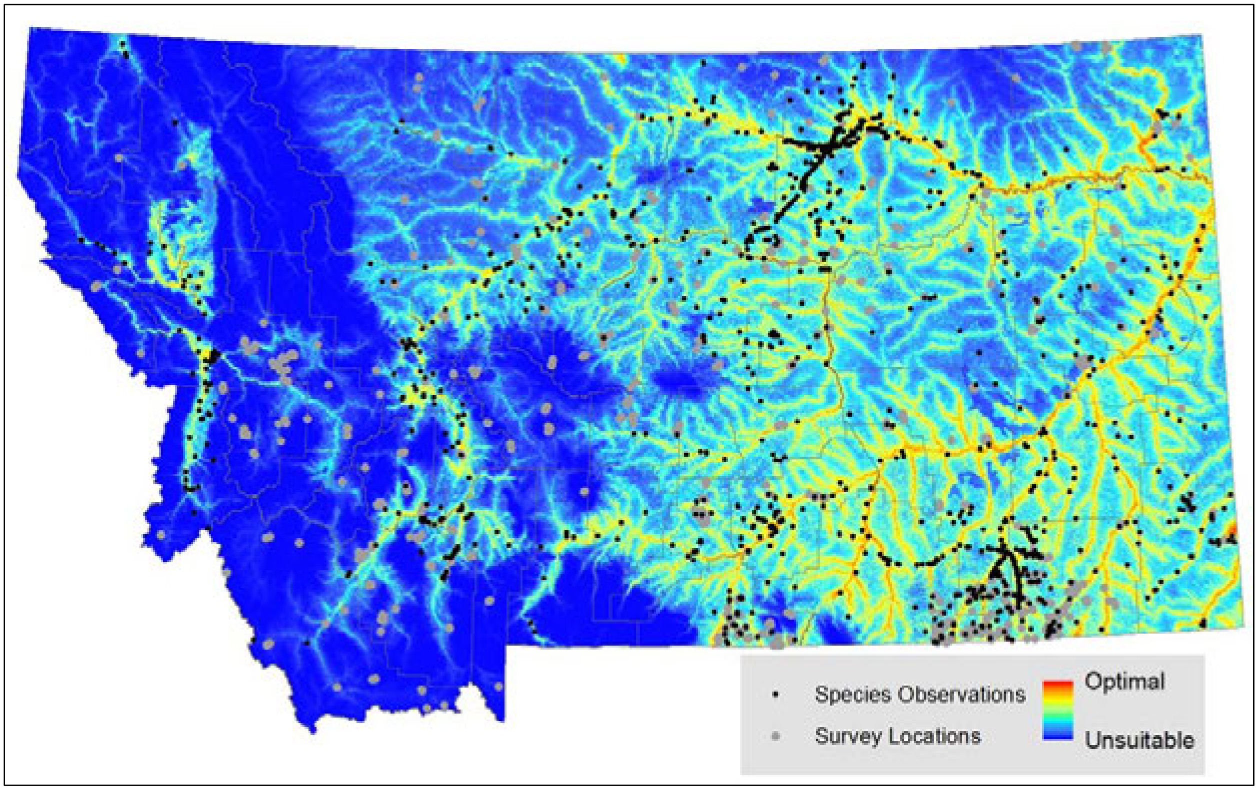


Figure 8. Model output classified into habitat suitability classes.

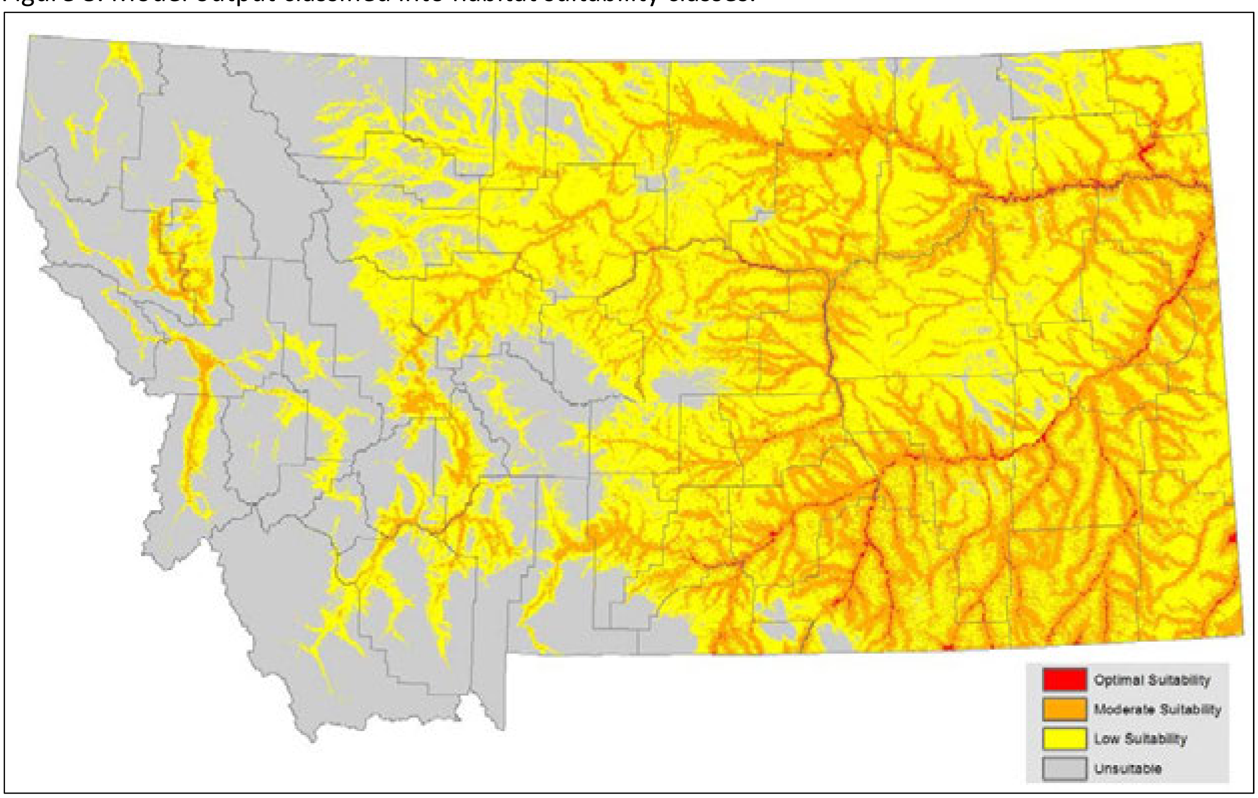
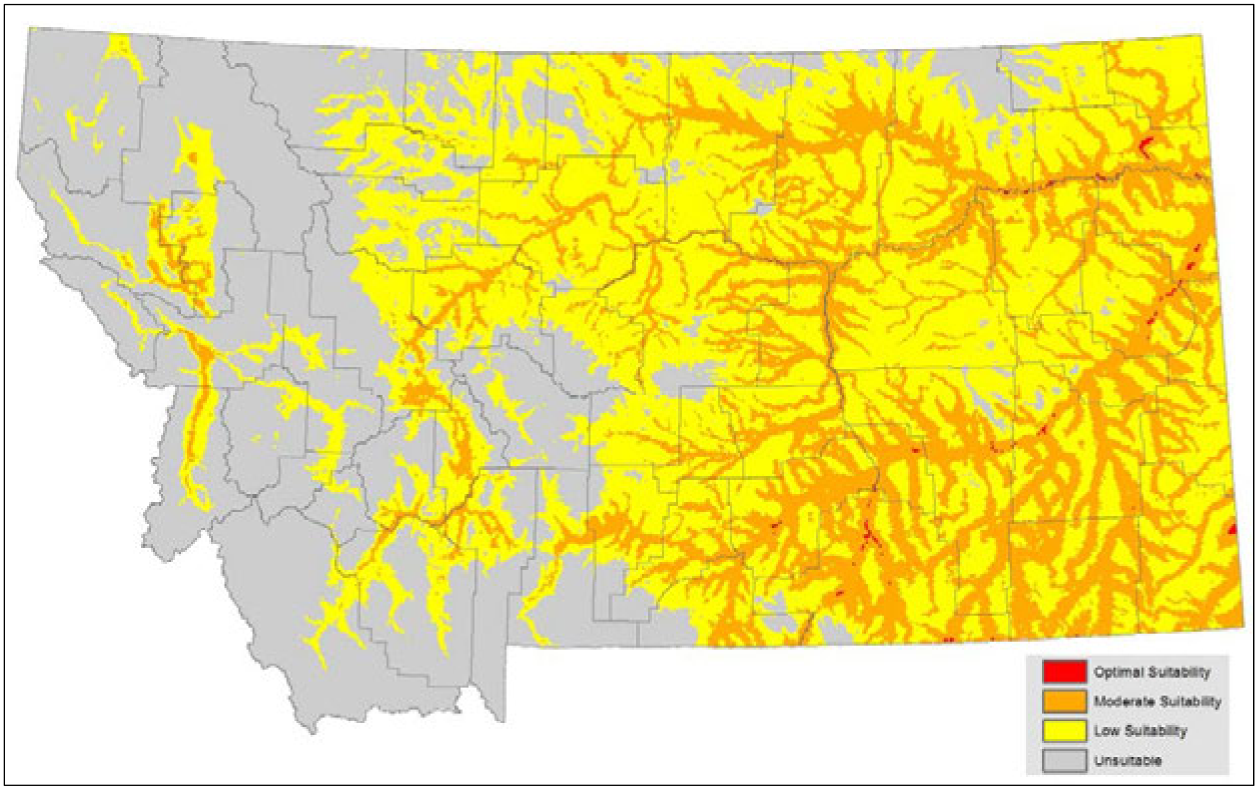


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5 Ecological Systems Associated with Gophersnake

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	111
Big Sagebrush Steppe	5454	Common	68
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	31
Great Plains Badlands	3114	Common	20
Great Plains Riparian	9326	Common	19
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	15
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Common	14
Great Plains Sand Prairie	7121	Common	13
Great Plains Floodplain	9159	Common	13
Pasture/Hay	81	Common	10
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	4
Montane Sagebrush Steppe	5455	Common	4
Greasewood Flat	9103	Common	4
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	4
Great Plains Wooded Draw and Ravine	4328	Common	3
Recently burned forest	8501	Common	3
Recently burned grassland	8502	Common	3
Burned Sagebrush	8504	Common	3
Post-Fire Recovery	8505	Common	3
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	2
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	1
Shale Badland	3139	Common	1
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	1
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	1
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Active and Stabilized Dune	3160	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen Forest and Woodland	4104	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Mat Saltbush Shrubland	5203	Common	0
Low Sagebrush Shrubland	5209	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Great Plains Shrubland	5262	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	0
Introduced Upland Vegetation - Shrub	8402	Common	0
Introduced Upland Vegetation - Annual Grassland	8404	Common	0
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	0

Table 5 Ecological Systems Associated with Gophersnake

Ecological System	Code	Association	Count[a]
Cultivated Crops	82	Occasional	22
Developed, Open Space	21	Occasional	7
Low Intensity Residential	22	Occasional	6
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Occasional	3
Introduced Riparian and Wetland Vegetation	8406	Occasional	3
Great Plains Saline Depression Wetland	9256	Occasional	3
Recently burned shrubland	8503	Occasional	2
Great Plains Open Freshwater Depression Wetland	9218	Occasional	1
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Occasional	0
Emergent Marsh	9222	Occasional	0
Insect-Killed Forest	8700	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 806 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

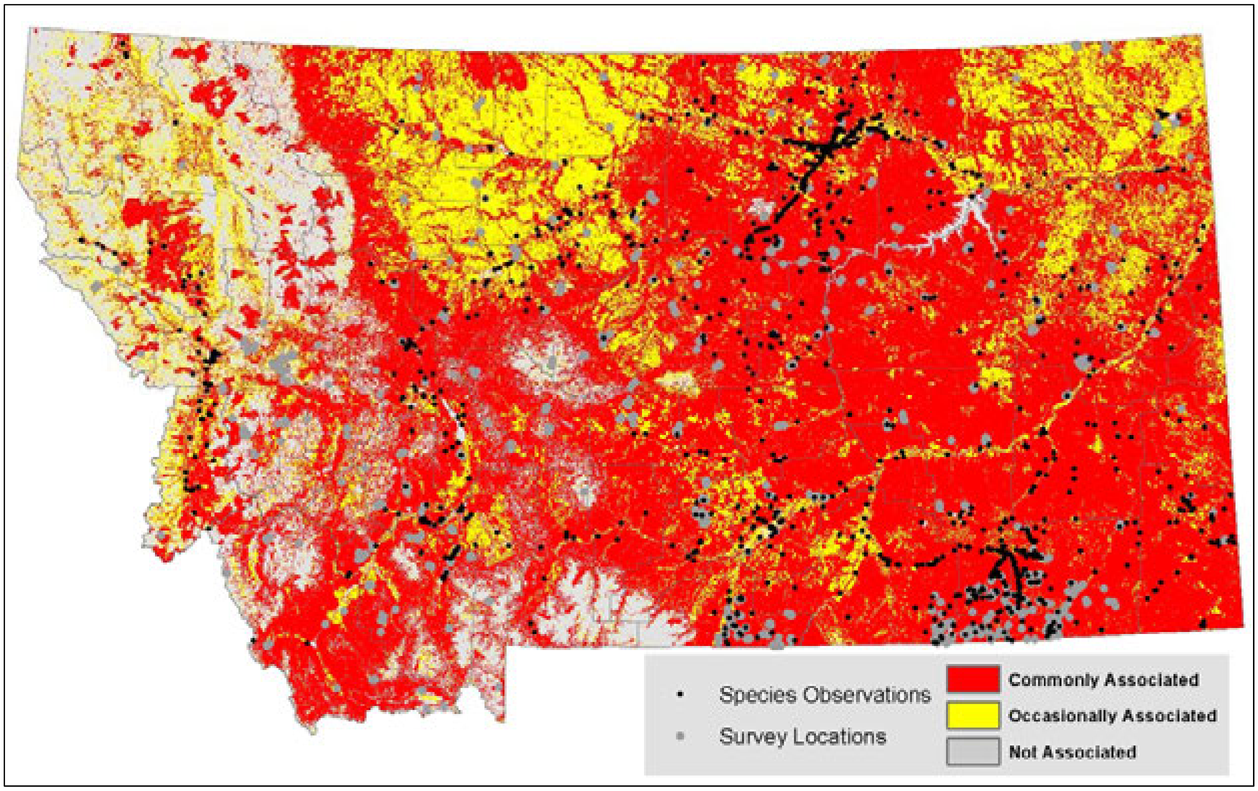
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	319,691.0 km^2
Area of Commonly Associated ES	238,735.0 km^2
Area of Occasionally Associated ES	80,956.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	49.5%
Commonly Associated ES AVI[a]	43.7%
Occasionally Associated ES AVI[a]	5.8%

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

Figure 10. Deductive model output classified into habitat associations.



Terrestrial Gartersnake (*Thamnophis elegans*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S5
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Terrestrial Gartersnake general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with may slightly over represent the amount of suitable habitat across the species' known range in Montana but are good tools for managers to use for decision making with regard to this wide-ranging species.

Suggested Citation: Montana Natural Heritage Program. 2017. Terrestrial Gartersnake (*Thamnophis elegans*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADB36050

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,204
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,957
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	1,187
Season Modeled	Year-round
Number of Model Background Locations	47,961

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	32.0%	contslope	3.0%
catsoiltemp	17.1%	contelev	1.7%
catgeol	10.8%	contfrsted	1.6%
contwinrad	5.0%	contwinpcp	1.3%
contstrmed	5.0%	contewasp	1.1%
contndvi	4.2%	contprecip	1.0%
conttmax	4.1%	contvrm	0.8%
contddays	3.7%	contsumrad	0.8%
catsoilord	3.4%	conttmin	0.1%
contnsasp	3.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.090
Moderate Logistic Threshold[b]	0.366
Optimal Logistic Threshold[c]	0.731
Area of entire modeled range (percent of Montana)	304,176.65 km^2 (79.9%)
Total area of predicted suitable habitat within modeled range	203,997.7 km^2
Area of predicted low suitability habitat within modeled range	151,931.2 km^2
Area of moderate suitability habitat within modeled range	47,226.2 km^2
Area of predicted optimal habitat within modeled range	4,840.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	97.7%
Moderate AVI[a]	72.9%
Optimal AVI[a]	26.1%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.548 ± 1.323
Training AUC[c]	0.871
Test AUC[d]	0.862

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.816, 2.008 and 0.627, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

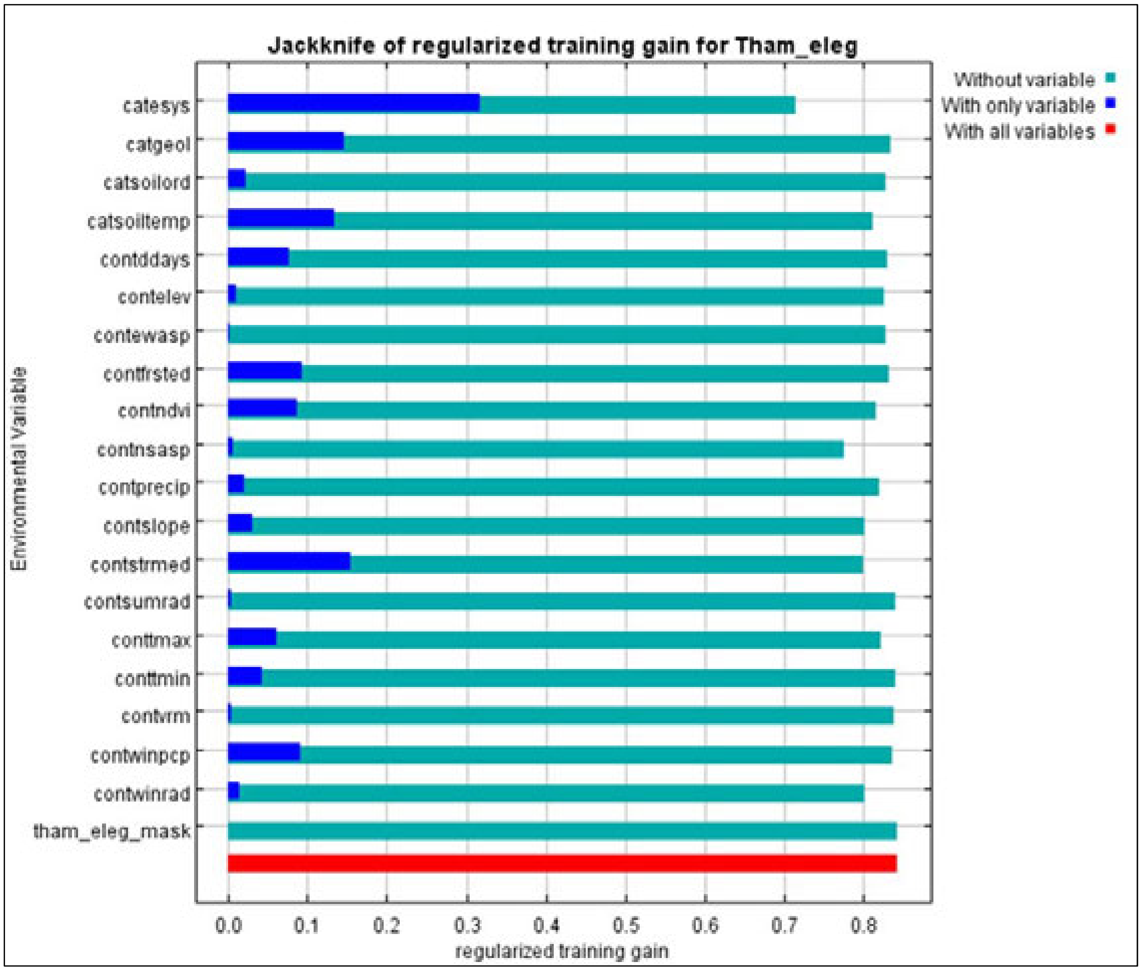
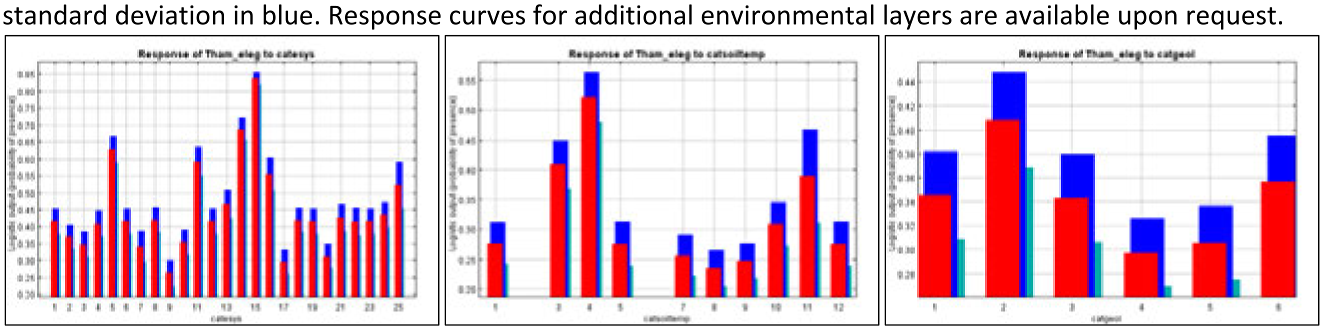


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

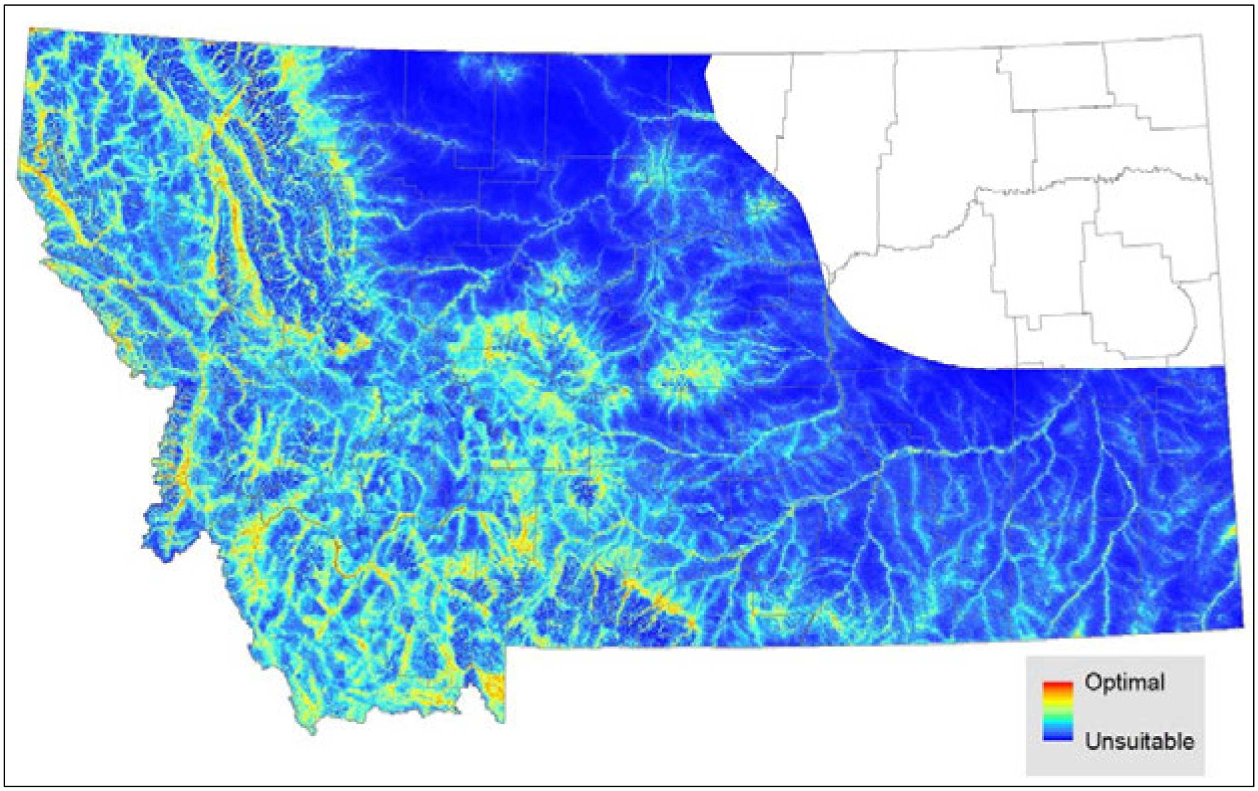


Figure 4. Standard deviation in the model output across the averaged models.

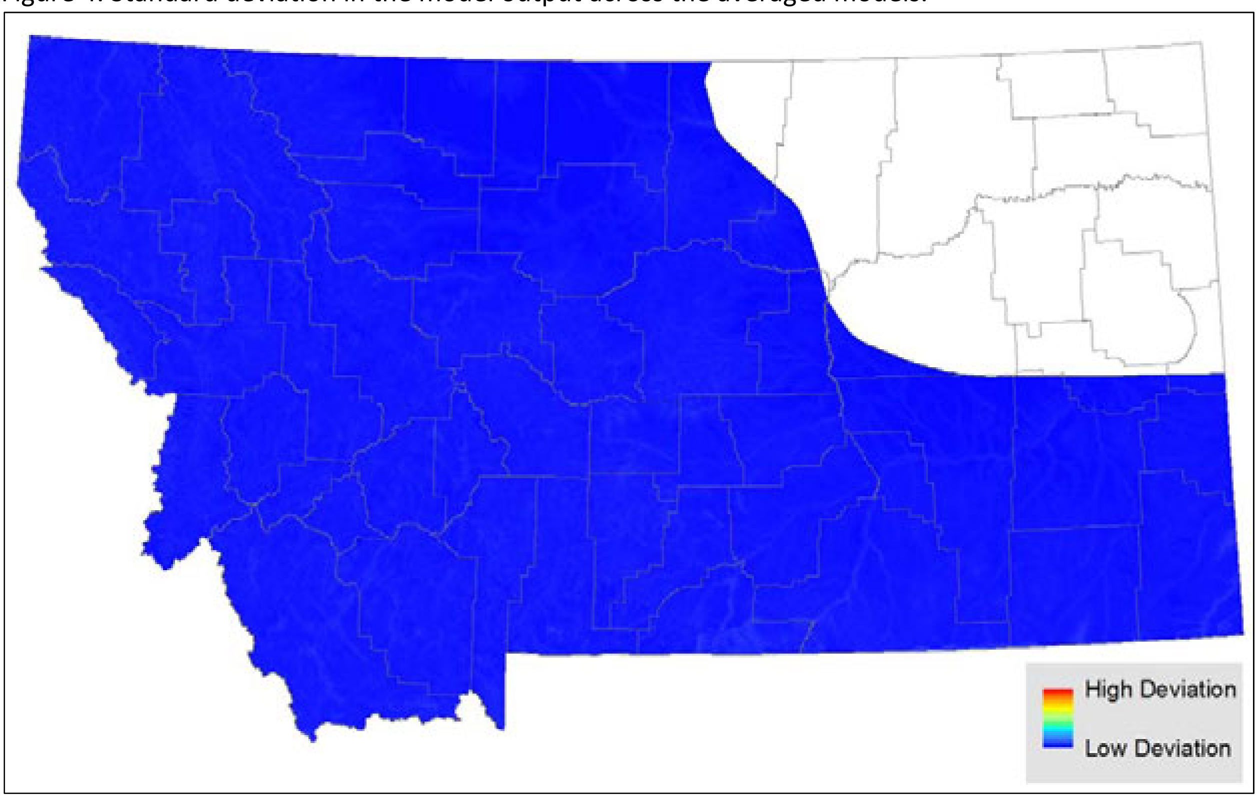


Figure 5. Continuous habitat suitability model output with the 1,187 observations used for modeling.

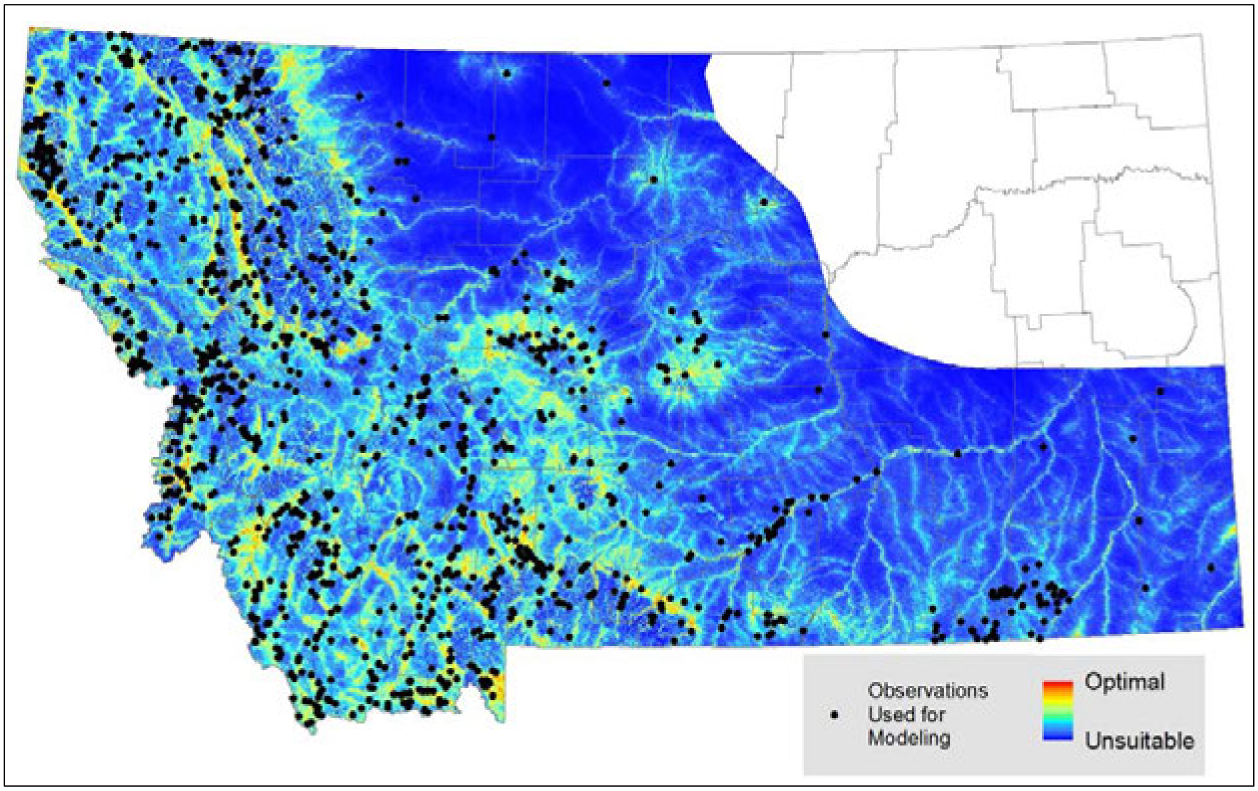


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

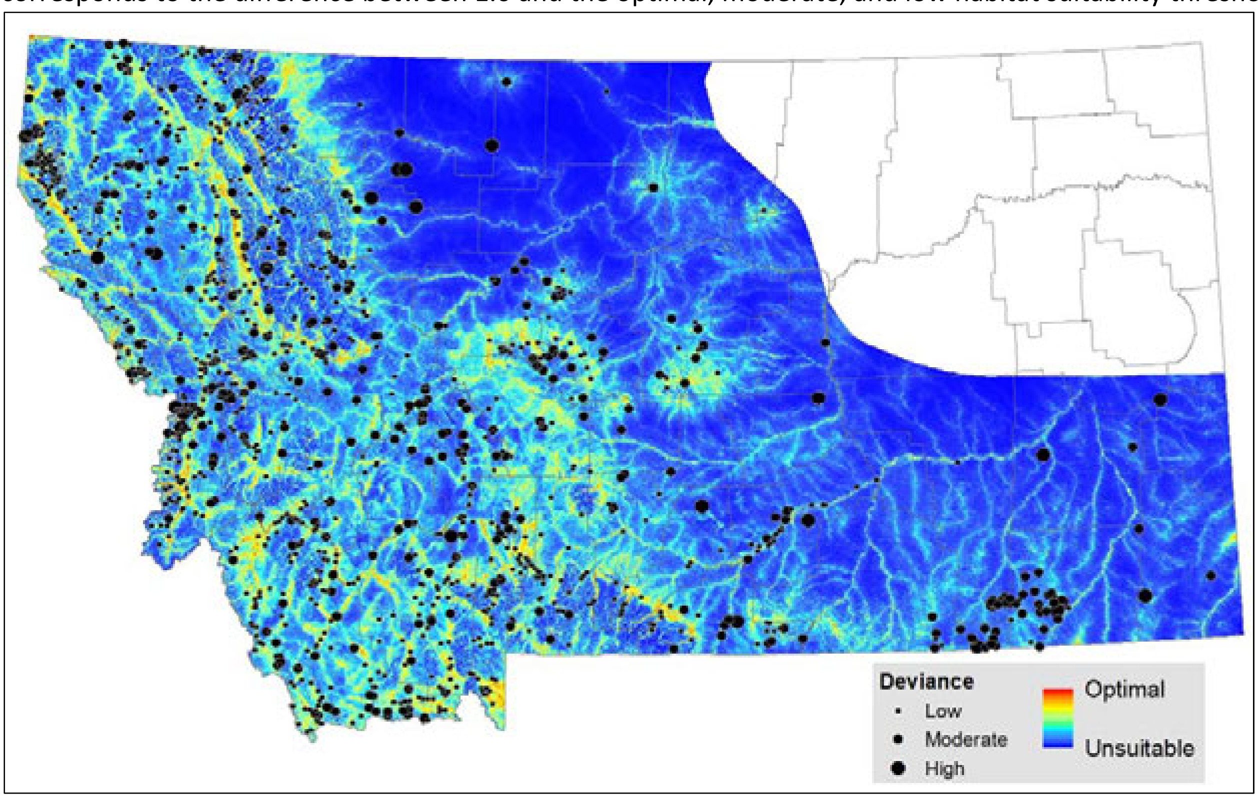


Figure 7. Continuous habitat suitability model output with all 2,204 observations (black) and survey locations that could have detected the species (gray).

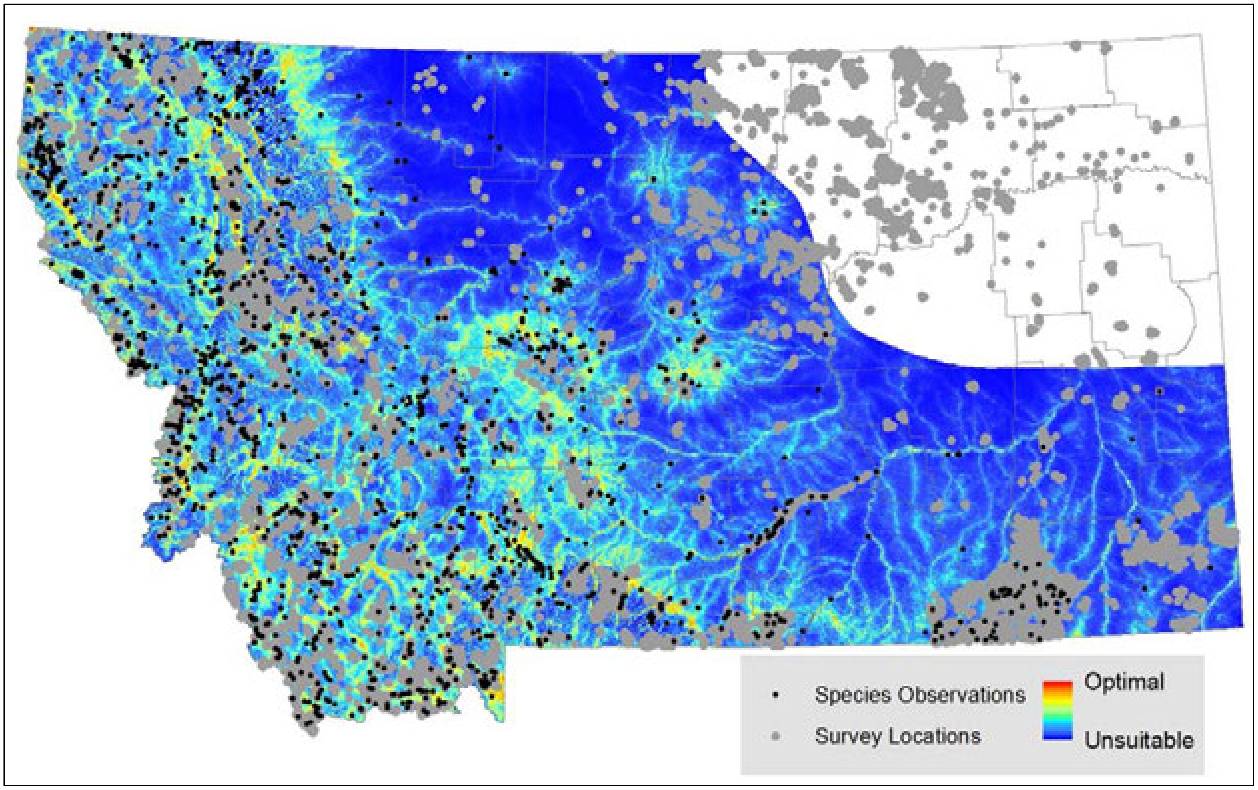


Figure 8. Model output classified into habitat suitability classes.

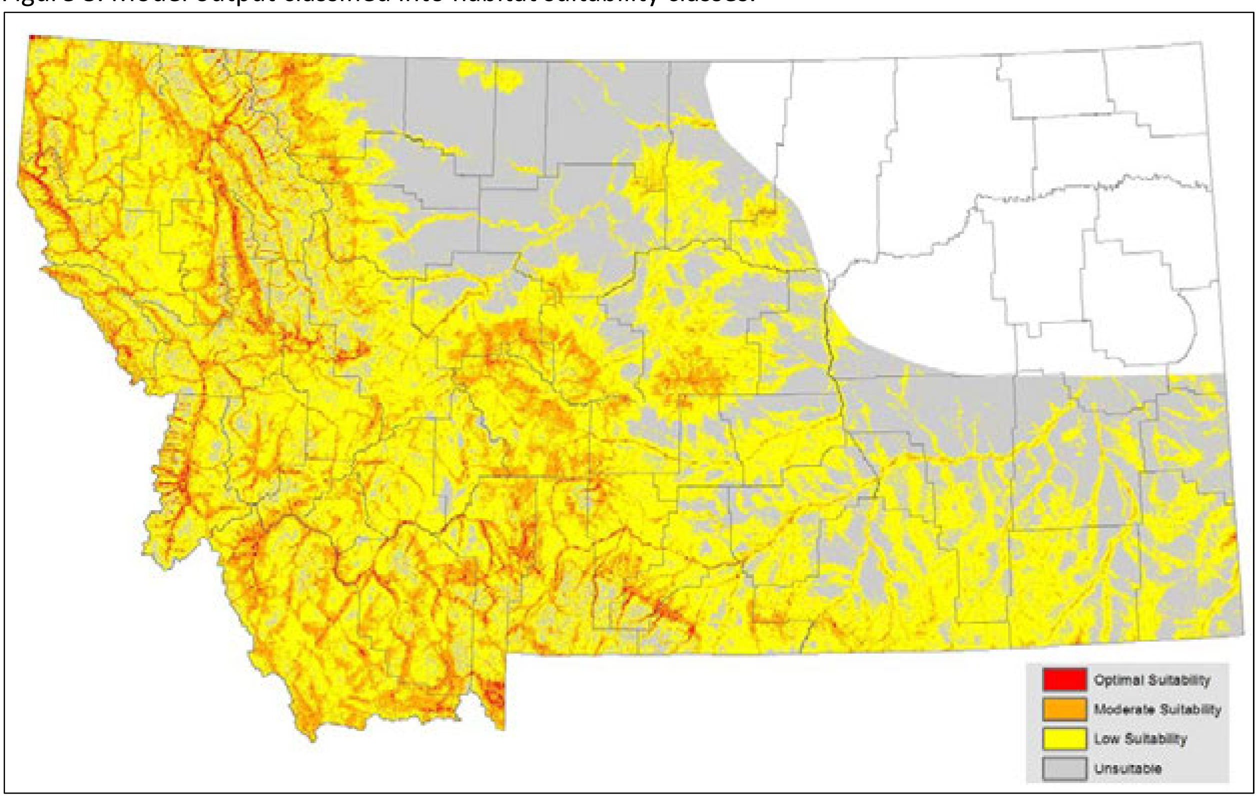
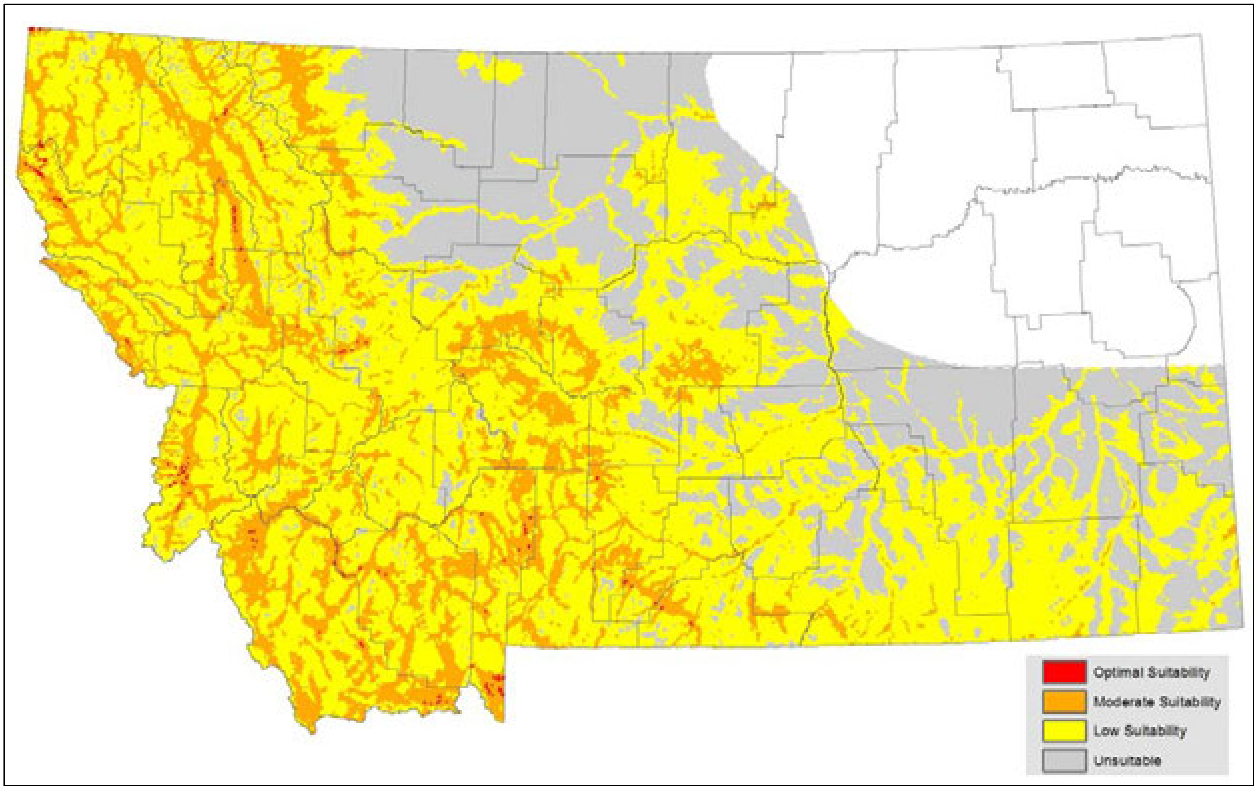


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Terrestrial Gartersnake

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	94
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	86
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	85
Open Water	11	Common	84
Montane Sagebrush Steppe	5455	Common	80
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	48
Rocky Mountain Lodgepole Pine Forest	4237	Common	46
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	46
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	35
Alpine-Montane Wet Meadow	9217	Common	34
Great Plains Mixedgrass Prairie	7114	Common	28
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	24
Great Plains Riparian	9326	Common	22
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	19
Aspen Forest and Woodland	4104	Common	18
Big Sagebrush Steppe	5454	Common	18
Recently burned forest	8501	Common	18
Post-Fire Recovery	8505	Common	17
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	16
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	15
Insect-Killed Forest	8700	Common	15
Rocky Mountain Subalpine Deciduous Shrubland	5326	Common	12
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	11
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	10
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	10
Great Plains Floodplain	9159	Common	8
Emergent Marsh	9222	Common	6
Recently burned grassland	8502	Common	5
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	4
Harvested forest-tree regeneration	8601	Common	4
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	3
Rocky Mountain Subalpine Woodland and Parkland	4233	Common	3
Aspen and Mixed Conifer Forest	4302	Common	2
Recently burned shrubland	8503	Common	2
Mountain Mahogany Woodland and Shrubland	4303	Common	1
Harvested forest-shrub regeneration	8602	Common	1
Rocky Mountain Conifer Swamp	9111	Common	1
Rocky Mountain Subalpine-Montane Fen	9234	Common	1
Quarries, Strip Mines and Gravel Pits	31	Common	0
Great Plains Cliff and Outcrop	3142	Common	0

Table 5: Ecological Systems Associated with Terrestrial Gartersnake

Ecological System	Code	Association	Count[a]
Active and Stabilized Dune	3160	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Great Plains Wooded Draw and Ravine	4328	Common	0
Burned Sagebrush	8504	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Cultivated Crops	82	Occasional	14
Low Intensity Residential	22	Occasional	10
Developed, Open Space	21	Occasional	9
Great Plains Badlands	3114	Occasional	5
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	4
Harvested forest-grass regeneration	8603	Occasional	4
Greasewood Flat	9103	Occasional	3
Pasture/Hay	81	Occasional	2
Great Plains Sand Prairie	7121	Occasional	2
Introduced Riparian and Wetland Vegetation	8406	Occasional	2
Alpine Bedrock and Scree	3135	Occasional	1
Low Sagebrush Shrubland	5209	Occasional	1
Great Plains Shrubland	5262	Occasional	1
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Occasional	1
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Alpine Dwarf-Shrubland	5207	Occasional	0
Big Sagebrush Shrubland	5257	Occasional	0
Mixed Salt Desert Scrub	5258	Occasional	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Occasional	0
Alpine Fell-Field	7116	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 1,187 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

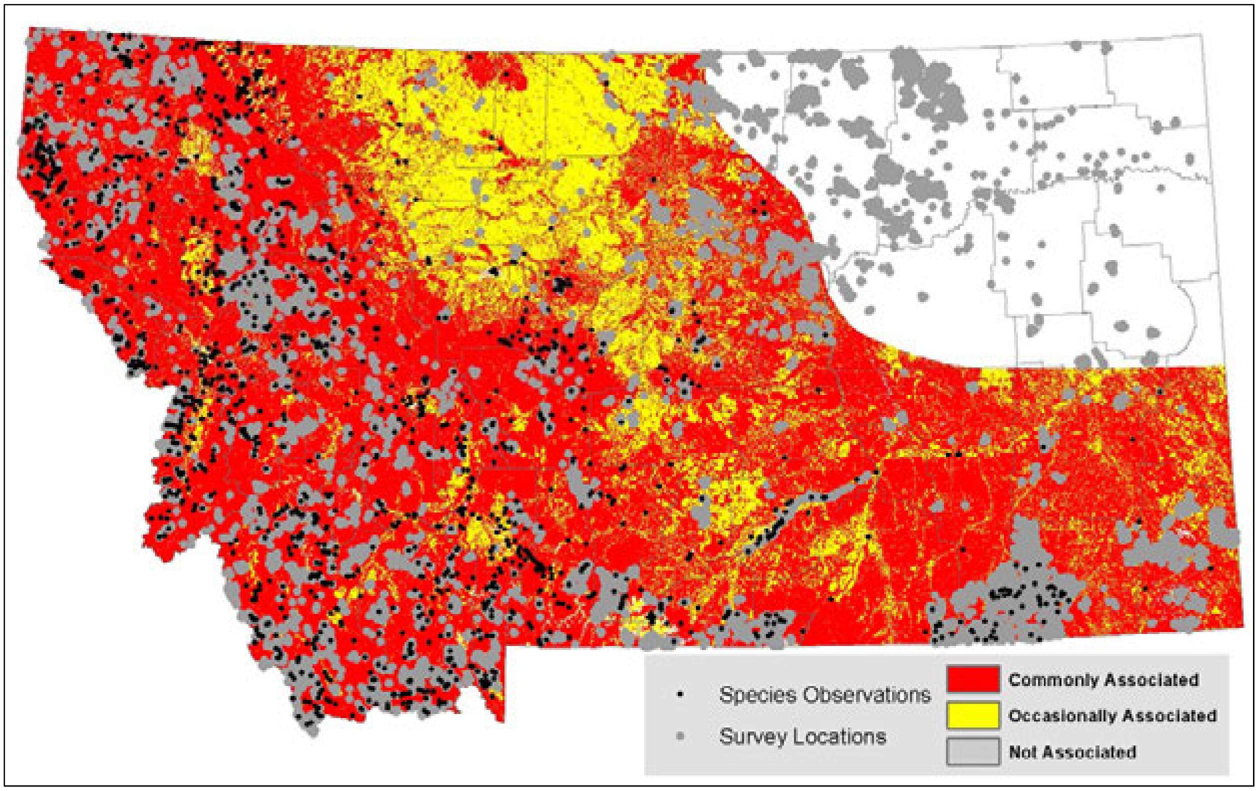
Measure	Value
Area of entire modeled range (percent of Montana)	304,176.65 km^2 (79.9%)
Area of Commonly and Occasionally Associated ES	297,783.0 km^2
Area of Commonly Associated ES	228,881.0 km^2
Area of Occasionally Associated ES	68,902.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	83.5%
Commonly Associated ES AVI[a]	78.5%
Occasionally Associated ES AVI[a]	5.0%

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

Figure 10. Deductive model output classified into habitat associations.



Common Gartersnake (*Thamnophis sirtalis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of representing the distribution of Common Gartersnake general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of suitable habitat within the species' known range in Montana because although the species can be found in more terrestrial habitats, it is truly more dependent on small wetland and aquatic habitats within terrestrially dominated landscapes. This deductive output should be used in conjunction with the inductive output for survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Common Gartersnake (*Thamnophis sirtalis*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADB36130

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,213
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,077
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	634
Season Modeled	Year-round
Number of Model Background Locations	53,526

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catgeol	25.2%	catsoilord	2.4%
catesys	21.3%	contwinrad	1.7%
catsoiltemp	14.3%	contddays	0.8%
contslope	9.6%	contnsasp	0.7%
contwinpcp	4.8%	contsumrad	0.7%
conttmax	4.4%	contewasp	0.4%
contelev	3.9%	contprecip	0.3%
conttmin	3.3%	contfrsted	0.2%
contstrmed	3.1%	contvrm	0.0%
contndvi	2.8%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.079
Moderate Logistic Threshold[b]	0.343
Optimal Logistic Threshold[c]	0.704
Area of entire modeled range (percent of Montana)	339,472.77 km^2 (89.2%)
Total area of predicted suitable habitat within modeled range	201,361.1 km^2
Area of predicted low suitability habitat within modeled range	156,752.2 km^2
Area of moderate suitability habitat within modeled range	37,589.4 km^2
Area of predicted optimal habitat within modeled range	7,019.5 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	95.9%
Moderate AVI[a]	76.3%
Optimal AVI[a]	41.3%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.478 ± 1.525
Training AUC[c]	0.909
Test AUC[d]	0.892

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.082, 2.142 and 0.703, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

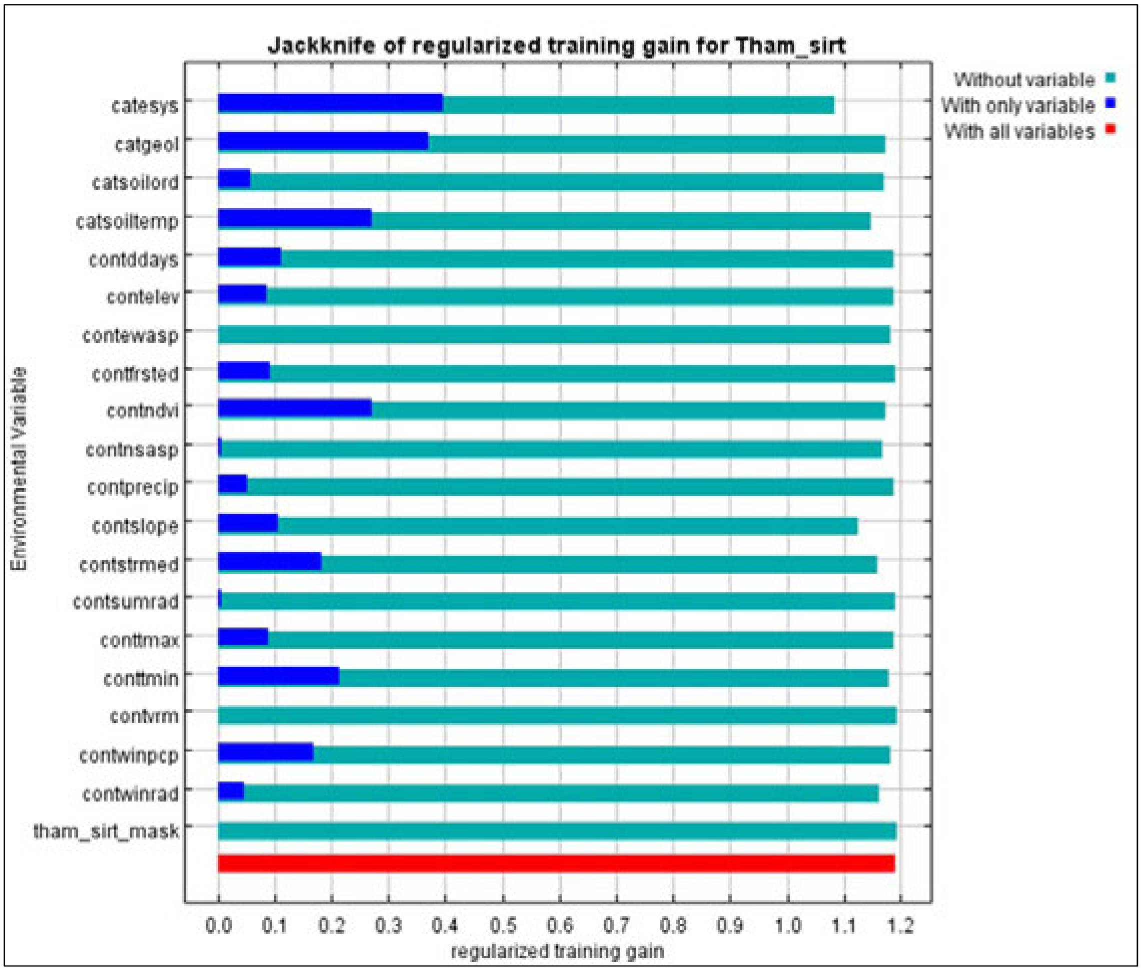
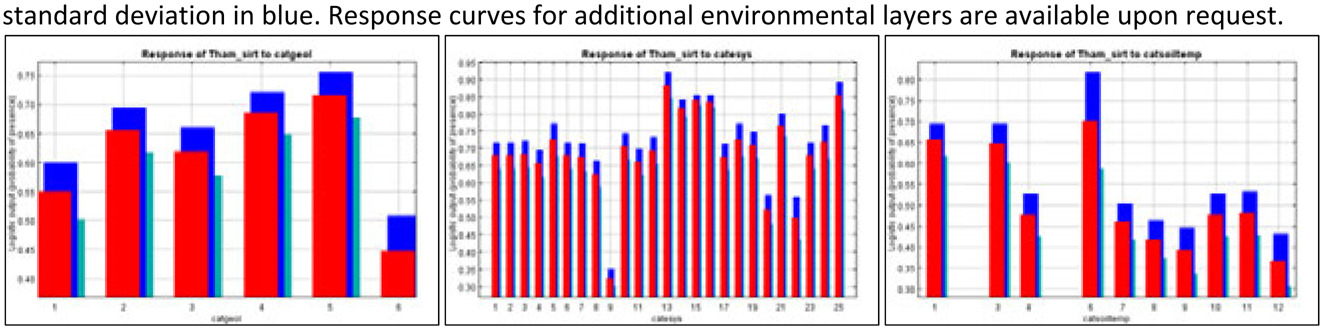


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

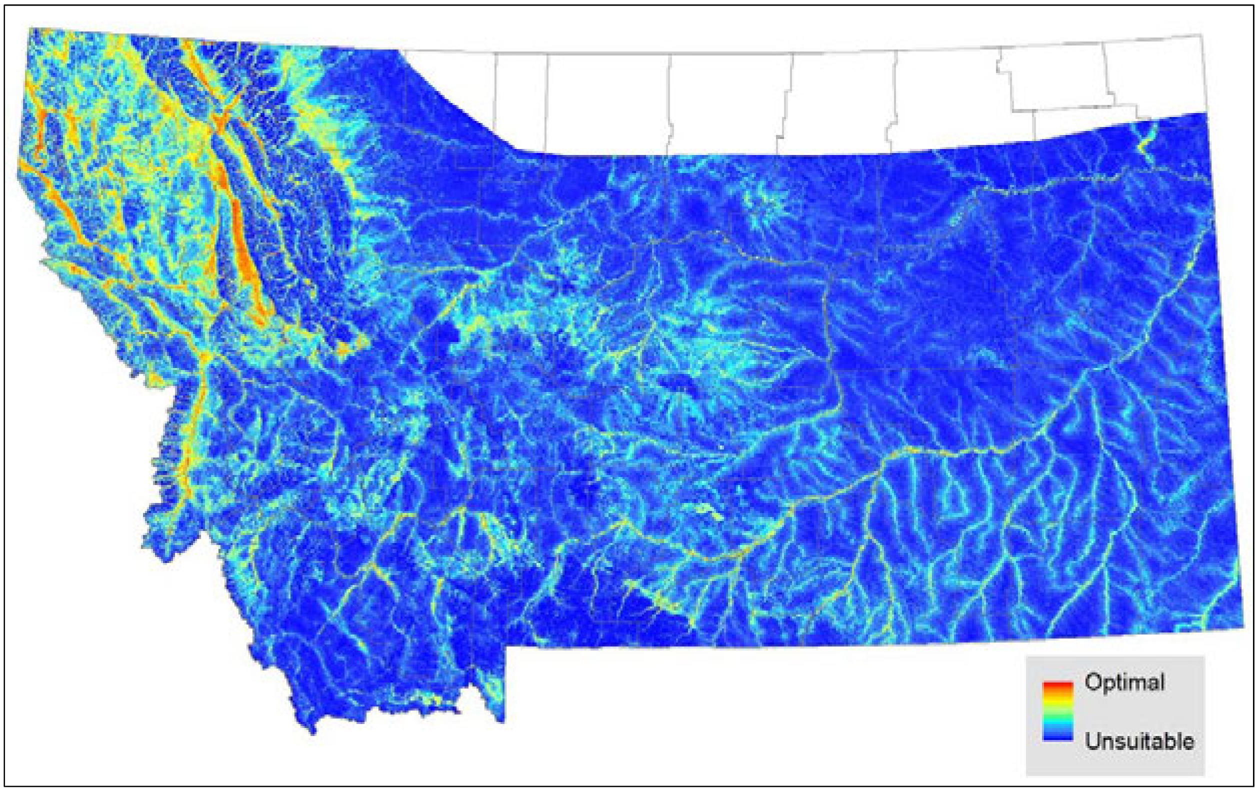


Figure 4. Standard deviation in the model output across the averaged models.

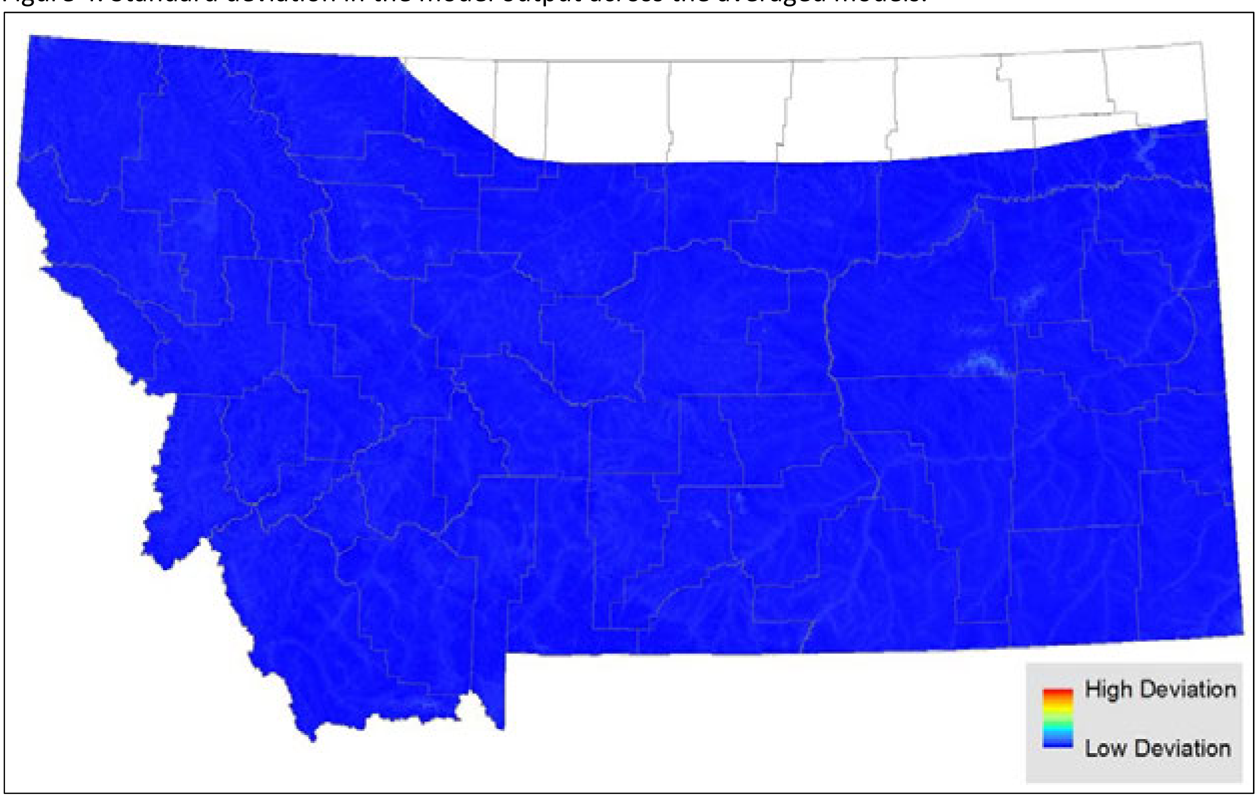


Figure 5. Continuous habitat suitability model output with the 634 observations used for modeling.

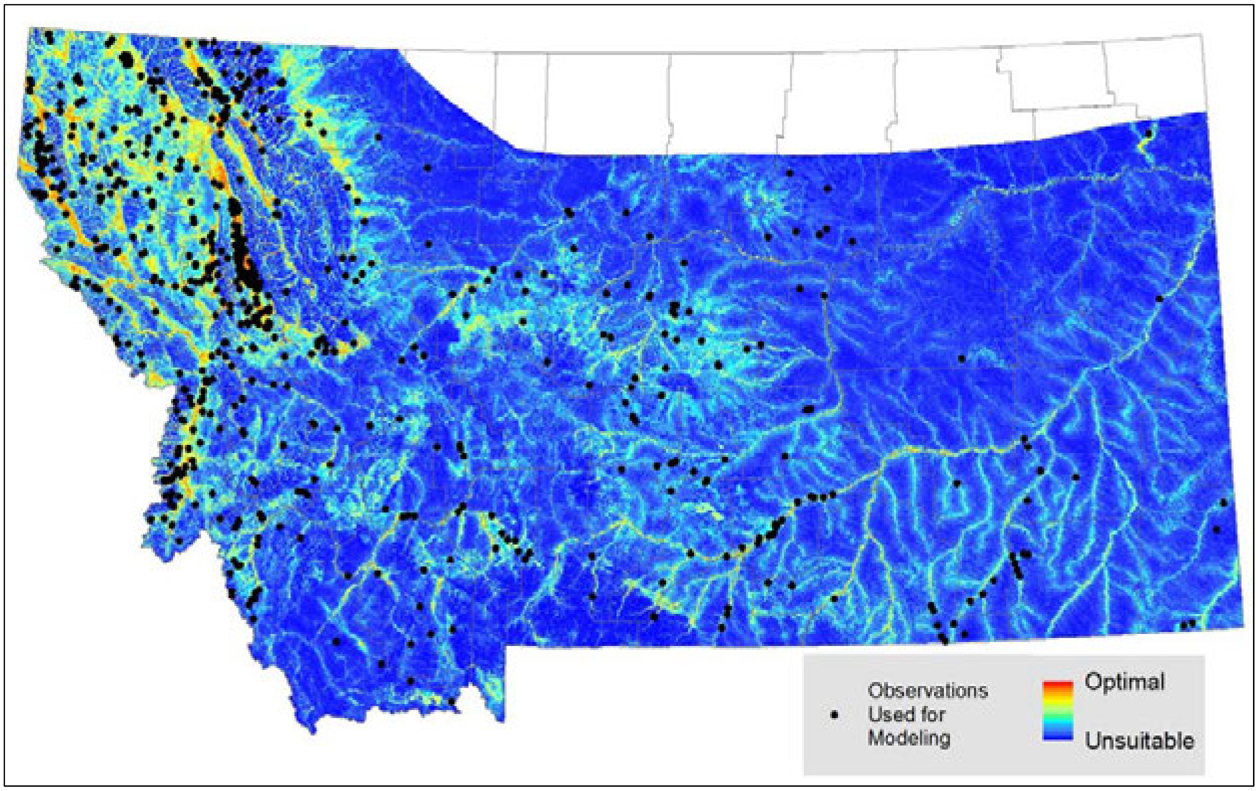


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

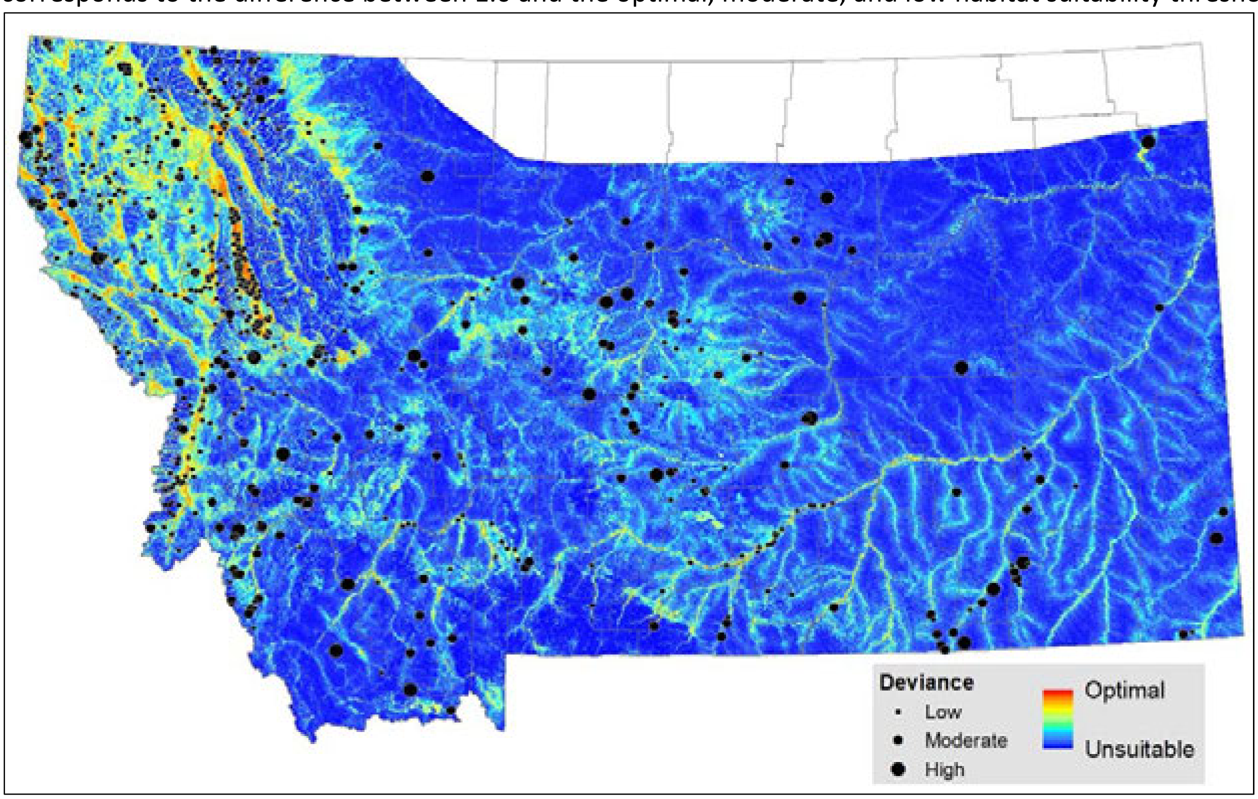


Figure 7. Continuous habitat suitability model output with all 1,213 observations (black) and survey locations that could have detected the species (gray).

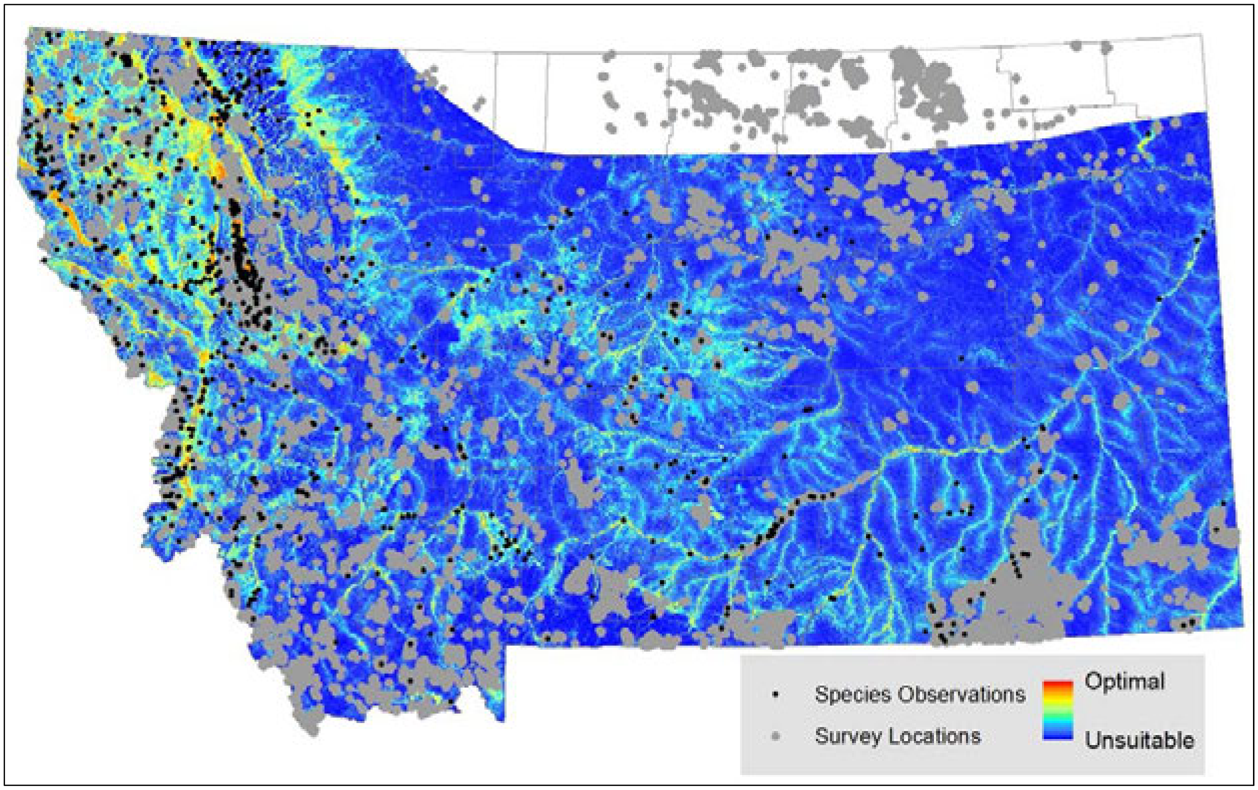


Figure 8. Model output classified into habitat suitability classes.

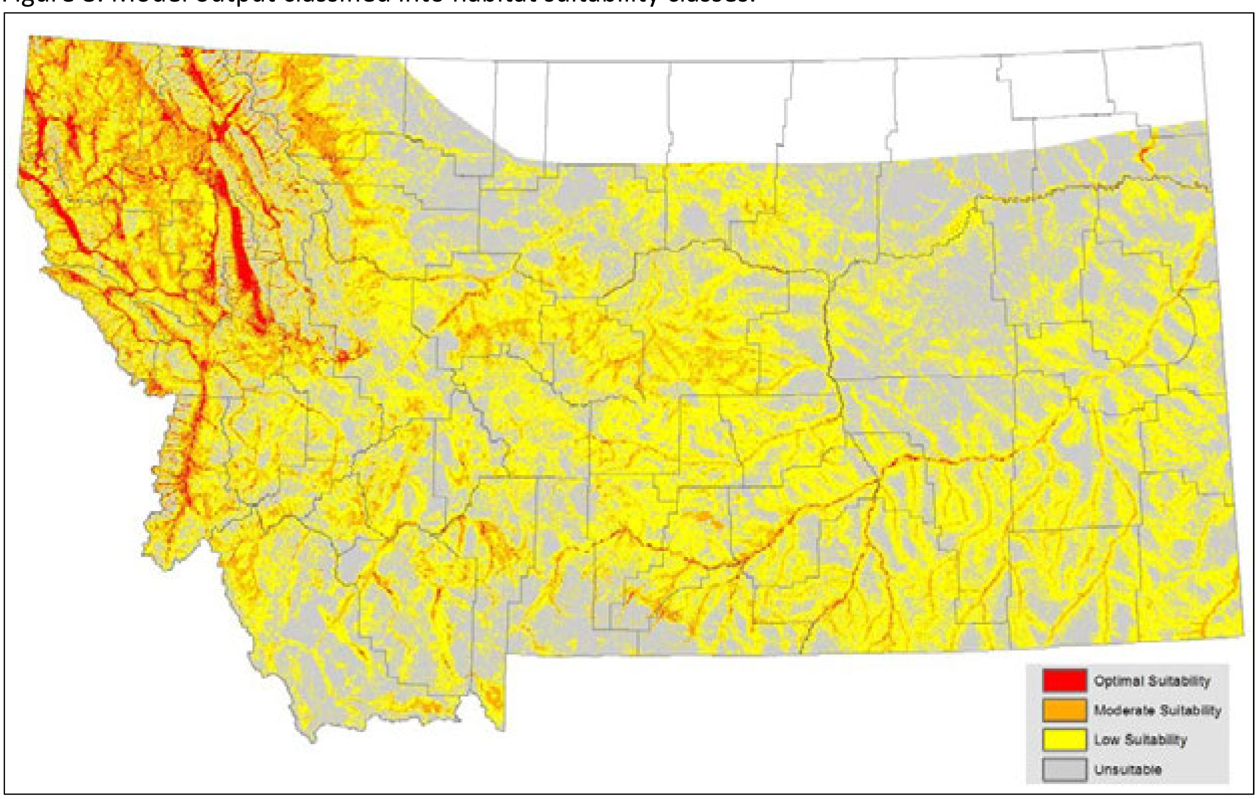
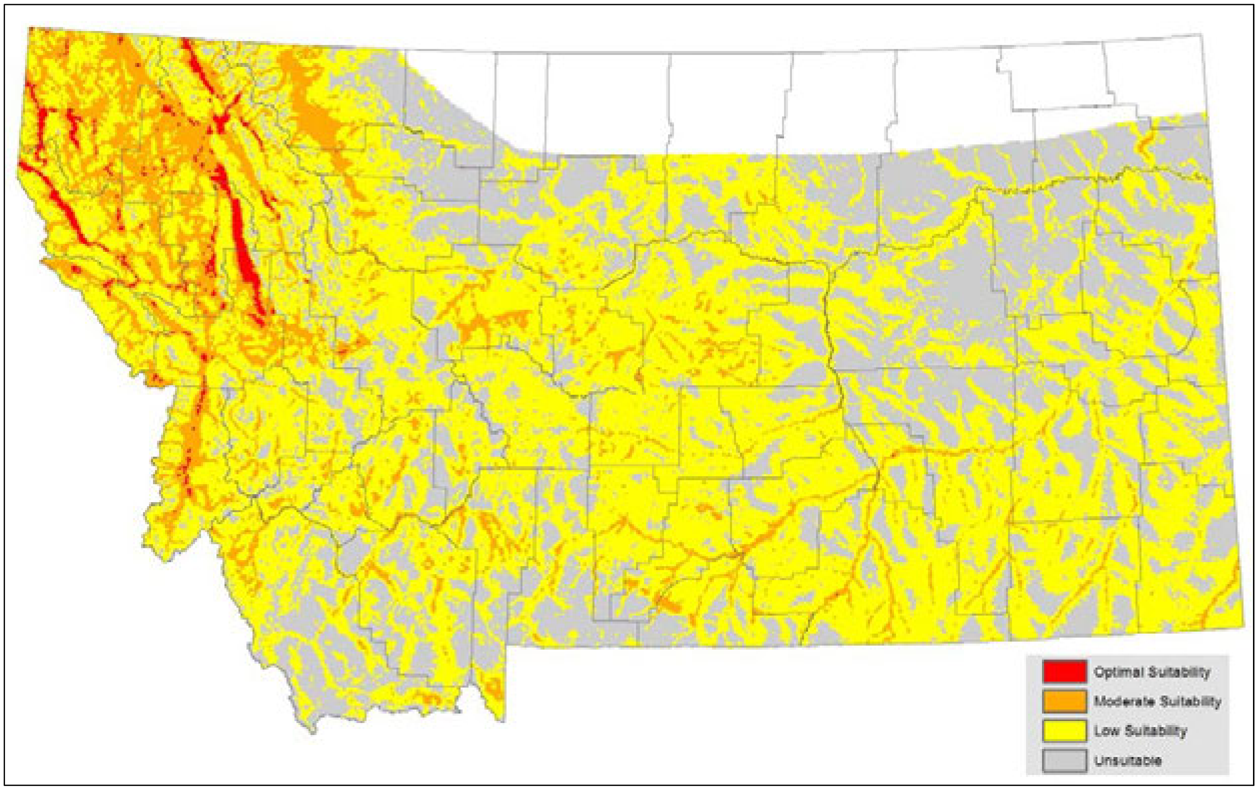


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Common Gartersnake

Ecological System	Code	Association	Count[a]
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	68
Open Water	11	Common	52
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	34
Great Plains Mixedgrass Prairie	7114	Common	26
Alpine-Montane Wet Meadow	9217	Common	26
Great Plains Riparian	9326	Common	16
Great Plains Floodplain	9159	Common	14
Harvested forest-tree regeneration	8601	Common	11
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	8
Rocky Mountain Subalpine Deciduous Shrubland	5326	Common	8
Post-Fire Recovery	8505	Common	8
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	5
Emergent Marsh	9222	Common	5
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	4
Insect-Killed Forest	8700	Common	4
Harvested forest-shrub regeneration	8602	Common	3
Rocky Mountain Subalpine-Montane Fen	9234	Common	3
Quarries, Strip Mines and Gravel Pits	31	Common	1
Recently burned grassland	8502	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Great Plains Saline Depression Wetland	9256	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Occasional	85
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Occasional	46
Rocky Mountain Lodgepole Pine Forest	4237	Occasional	21
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Occasional	15
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	10
Recently burned forest	8501	Occasional	10
Montane Sagebrush Steppe	5455	Occasional	9
Low Intensity Residential	22	Occasional	8
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Occasional	6
Big Sagebrush Steppe	5454	Occasional	6
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	6
Pasture/Hay	81	Occasional	5
Aspen Forest and Woodland	4104	Occasional	5

Table 5: Ecological Systems Associated with Common Gartersnake

Ecological System	Code	Association	Count[a]
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	5
Developed, Open Space	21	Occasional	4
Cultivated Crops	82	Occasional	4
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Occasional	4
Great Plains Shrubland	5262	Occasional	4
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	4
Great Plains Badlands	3114	Occasional	3
Great Plains Ponderosa Pine Woodland and Savanna	4280	Occasional	3
Harvested forest-grass regeneration	8603	Occasional	2
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	1
Great Plains Wooded Draw and Ravine	4328	Occasional	1
Great Plains Sand Prairie	7121	Occasional	1
Introduced Riparian and Wetland Vegetation	8406	Occasional	1
Greasewood Flat	9103	Occasional	1
Active and Stabilized Dune	3160	Occasional	0
Wyoming Basin Cliff and Canyon	3173	Occasional	0
Alpine Fell-Field	7116	Occasional	0
Recently burned shrubland	8503	Occasional	0
Burned Sagebrush	8504	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 634 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

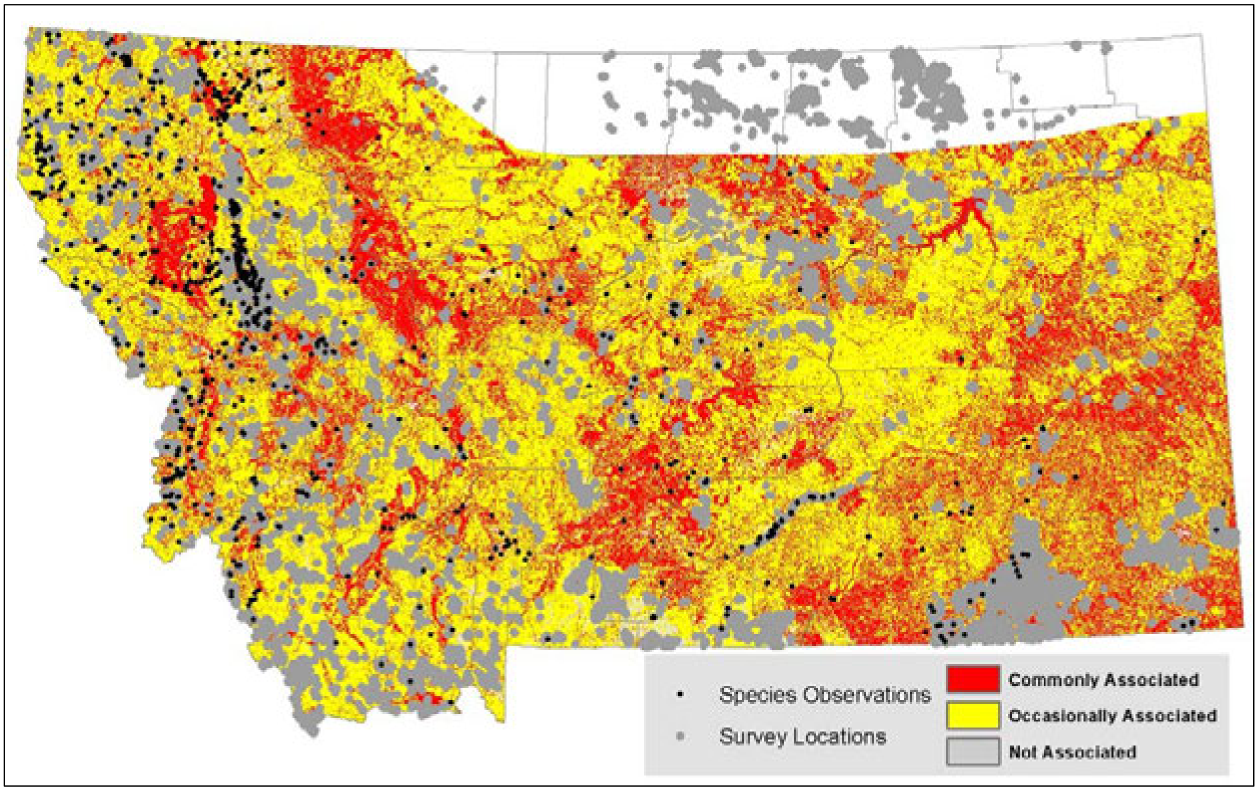
Measure	Value
Area of entire modeled range (percent of Montana)	339,472.77 km^2 (89.2%)
Area of Commonly and Occasionally Associated ES	326,574.0 km^2
Area of Commonly Associated ES	107,086.0 km^2
Area of Occasionally Associated ES	219,488.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	89.8%
Commonly Associated ES AVI[a]	47.2%
Occasionally Associated ES AVI[a]	42.6%

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

Figure 10. Deductive model output classified into habitat associations.



Prairie Rattlesnake (*Crotalus viridis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 1, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 1, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of reflecting the distribution of Prairie Rattlesnake general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do an adequate job of representing the amount of suitable habitat across the species' known range in Montana. Low AVI evaluations are a result of the fact that a large portion of observations for this species are made on roads which are not suitable habitat.

Suggested Citation: Montana Natural Heritage Program. 2017. Prairie Rattlesnake (*Crotalus viridis*) predicted suitable habitat models created on October 01, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=ARADE02120

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,421
Location Data Selection Rule 1	Records with <= 1600 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	987
Location Data Selection Rule 2	No overlap in locations within 500 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	646
Season Modeled	Year-round
Number of Model Background Locations	56,355

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoiltemp	20.2%	contnsasp	2.1%
catesys	17.7%	contvrm	1.8%
conttmax	11.3%	contwinrad	1.5%
contddays	11.1%	contfrsted	1.5%
contsumrad	5.7%	conttmin	1.0%
contwinpcp	5.5%	contslope	1.0%
contstrmed	5.3%	contewasp	0.8%
catgeol	5.2%	contndvi	0.7%
catsoilord	4.8%	contprecip	0.4%
contelev	2.4%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.092
Moderate Logistic Threshold[b]	0.429
Optimal Logistic Threshold[c]	0.846
Area of entire modeled range (percent of Montana)	357,412.63 km^2 (93.9%)
Total area of predicted suitable habitat within modeled range	282,380.8 km^2
Area of predicted low suitability habitat within modeled range	169,320.3 km^2
Area of moderate suitability habitat within modeled range	112,644.3 km^2
Area of predicted optimal habitat within modeled range	416.2 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.5%
Moderate AVI[a]	69.5%
Optimal AVI[a]	1.9%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.506 ± 0.976
Training AUC[c]	0.790
Test AUC[d]	0.766

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.781, 1.692 and 0.335, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

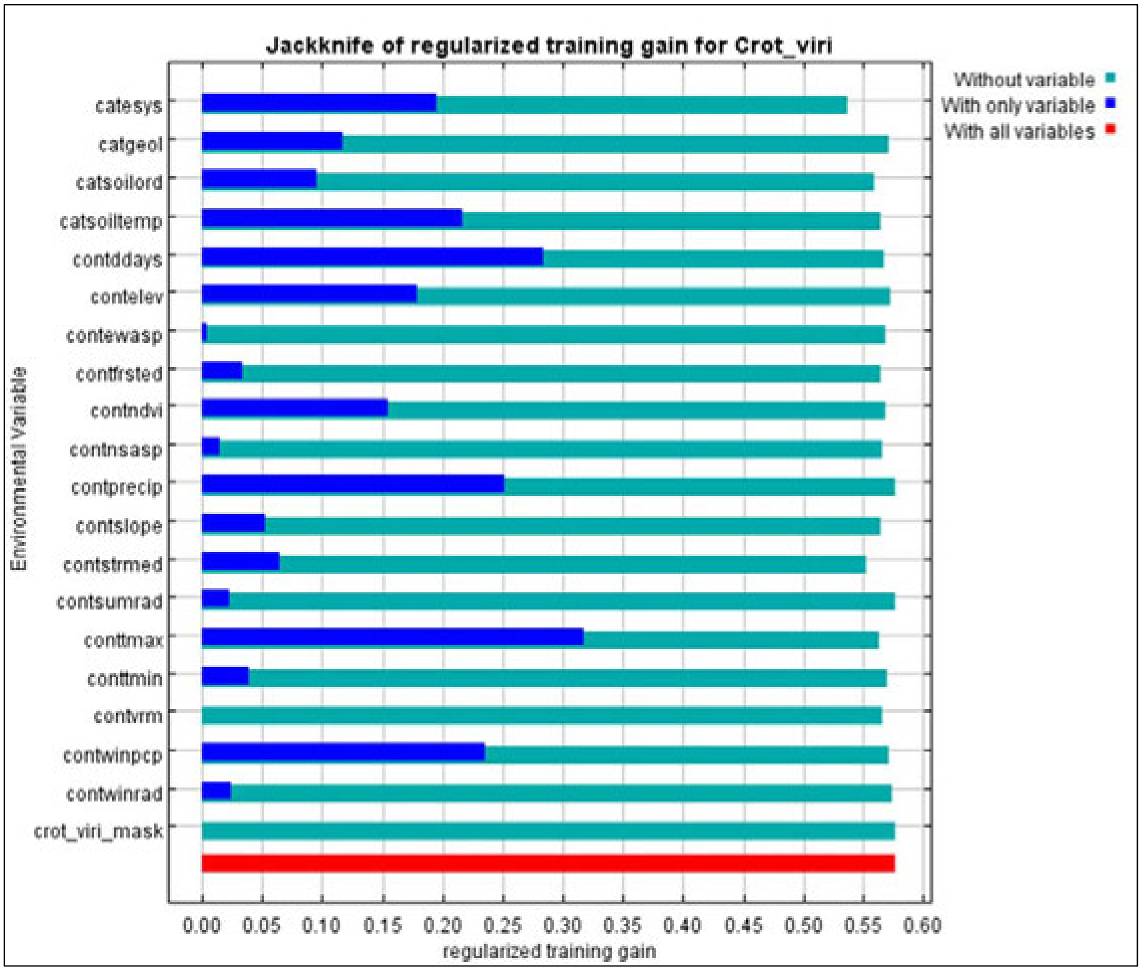
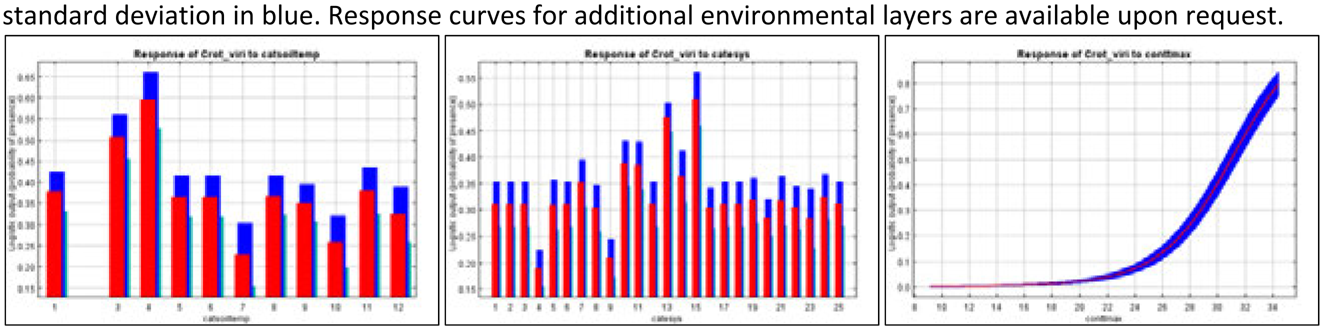


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

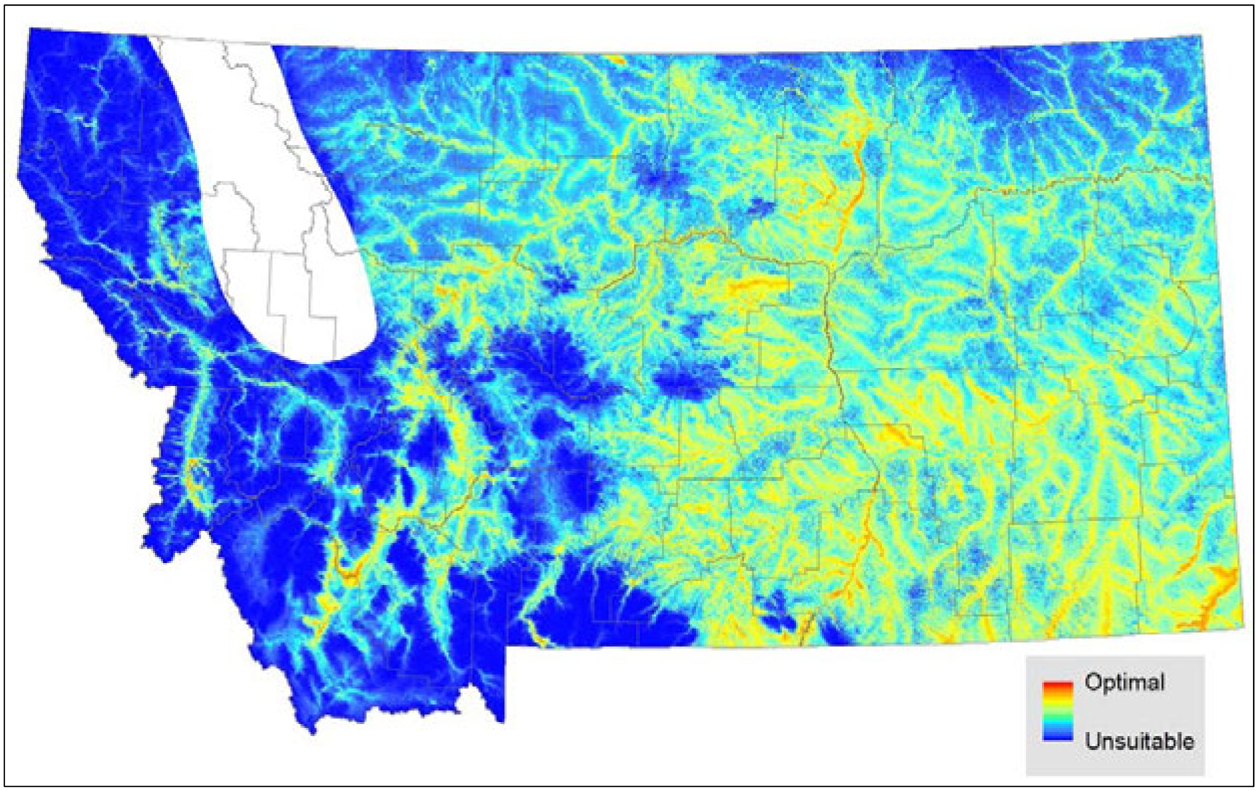


Figure 4. Standard deviation in the model output across the averaged models.

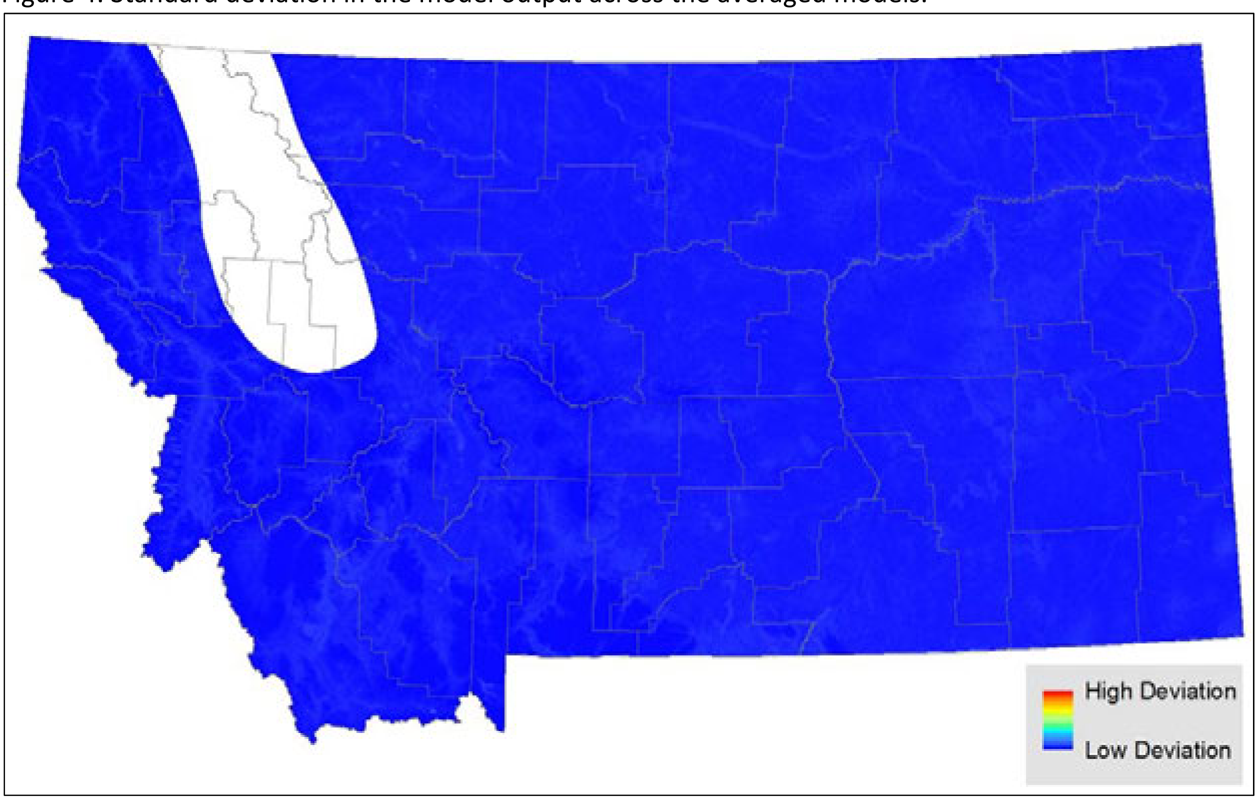


Figure 5. Continuous habitat suitability model output with the 646 observations used for modeling.

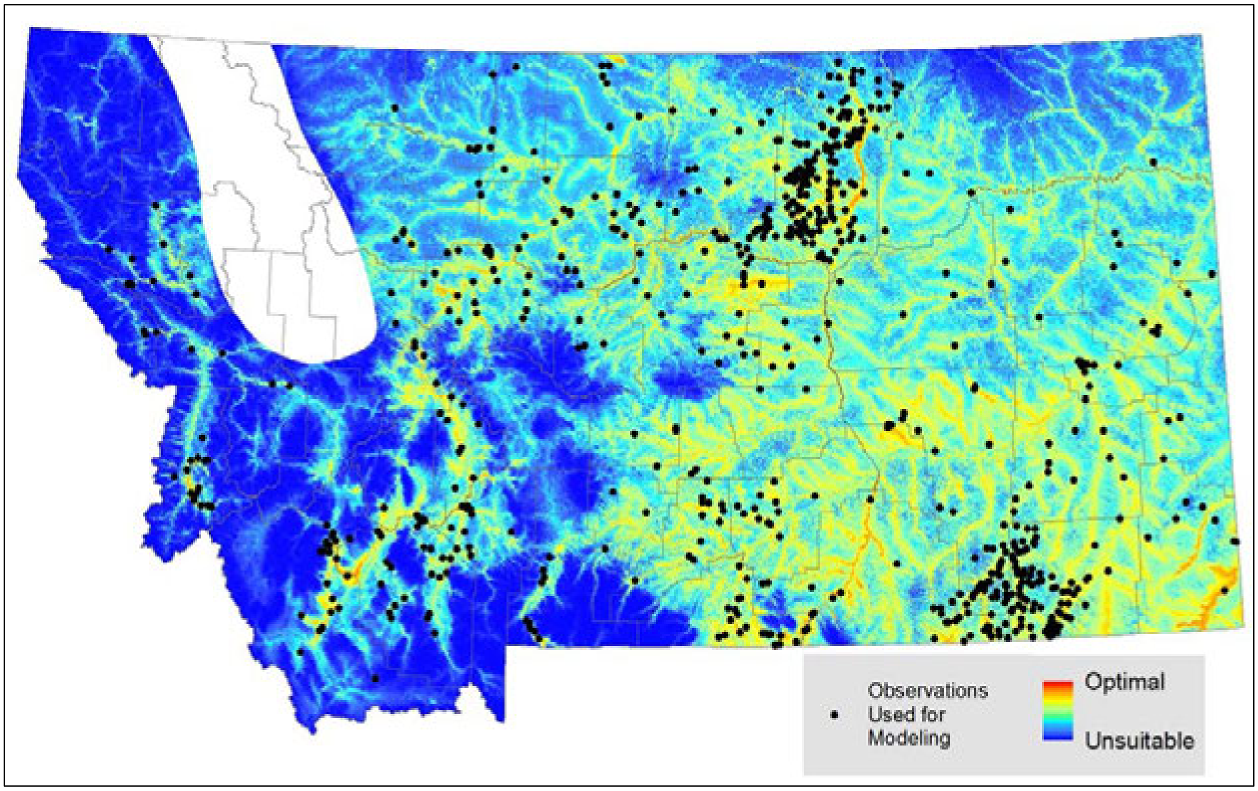


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

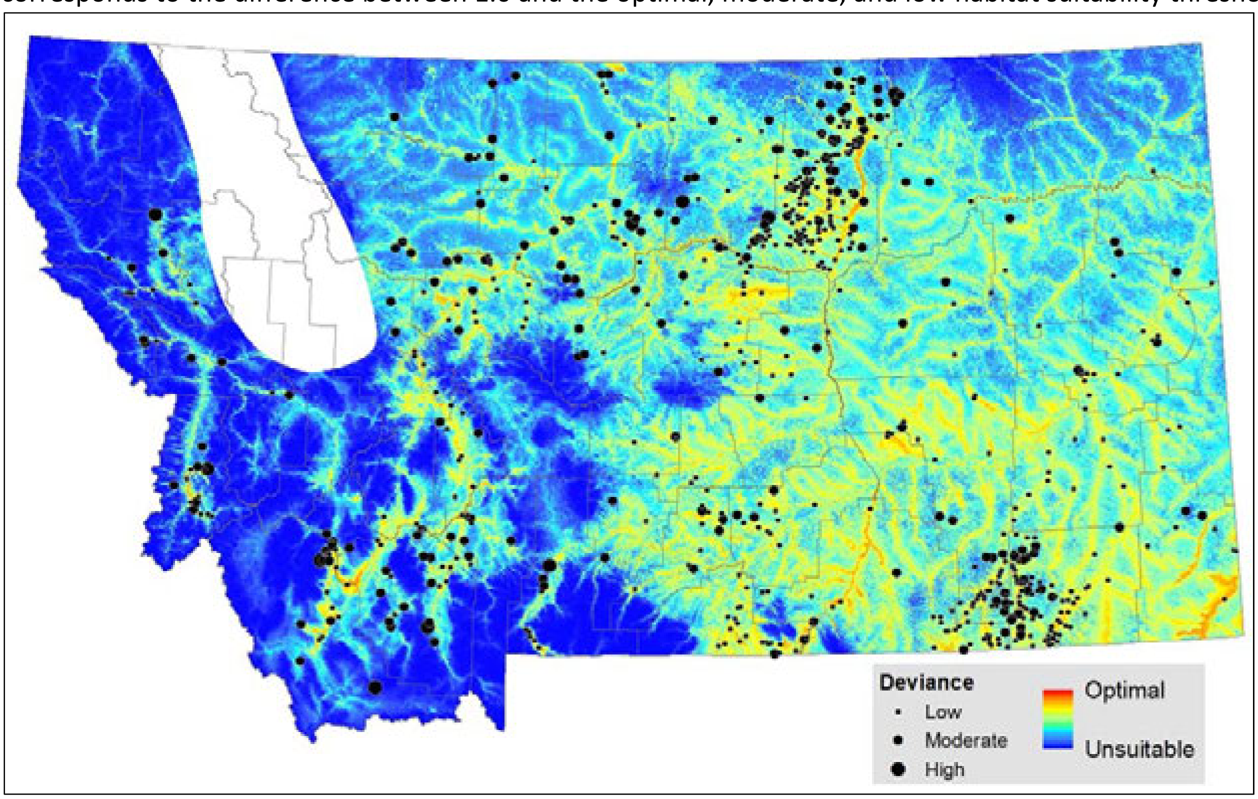


Figure 7. Continuous habitat suitability model output with all 1,421 observations (black) and survey locations that could have detected the species (gray).

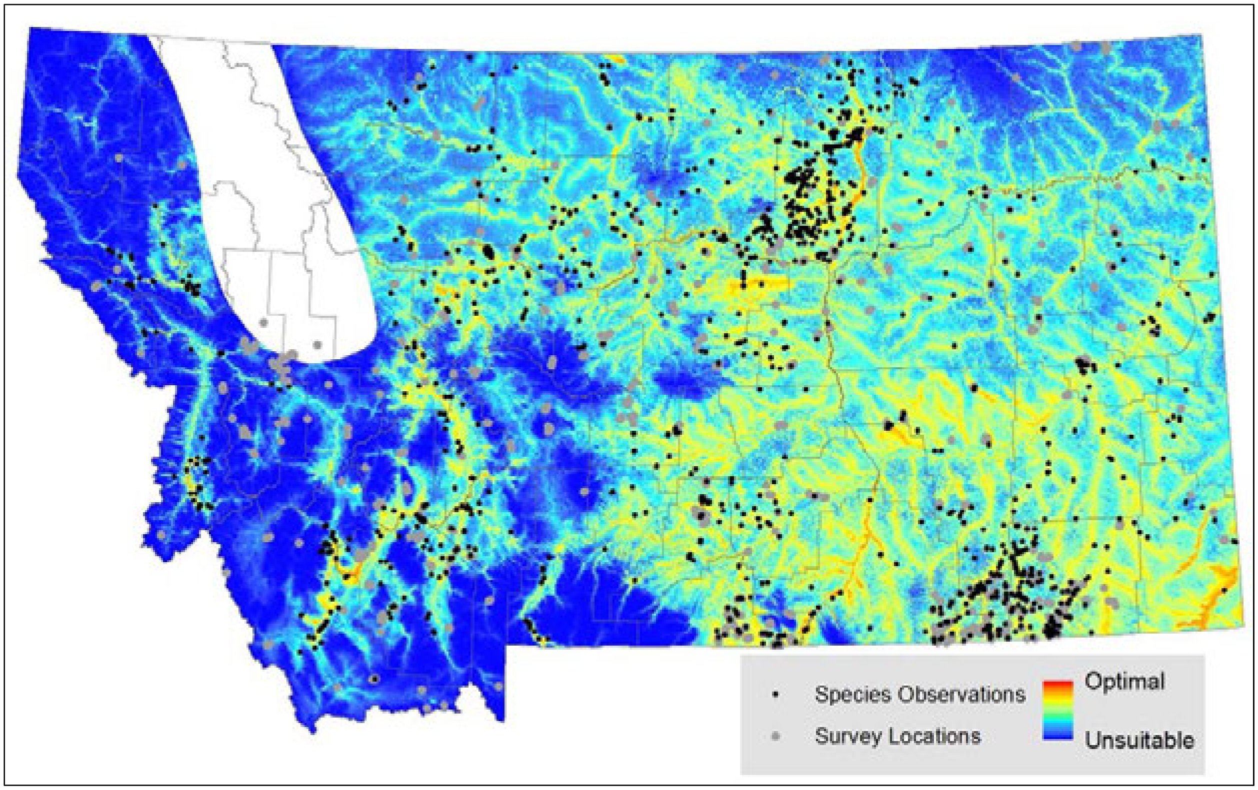


Figure 8. Model output classified into habitat suitability classes.

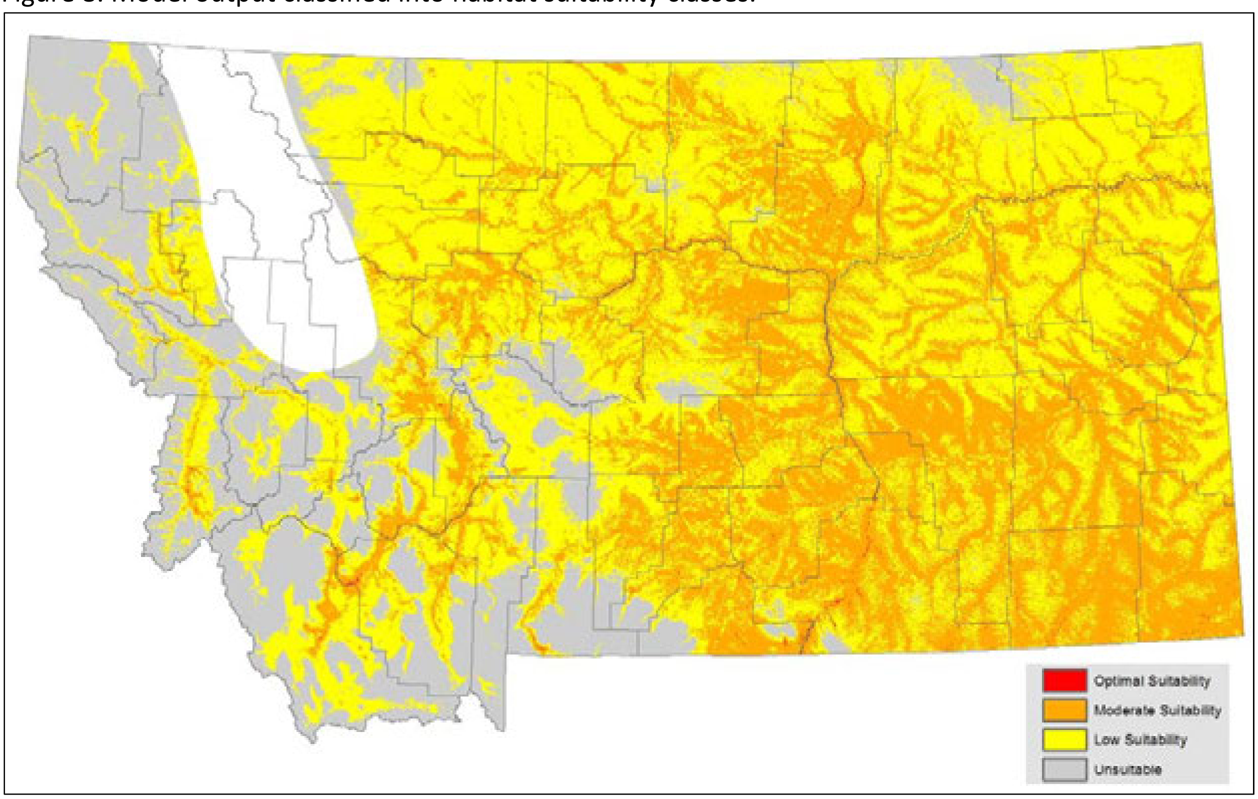
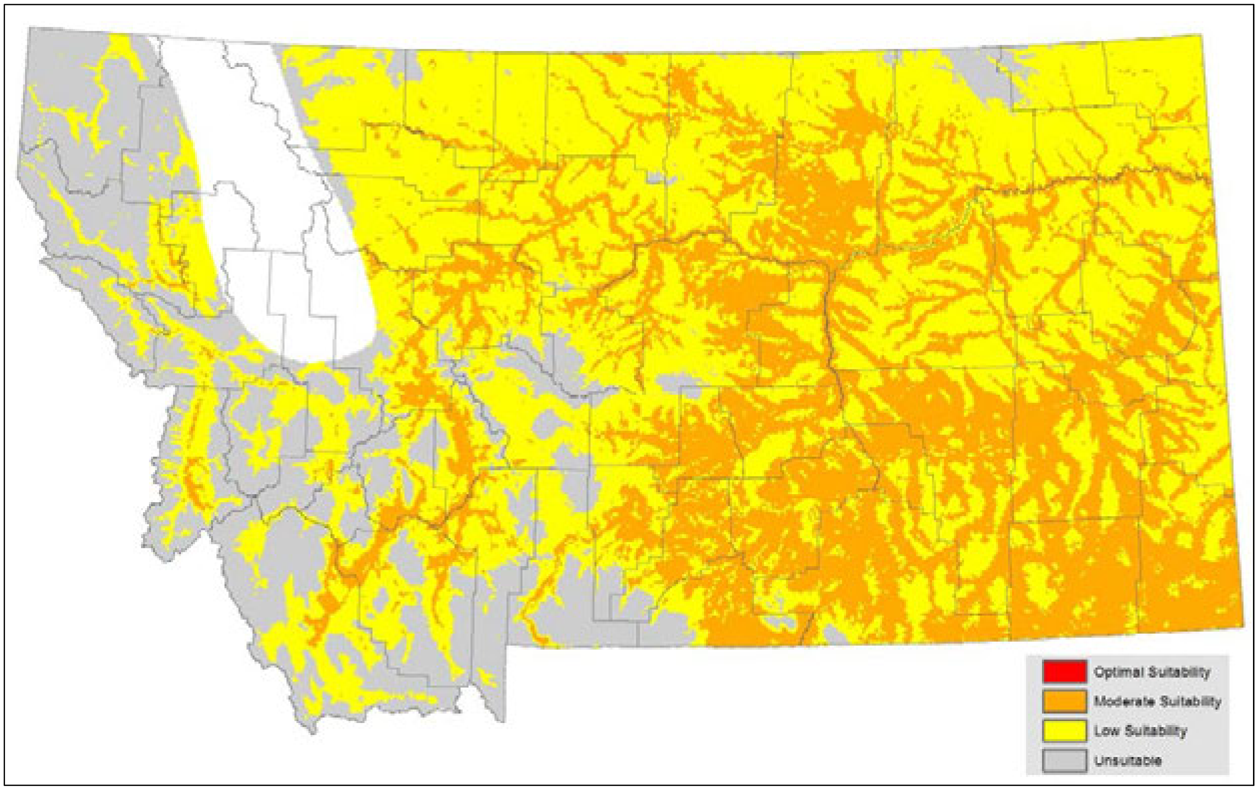


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Prairie Rattlesnake

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	145
Big Sagebrush Steppe	5454	Common	76
Great Plains Badlands	3114	Common	28
Montane Sagebrush Steppe	5455	Common	21
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	21
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	20
Great Plains Riparian	9326	Common	16
Recently burned forest	8501	Common	10
Mat Saltbush Shrubland	5203	Common	8
Great Plains Sand Prairie	7121	Common	8
Great Plains Floodplain	9159	Common	7
Recently burned grassland	8502	Common	6
Recently burned shrubland	8503	Common	3
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	2
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Shale Badland	3139	Common	1
Great Plains Cliff and Outcrop	3142	Common	1
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	1
Burned Sagebrush	8504	Common	1
Greasewood Flat	9103	Common	1
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	1
Active and Stabilized Dune	3160	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Great Plains Shrubland	5262	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Cultivated Crops	82	Occasional	26
Low Intensity Residential	22	Occasional	8
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	7
Pasture/Hay	81	Occasional	5
Developed, Open Space	21	Occasional	2
Rocky Mountain Lodgepole Pine Forest	4237	Occasional	2
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	2
Post-Fire Recovery	8505	Occasional	2
Great Plains Wooded Draw and Ravine	4328	Occasional	1
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Occasional	1
Quarries, Strip Mines and Gravel Pits	31	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0

Table 5: Ecological Systems Associated with Prairie Rattlesnake

Ecological System	Code	Association	Count[a]
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 646 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

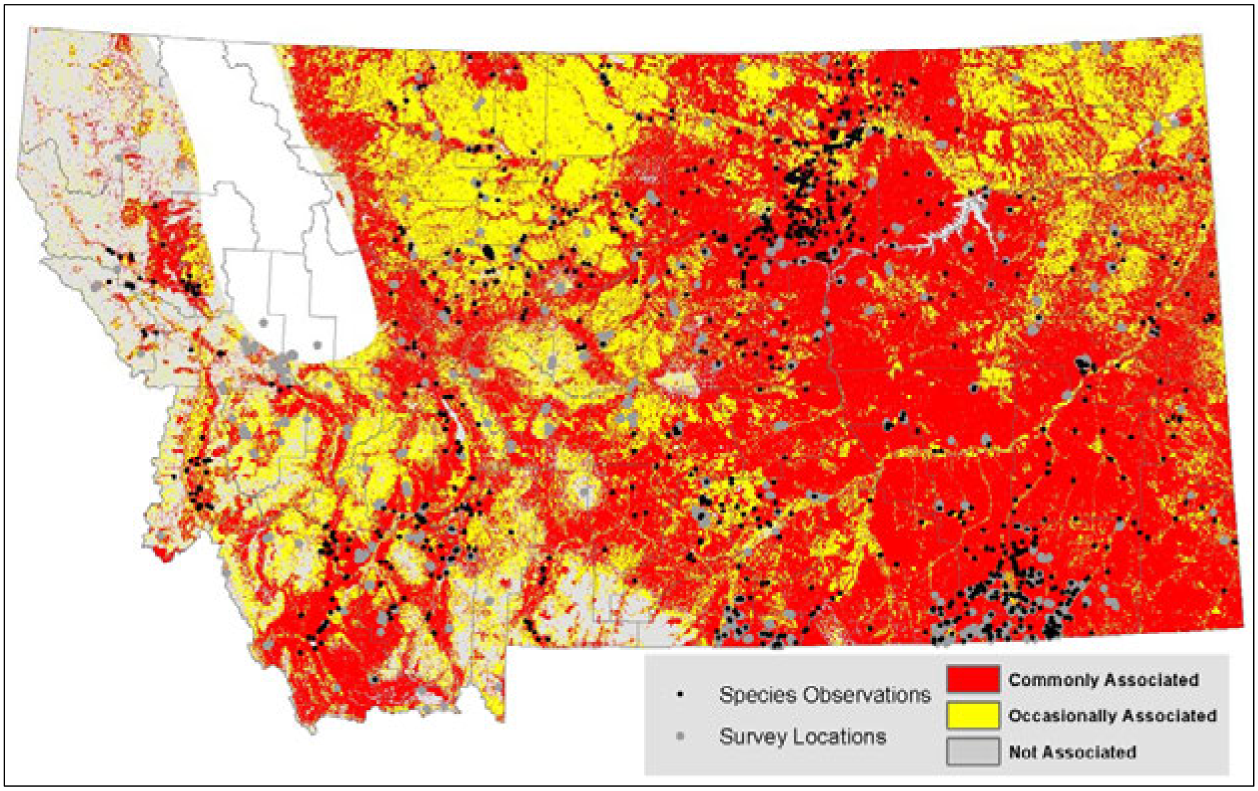
Measure	Value
Area of entire modeled range (percent of Montana)	357,412.63 km^2 (93.9%)
Area of Commonly and Occasionally Associated ES	305,641.0 km^2
Area of Commonly Associated ES	202,444.0 km^2
Area of Occasionally Associated ES	103,197.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	67.3%
Commonly Associated ES AVI[a]	58.7%
Occasionally Associated ES AVI[a]	8.7%

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

Figure 10. Deductive model output classified into habitat associations.



Townsend's Big-eared Bat (*Corynorhinus townsendii*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3 (Species of Concern)
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general active season habitat at large spatial scales across the entire state of Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model seems to do a reasonably good job of reflecting the distribution of Townsend's Big-eared Bat general active season habitat suitability at larger spatial scales across the entire state of Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across the entire state of Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with greatly overpredict the amount of suitable habitat for Townsend's Big-eared Bat across the entire state of Montana. Use of the inductive model is recommended to inform survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Townsend's Big-eared Bat (*Corynorhinus townsendii*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.
Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC08010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	346
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	327
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	156
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	13.6%	conttmax	3.6%
catsoiltemp	10.7%	contprecip	3.3%
catgeol	9.5%	contnsasp	3.2%
contndvi	8.4%	contewasp	2.5%
contddays	8.0%	catsoilord	2.3%
conttmin	7.8%	contsumrad	1.7%
contwinpcp	6.9%	contstrmed	1.2%
contelev	5.9%	contslope	1.1%
contfrsted	4.9%	contwinrad	0.6%
contvrm	4.8%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.043
Moderate Logistic Threshold[b]	0.255
Optimal Logistic Threshold[c]	0.669
Area of entire modeled range (percent of Montana)	380,529.02 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	209,938.1 km^2
Area of predicted low suitability habitat within modeled range	150,910.3 km^2
Area of moderate suitability habitat within modeled range	53,746.5 km^2
Area of predicted optimal habitat within modeled range	5,281.2 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	94.9%
Moderate AVI[a]	73.7%
Optimal AVI[a]	25.0%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.194 ± 1.948
Training AUC[c]	0.918
Test AUC[d]	0.866

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 6.288, 2.736 and 0.804, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

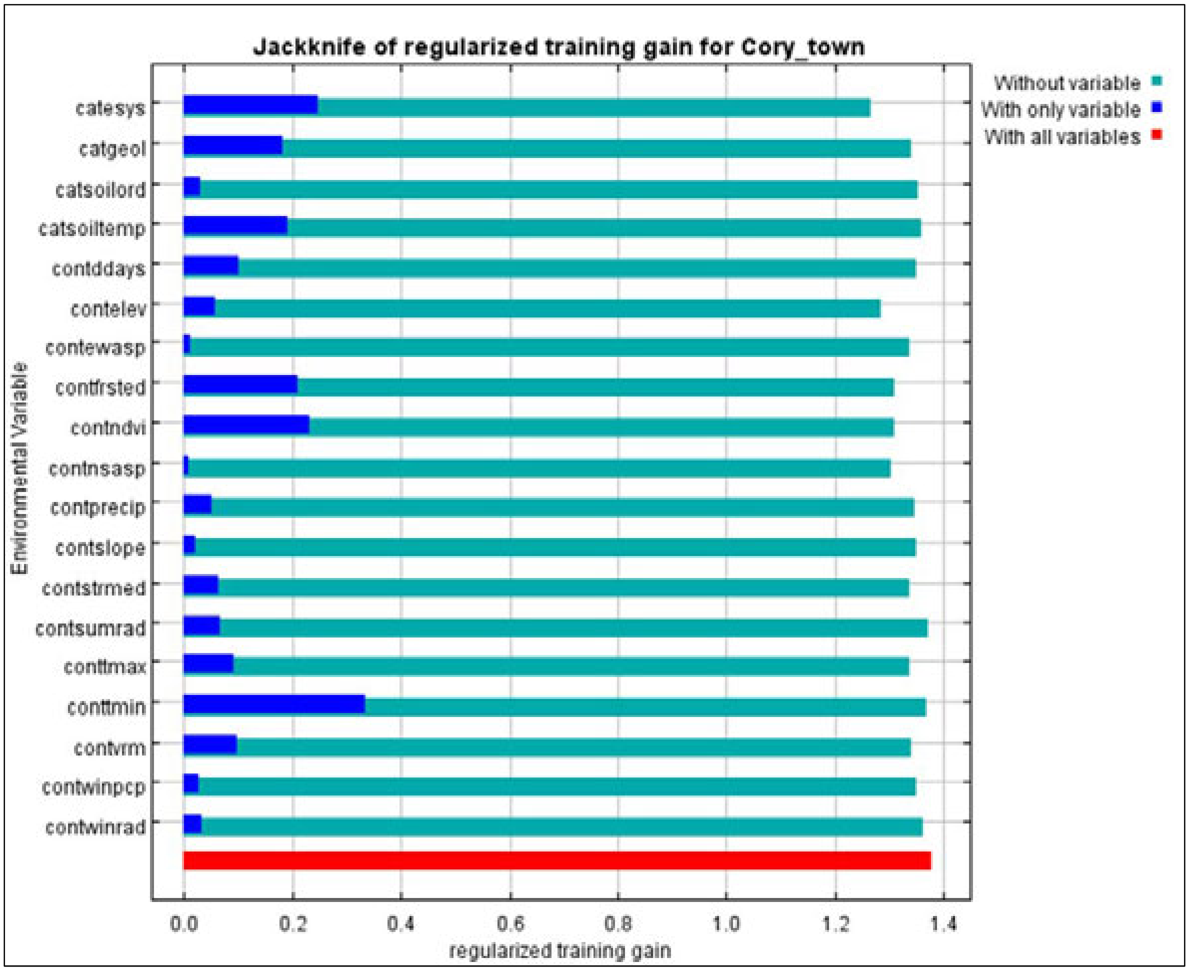
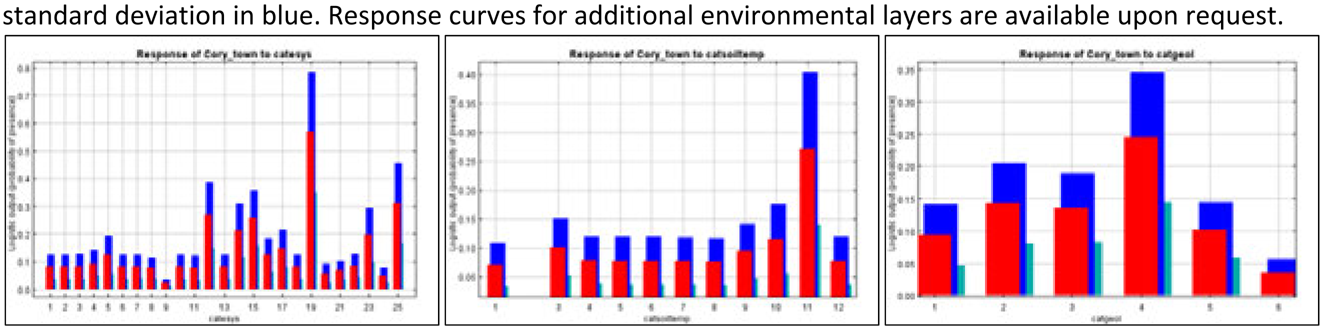


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

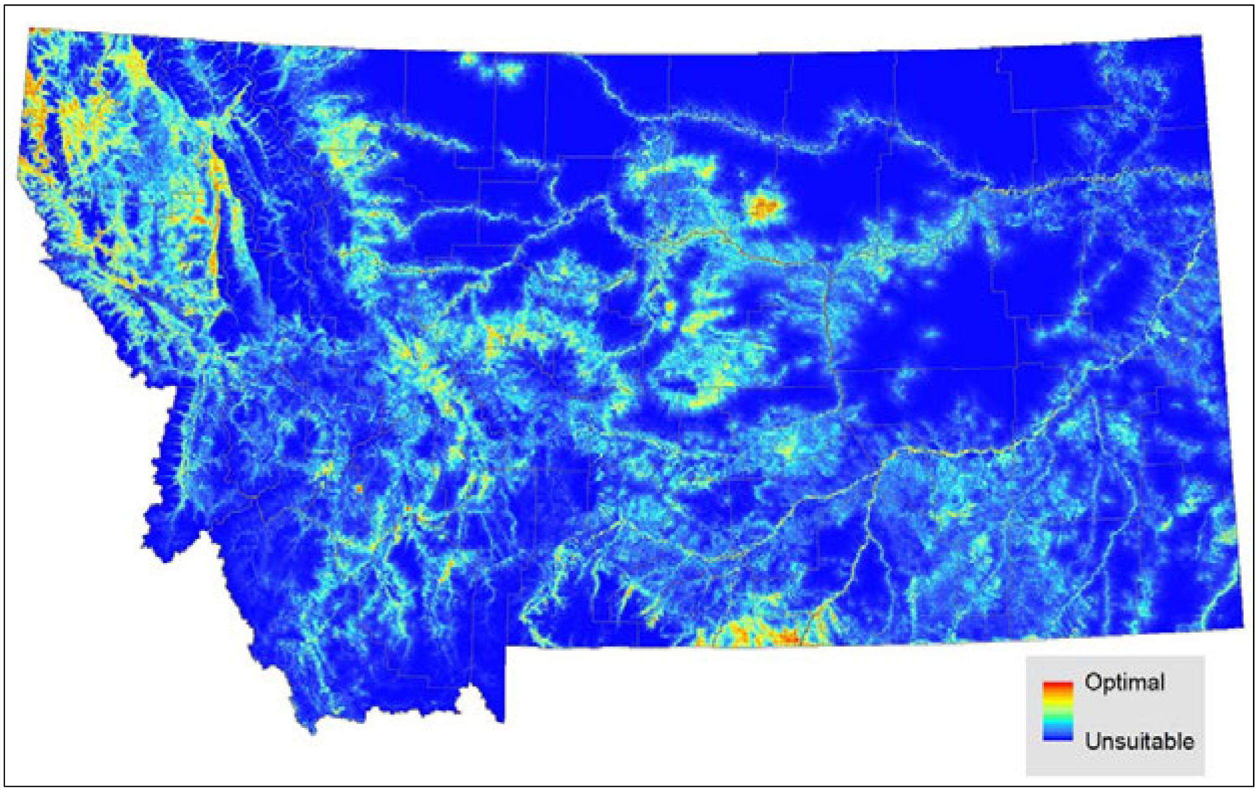


Figure 4. Standard deviation in the model output across the averaged models.

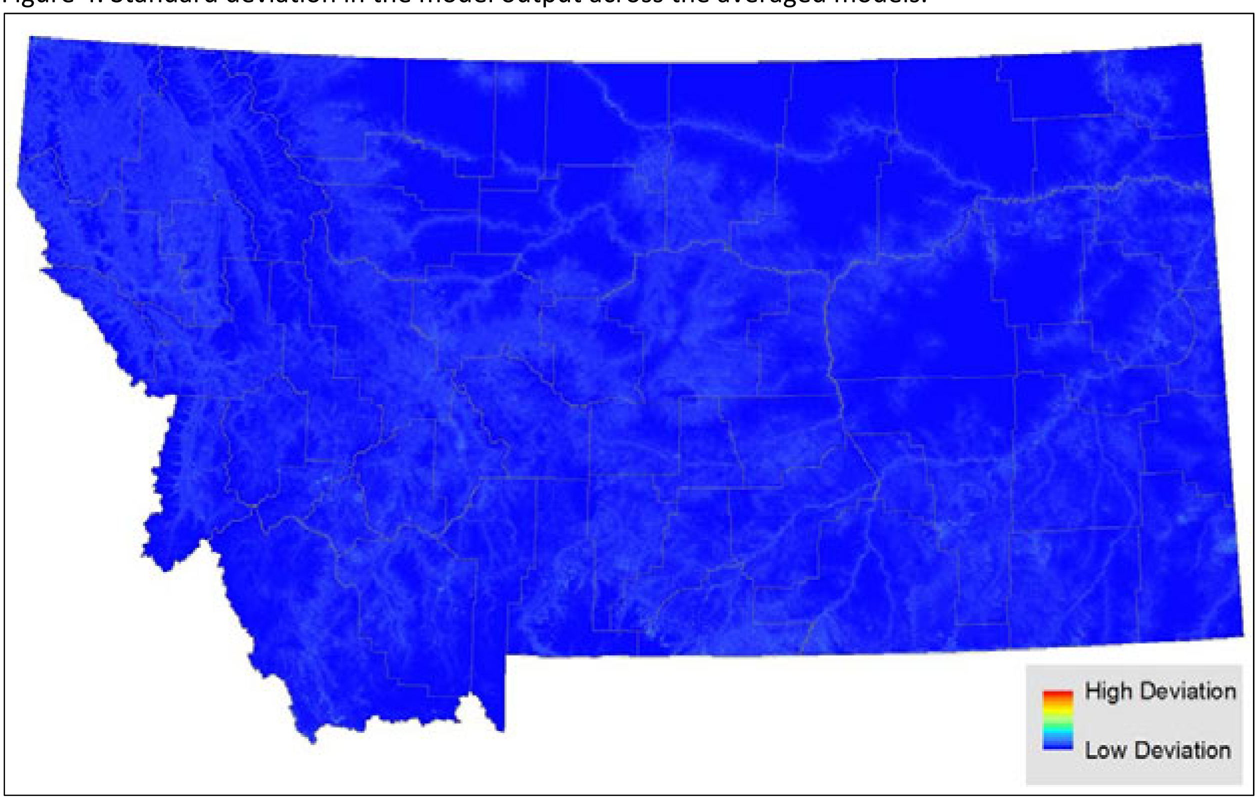


Figure 5. Continuous habitat suitability model output with the 156 observations used for modeling.

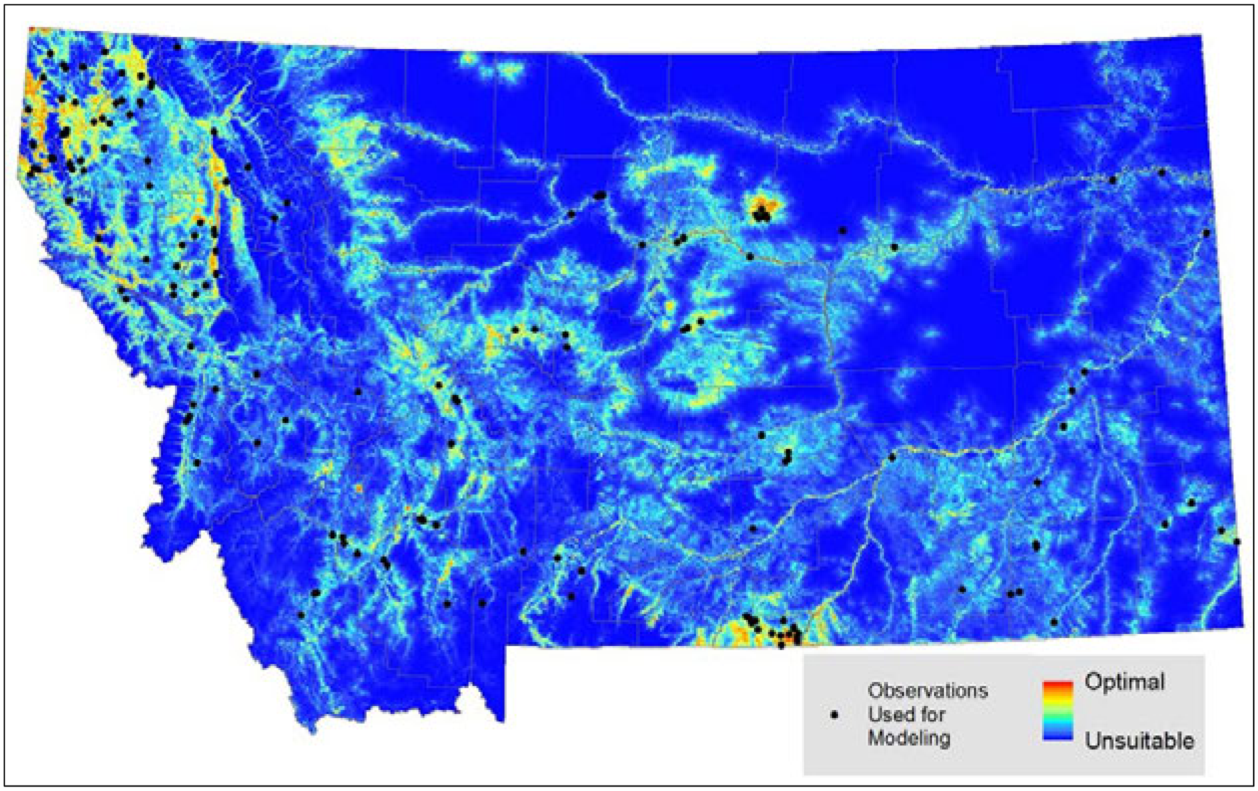


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

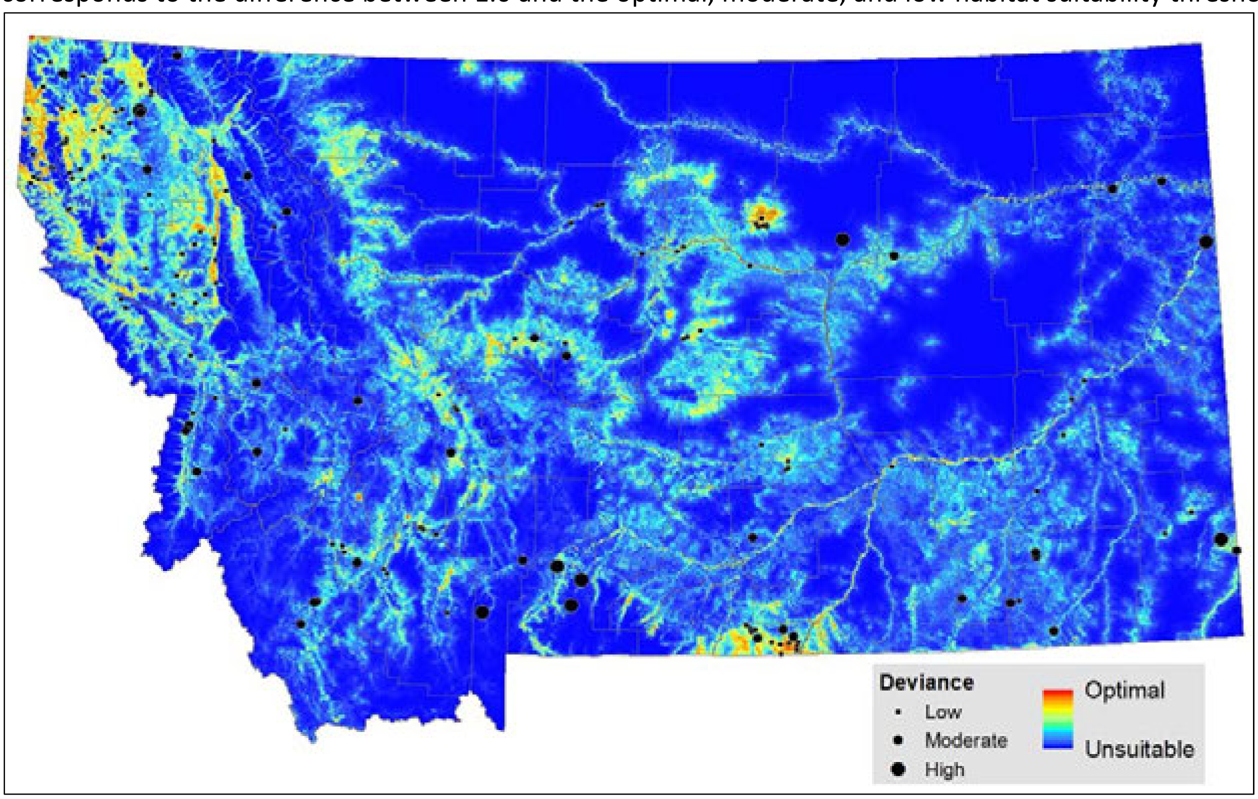


Figure 7. Continuous habitat suitability model output with all 346 observations (black) and survey locations that could have detected the species (gray).

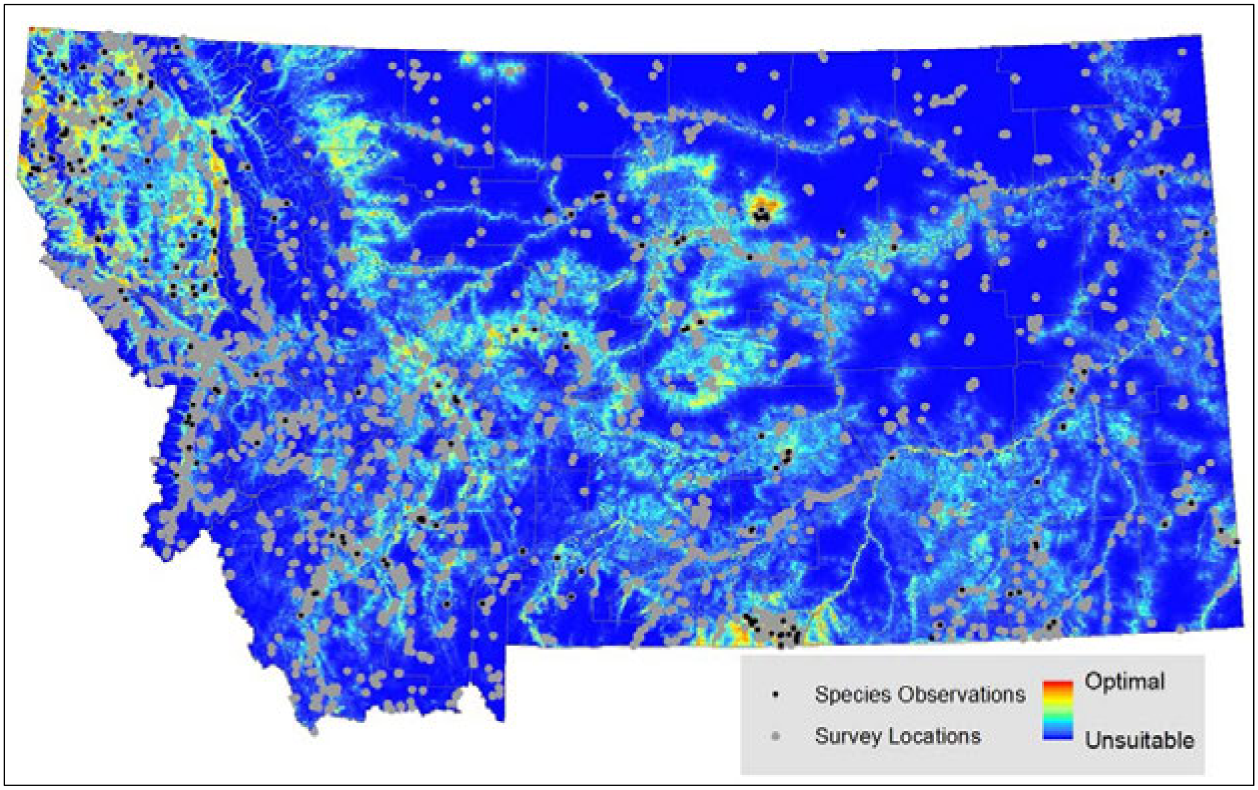


Figure 8. Model output classified into habitat suitability classes.

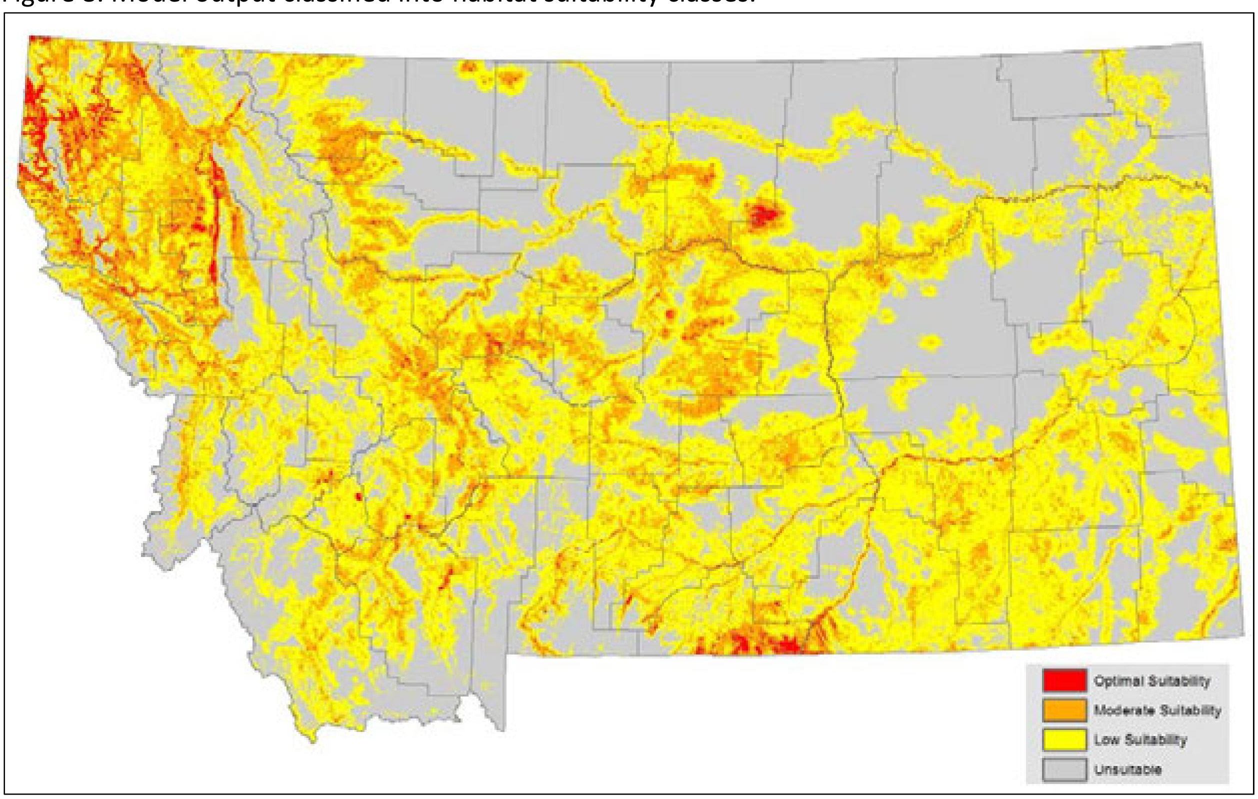
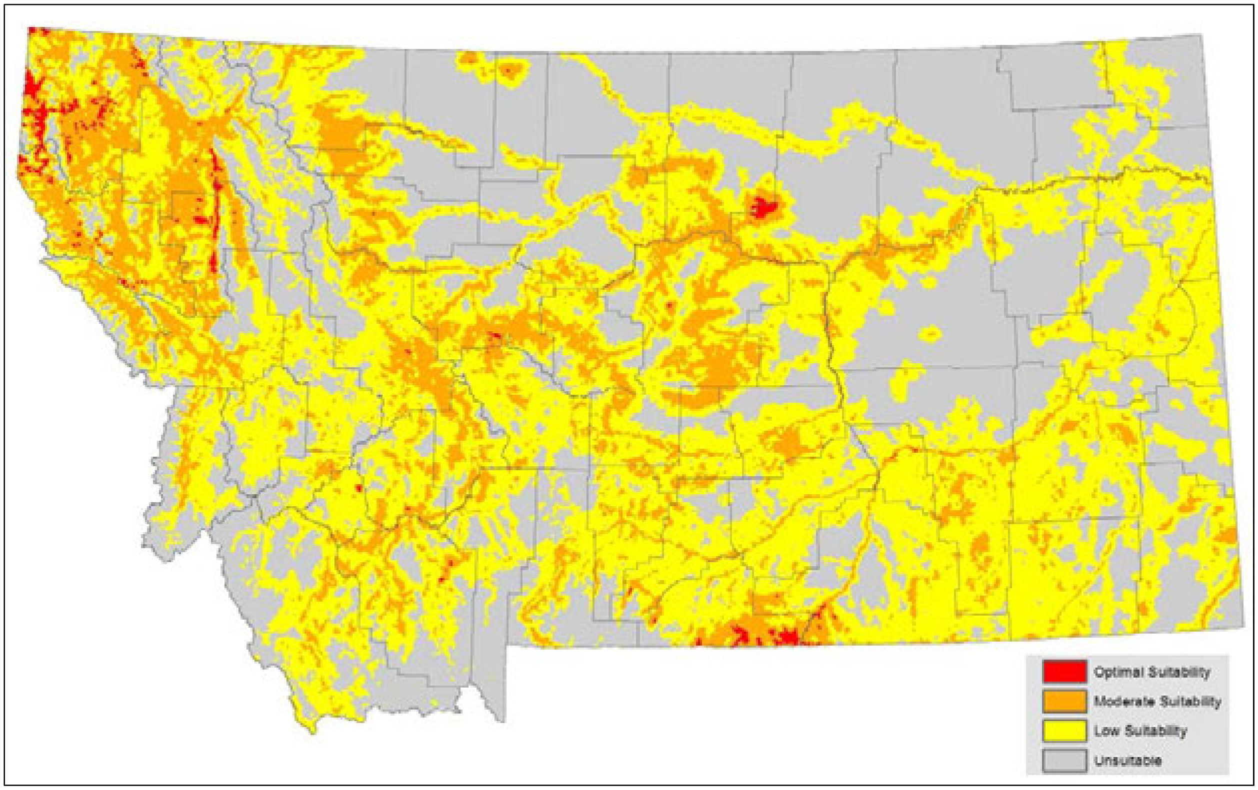


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Townsend's Big-eared Bat

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	20
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	15
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	14
Great Plains Floodplain	9159	Common	10
Big Sagebrush Steppe	5454	Common	9
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	8
Montane Sagebrush Steppe	5455	Common	7
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	6
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	6
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	4
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	4
Great Plains Riparian	9326	Common	4
Open Water	11	Common	3
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	3
Post-Fire Recovery	8505	Common	3
Rocky Mountain Lodgepole Pine Forest	4237	Common	2
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Recently burned forest	8501	Common	2
Great Plains Wooded Draw and Ravine	4328	Common	1
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	1
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen Forest and Woodland	4104	Common	0
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Emergent Marsh	9222	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Insect-Killed Forest	8700	Common	0
Great Plains Mixedgrass Prairie	7114	Occasional	7
Harvested forest-tree regeneration	8601	Occasional	3
Developed, Open Space	21	Occasional	2

Table 5: Ecological Systems Associated with Townsend's Big-eared Bat

Ecological System	Code	Association	Count[a]
Great Plains Badlands	3114	Occasional	1
Great Plains Shrubland	5262	Occasional	1
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	1
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	1
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	1
Low Intensity Residential	22	Occasional	0
Alpine Bedrock and Scree	3135	Occasional	0
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Mat Saltbush Shrubland	5203	Occasional	0
Big Sagebrush Shrubland	5257	Occasional	0
Mixed Salt Desert Scrub	5258	Occasional	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Greasewood Flat	9103	Occasional	0
Alpine-Montane Wet Meadow	9217	Occasional	0
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 156 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

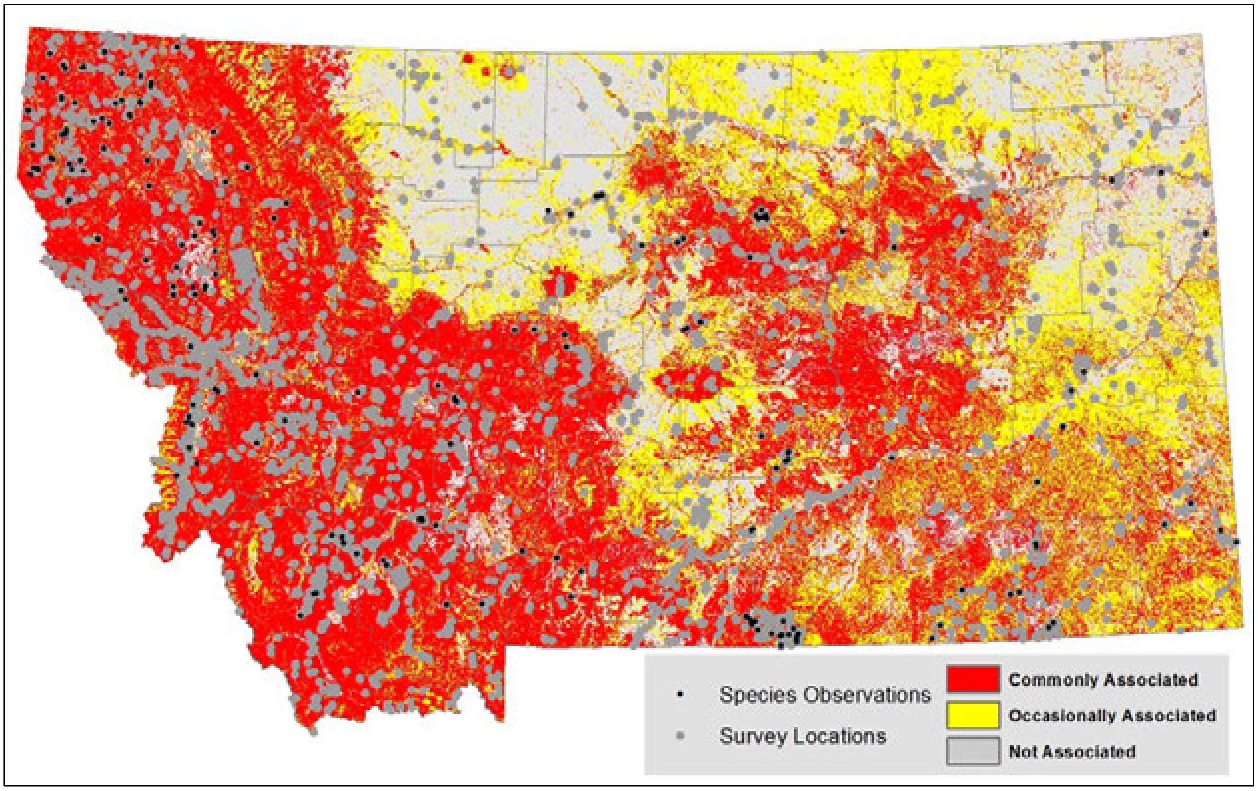
Measure	Value
Area of entire modeled range (percent of Montana)	380,529.02 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	282,402.0 km^2
Area of Commonly Associated ES	185,847.0 km^2
Area of Occasionally Associated ES	96,555.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	91.0%
Commonly Associated ES AVI[a]	80.1%
Occasionally Associated ES AVI[a]	10.9%

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

Figure 10. Deductive model output classified into habitat associations.



Big Brown Bat (*Eptesicus fuscus*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 10, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 10, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Big Brown Bat active season habitat suitability at larger spatial scales across Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the summer, across the species' known summer range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of suitable habitat for Big Brown Bat across the species' known summer range in Montana. Use of inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Big Brown Bat (*Eptesicus fuscus*) predicted suitable habitat models created on October 10, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC04010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,147
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	977
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	559
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	26.9%	contprecip	3.3%
contwinpcp	8.7%	contnsasp	3.0%
catgeol	8.5%	contddays	2.8%
contfrsted	7.7%	conttmin	2.4%
catsoiltemp	7.6%	contsumrad	2.1%
contstrmed	5.4%	conttmax	2.0%
contelev	4.7%	contewasp	1.4%
contvrm	4.5%	catsoilord	1.1%
contslope	3.4%	contwinrad	1.1%
contndvi	3.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.090
Moderate Logistic Threshold[b]	0.379
Optimal Logistic Threshold[c]	0.810
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	277,741.8 km^2
Area of predicted low suitability habitat within modeled range	185,045.7 km^2
Area of moderate suitability habitat within modeled range	90,069.2 km^2
Area of predicted optimal habitat within modeled range	2,626.9 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	97.3%
Moderate AVI[a]	70.5%
Optimal AVI[a]	10.9%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.653 ± 1.255
Training AUC[c]	0.835
Test AUC[d]	0.806

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.811, 1.938 and 0.422, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

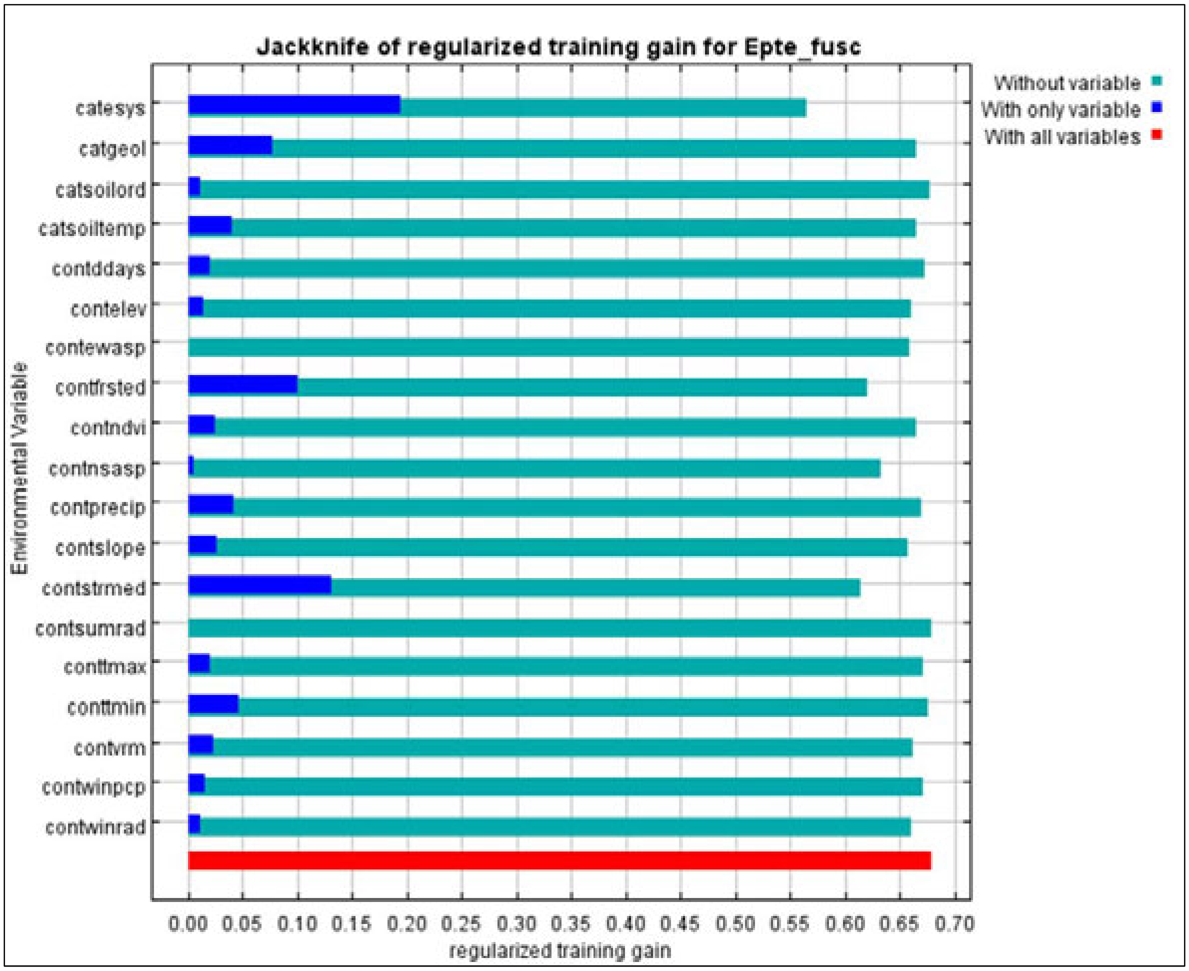
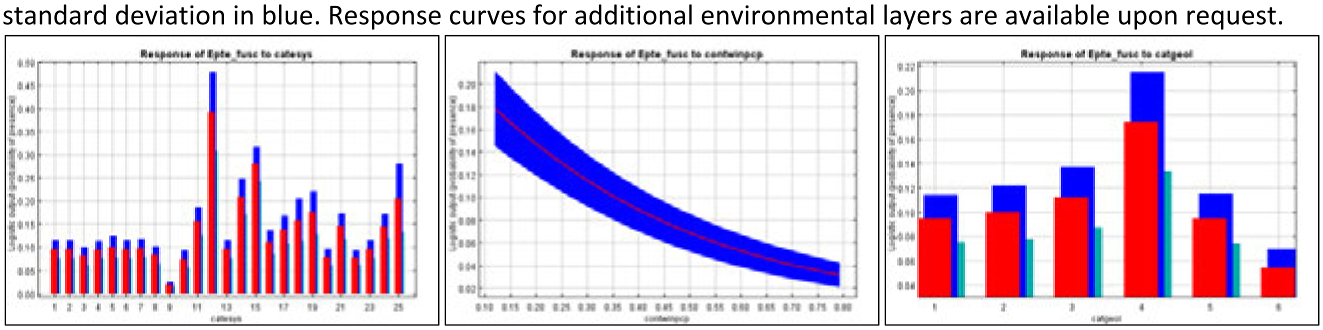


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

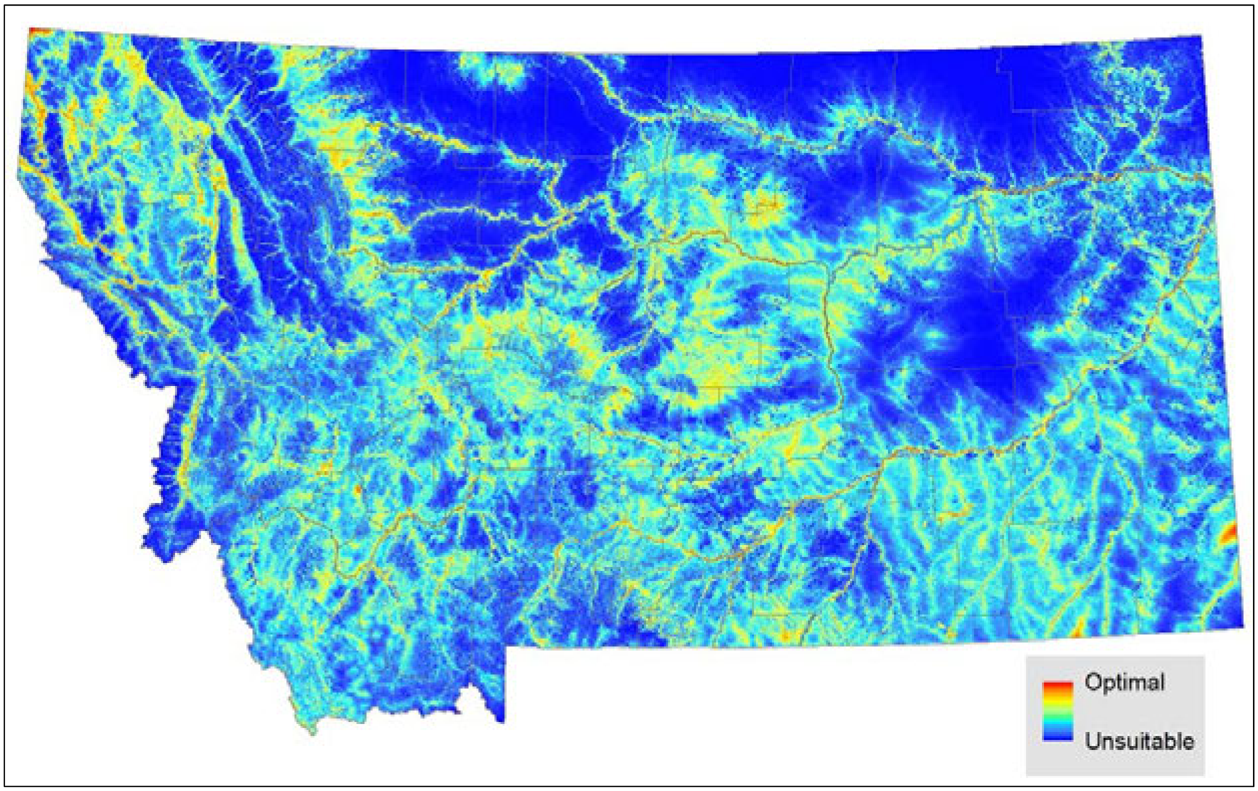


Figure 4. Standard deviation in the model output across the averaged models.

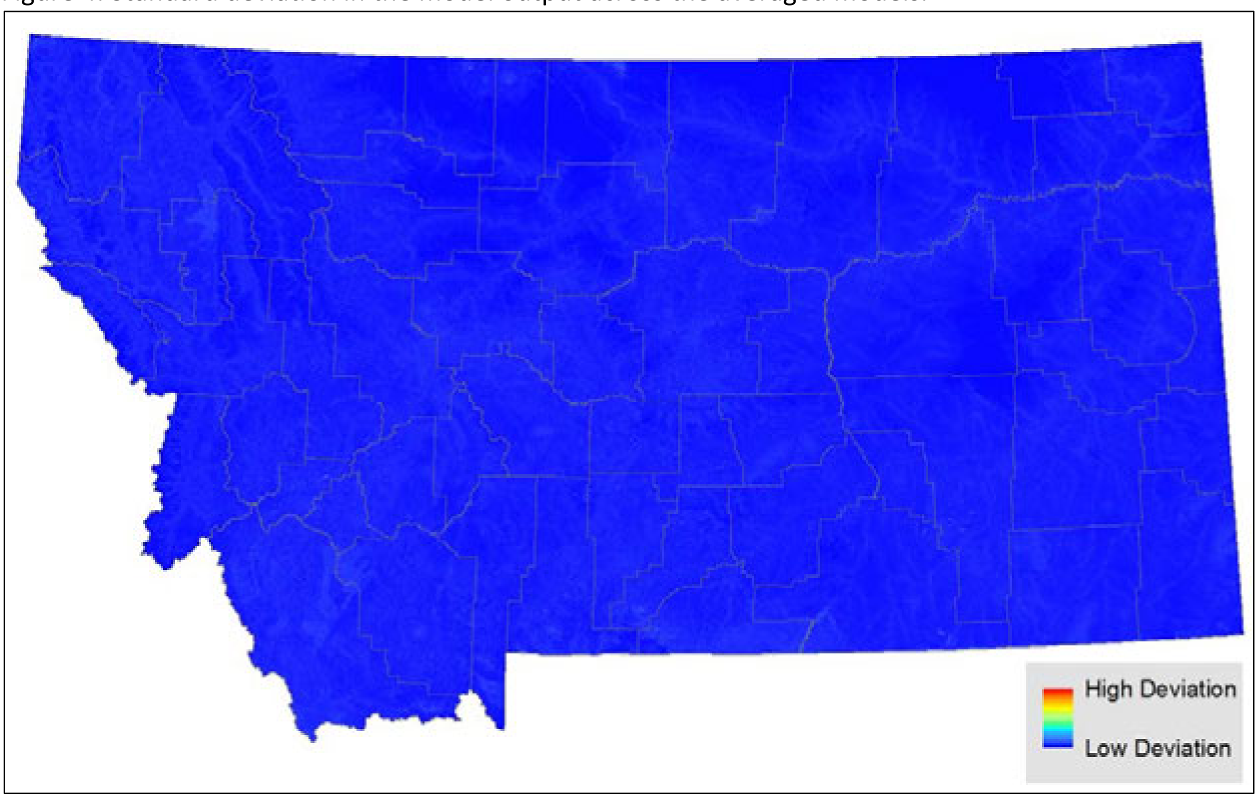


Figure 5. Continuous habitat suitability model output with the 559 observations used for modeling.

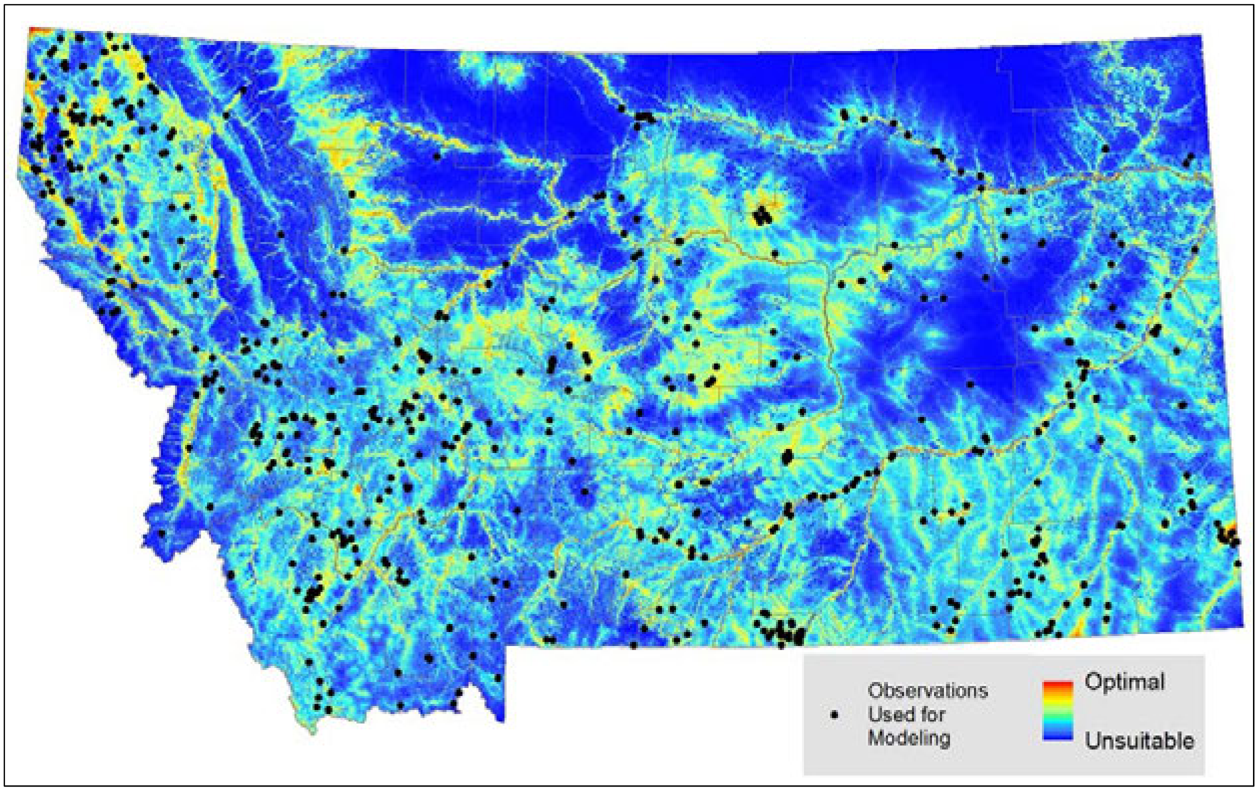


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

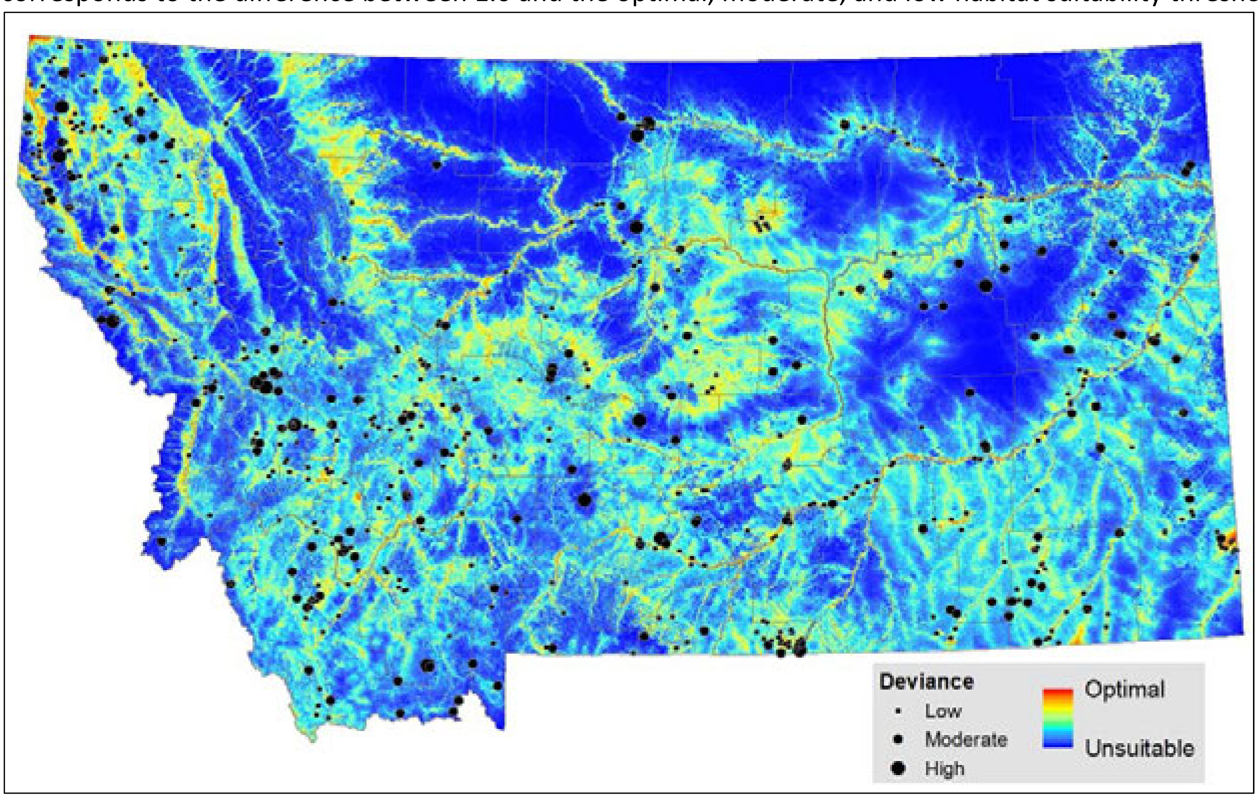


Figure 7. Continuous habitat suitability model output with all 1,147 observations (black) and survey locations that could have detected the species (gray).

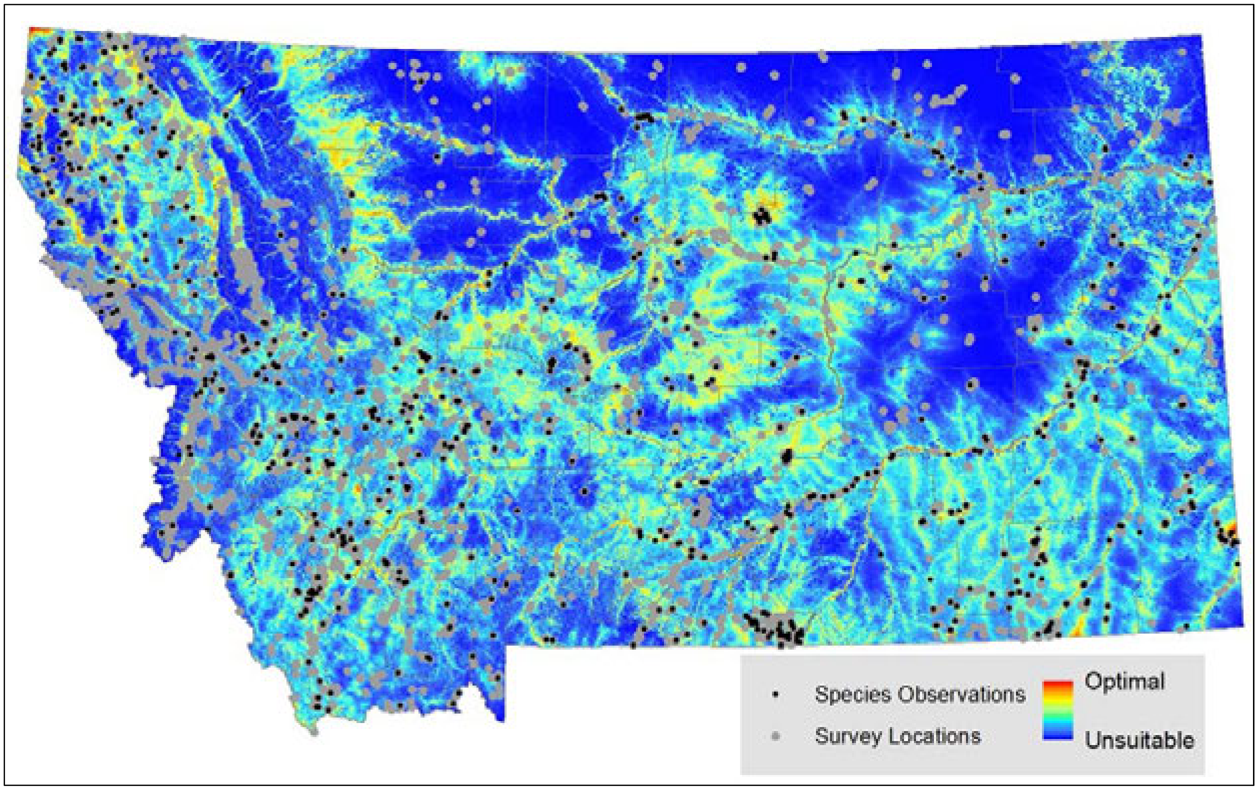


Figure 8. Model output classified into habitat suitability classes.

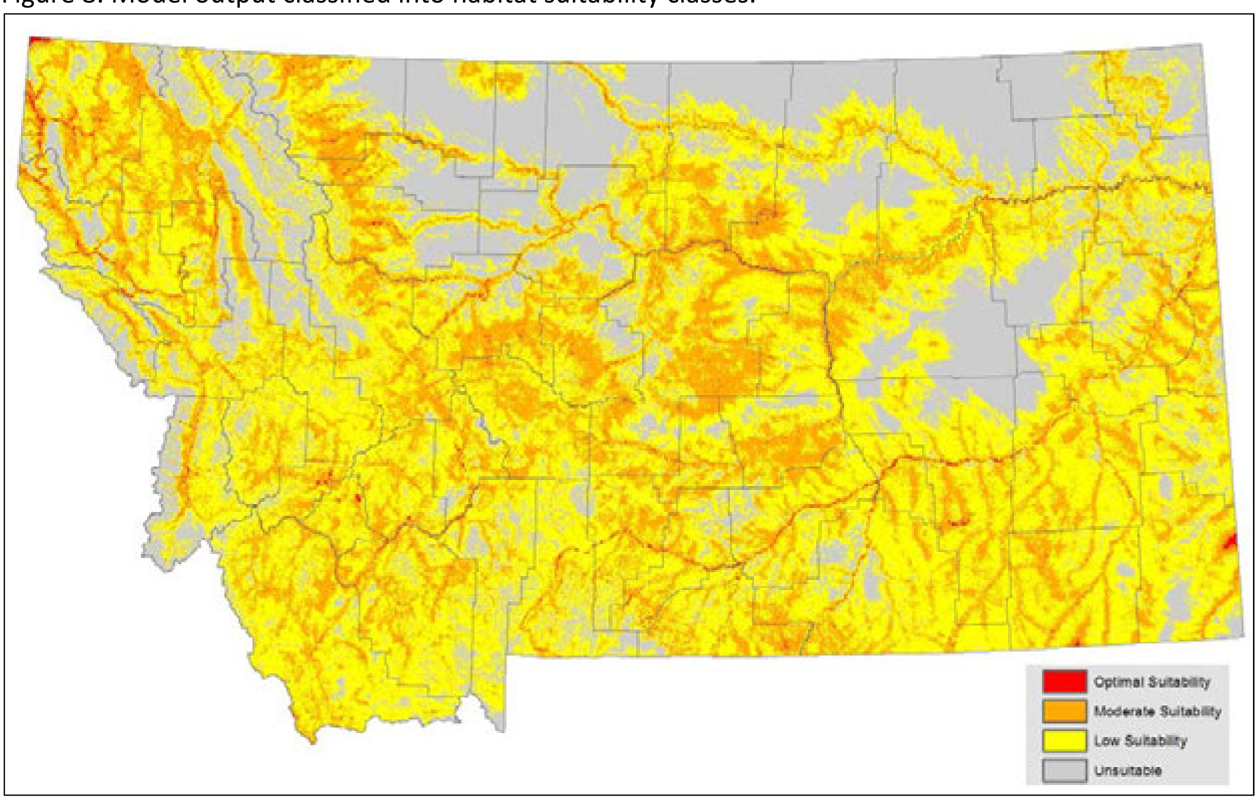
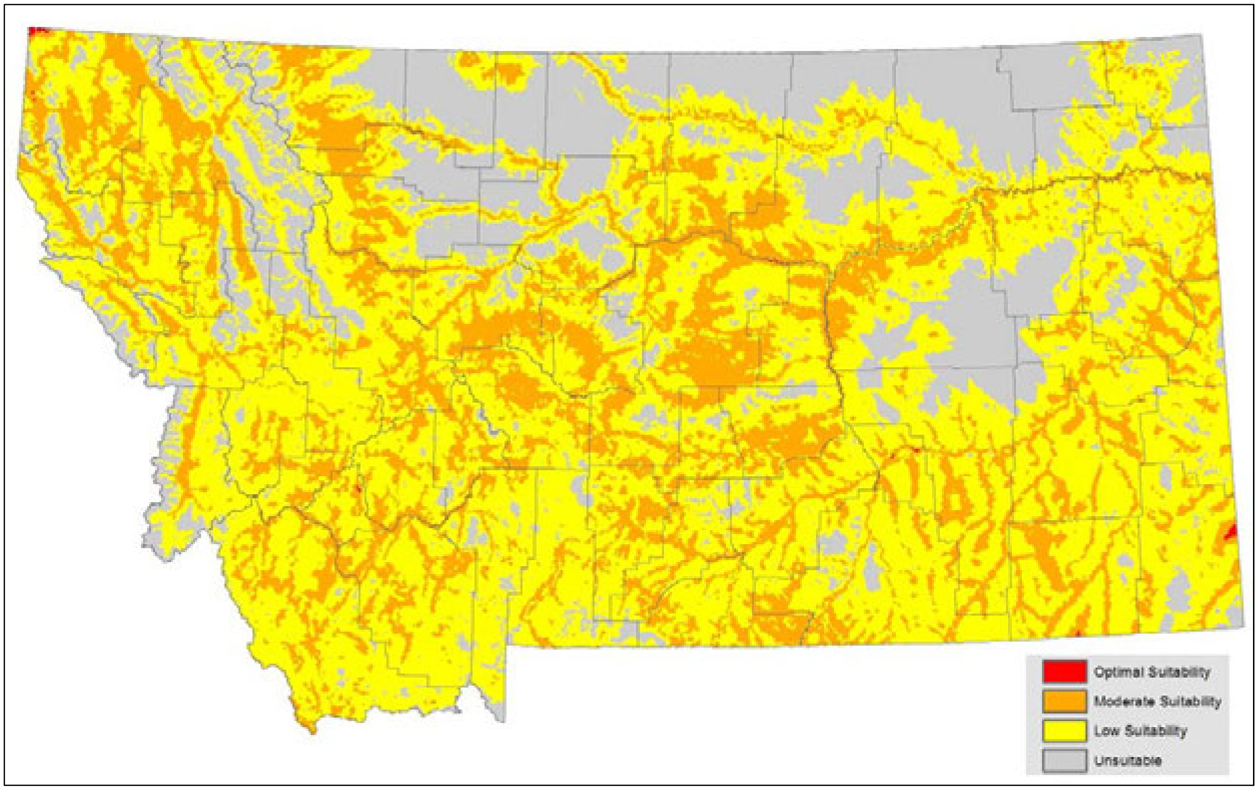


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Big Brown Bat

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	49
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	41
Great Plains Floodplain	9159	Common	31
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	30
Montane Sagebrush Steppe	5455	Common	27
Open Water	11	Common	23
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	21
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	21
Big Sagebrush Steppe	5454	Common	21
Great Plains Badlands	3114	Common	19
Rocky Mountain Lodgepole Pine Forest	4237	Common	19
Great Plains Riparian	9326	Common	17
Low Intensity Residential	22	Common	10
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	10
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	10
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	10
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	9
Alpine-Montane Wet Meadow	9217	Common	9
Post-Fire Recovery	8505	Common	8
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	6
Recently burned forest	8501	Common	6
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	5
Harvested forest-grass regeneration	8603	Common	5
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	4
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	4
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	4
Great Plains Wooded Draw and Ravine	4328	Common	4
Harvested forest-tree regeneration	8601	Common	4
Insect-Killed Forest	8700	Common	4
Great Plains Sand Prairie	7121	Common	3
Developed, Open Space	21	Common	2
Aspen Forest and Woodland	4104	Common	2
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	2
Mountain Mahogany Woodland and Shrubland	4303	Common	2
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Rocky Mountain Subalpine-Montane Fen	9234	Common	2
Great Plains Cliff and Outcrop	3142	Common	1
Great Plains Shrubland	5262	Common	1
Harvested forest-shrub regeneration	8602	Common	1
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	1

Table 5: Ecological Systems Associated with Big Brown Bat

Ecological System	Code	Association	Count[a]
Emergent Marsh	9222	Common	1
Great Plains Closed Depressional Wetland	9252	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Greasewood Flat	9103	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Prairie Pothole	9203	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Other Roads	28	Occasional	59
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	7
Interstate	26	Occasional	6
Cultivated Crops	82	Occasional	6
Recently burned grassland	8502	Occasional	6
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	5
Commercial/Industrial	24	Occasional	4
Major Roads	27	Occasional	4
Quarries, Strip Mines and Gravel Pits	31	Occasional	4
High Intensity Residential	23	Occasional	1
Railroad	25	Occasional	1
Pasture/Hay	81	Occasional	1
Mat Saltbush Shrubland	5203	Occasional	1
Recently burned shrubland	8503	Occasional	1
Burned Sagebrush	8504	Occasional	1
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Coal Bed Methane	32	Occasional	0
Gas and Gas Storage	33	Occasional	0
Injection	34	Occasional	0
Oil and Oil and Gas	35	Occasional	0
Wind Turbine	40	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 559 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

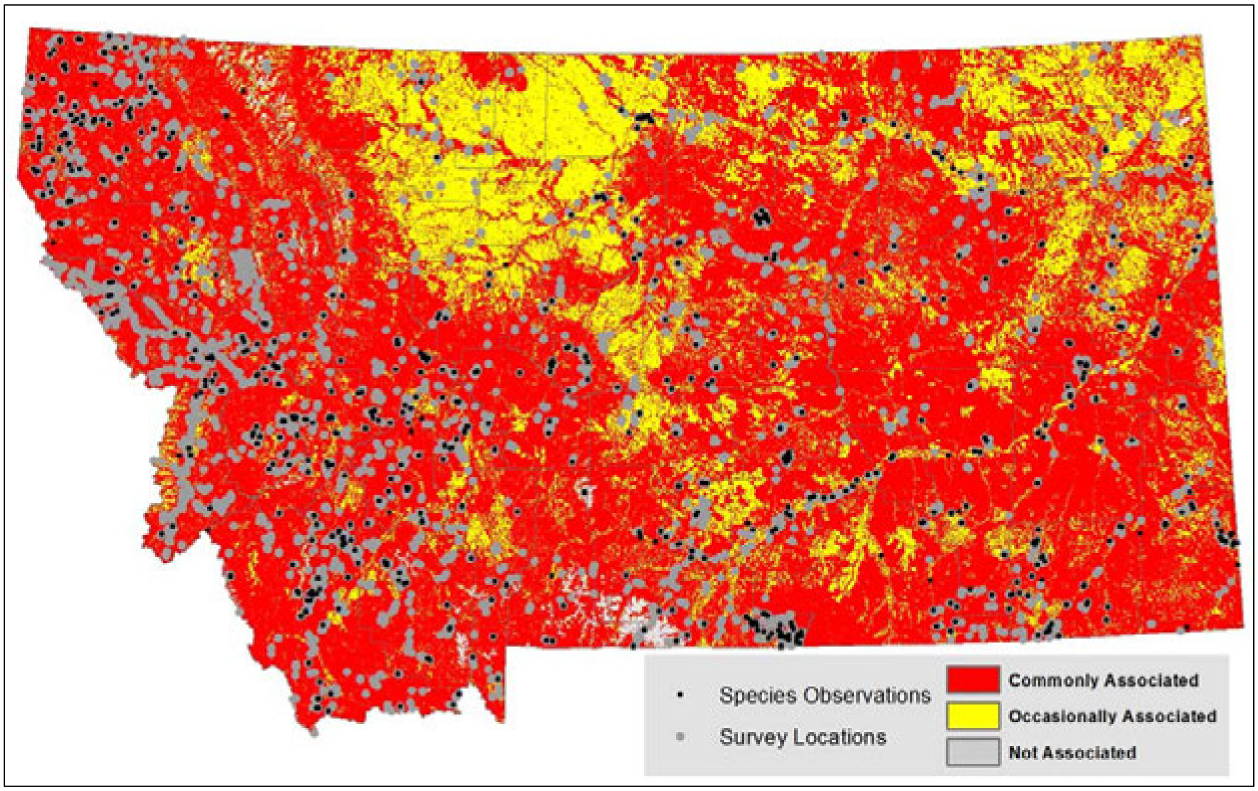
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	376,964.0 km^2
Area of Commonly Associated ES	285,374.0 km^2
Area of Occasionally Associated ES	91,591.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	100.0%
Commonly Associated ES AVI[a]	80.9%
Occasionally Associated ES AVI[a]	19.1%

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

Figure 10. Deductive model output classified into habitat associations.



Spotted Bat (*Euderma maculatum*)
Predicted Suitable Habitat Modeling

Distribution Status: Migratory Summer Breeder
State Rank: S3 (Species of Concern)
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 15, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 15, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across the species' known active season range in Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting what is known about the distribution of Spotted Bat active season habitat suitability at larger spatial scales across the species' known active season range in Montana. Evaluation metrics indicate an acceptable model fit despite some variance in model output resulting from low sample size. The delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the summer, across the species' known active season range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with greatly overpredict the amount of suitable habitat for Spotted Bat across the species' known active season range in Montana. Use of the inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Spotted Bat (*Euderma maculatum*) predicted suitable habitat models created on October 15, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.
Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC07010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	158
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	137
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	50
Season Modeled	Summer
Number of Model Background Locations	37,457

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
conttmin	18.4%	contndvi	2.9%
catesys	17.8%	conttmax	2.9%
contvrm	11.6%	contewasp	1.9%
contstrmed	7.4%	contddays	1.8%
catsoilord	6.8%	contslope	1.0%
contfrsted	5.8%	contwinrad	1.0%
catgeol	5.7%	contelev	0.3%
catsoiltemp	5.2%	contwinpcp	0.1%
contnsasp	4.8%	contsumrad	0.0%
contprecip	4.6%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.051
Moderate Logistic Threshold[b]	0.235
Optimal Logistic Threshold[c]	0.596
Area of entire modeled range (percent of Montana)	237,558.61 km^2 (62.4%)
Total area of predicted suitable habitat within modeled range	100,308.9 km^2
Area of predicted low suitability habitat within modeled range	75,519.3 km^2
Area of moderate suitability habitat within modeled range	21,410.9 km^2
Area of predicted optimal habitat within modeled range	3,378.8 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	92.0%
Moderate AVI[a]	74.0%
Optimal AVI[a]	40.0%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	2.406 ± 3.207
Training AUC[c]	0.937
Test AUC[d]	0.890

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.972, 2.892 and 1.037, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

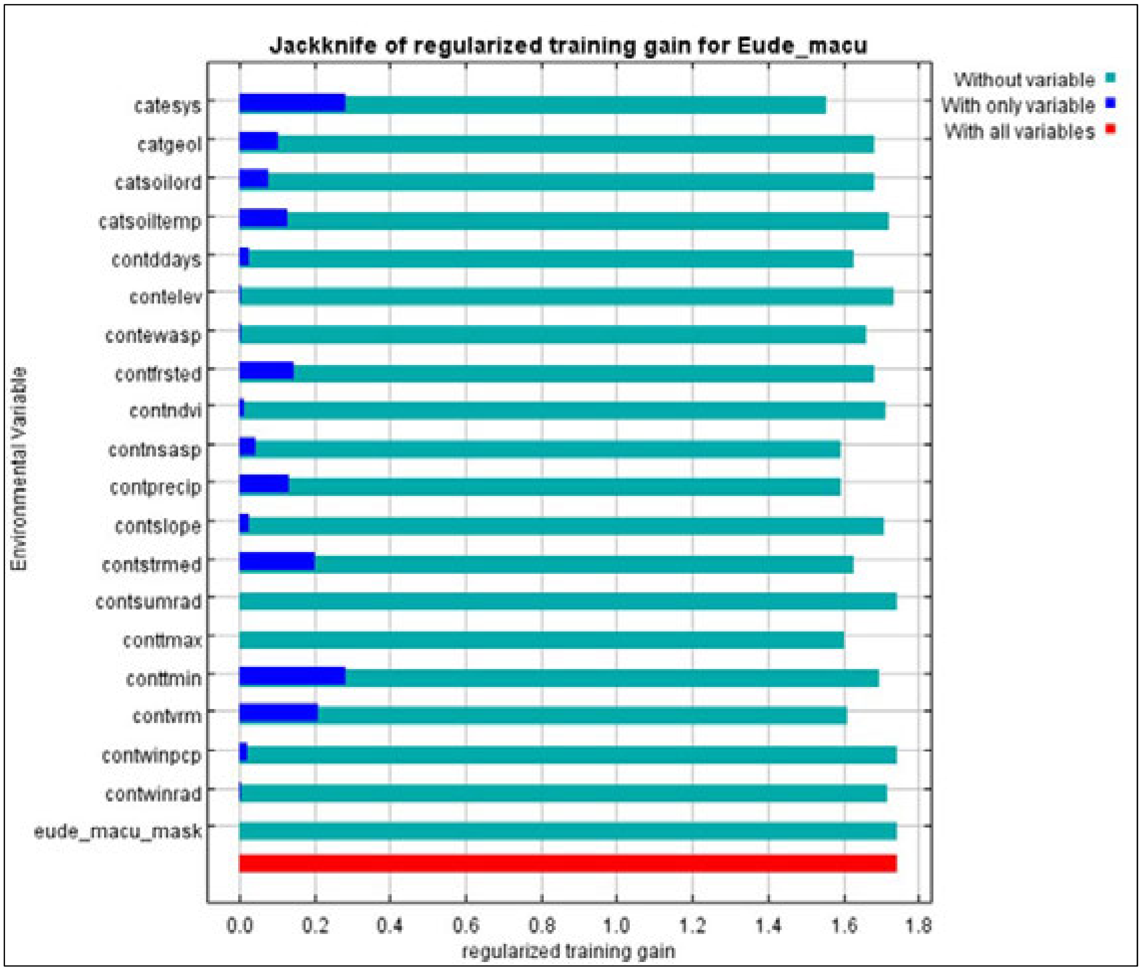
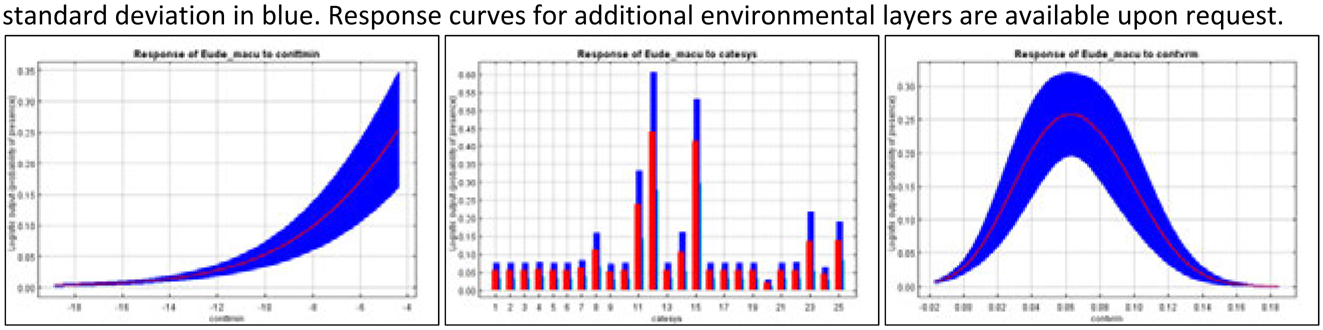


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

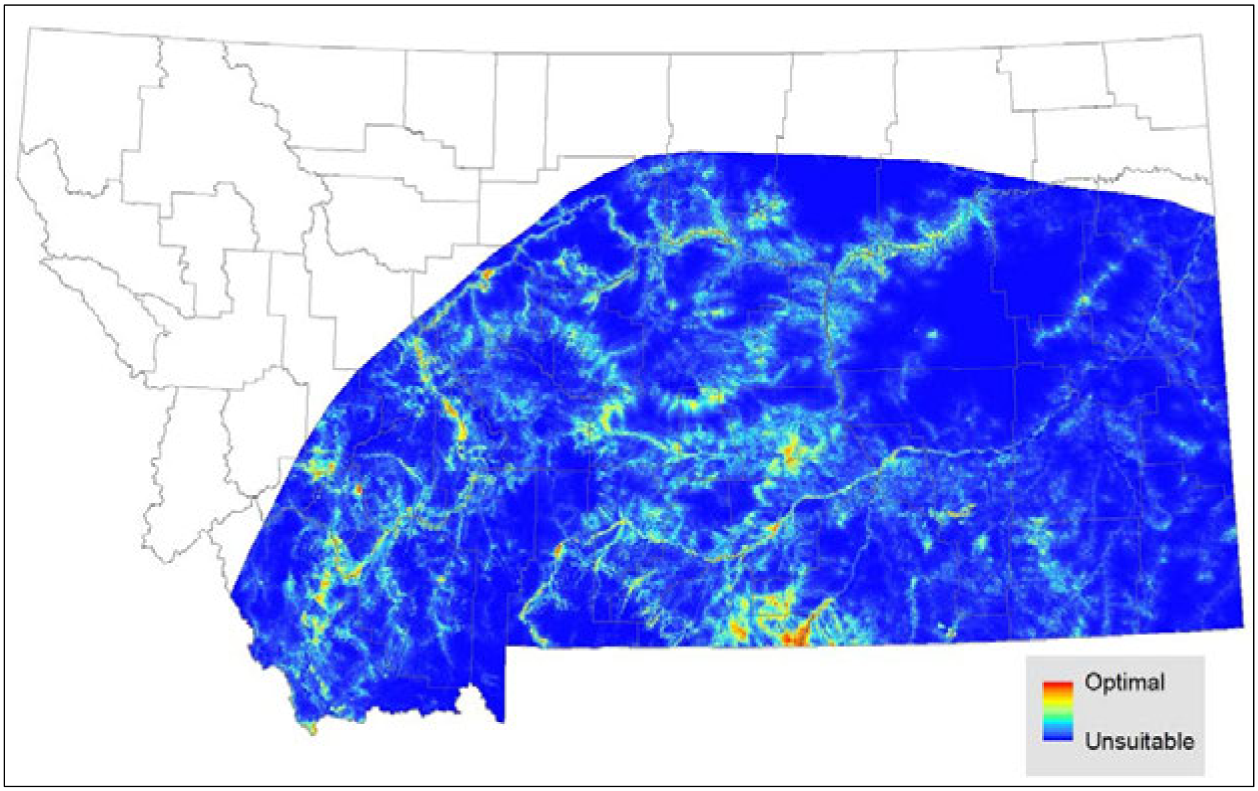


Figure 4. Standard deviation in the model output across the averaged models.

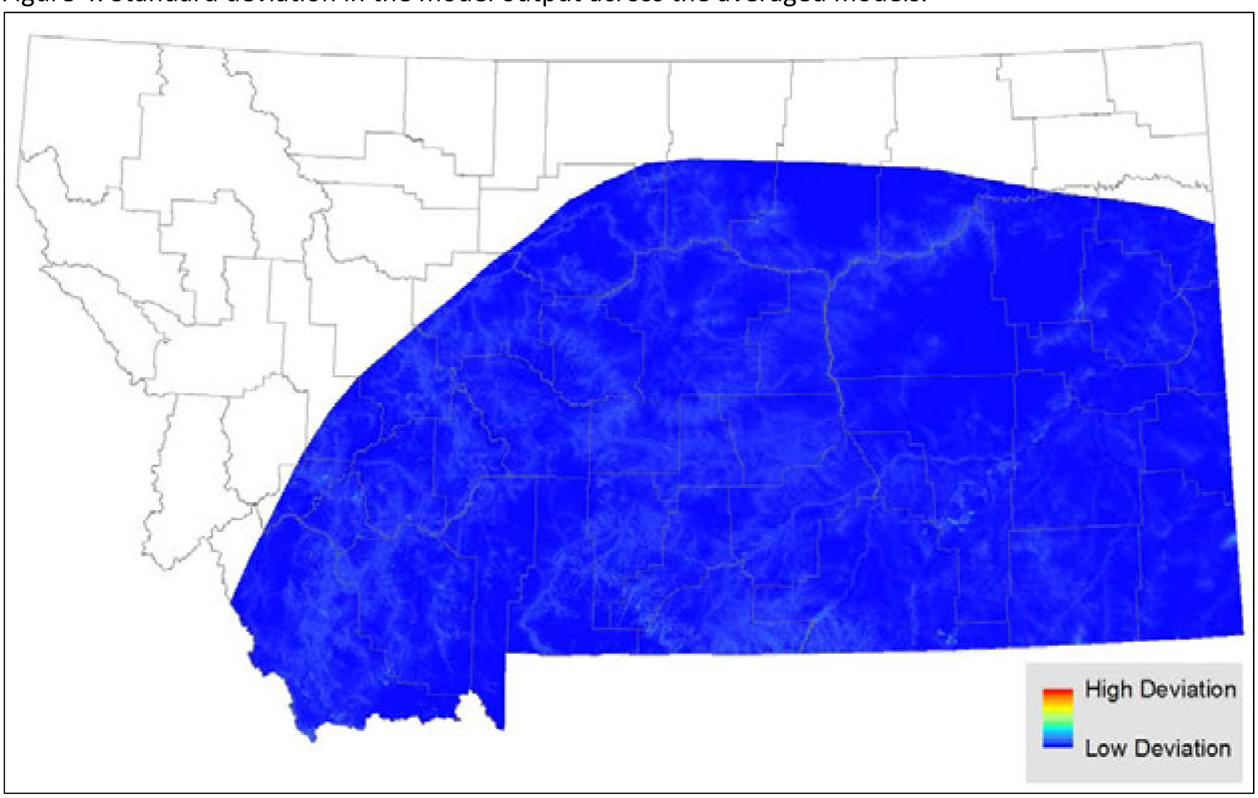


Figure 5. Continuous habitat suitability model output with the 50 observations used for modeling.

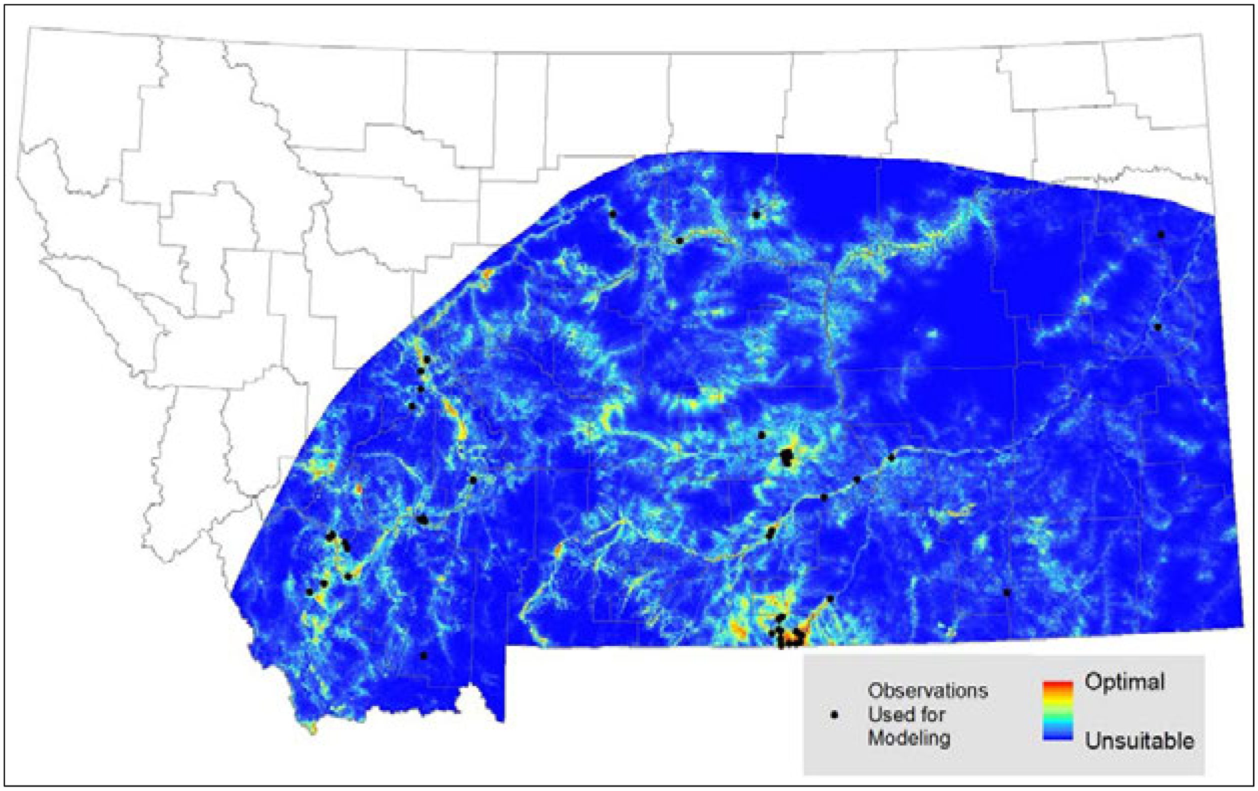


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

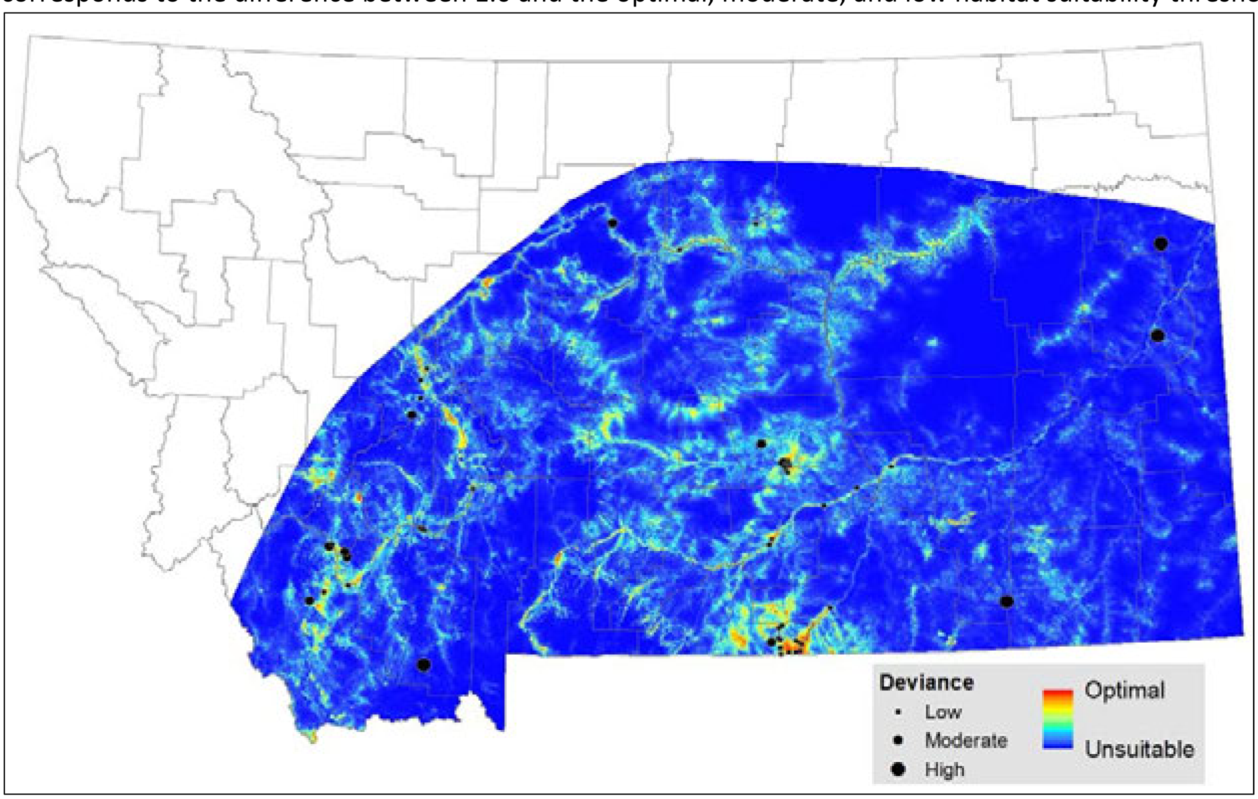


Figure 7. Continuous habitat suitability model output with all 158 observations (black) and survey locations that could have detected the species (gray).

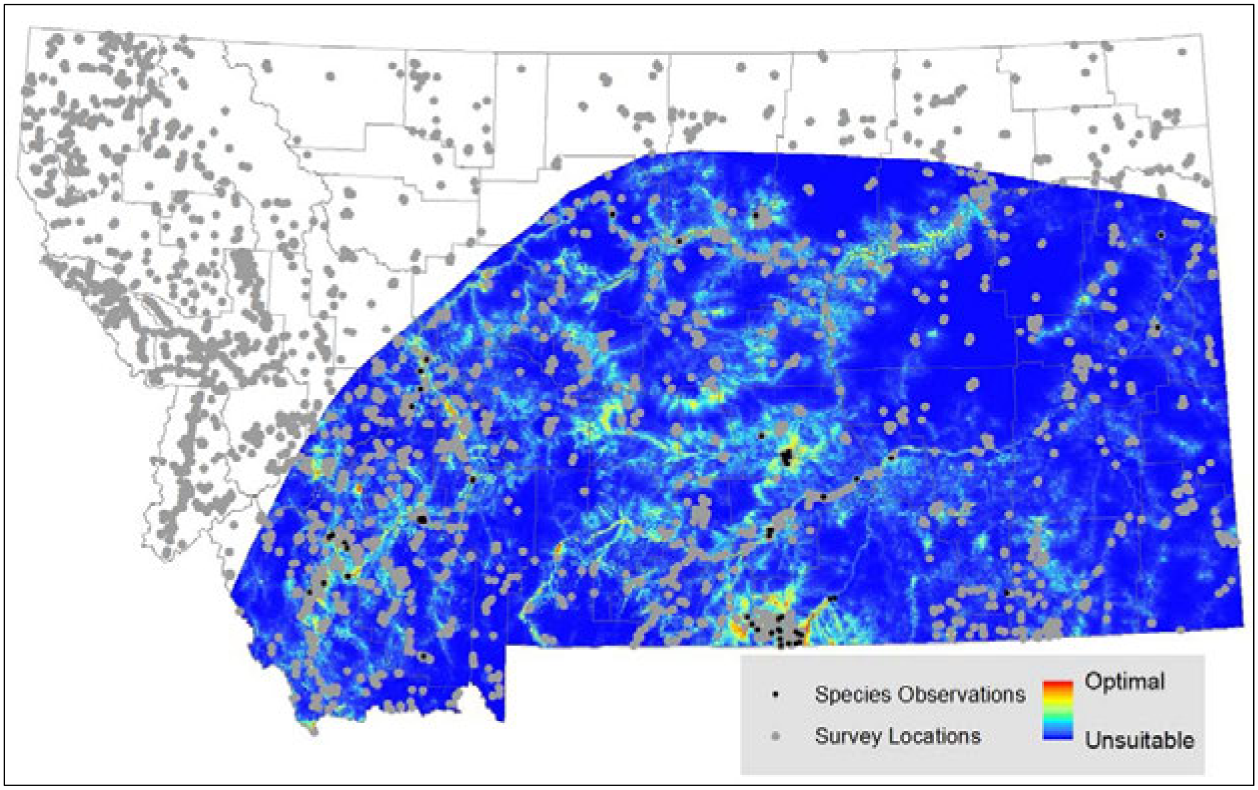


Figure 8. Model output classified into habitat suitability classes.

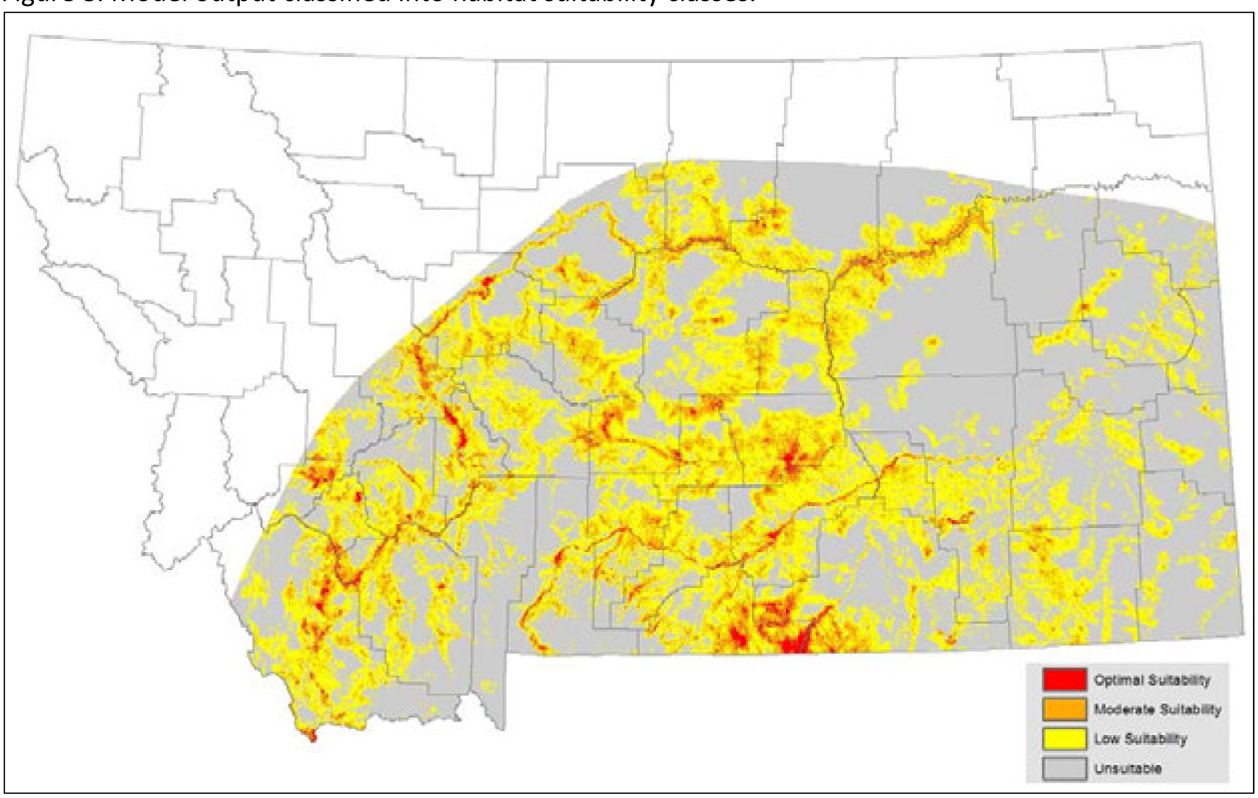
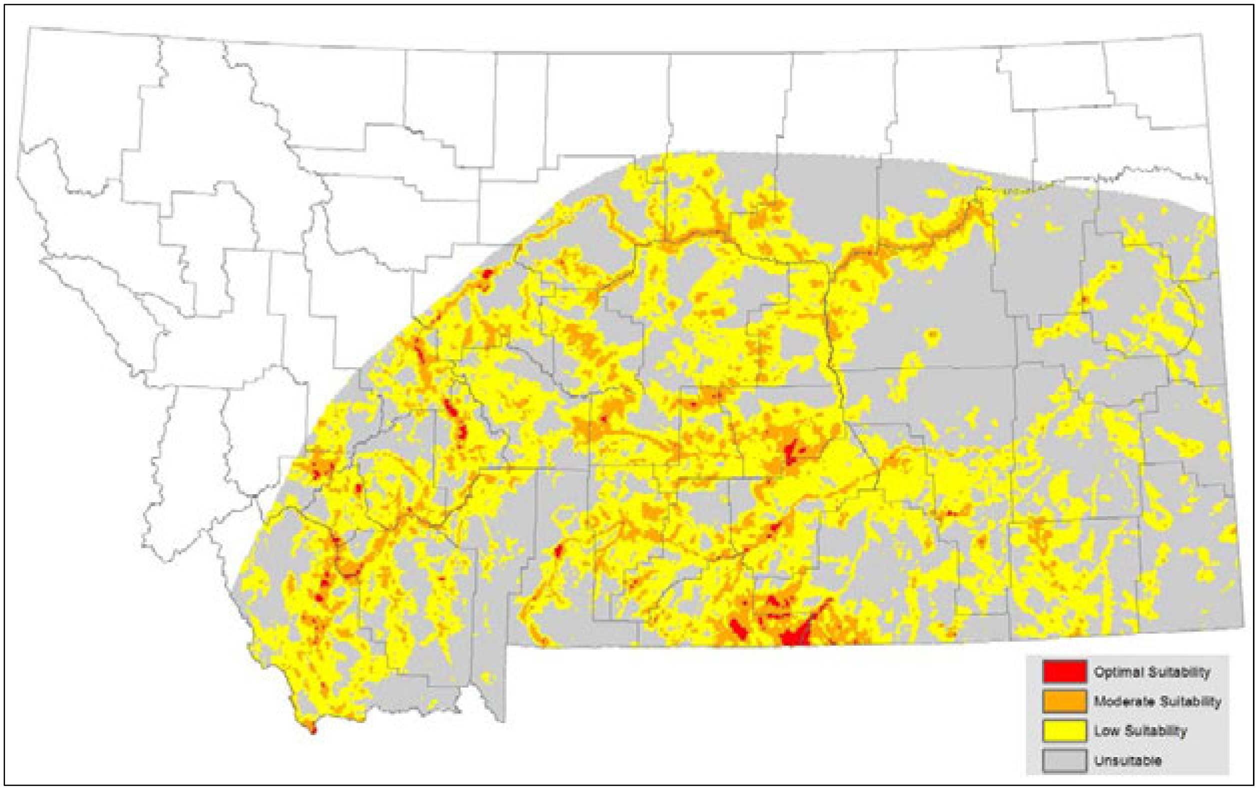


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Spotted Bat

Ecological System	Code	Association	Count[a]
Montane Sagebrush Steppe	5455	Common	6
Big Sagebrush Steppe	5454	Common	5
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	5
Great Plains Mixedgrass Prairie	7114	Common	5
Open Water	11	Common	4
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	4
Great Plains Floodplain	9159	Common	3
Great Plains Badlands	3114	Common	1
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	1
Great Plains Cliff and Outcrop	3142	Common	1
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	1
Mountain Mahogany Woodland and Shrubland	4303	Common	1
Great Plains Shrubland	5262	Common	1
Great Plains Riparian	9326	Common	1
Shale Badland	3139	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Mat Saltbush Shrubland	5203	Common	0
Low Sagebrush Shrubland	5209	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	0
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	0
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	0
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	0
Great Plains Sand Prairie	7121	Common	0
Recently burned grassland	8502	Common	0
Recently burned shrubland	8503	Common	0
Burned Sagebrush	8504	Common	0
Greasewood Flat	9103	Common	0
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	0
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Emergent Marsh	9222	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Occasional	2
Railroad	25	Occasional	1
Quarries, Strip Mines and Gravel Pits	31	Occasional	1

Table 5: Ecological Systems Associated with Spotted Bat

Ecological System	Code	Association	Count[a]
Developed, Open Space	21	Occasional	0
Low Intensity Residential	22	Occasional	0
Pasture/Hay	81	Occasional	0
Aspen Forest and Woodland	4104	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Occasional	0
Great Plains Wooded Draw and Ravine	4328	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Recently burned forest	8501	Occasional	0
Post-Fire Recovery	8505	Occasional	0
Harvested forest-grass regeneration	8603	Occasional	0
Alpine-Montane Wet Meadow	9217	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 50 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

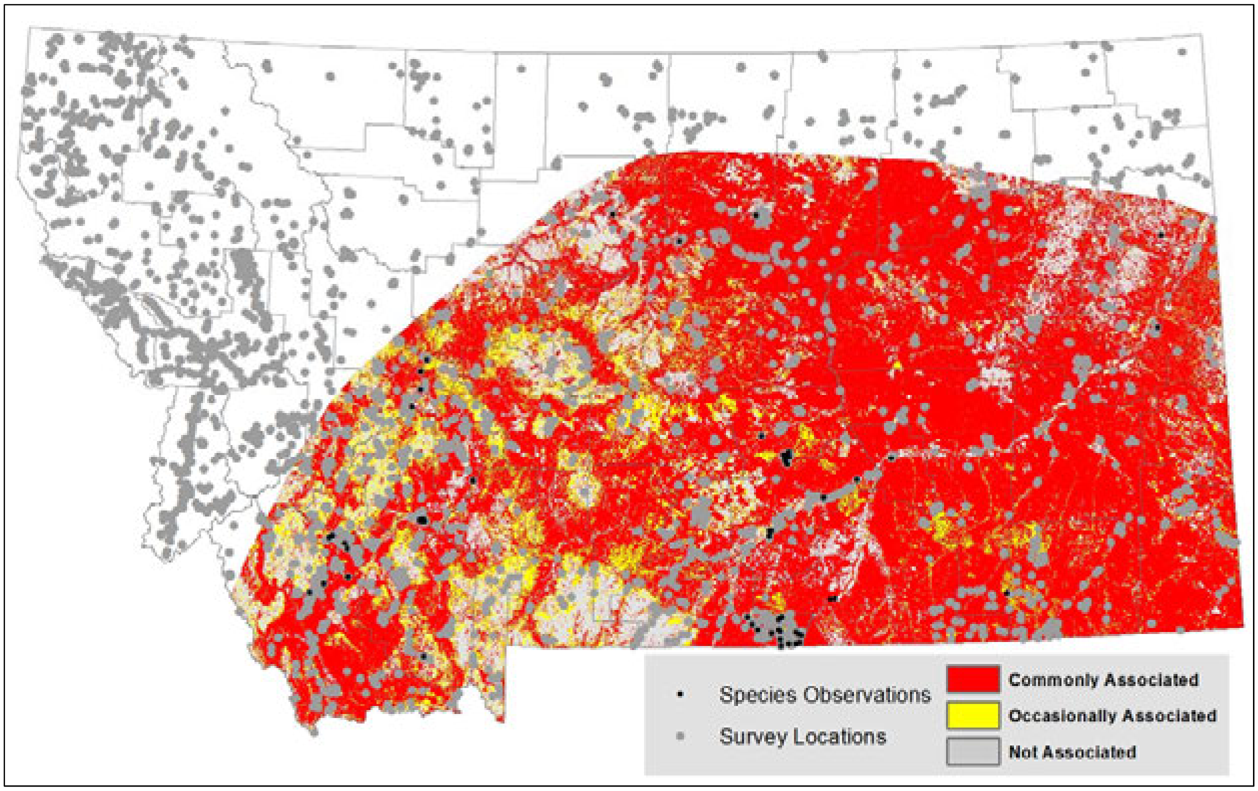
Measure	Value
Area of entire modeled range (percent of Montana)	237,558.61 km^2 (62.4%)
Area of Commonly and Occasionally Associated ES	191,922.0 km^2
Area of Commonly Associated ES	164,932.0 km^2
Area of Occasionally Associated ES	26,991.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	86.0%
Commonly Associated ES AVI[a]	78.0%
Occasionally Associated ES AVI[a]	8.0%

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

Figure 10. Deductive model output classified into habitat associations.



Silver-haired Bat (*Lasionycteris noctivagans*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4 (Potential Species of Concern)
Global Rank: G3G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Silver-haired Bat active season habitat suitability at larger spatial scales across Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of suitable active season habitat for Silver-haired Bat across Montana. Use of the inductive model output is recommended to inform survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Silver-haired Bat (*Lasionycteris noctivagans*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC02010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,540
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,373
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	860
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 3: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	37.5%	conttmax	2.7%
contslope	7.1%	catsoilord	2.6%
catsoiltemp	6.8%	contwinrad	2.2%
catgeol	6.3%	contndvi	1.9%
contsumrad	6.3%	contddays	1.7%
contwinpcp	5.7%	contewasp	1.4%
contstrmed	5.0%	contprecip	0.9%
contnsasp	4.3%	contelev	0.7%
contvrm	3.1%	conttmin	0.6%
contfrsted	3.0%		

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

Table 4: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.089
Moderate Logistic Threshold[b]	0.382
Optimal Logistic Threshold[c]	0.816
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	312,850.8 km^2
Area of predicted low suitability habitat within modeled range	224,533.1 km^2
Area of moderate suitability habitat within modeled range	85,098.0 km^2
Area of predicted optimal habitat within modeled range	3,219.7 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 5: Evaluation Metrics

Metric	Value
Low AVI[a]	97.9%
Moderate AVI[a]	67.1%
Optimal AVI[a]	10.7%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.629 ± 1.205
Training AUC[c]	0.816
Test AUC[d]	0.799

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.840, 1.923 and 0.408, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

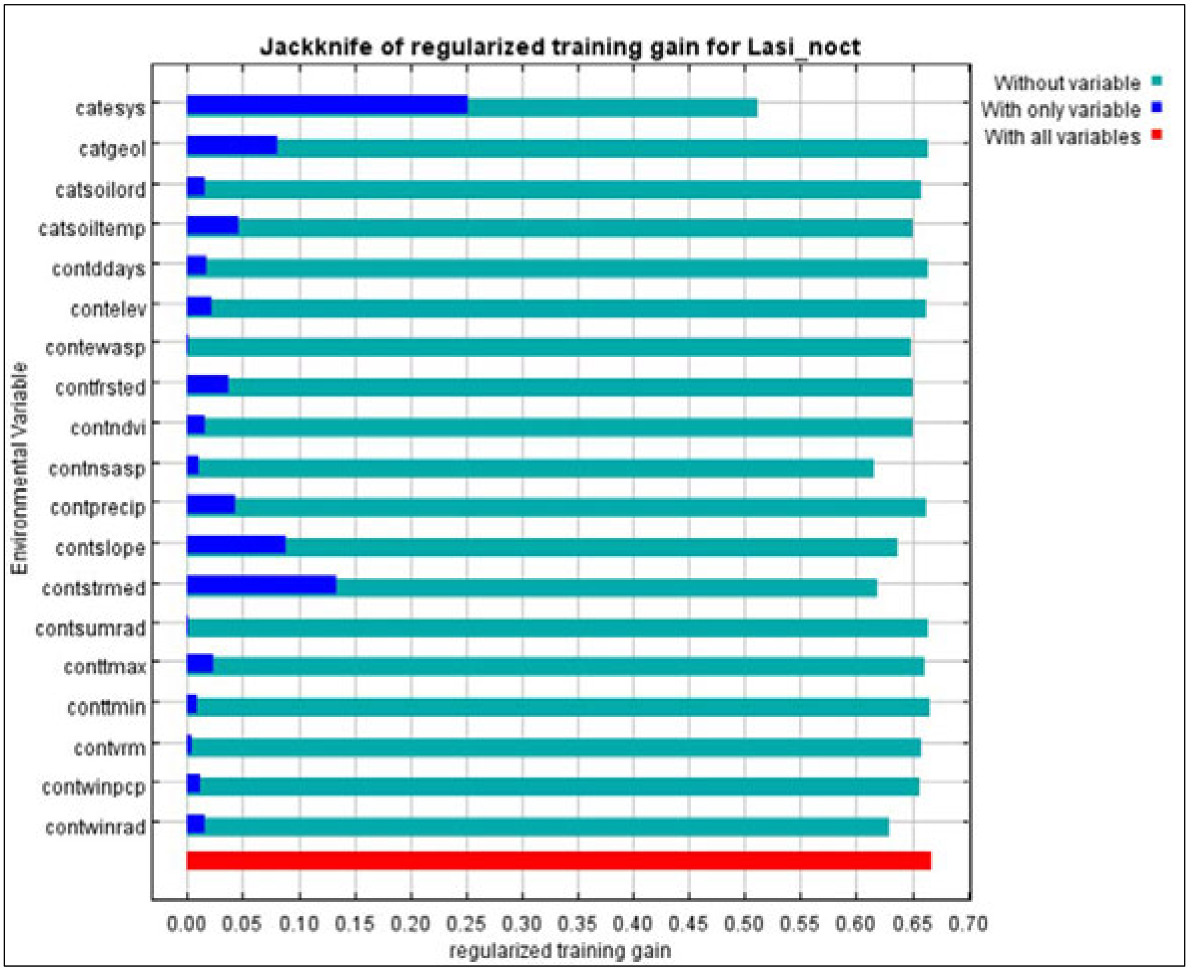
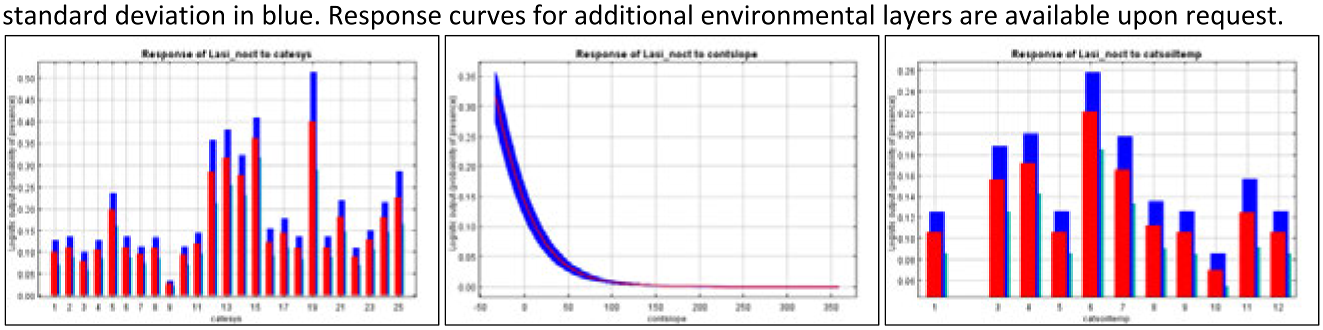


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

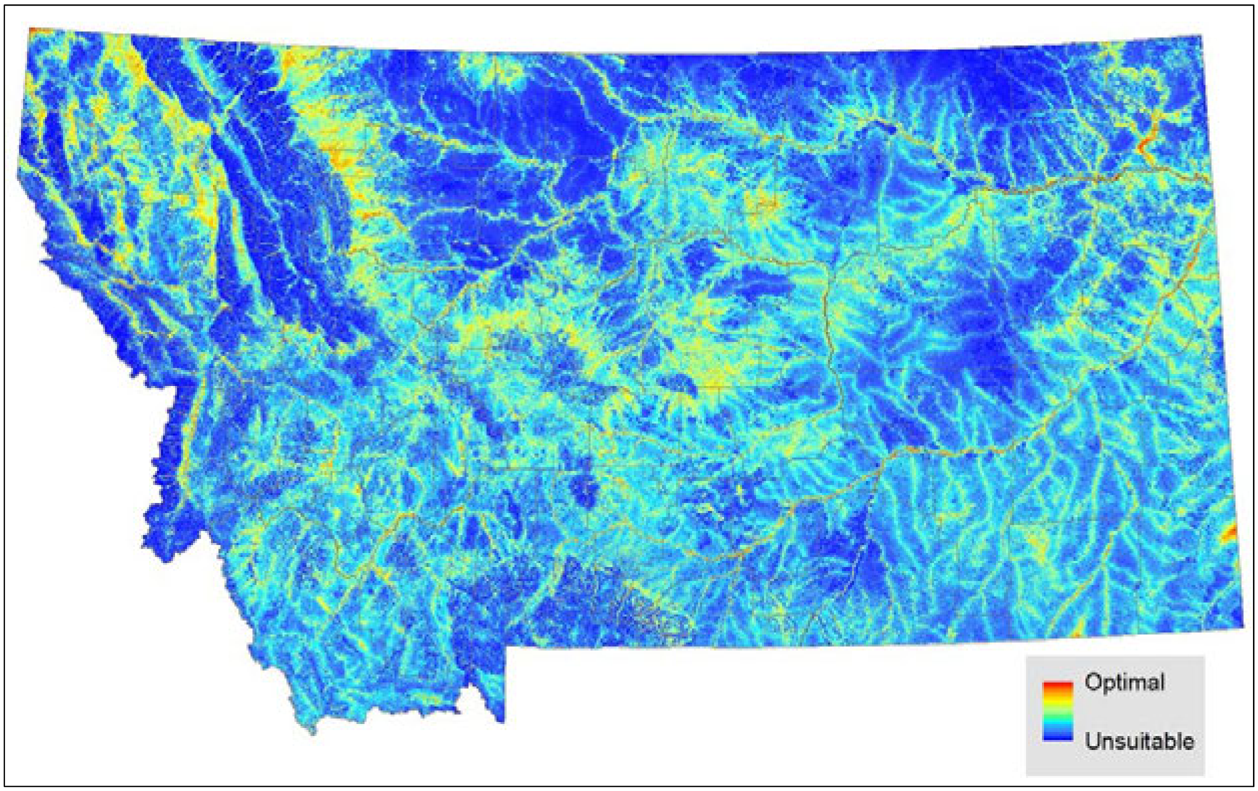


Figure 4. Standard deviation in the model output across the averaged models.

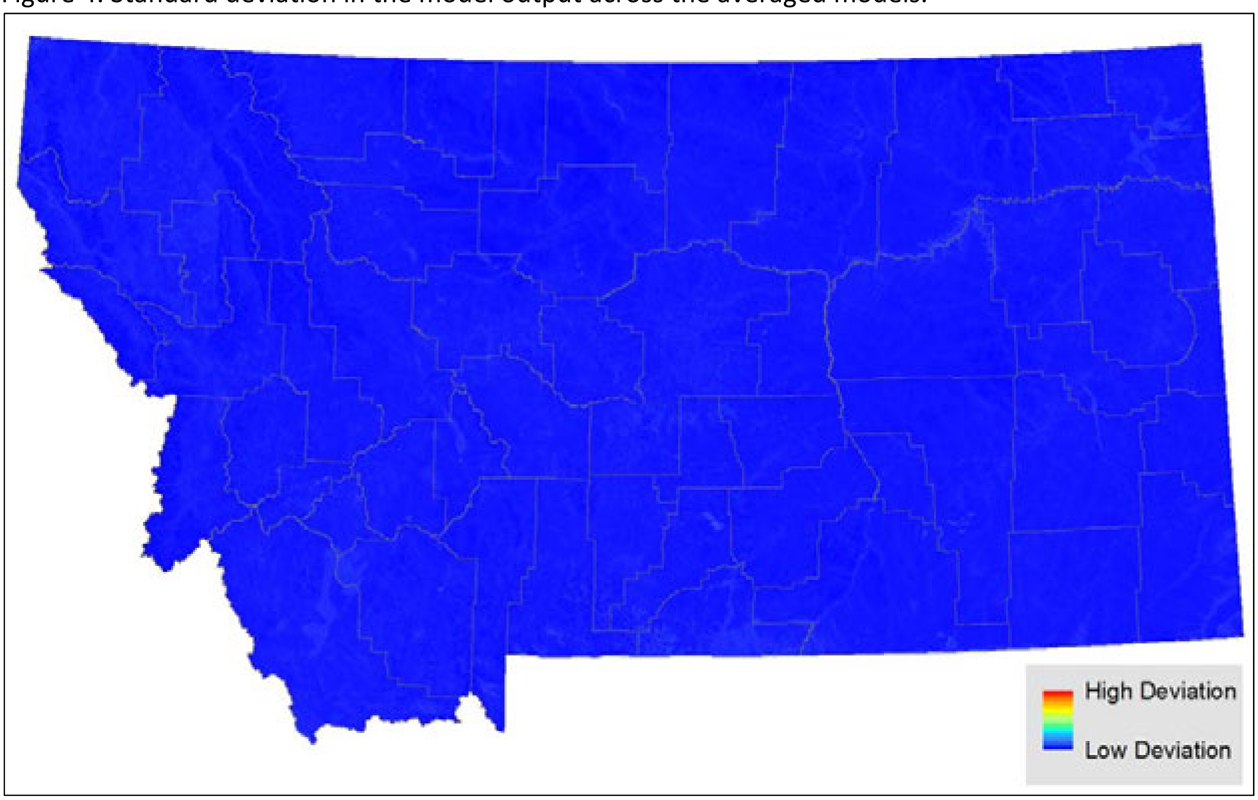


Figure 5. Continuous habitat suitability model output with the 860 observations used for modeling.

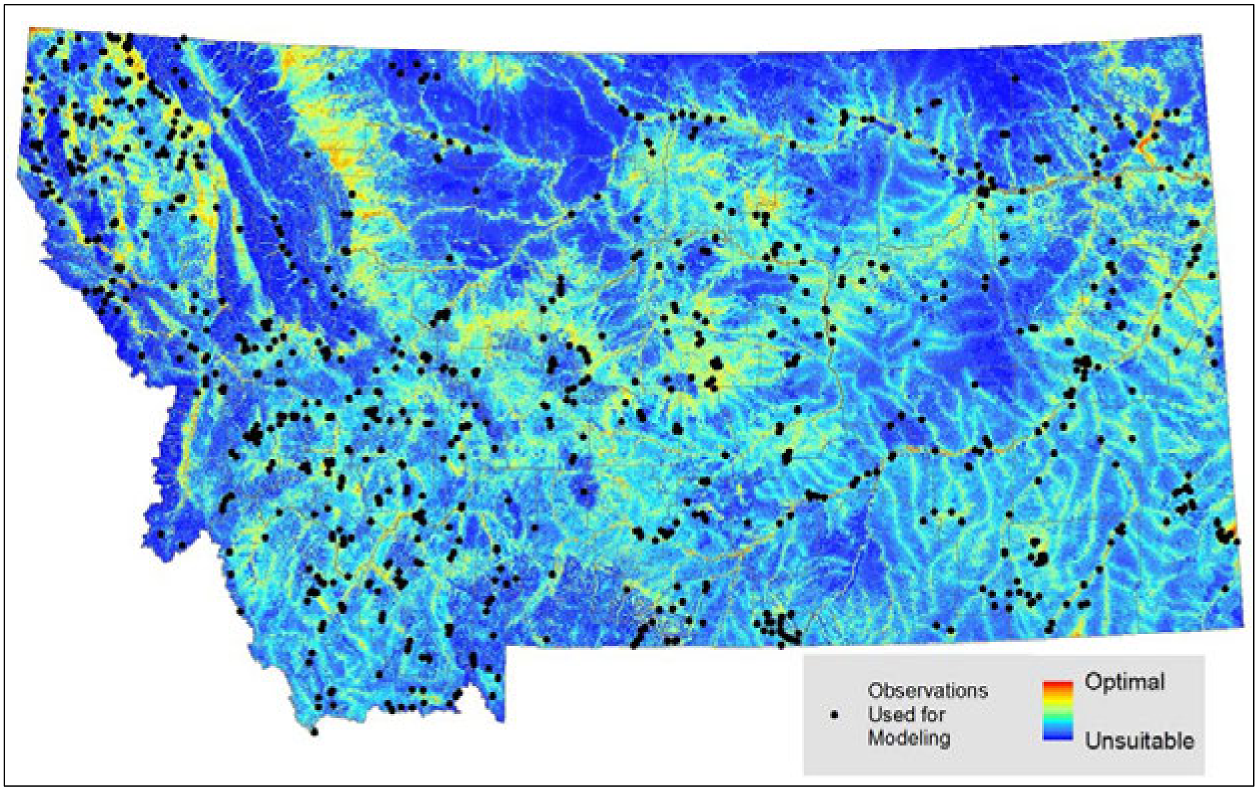


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

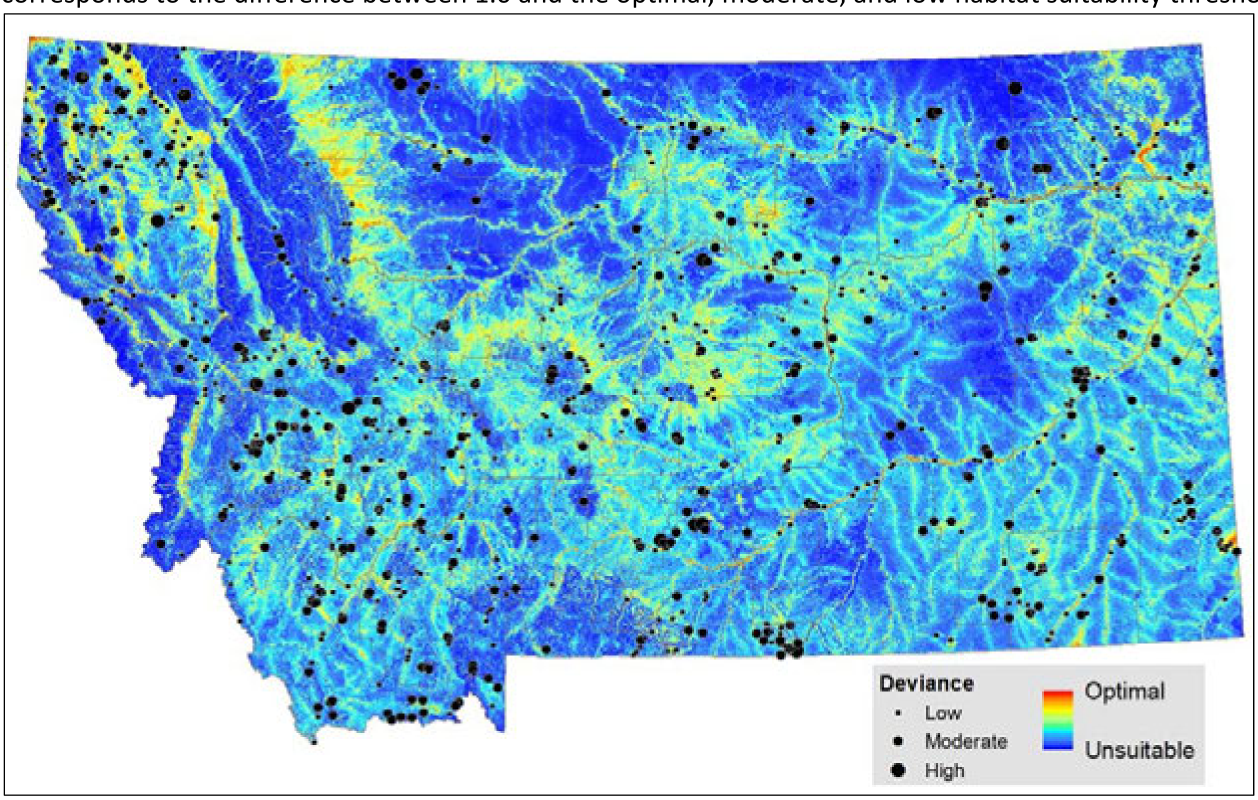


Figure 7. Continuous habitat suitability model output with all 1,540 observations (black) and survey locations that could have detected the species (gray).

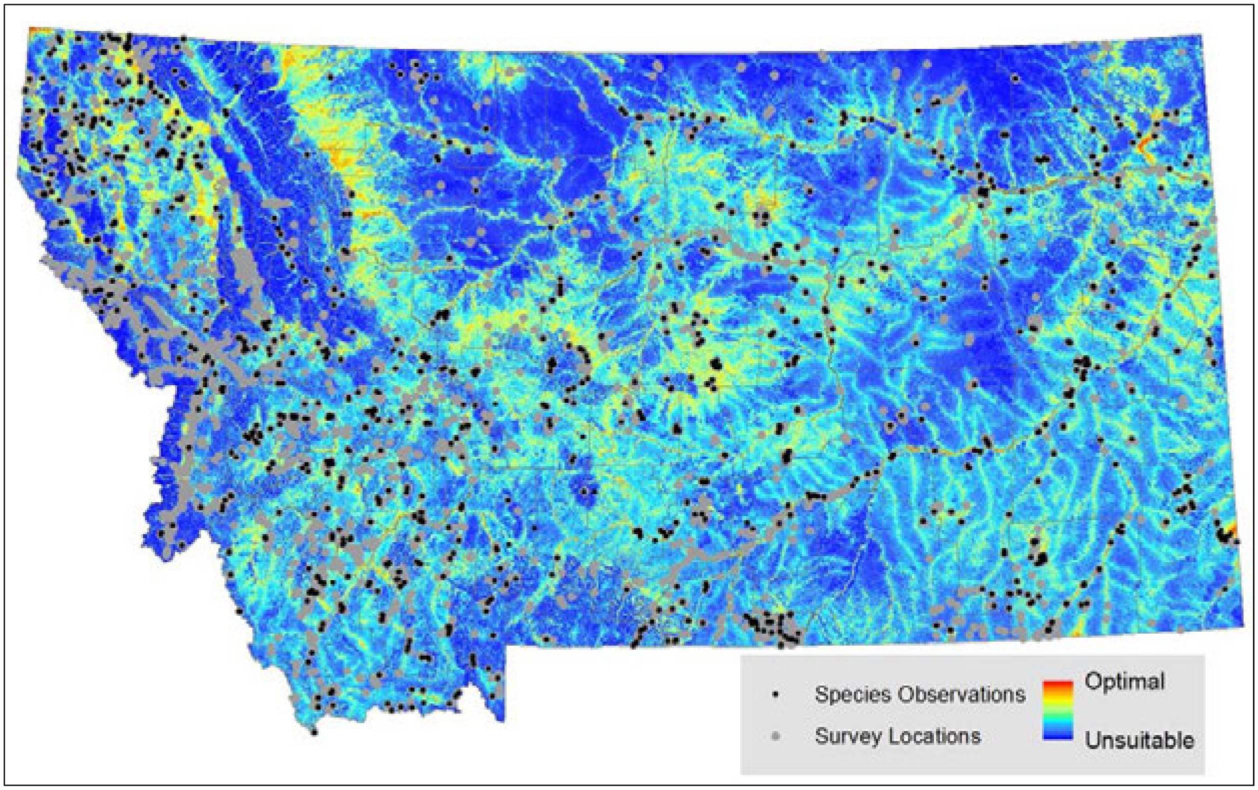


Figure 8. Model output classified into habitat suitability classes.

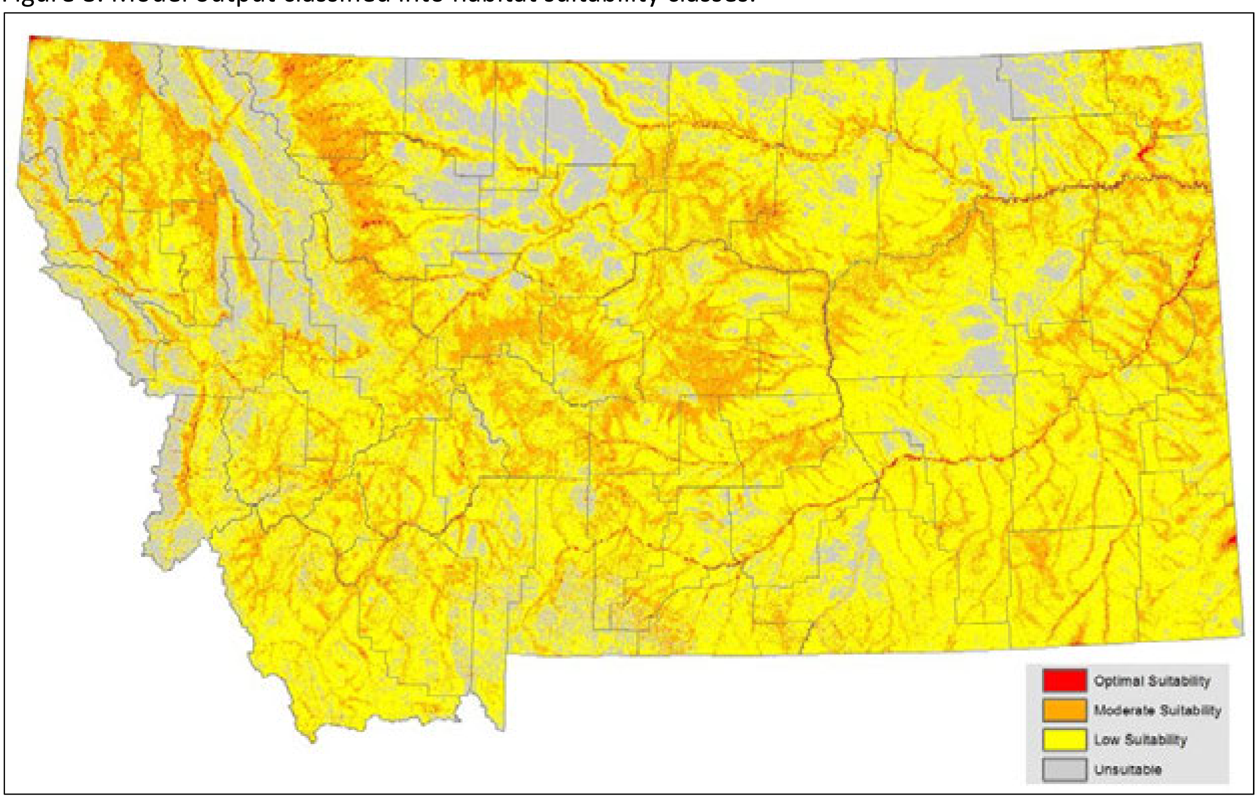
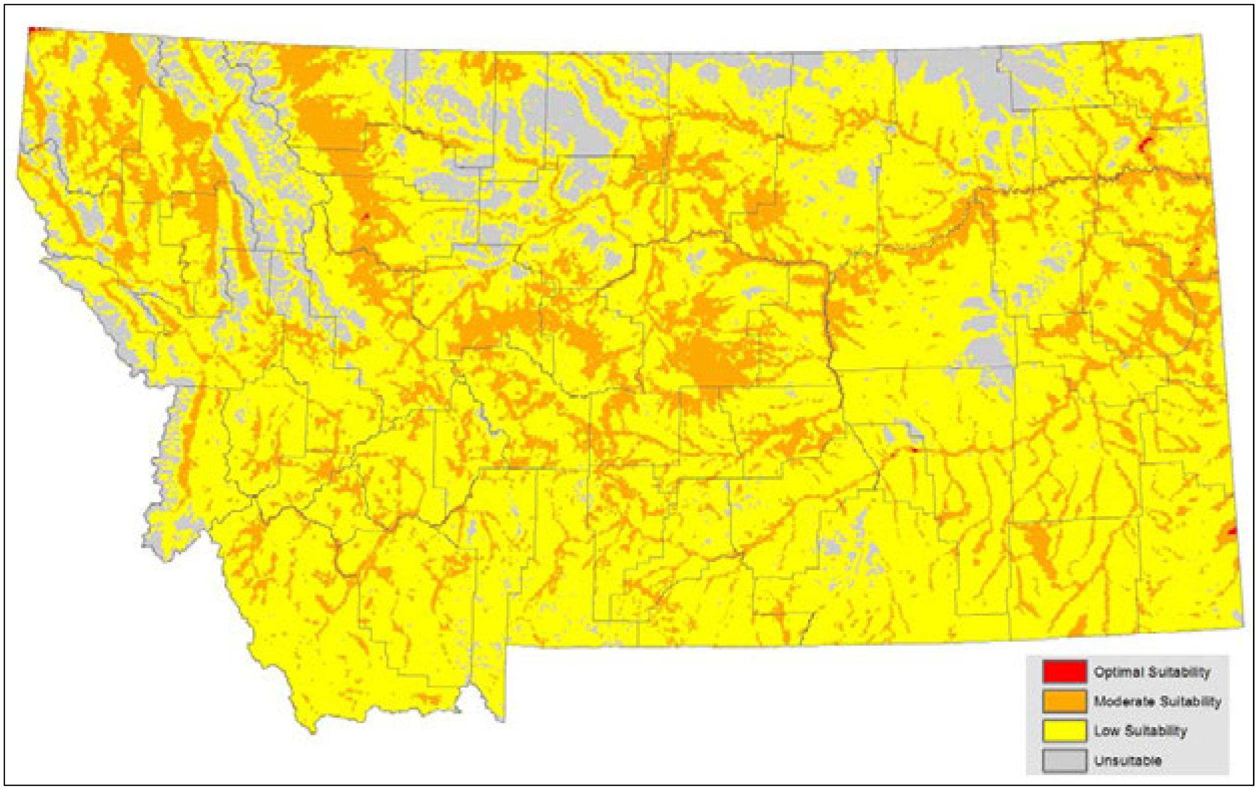


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Silver-haired Bat

Ecological System	Code	Association	Count[a]
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	68
Great Plains Mixedgrass Prairie	7114	Common	63
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	50
Big Sagebrush Steppe	5454	Common	44
Open Water	11	Common	43
Great Plains Riparian	9326	Common	38
Great Plains Floodplain	9159	Common	37
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	35
Montane Sagebrush Steppe	5455	Common	33
Great Plains Badlands	3114	Common	25
Rocky Mountain Lodgepole Pine Forest	4237	Common	23
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	21
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	14
Recently burned forest	8501	Common	14
Alpine-Montane Wet Meadow	9217	Common	14
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	13
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	13
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	11
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	11
Post-Fire Recovery	8505	Common	10
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	9
Great Plains Sand Prairie	7121	Common	8
Aspen Forest and Woodland	4104	Common	7
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	7
Harvested forest-grass regeneration	8603	Common	7
Insect-Killed Forest	8700	Common	7
Great Plains Wooded Draw and Ravine	4328	Common	6
Great Plains Shrubland	5262	Common	6
Harvested forest-tree regeneration	8601	Common	4
Mountain Mahogany Woodland and Shrubland	4303	Common	3
Emergent Marsh	9222	Common	3
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	2
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	2
Harvested forest-shrub regeneration	8602	Common	2
Great Plains Open Freshwater Depression Wetland	9218	Common	2
Rocky Mountain Subalpine-Montane Fen	9234	Common	2
Great Plains Saline Depression Wetland	9256	Common	2
Greasewood Flat	9103	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1

Table 5: Ecological Systems Associated with Silver-haired Bat

Ecological System	Code	Association	Count[a]
Great Plains Closed Depressional Wetland	9252	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Great Plains Prairie Pothole	9203	Common	0
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	12
Cultivated Crops	82	Occasional	11
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	9
Recently burned grassland	8502	Occasional	7
Low Intensity Residential	22	Occasional	5
Commercial/Industrial	24	Occasional	5
Pasture/Hay	81	Occasional	4
Introduced Riparian and Wetland Vegetation	8406	Occasional	4
Recently burned shrubland	8503	Occasional	4
Developed, Open Space	21	Occasional	2
Mat Saltbush Shrubland	5203	Occasional	2
Burned Sagebrush	8504	Occasional	2
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	1
High Intensity Residential	23	Occasional	0
Shale Badland	3139	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 860 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

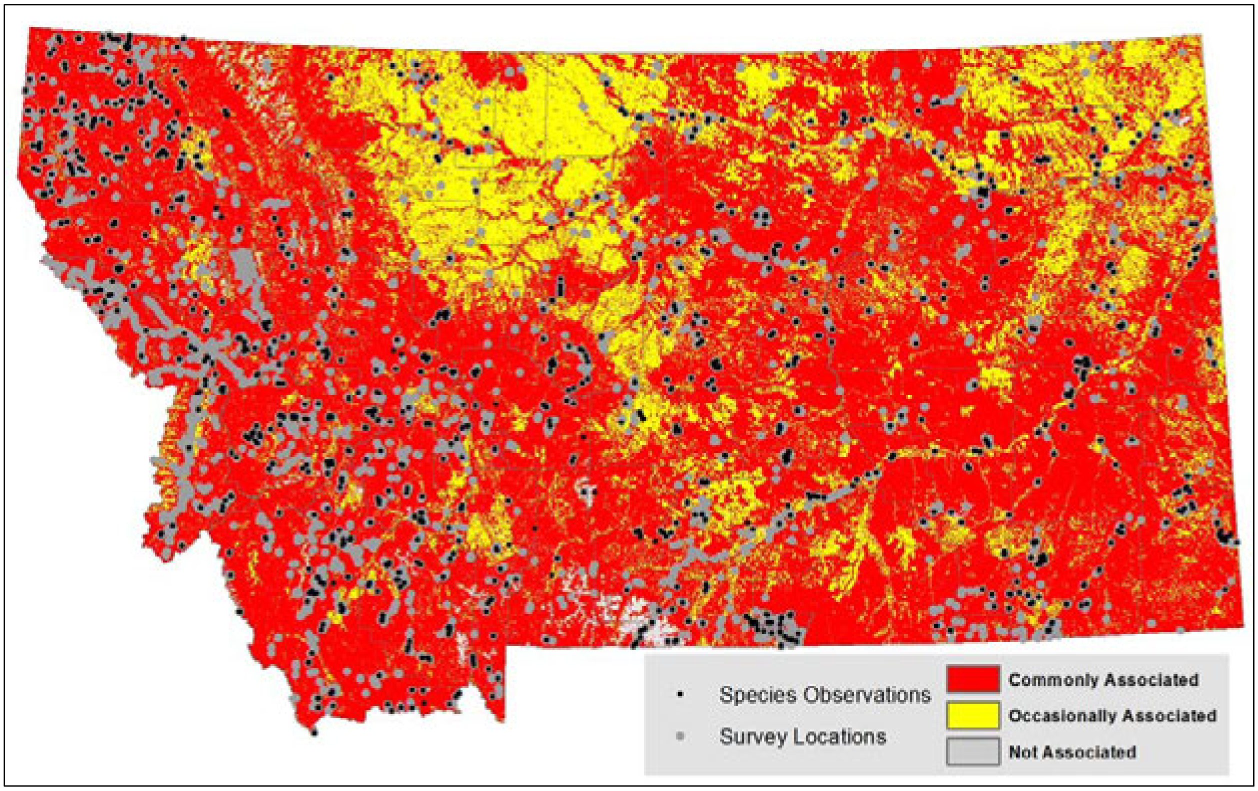
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	371,879.0 km^2
Area of Commonly Associated ES	283,861.0 km^2
Area of Occasionally Associated ES	88,018.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	85.0%
Commonly Associated ES AVI[a]	77.1%
Occasionally Associated ES AVI[a]	7.9%

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

Figure 10. Deductive model output classified into habitat associations.



Hoary Bat (*Lasiurus cinereus*)
Predicted Suitable Habitat Modeling

Distribution Status: Migratory Summer Breeder
State Rank: S3 (Species of Concern)
Global Rank: G3G4

Modeling Overview
Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Hoary Bat active season habitat suitability at larger spatial scales across Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of active season suitable habitat across Montana. Inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Hoary Bat (*Lasiurus cinereus*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC05030

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,352
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,309
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	755
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	43.4%	contfrsted	2.3%
catsoiltemp	7.9%	contwinrad	2.1%
contstrmed	7.3%	catsoilord	2.0%
contwinpcp	6.3%	contndvi	2.0%
catgeol	5.6%	contsumrad	1.5%
contslope	4.9%	contddays	1.4%
contnsasp	3.7%	contewasp	1.1%
conttmax	2.8%	contprecip	0.7%
conttmin	2.4%	contelev	0.3%
contvrm	2.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.078
Moderate Logistic Threshold[b]	0.375
Optimal Logistic Threshold[c]	0.811
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	318,445.7 km^2
Area of predicted low suitability habitat within modeled range	227,985.9 km^2
Area of moderate suitability habitat within modeled range	87,159.1 km^2
Area of predicted optimal habitat within modeled range	3,300.7 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.0%
Moderate AVI[a]	64.4%
Optimal AVI[a]	11.5%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.695 ± 1.249
Training AUC[c]	0.807
Test AUC[d]	0.788

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.097, 1.961 and 0.419, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

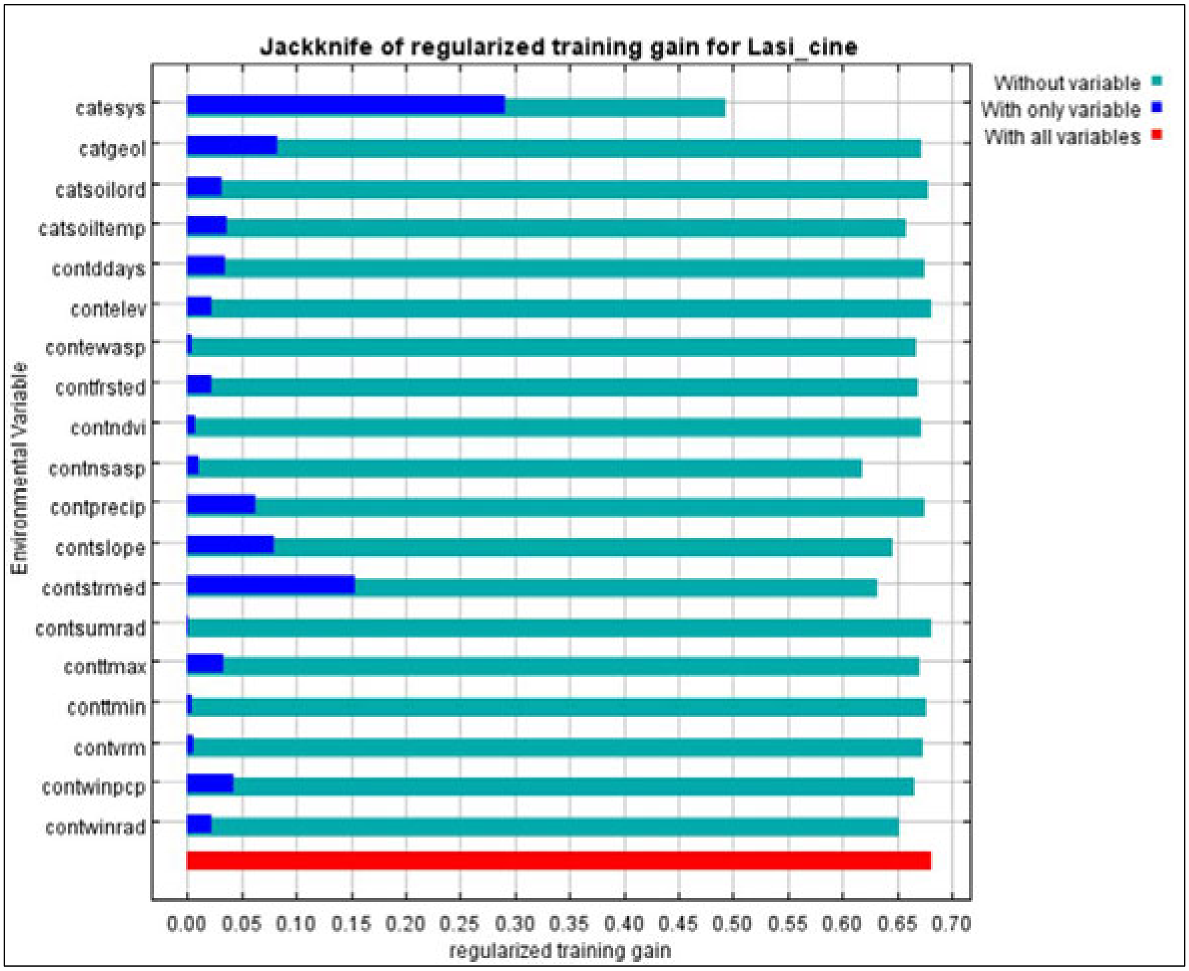
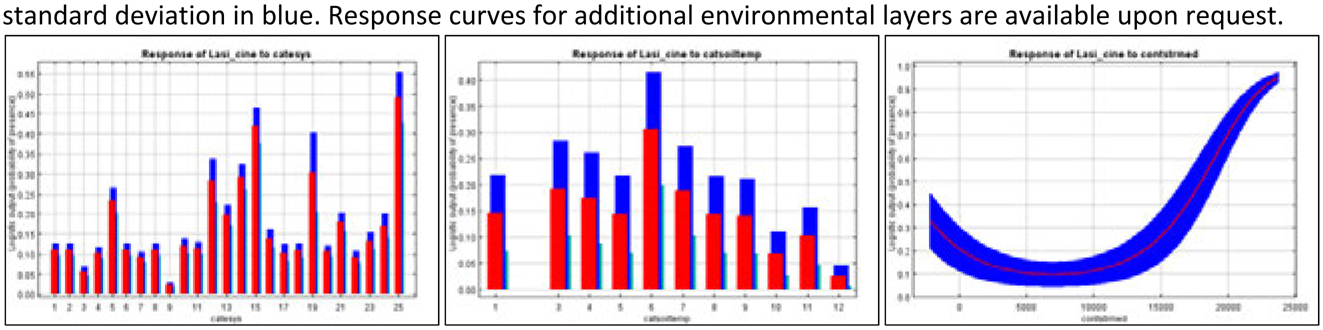


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

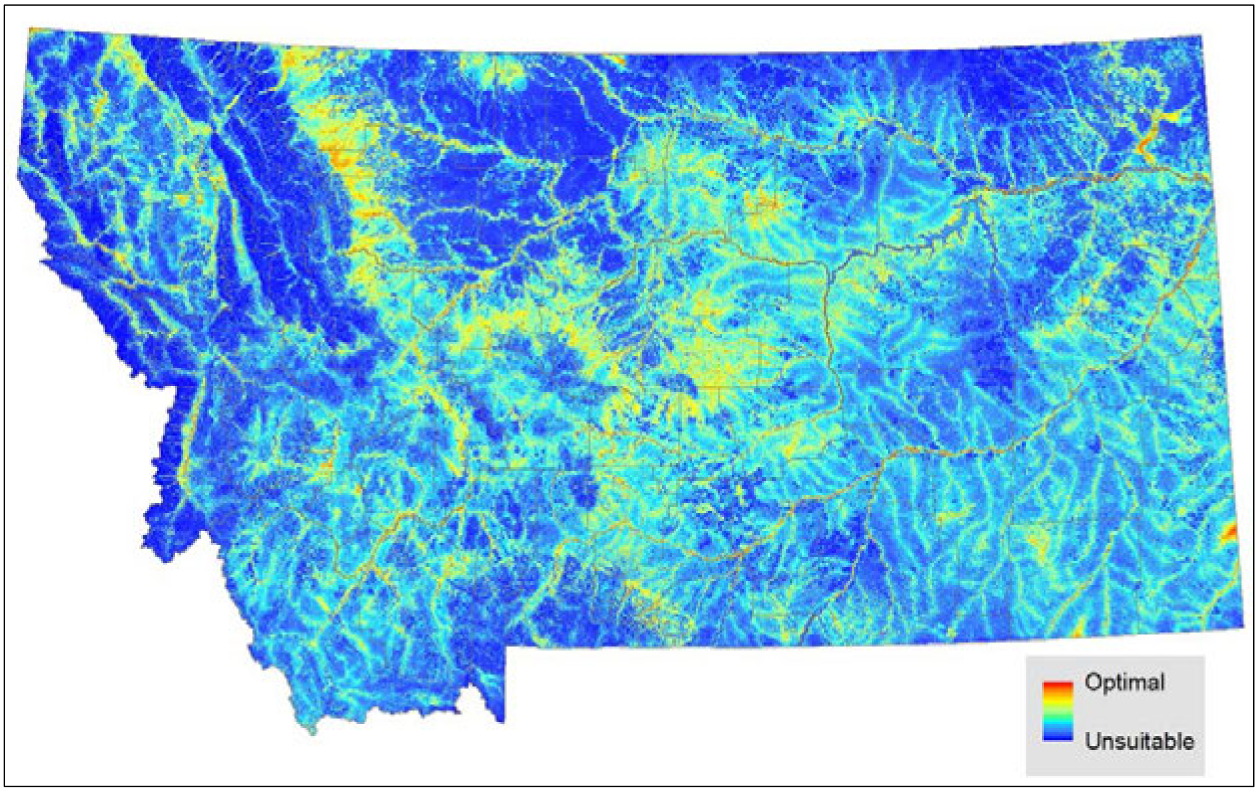


Figure 4. Standard deviation in the model output across the averaged models.

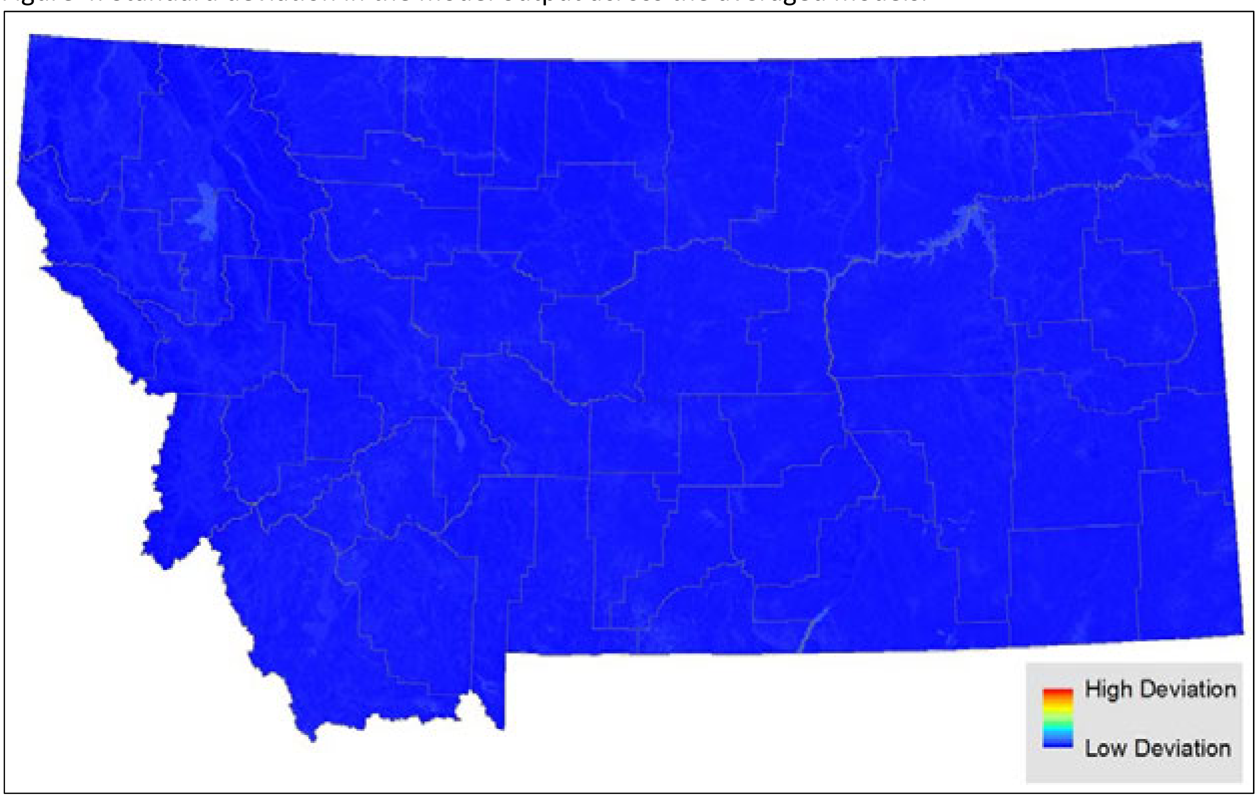


Figure 5. Continuous habitat suitability model output with the 755 observations used for modeling.

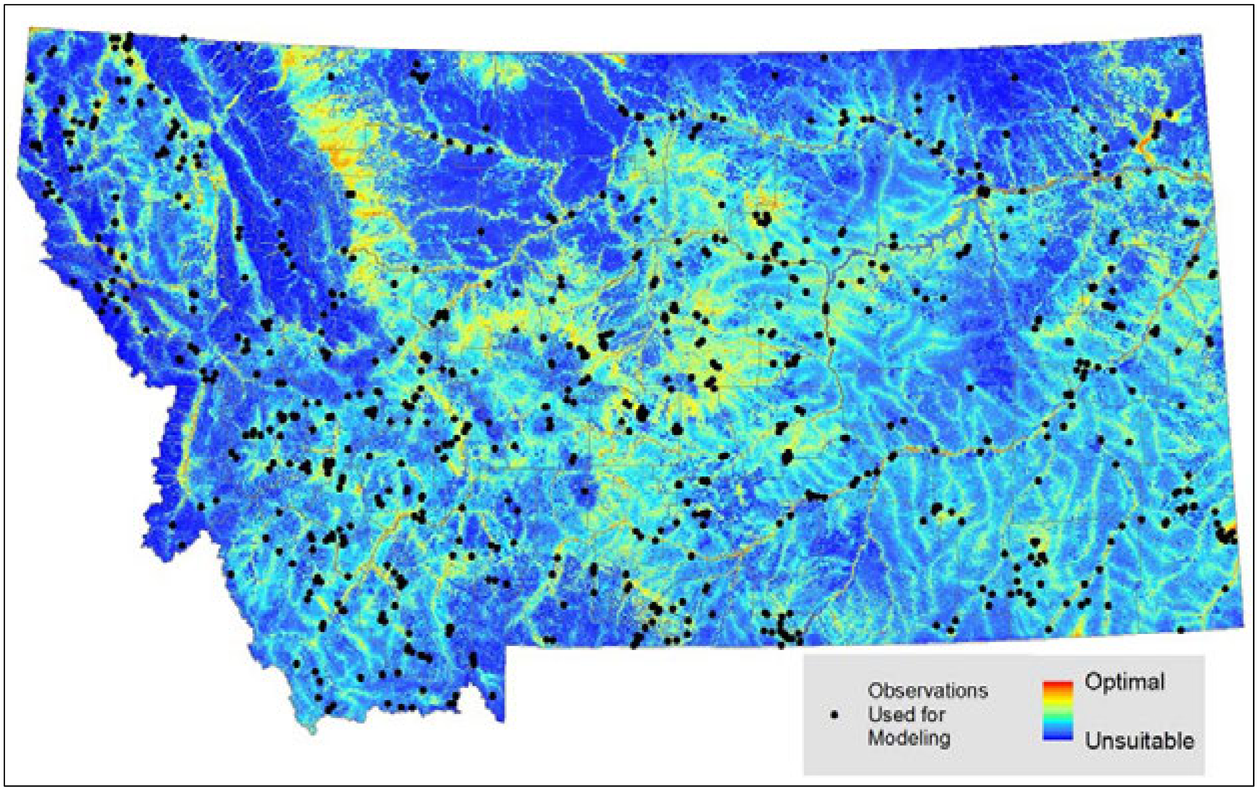


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

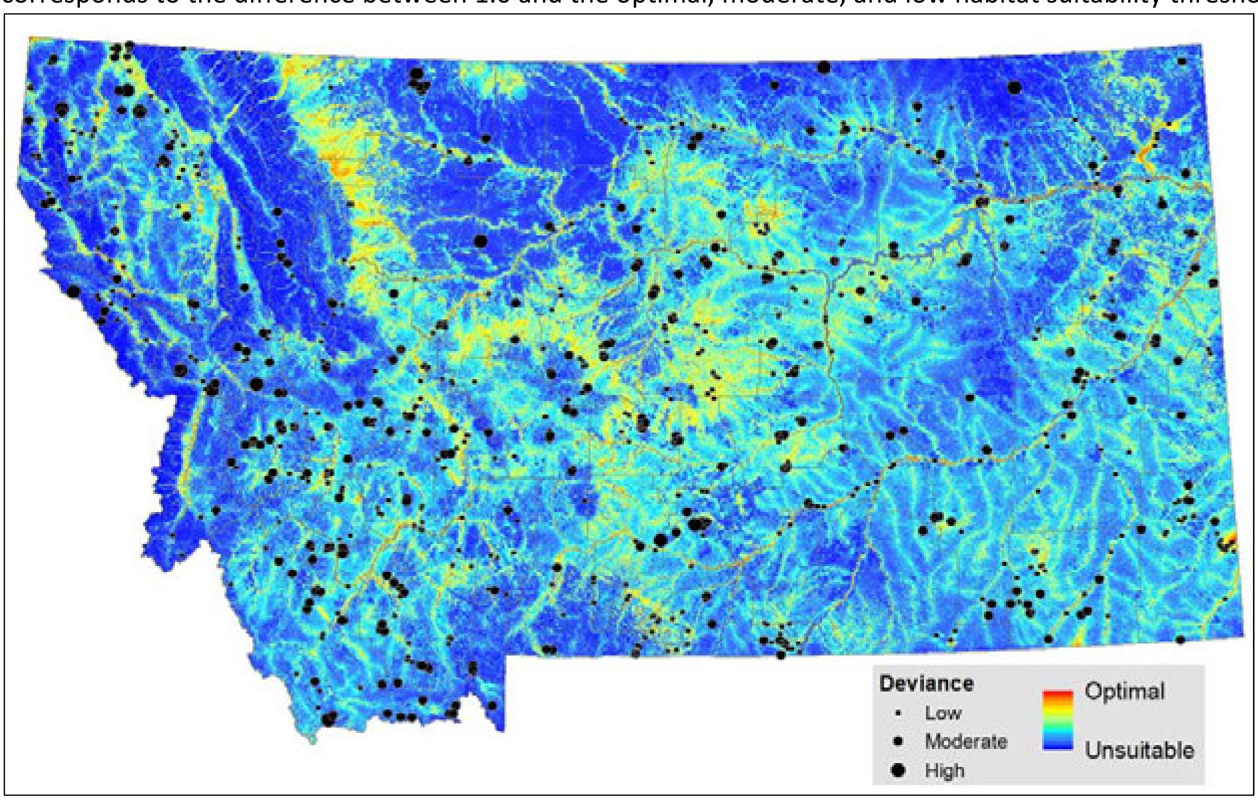


Figure 7. Continuous habitat suitability model output with all 1,352 observations (black) and survey locations that could have detected the species (gray).

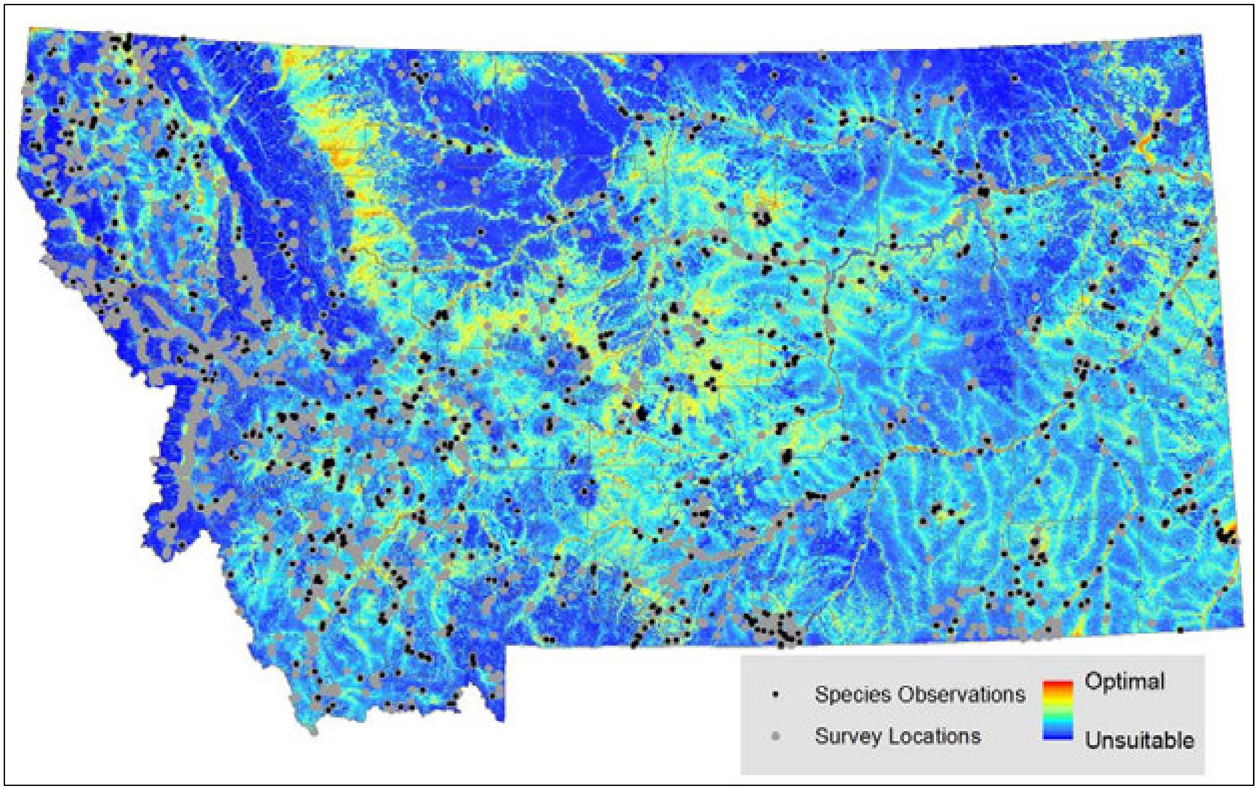


Figure 8. Model output classified into habitat suitability classes.

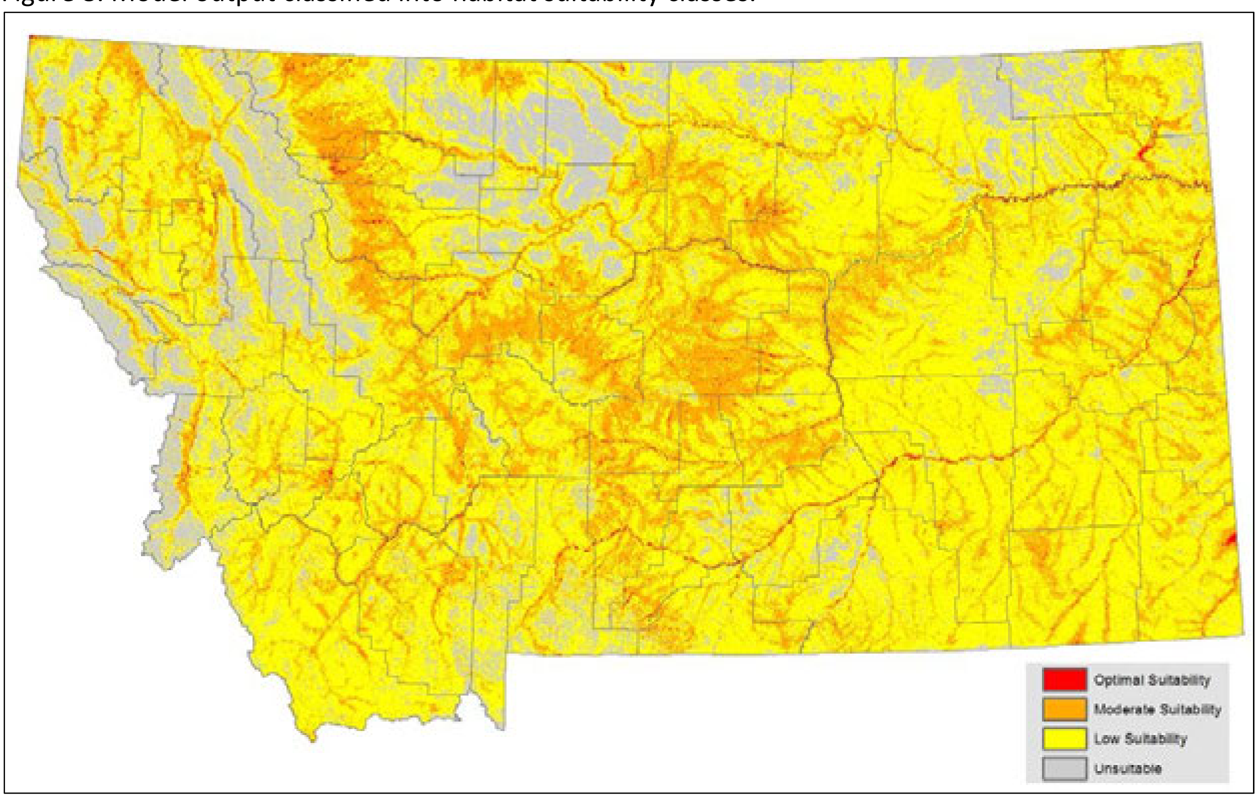
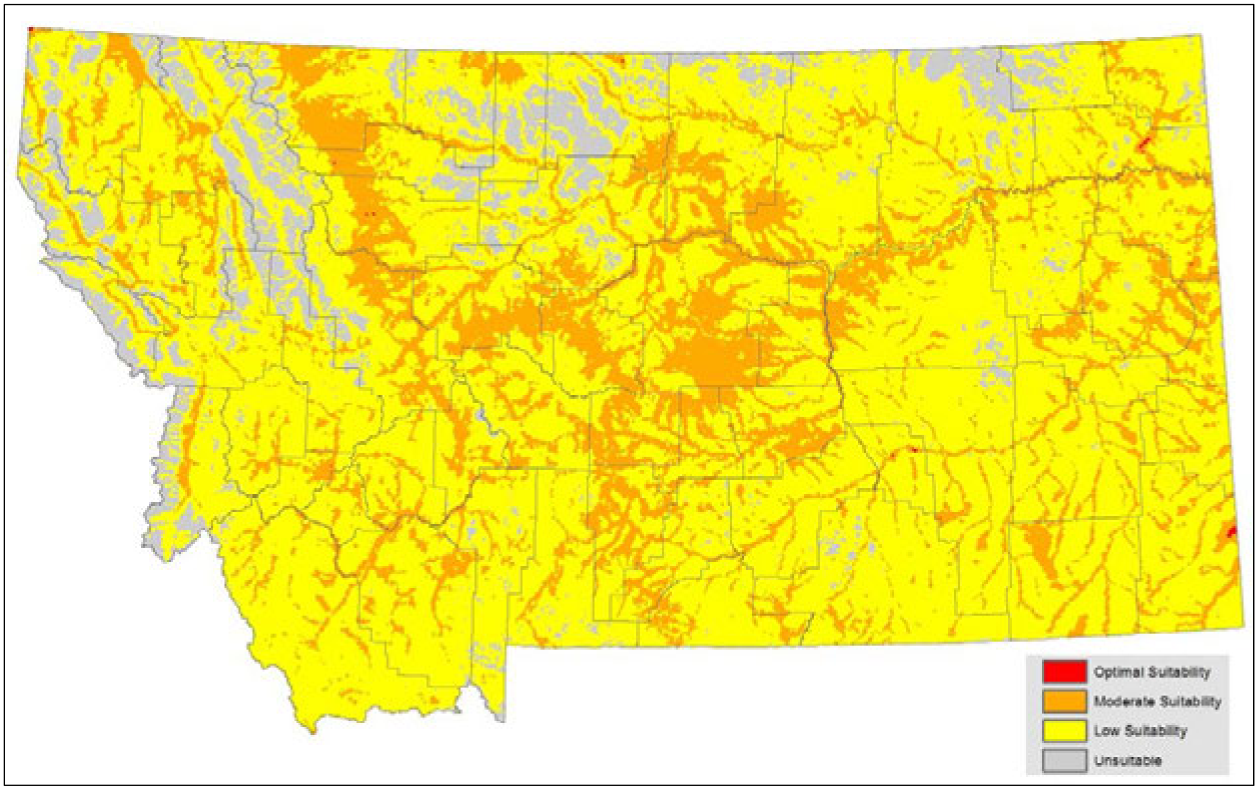


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Hoary Bat

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	69
Open Water	11	Common	52
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	52
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	41
Big Sagebrush Steppe	5454	Common	39
Montane Sagebrush Steppe	5455	Common	28
Great Plains Floodplain	9159	Common	28
Great Plains Riparian	9326	Common	28
Great Plains Badlands	3114	Common	24
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	21
Rocky Mountain Lodgepole Pine Forest	4237	Common	19
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	18
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	17
Alpine-Montane Wet Meadow	9217	Common	14
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	12
Great Plains Sand Prairie	7121	Common	10
Recently burned forest	8501	Common	10
Aspen Forest and Woodland	4104	Common	9
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	9
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	8
Great Plains Shrubland	5262	Common	8
Post-Fire Recovery	8505	Common	8
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	7
Great Plains Wooded Draw and Ravine	4328	Common	7
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	7
Recently burned grassland	8502	Common	7
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	5
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	5
Insect-Killed Forest	8700	Common	5
Introduced Riparian and Wetland Vegetation	8406	Common	4
Great Plains Saline Depression Wetland	9256	Common	4
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	3
Recently burned shrubland	8503	Common	3
Harvested forest-grass regeneration	8603	Common	3
Greasewood Flat	9103	Common	3
Mountain Mahogany Woodland and Shrubland	4303	Common	2
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Great Plains Open Freshwater Depression Wetland	9218	Common	2
Rocky Mountain Subalpine Woodland and Parkland	4233	Common	1
Harvested forest-tree regeneration	8601	Common	1

Table 5: Ecological Systems Associated with Hoary Bat

Ecological System	Code	Association	Count[a]
Harvested forest-shrub regeneration	8602	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	1
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Emergent Marsh	9222	Common	1
Great Plains Closed Depressional Wetland	9252	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Low Sagebrush Shrubland	5209	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Burned Sagebrush	8504	Common	0
Great Plains Prairie Pothole	9203	Common	0
Other Roads	28	Occasional	85
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	17
Cultivated Crops	82	Occasional	11
Developed, Open Space	21	Occasional	4
Low Intensity Residential	22	Occasional	4
Railroad	25	Occasional	3
Quarries, Strip Mines and Gravel Pits	31	Occasional	3
Pasture/Hay	81	Occasional	3
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Occasional	2
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	2
Great Plains Cliff and Outcrop	3142	Occasional	1
Active and Stabilized Dune	3160	Occasional	1
Mat Saltbush Shrubland	5203	Occasional	1
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	1
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 755 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

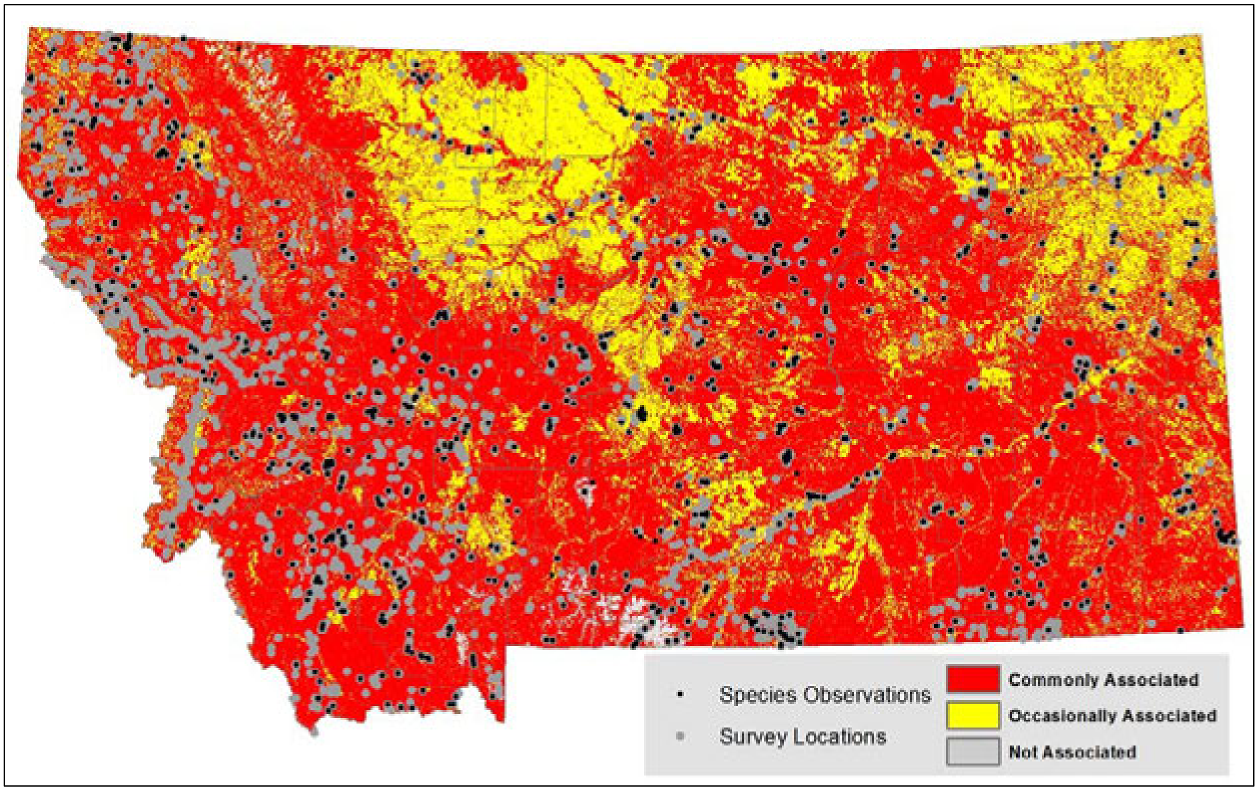
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	375,711.0 km^2
Area of Commonly Associated ES	274,844.0 km^2
Area of Occasionally Associated ES	100,867.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	97.9%
Commonly Associated ES AVI[a]	78.2%
Occasionally Associated ES AVI[a]	19.7%

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

Figure 10. Deductive model output classified into habitat associations.



California Myotis (*Myotis californicus*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 10, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 10, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across the species' known active season range in Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting what is known about the distribution of California Myotis active season habitat suitability at larger spatial scales across the species' known active season range in Montana. Evaluation metrics indicate a reasonably good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season, across the species' known active season range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of active season suitable habitat for California Myotis across the species' known active season range in Montana. Use of the inductive model is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. California Myotis (*Myotis californicus*) predicted suitable habitat models created on October 10, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.
Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01120

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	228
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	188
Location Data Selection Rule 2	No overlap in locations within 500 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	130
Season Modeled	Summer
Number of Model Background Locations	21,090

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catsoiltemp	15.7%	contwinrad	3.5%
catesys	13.0%	contwinpcp	3.4%
contelev	10.1%	contprecip	3.3%
contddays	9.2%	contfrsted	2.9%
catgeol	7.1%	contvrm	2.4%
contndvi	6.9%	catsoilord	2.2%
contslope	5.0%	contewasp	1.2%
contnsasp	4.6%	contstrmed	0.8%
conttmin	4.4%	contsumrad	0.7%
conttmax	3.6%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.052
Moderate Logistic Threshold[b]	0.250
Optimal Logistic Threshold[c]	0.700
Area of entire modeled range (percent of Montana)	133,756.6 km^2 (35.2%)
Total area of predicted suitable habitat within modeled range	67,561.2 km^2
Area of predicted low suitability habitat within modeled range	46,594.9 km^2
Area of moderate suitability habitat within modeled range	19,028.0 km^2
Area of predicted optimal habitat within modeled range	1,938.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	90.0%
Moderate AVI[a]	71.5%
Optimal AVI[a]	25.4%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.482 ± 2.503
Training AUC[c]	0.906
Test AUC[d]	0.843

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.894, 2.771 and 0.714, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

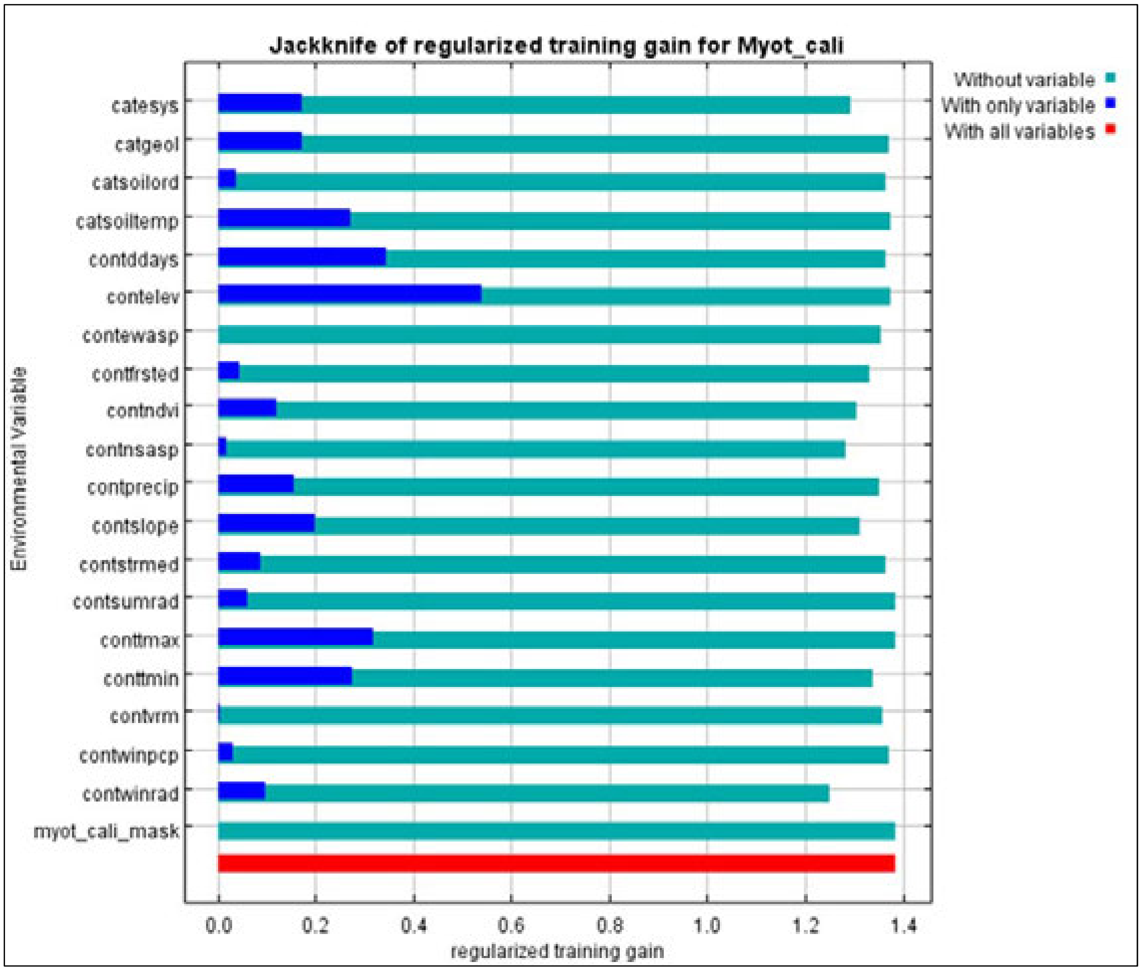
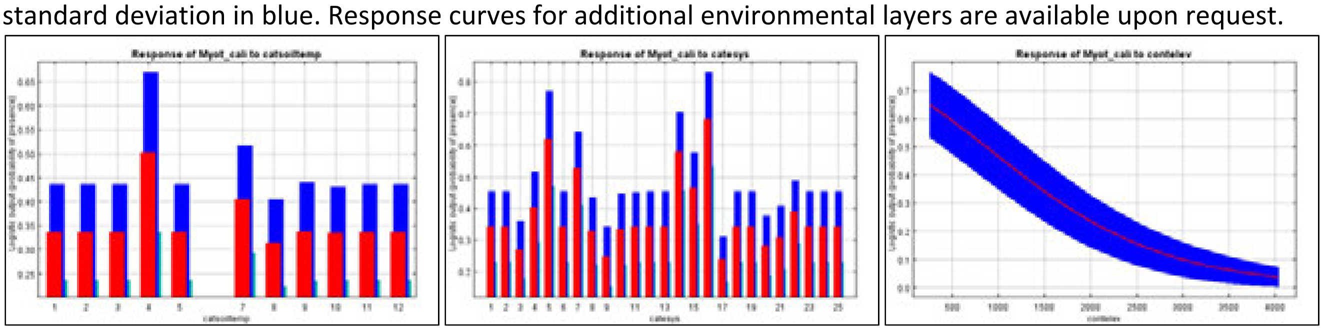


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

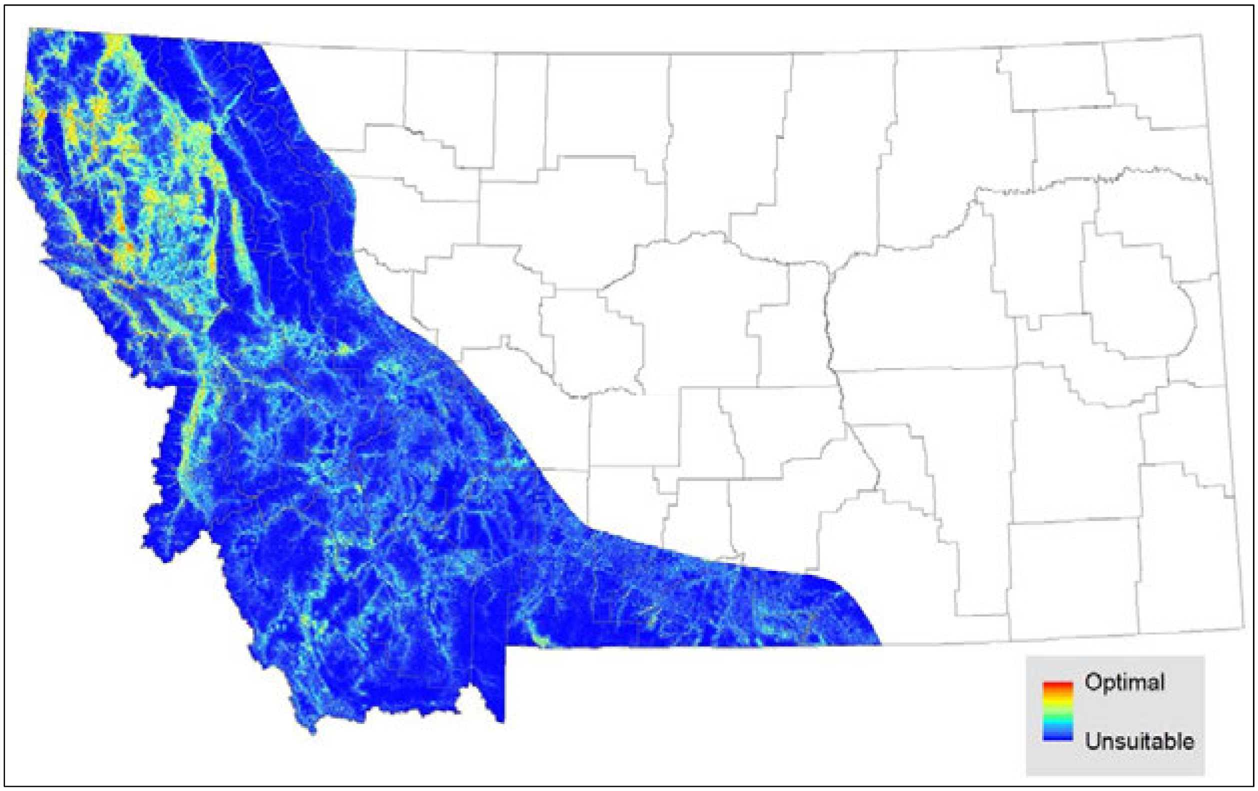


Figure 4. Standard deviation in the model output across the averaged models.

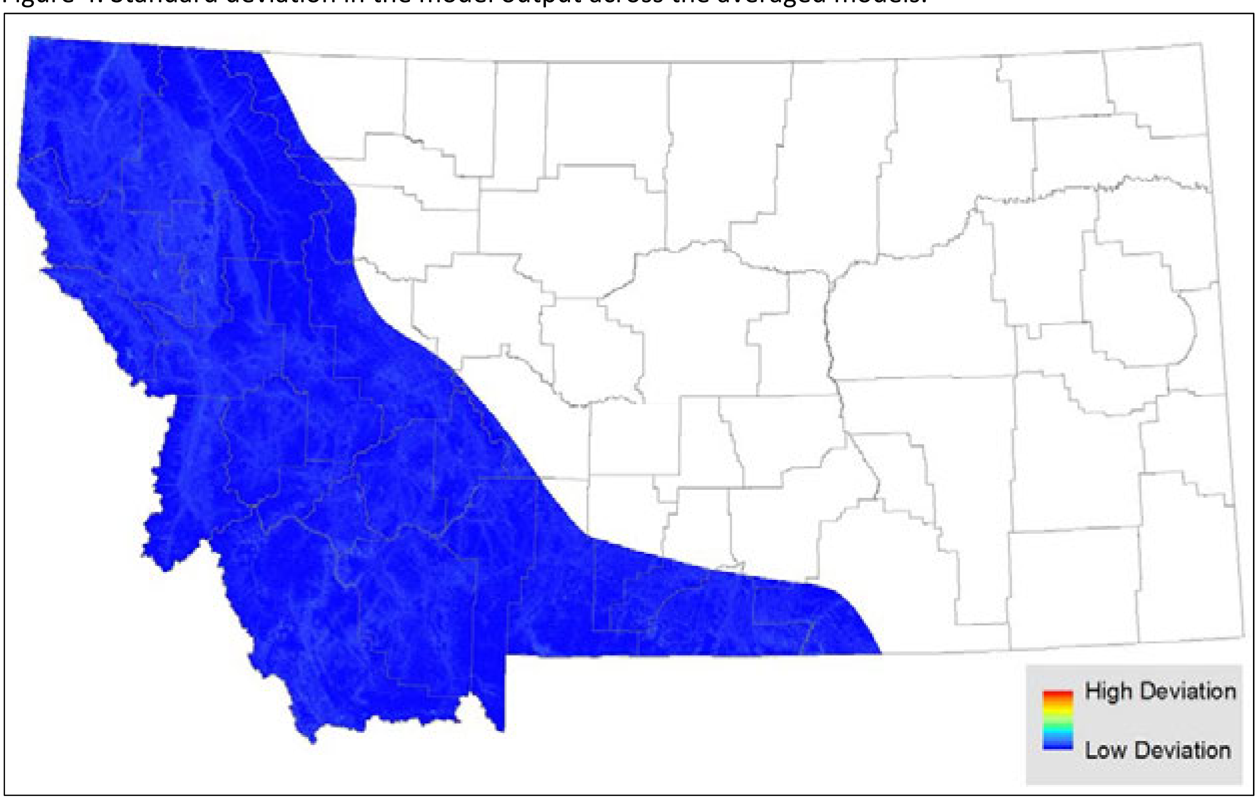


Figure 5. Continuous habitat suitability model output with the 130 observations used for modeling.

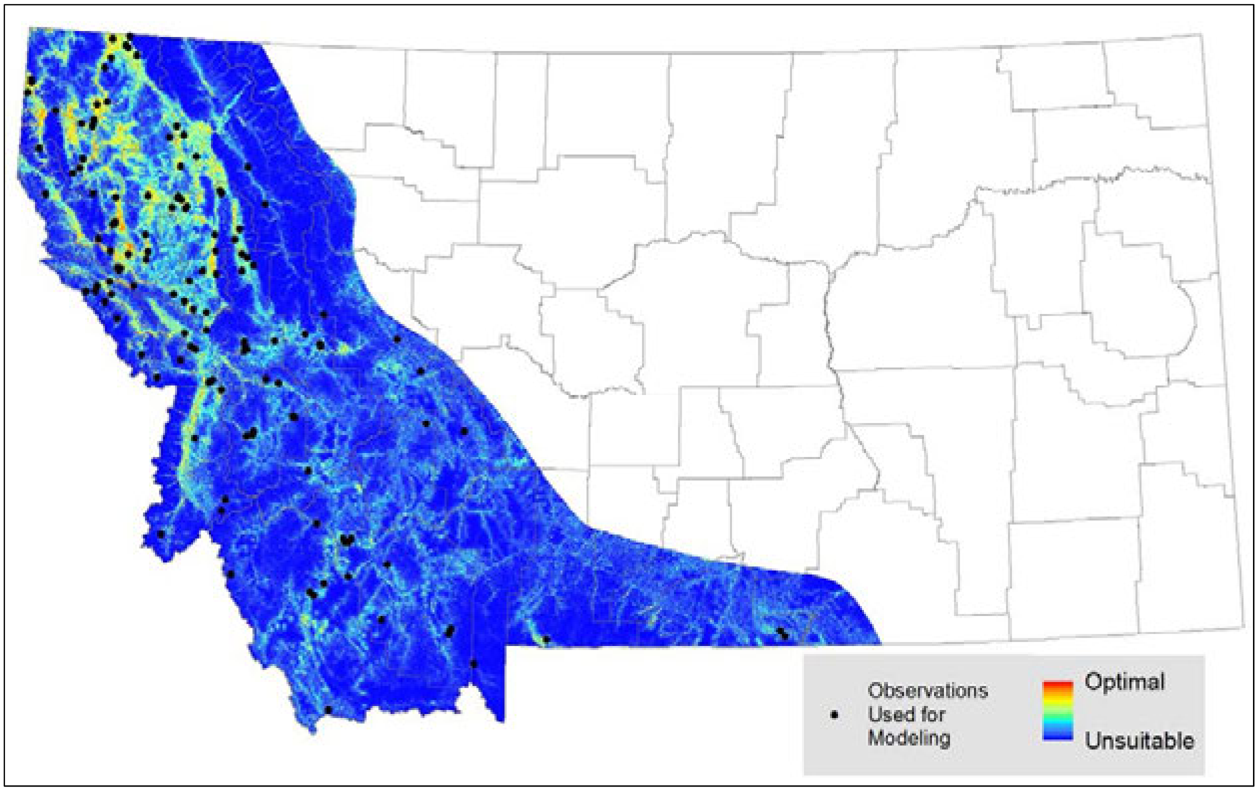


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

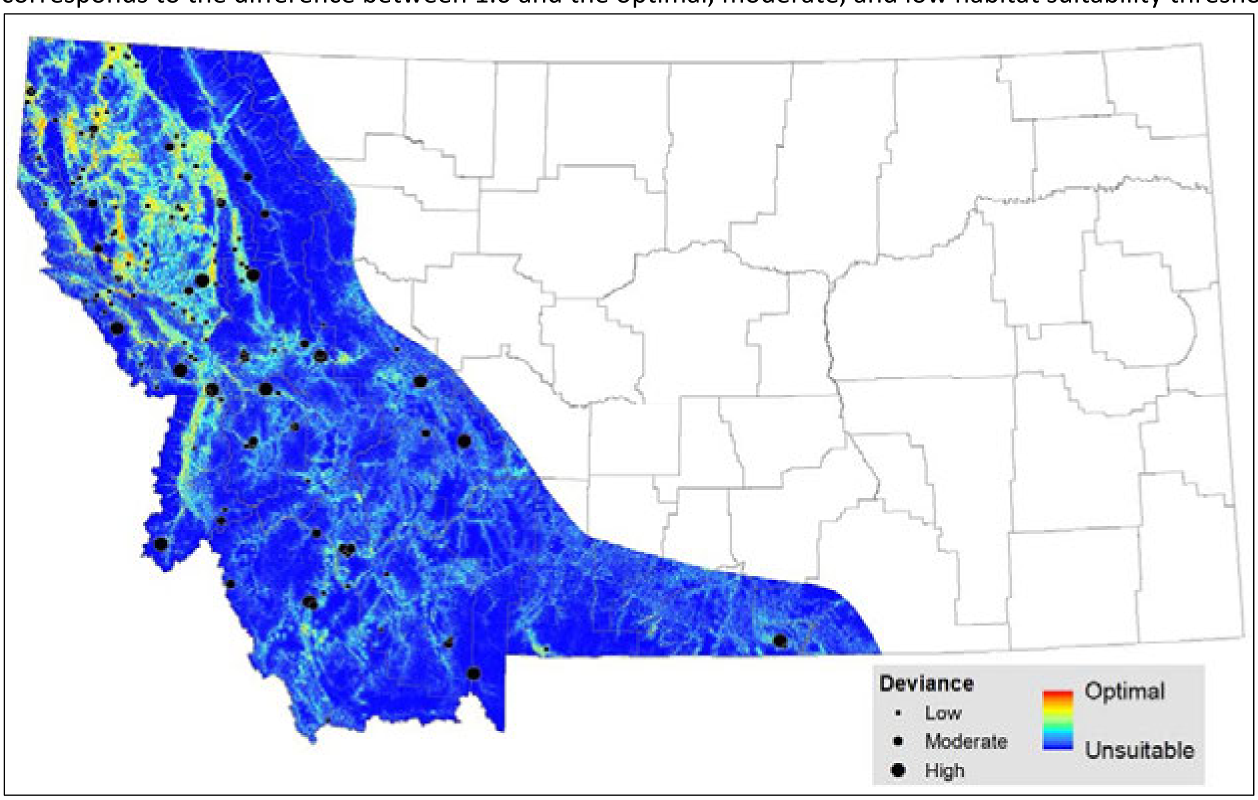


Figure 7. Continuous habitat suitability model output with all 228 observations (black) and survey locations that could have detected the species (gray).

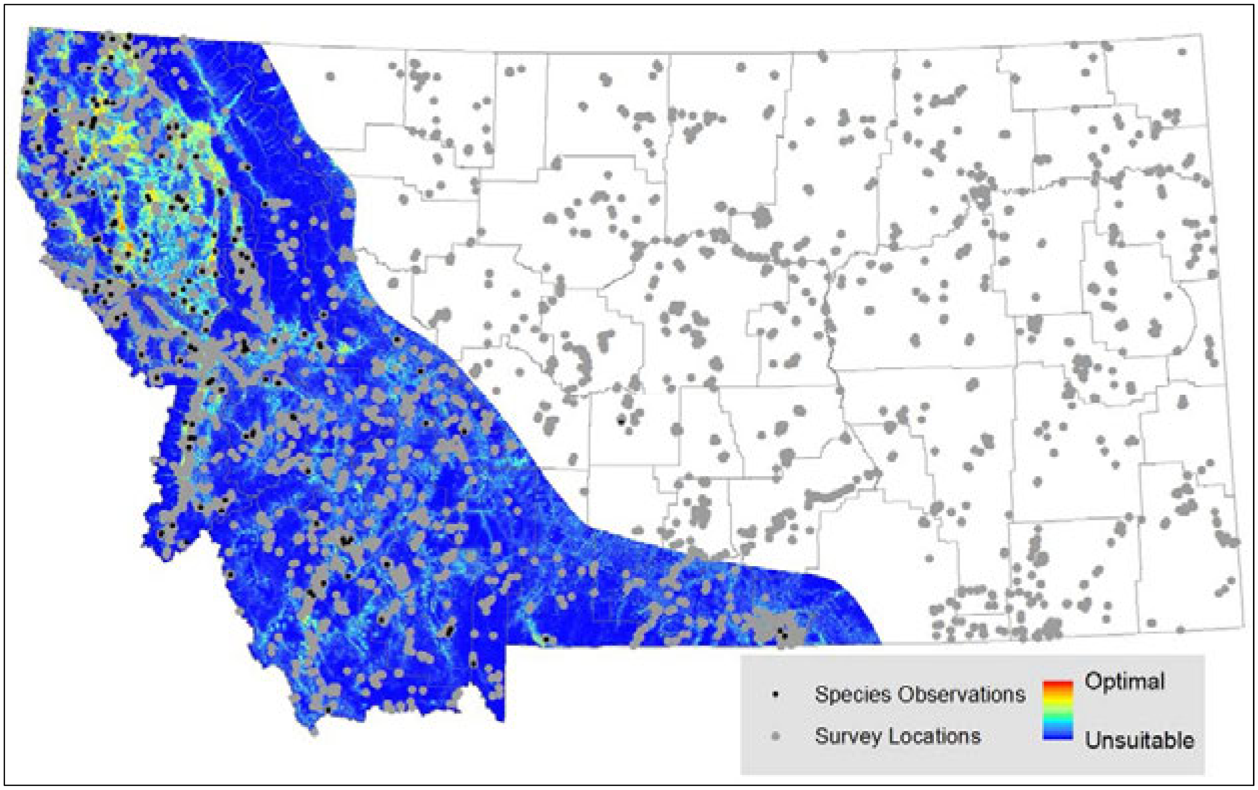


Figure 8. Model output classified into habitat suitability classes.

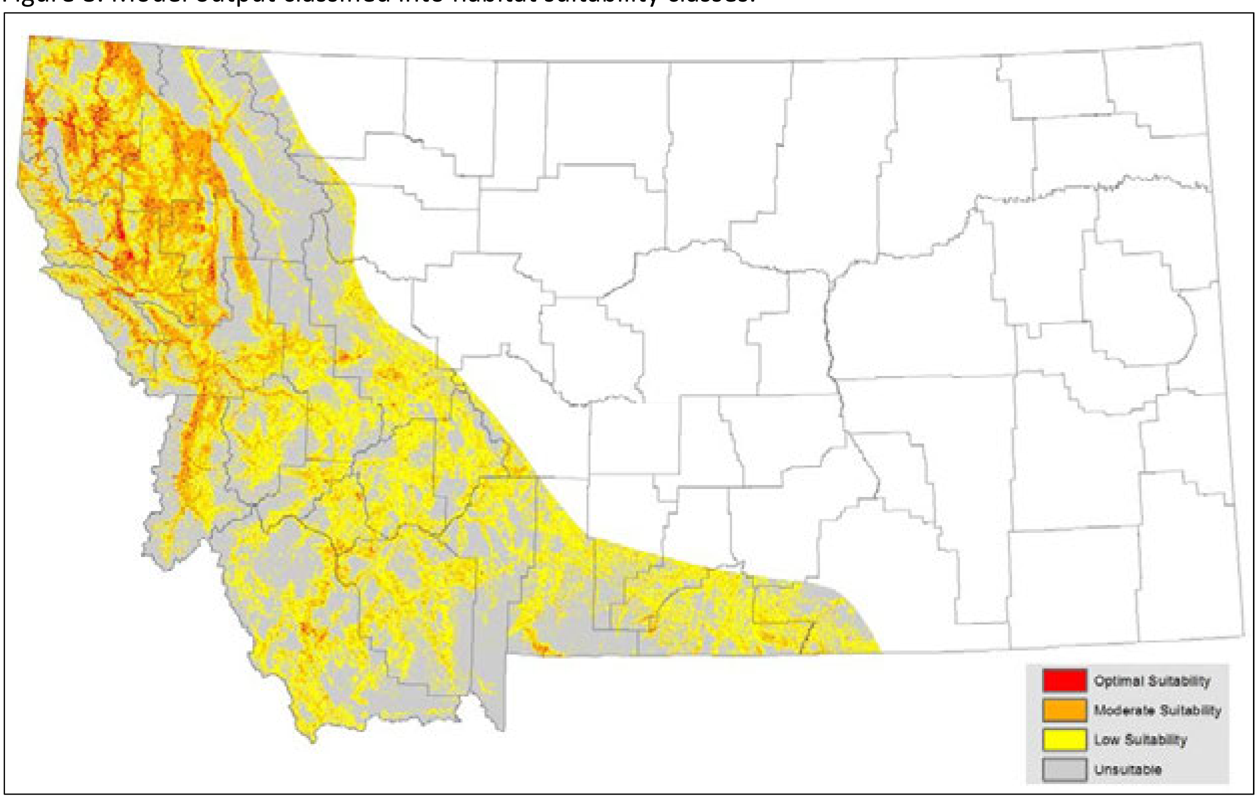
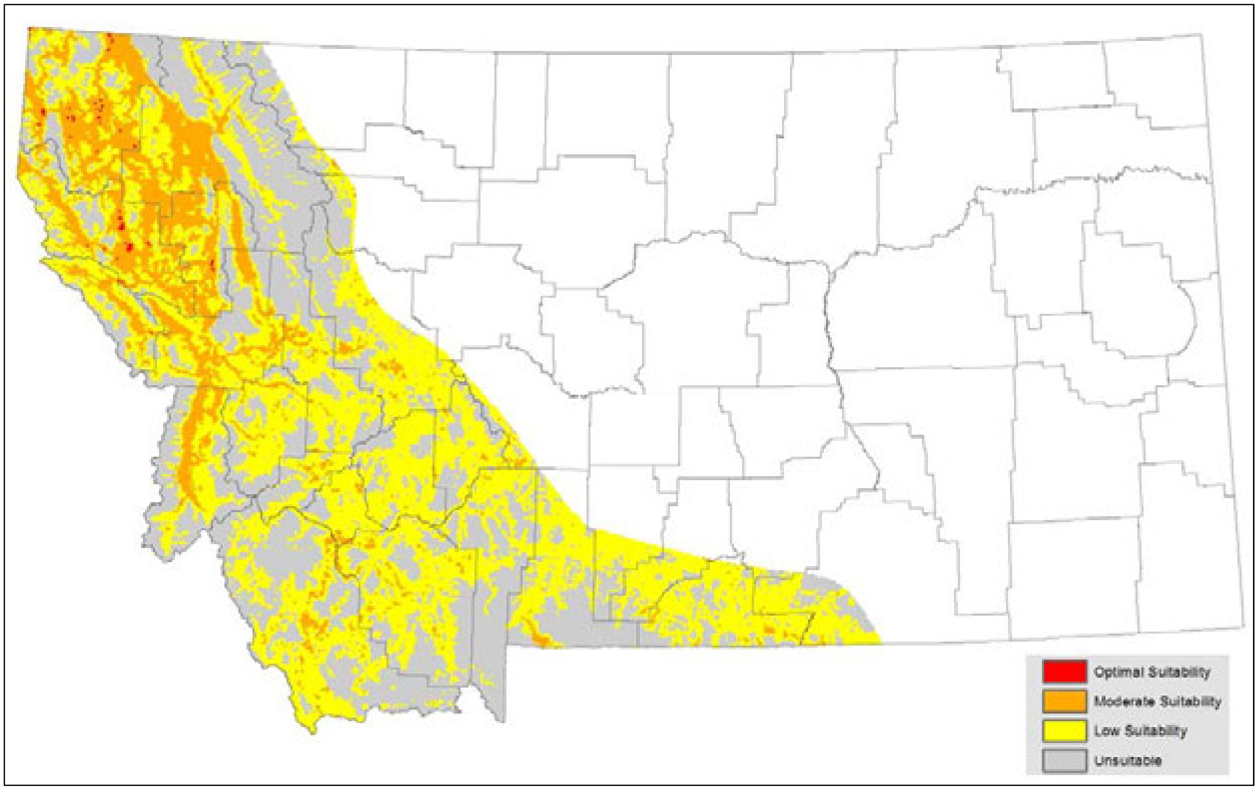


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with California Myotis

Ecological System	Code	Association	Count[a]
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	19
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	16
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	15
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	14
Montane Sagebrush Steppe	5455	Common	11
Rocky Mountain Lodgepole Pine Forest	4237	Common	6
Open Water	11	Common	4
Alpine-Montane Wet Meadow	9217	Common	4
Harvested forest-tree regeneration	8601	Common	3
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	2
Post-Fire Recovery	8505	Common	2
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	1
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	1
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	1
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	1
Recently burned forest	8501	Common	1
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	1
Insect-Killed Forest	8700	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen Forest and Woodland	4104	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Mountain Mahogany Woodland and Shrubland	4303	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Harvested forest-shrub regeneration	8602	Common	0
Harvested forest-grass regeneration	8603	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Emergent Marsh	9222	Common	0
Rocky Mountain Subalpine-Montane Fen	9234	Common	0
Other Roads	28	Occasional	16
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	2
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	2
Major Roads	27	Occasional	1
Pasture/Hay	81	Occasional	1
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Occasional	1
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	1
Developed, Open Space	21	Occasional	0

Table 5: Ecological Systems Associated with California Myotis

Ecological System	Code	Association	Count[a]
Low Intensity Residential	22	Occasional	0
Railroad	25	Occasional	0
Quarries, Strip Mines and Gravel Pits	31	Occasional	0
Cultivated Crops	82	Occasional	0
Shale Badland	3139	Occasional	0
Great Plains Cliff and Outcrop	3142	Occasional	0
Active and Stabilized Dune	3160	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Great Plains Ponderosa Pine Woodland and Savanna	4280	Occasional	0
Great Plains Wooded Draw and Ravine	4328	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Big Sagebrush Shrubland	5257	Occasional	0
Big Sagebrush Steppe	5454	Occasional	0
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Recently burned grassland	8502	Occasional	0
Recently burned shrubland	8503	Occasional	0
Burned Sagebrush	8504	Occasional	0
Great Plains Saline Depression Wetland	9256	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 130 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

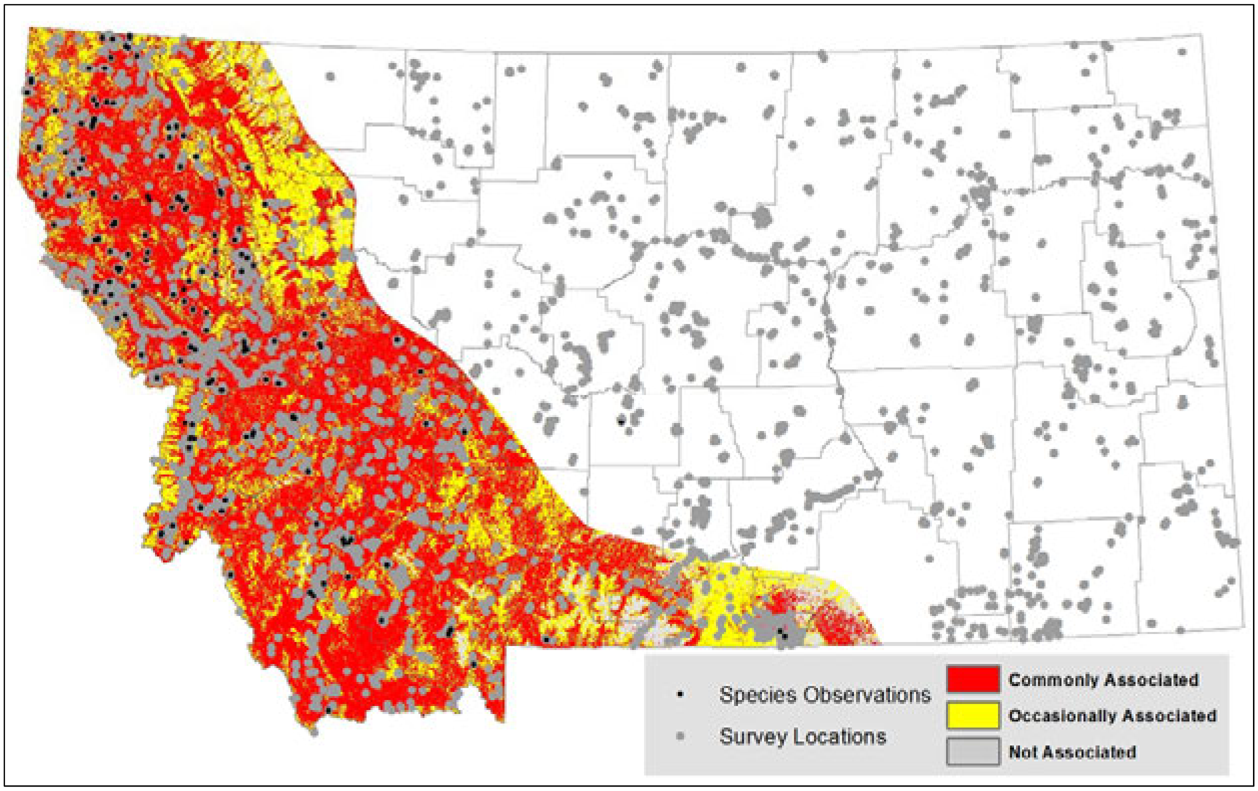
Measure	Value
Area of entire modeled range (percent of Montana)	133,756.6 km^2 (35.2%)
Area of Commonly and Occasionally Associated ES	127,466.0 km^2
Area of Commonly Associated ES	86,521.0 km^2
Area of Occasionally Associated ES	40,945.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	97.7%
Commonly Associated ES AVI[a]	79.2%
Occasionally Associated ES AVI[a]	18.5%

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

Figure 10. Deductive model output classified into habitat associations.



Western Small-footed Myotis (*Myotis ciliolabrum*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.

Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Western Small-footed Myotis active season habitat suitability at larger spatial scales across Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.

Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with likely greatly overpredict the amount of active season suitable habitat for Western Small-footed Myotis across Montana. Use of the inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Western Small-footed Myotis (*Myotis ciliolabrum*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01140

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,010
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	874
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	510
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	31.4%	conttmax	2.8%
contwinpcp	13.8%	conttmin	1.5%
catsoiltemp	8.4%	contddays	1.2%
catgeol	8.0%	contelev	1.1%
contvrm	6.2%	contslope	1.1%
contfrsted	5.3%	contewasp	1.1%
catsoilord	5.1%	contwinrad	1.0%
contstrmed	3.7%	contndvi	0.9%
contnsasp	3.6%	contsumrad	0.7%
contprecip	2.9%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.079
Moderate Logistic Threshold[b]	0.363
Optimal Logistic Threshold[c]	0.780
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	283,249.4 km^2
Area of predicted low suitability habitat within modeled range	196,165.4 km^2
Area of moderate suitability habitat within modeled range	83,074.0 km^2
Area of predicted optimal habitat within modeled range	4,010.0 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	96.9%
Moderate AVI[a]	66.7%
Optimal AVI[a]	17.8%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.733 ± 1.367
Training AUC[c]	0.829
Test AUC[d]	0.803

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.082, 2.027 and 0.496, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

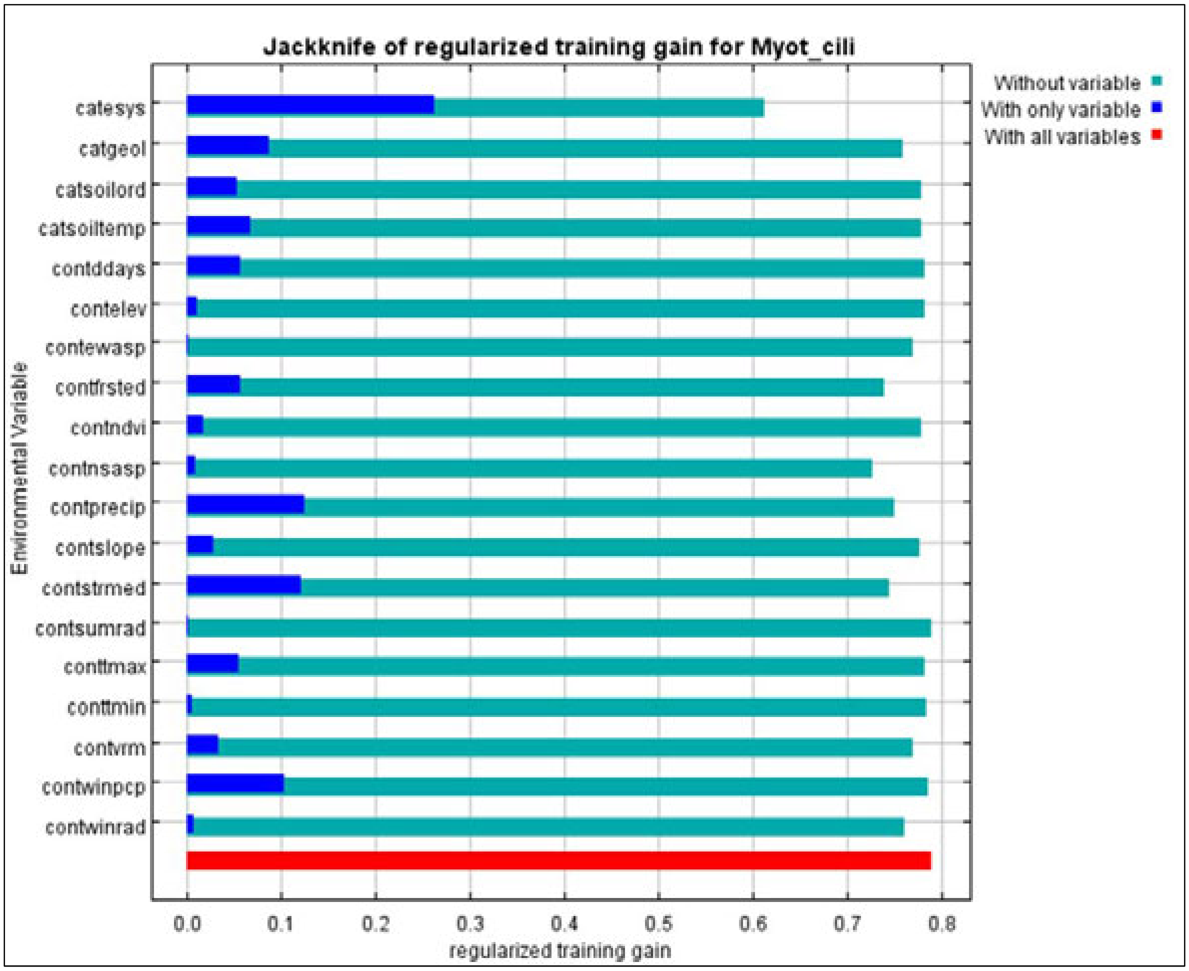
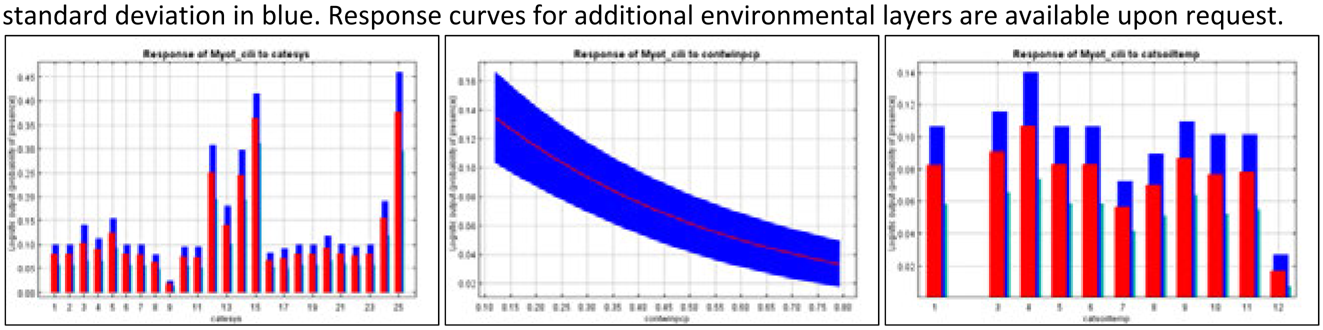


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

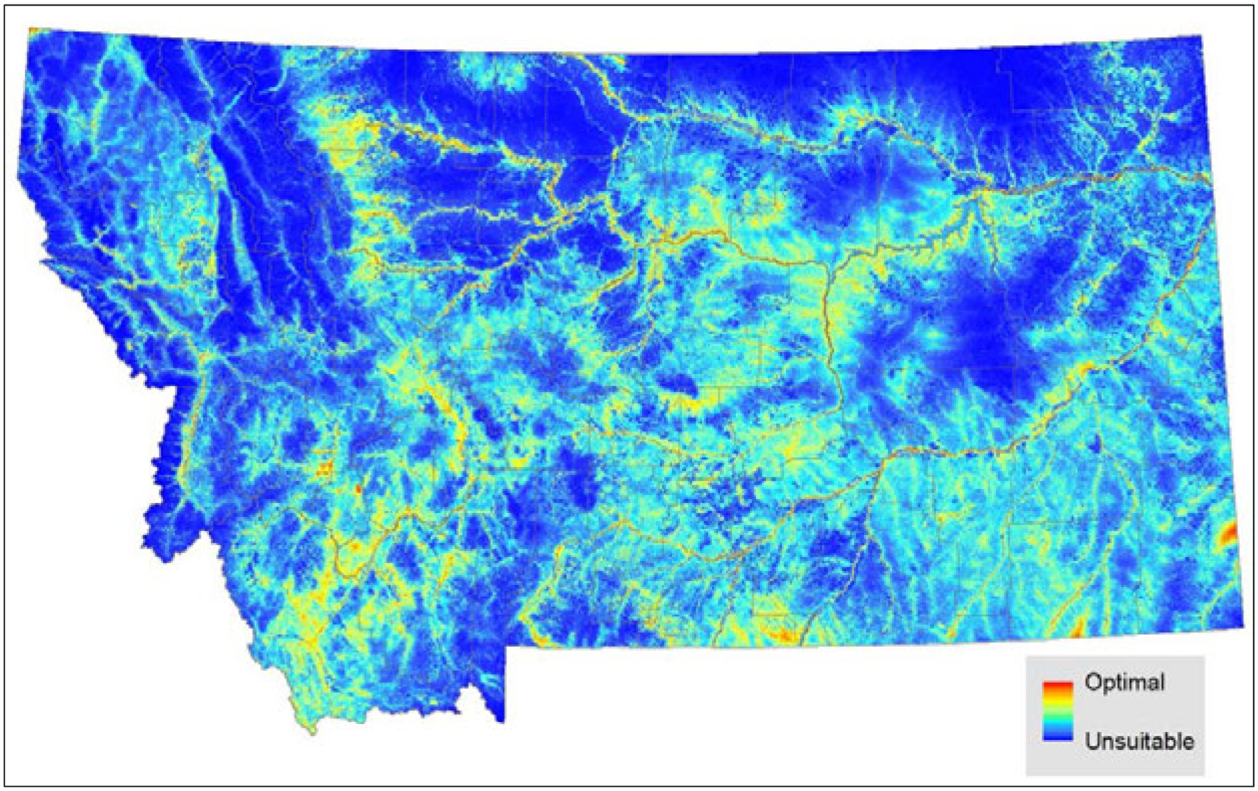


Figure 4. Standard deviation in the model output across the averaged models.

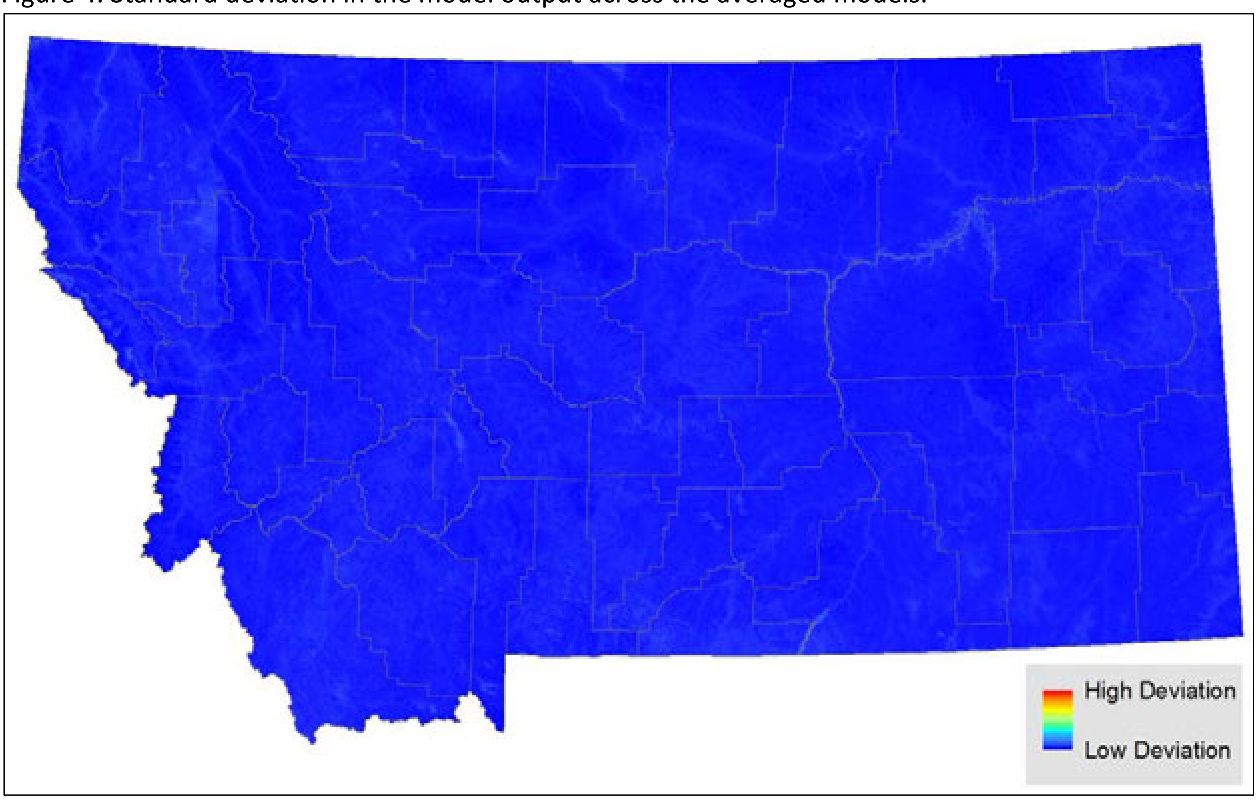


Figure 5. Continuous habitat suitability model output with the 510 observations used for modeling.

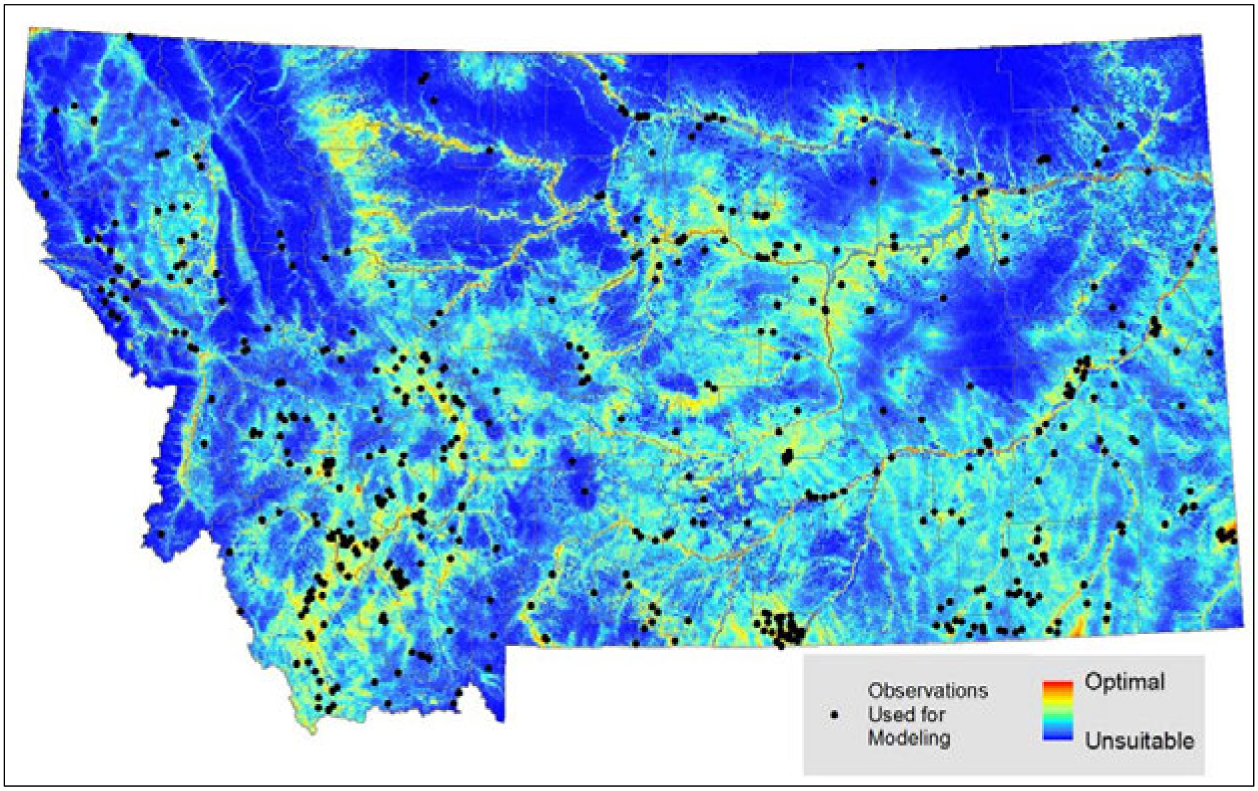


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

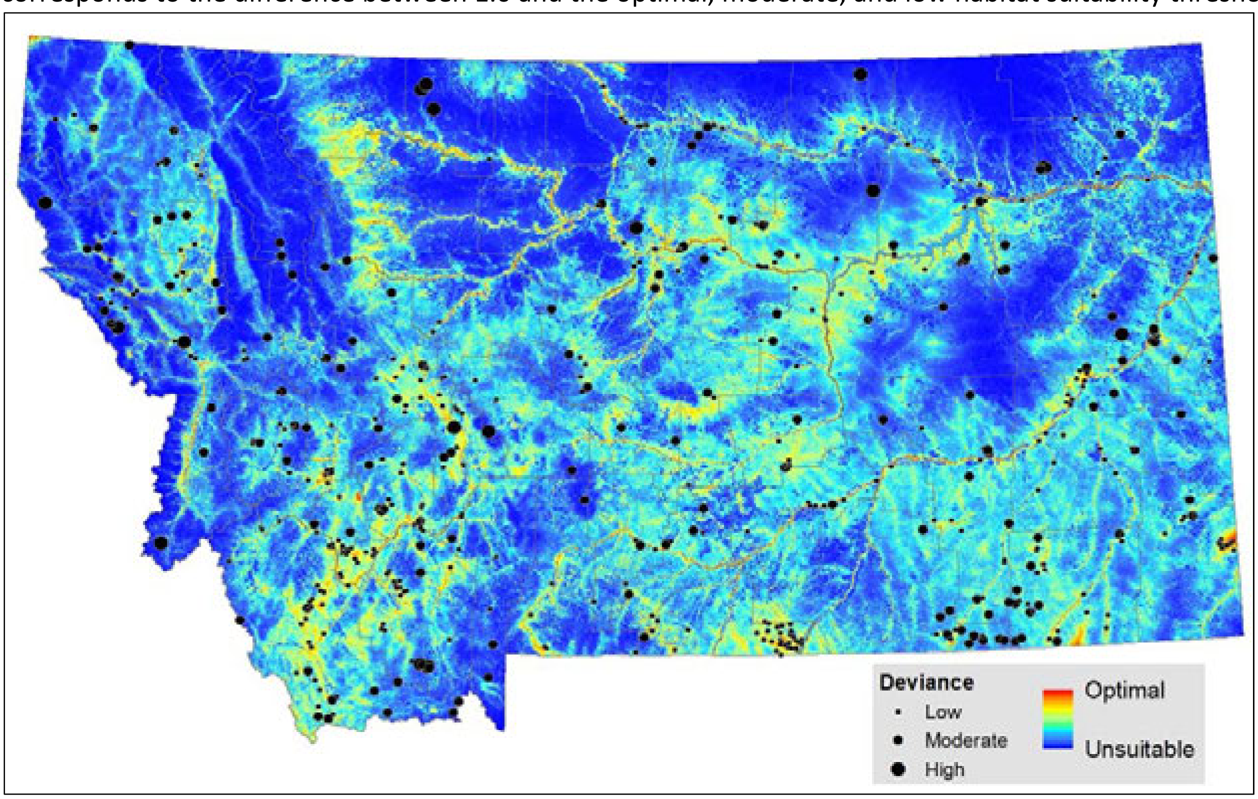


Figure 7. Continuous habitat suitability model output with all 1,010 observations (black) and survey locations that could have detected the species (gray).

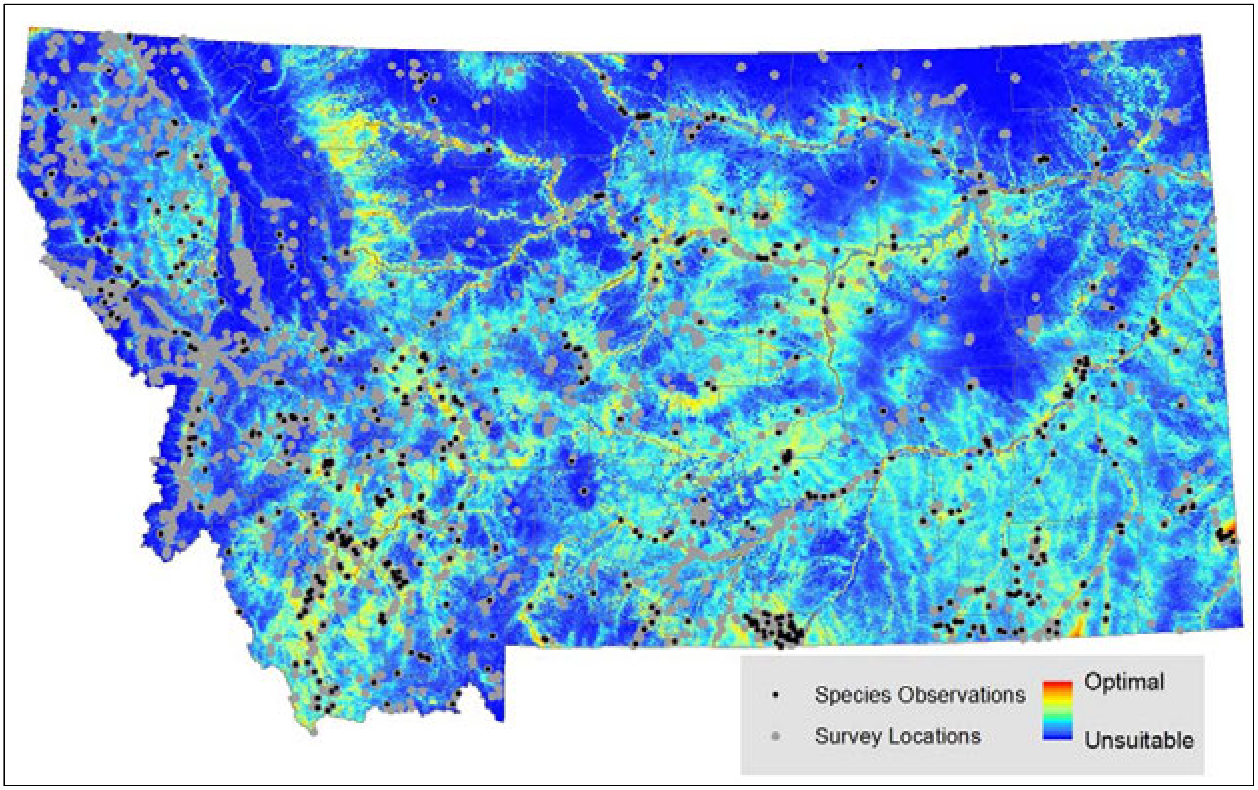


Figure 8. Model output classified into habitat suitability classes.

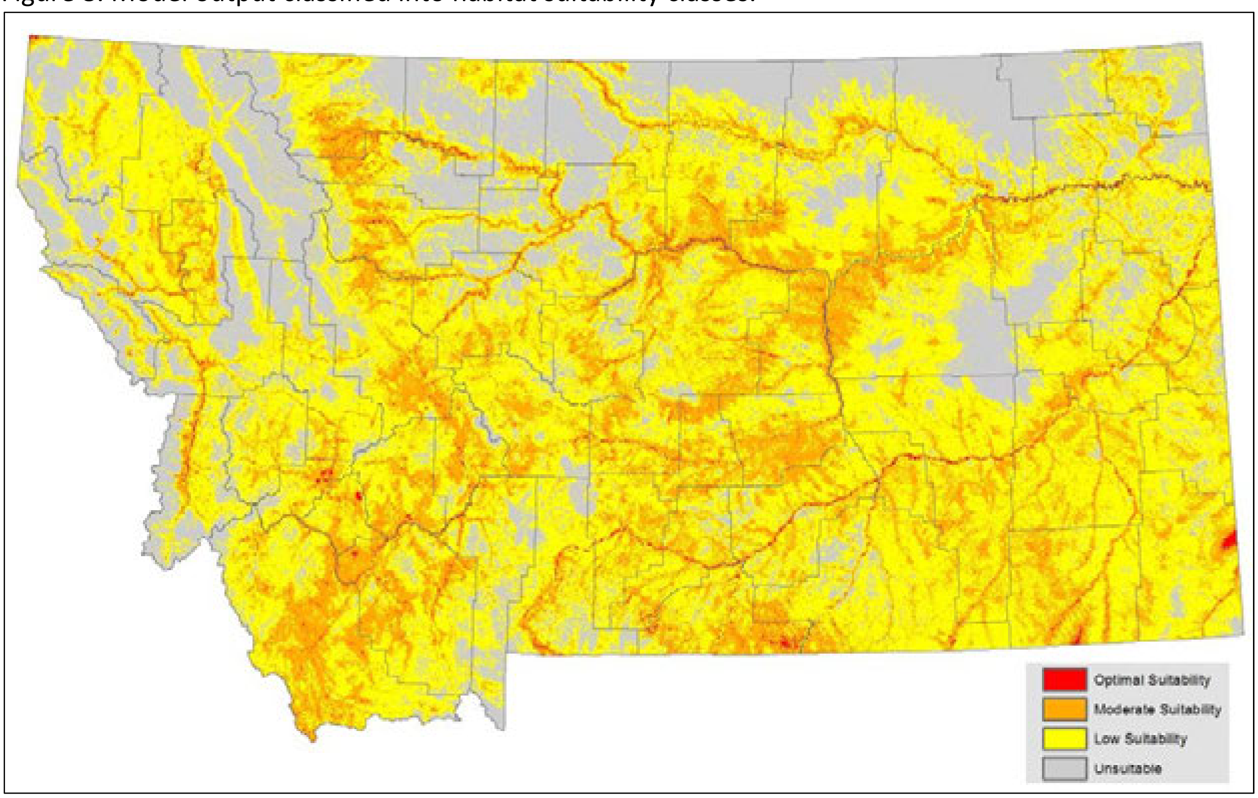
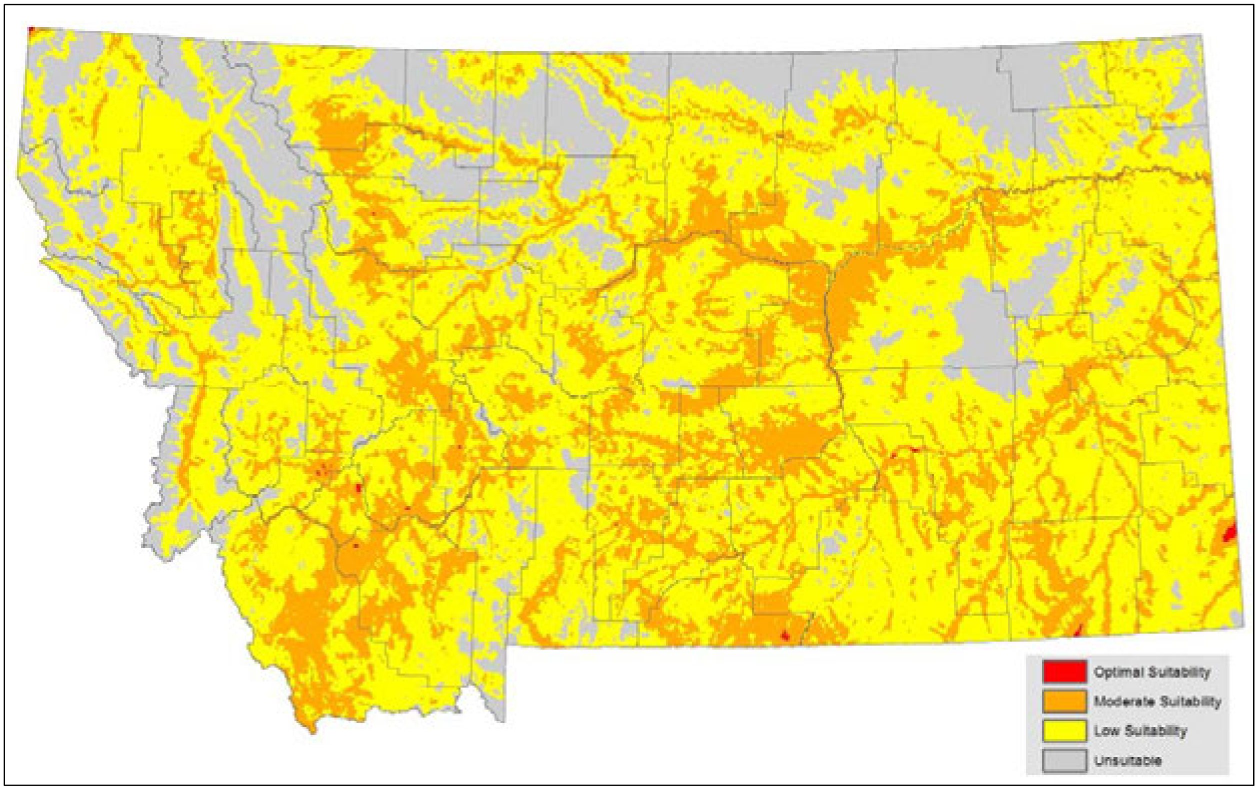


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Western Small-footed Myotis

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	50
Montane Sagebrush Steppe	5455	Common	43
Big Sagebrush Steppe	5454	Common	33
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	30
Open Water	11	Common	28
Great Plains Badlands	3114	Common	24
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	24
Great Plains Floodplain	9159	Common	23
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	19
Great Plains Riparian	9326	Common	19
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	12
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	12
Recently burned forest	8501	Common	10
Rocky Mountain Lodgepole Pine Forest	4237	Common	9
Post-Fire Recovery	8505	Common	9
Alpine-Montane Wet Meadow	9217	Common	9
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	8
Great Plains Sand Prairie	7121	Common	7
Low Intensity Residential	22	Common	5
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	5
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	5
Great Plains Wooded Draw and Ravine	4328	Common	5
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	4
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	4
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	3
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	3
Insect-Killed Forest	8700	Common	3
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	2
Harvested forest-grass regeneration	8603	Common	2
Developed, Open Space	21	Common	1
Great Plains Cliff and Outcrop	3142	Common	1
Aspen Forest and Woodland	4104	Common	1
Mountain Mahogany Woodland and Shrubland	4303	Common	1
Great Plains Open Freshwater Depression Wetland	9218	Common	1
Emergent Marsh	9222	Common	1
Great Plains Closed Depressional Wetland	9252	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0

Table 5: Ecological Systems Associated with Western Small-footed Myotis

Ecological System	Code	Association	Count[a]
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Great Plains Shrubland	5262	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Harvested forest-tree regeneration	8601	Common	0
Harvested forest-shrub regeneration	8602	Common	0
Greasewood Flat	9103	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Great Plains Prairie Pothole	9203	Common	0
Rocky Mountain Subalpine-Montane Fen	9234	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Other Roads	28	Occasional	58
Major Roads	27	Occasional	5
Recently burned grassland	8502	Occasional	5
Interstate	26	Occasional	3
Quarries, Strip Mines and Gravel Pits	31	Occasional	3
Cultivated Crops	82	Occasional	3
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	3
Introduced Riparian and Wetland Vegetation	8406	Occasional	2
Recently burned shrubland	8503	Occasional	2
Commercial/Industrial	24	Occasional	1
Railroad	25	Occasional	1
Pasture/Hay	81	Occasional	1
Shale Badland	3139	Occasional	1
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	1
Mat Saltbush Shrubland	5203	Occasional	1
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	1
High Intensity Residential	23	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Burned Sagebrush	8504	Occasional	0
Coal Bed Methane	32	Occasional	0
Gas and Gas Storage	33	Occasional	0
Injection	34	Occasional	0
Oil and Oil and Gas	35	Occasional	0
Wind Turbine	40	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 510 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

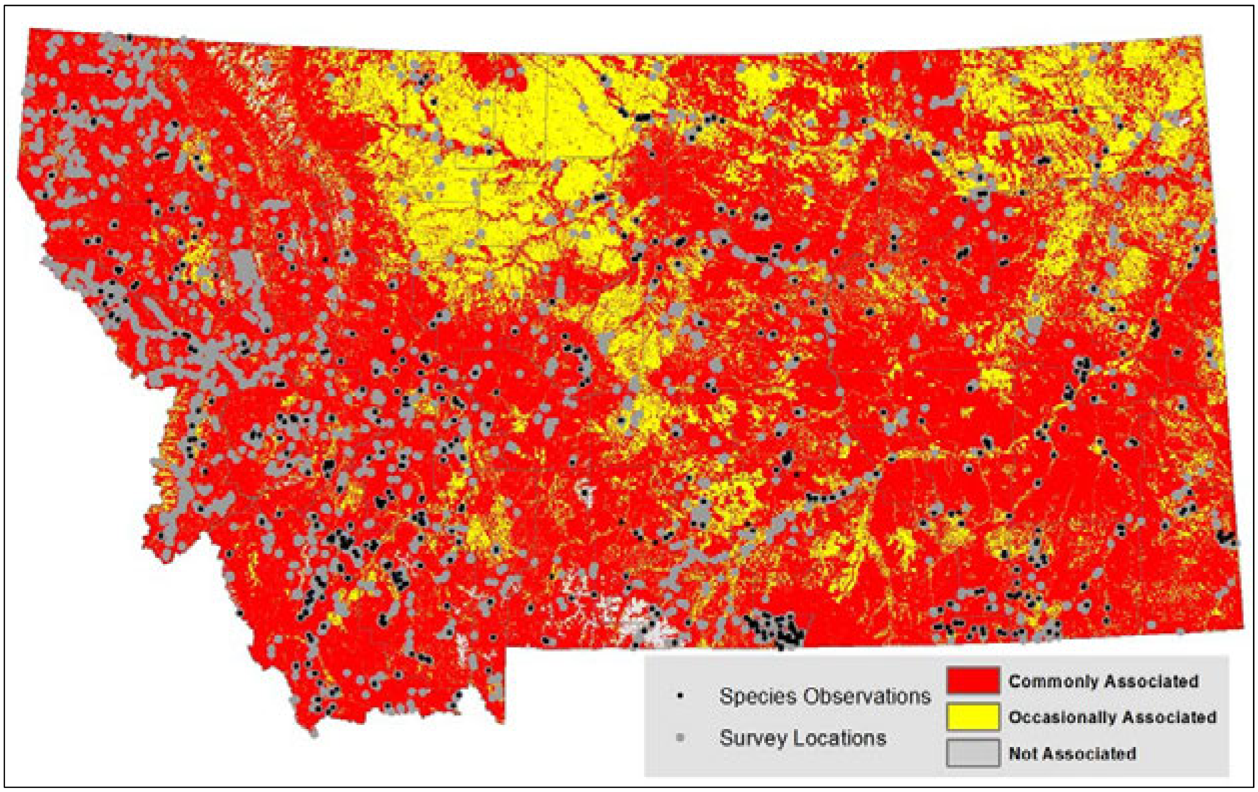
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	376,964.0 km^2
Area of Commonly Associated ES	285,374.0 km^2
Area of Occasionally Associated ES	91,591.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	100.0%
Commonly Associated ES AVI[a]	82.2%
Occasionally Associated ES AVI[a]	17.8%

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

Figure 10. Deductive model output classified into habitat associations.



Long-eared Myotis (*Myotis evotis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Long-eared Myotis active season habitat suitability at larger spatial scales across Montana. Evaluation metrics suggest a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with seem to overpredict the amount of suitable active season habitat for Long-eared Myotis across Montana. Use of the inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Long-eared Myotis (*Myotis evotis*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01070

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,361
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,244
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	687
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	26.6%	contstrmed	3.7%
contfrsted	8.1%	catsoilord	3.5%
contvrm	8.0%	conttmin	3.0%
catsoiltemp	6.4%	contwinrad	2.9%
contwinpcp	5.9%	contndvi	2.8%
contprecip	5.3%	contddays	2.0%
contslope	5.0%	contelev	1.3%
conttmax	4.9%	contewasp	1.1%
catgeol	4.3%	contsumrad	0.9%
contnsasp	4.2%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.082
Moderate Logistic Threshold[b]	0.379
Optimal Logistic Threshold[c]	0.771
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	279,244.0 km^2
Area of predicted low suitability habitat within modeled range	196,614.9 km^2
Area of moderate suitability habitat within modeled range	78,461.1 km^2
Area of predicted optimal habitat within modeled range	4,168.0 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

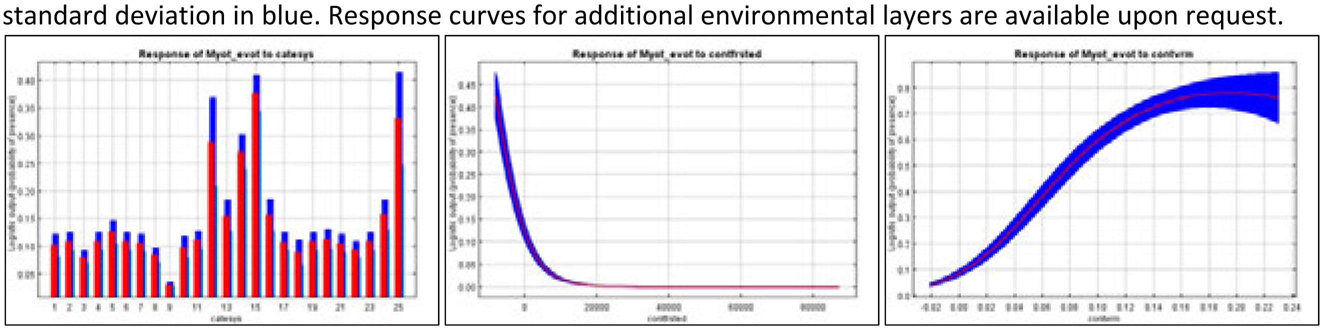
Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.1%
Moderate AVI[a]	72.0%
Optimal AVI[a]	16.7%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.588 ± 1.203
Training AUC[c]	0.847
Test AUC[d]	0.829

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 5.007, 1.939 and 0.521, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

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



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

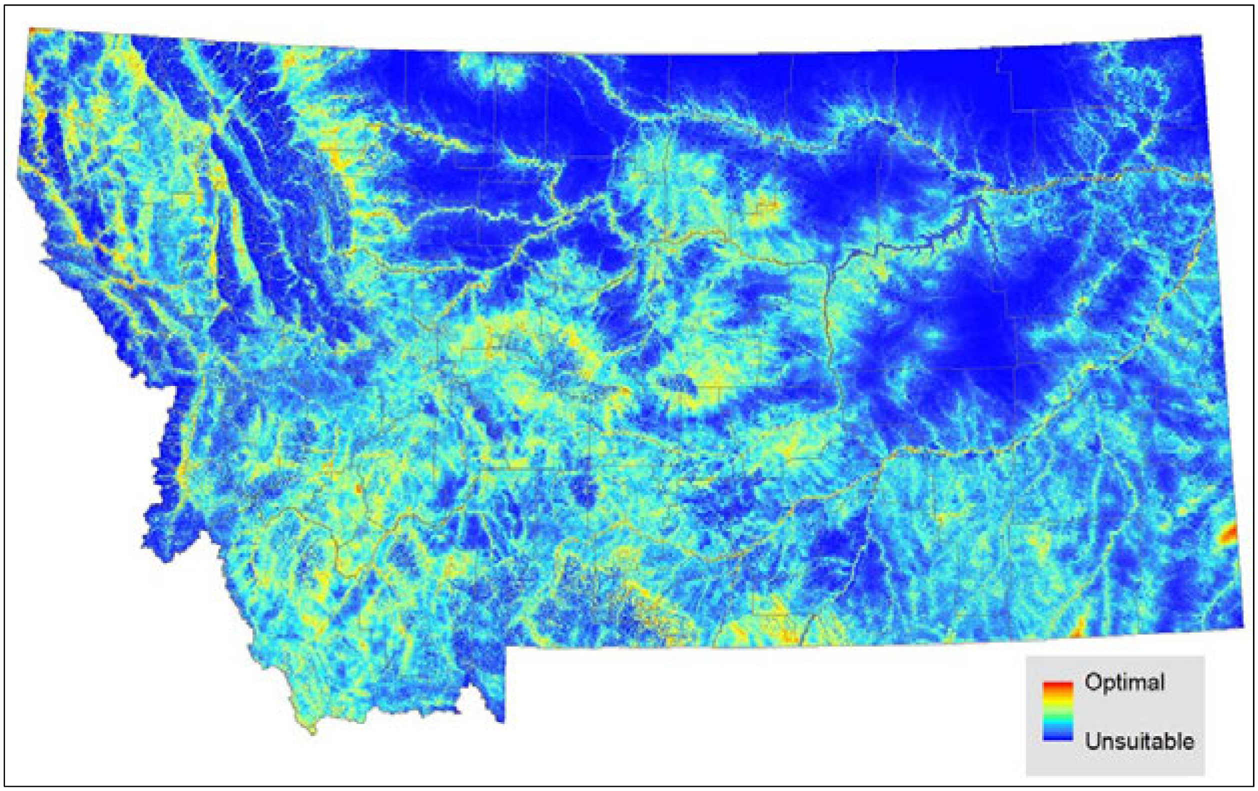


Figure 4. Standard deviation in the model output across the averaged models.

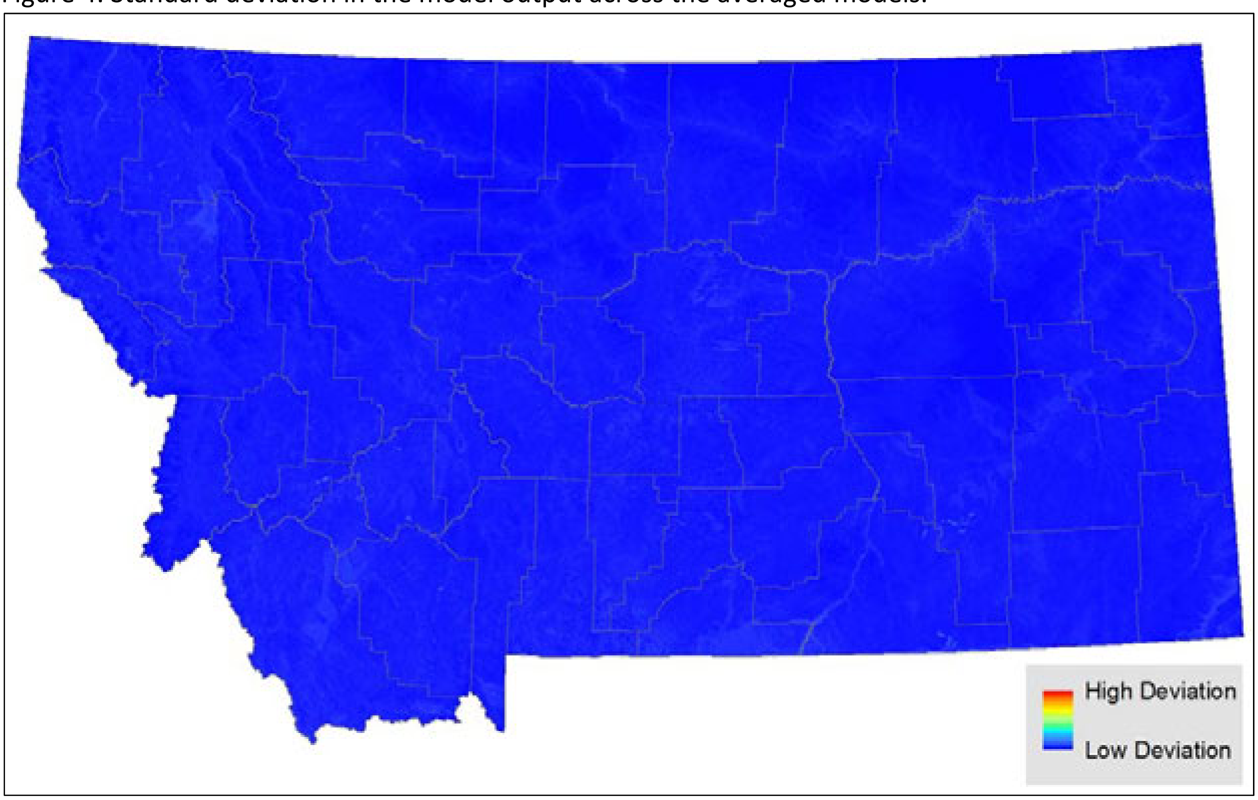


Figure 5. Continuous habitat suitability model output with the 687 observations used for modeling.

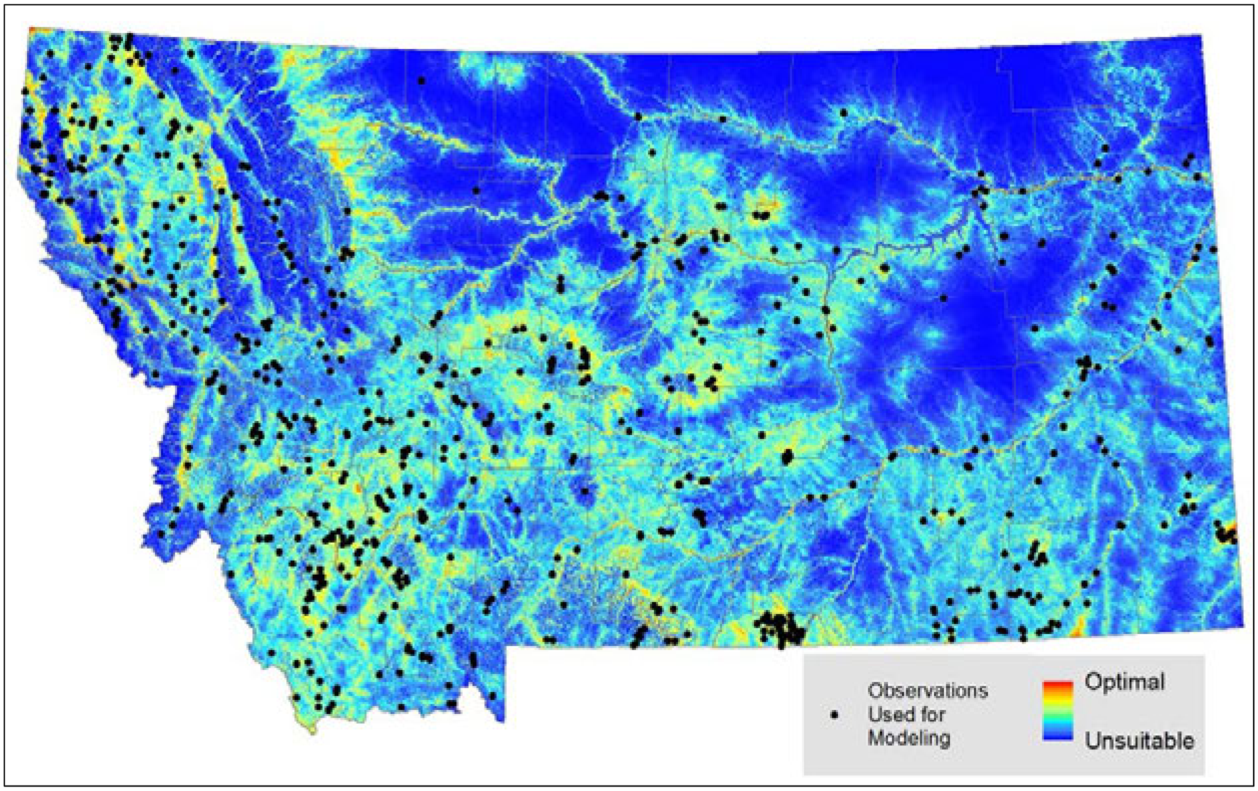


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

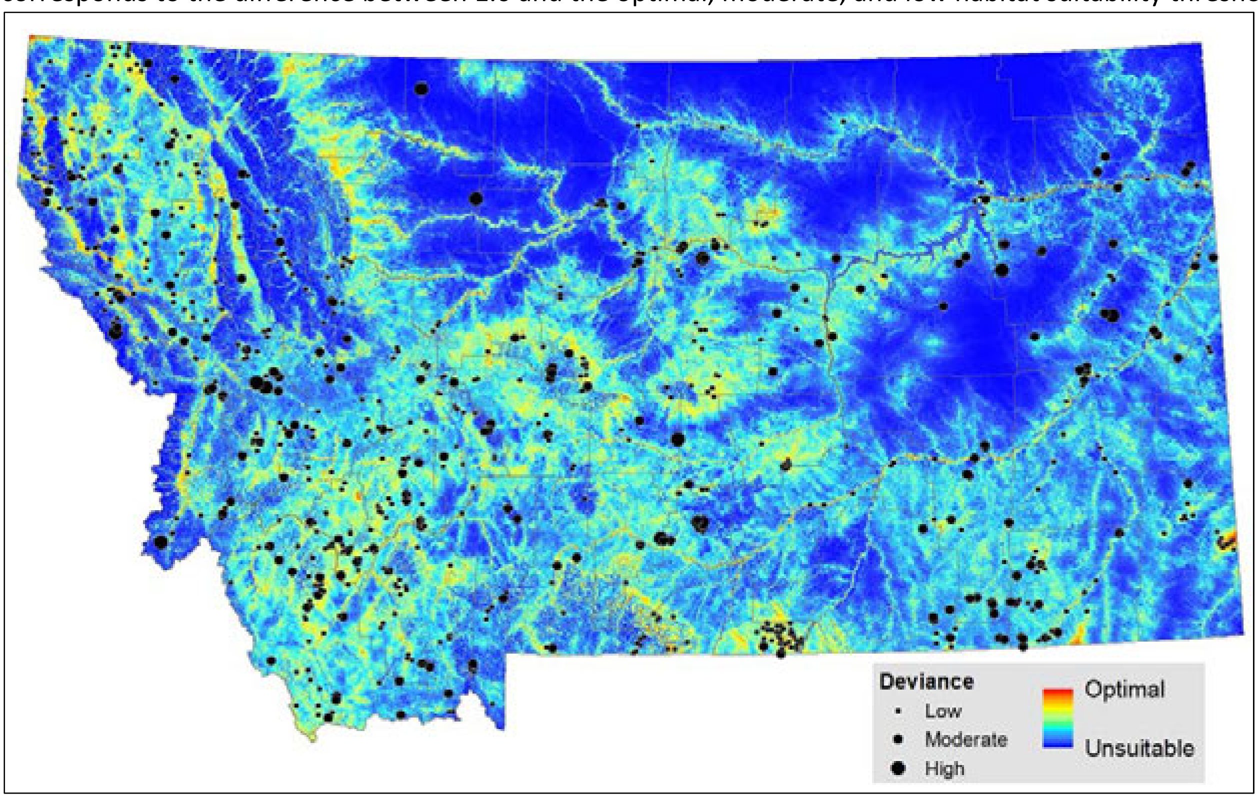


Figure 7. Continuous habitat suitability model output with all 1,361 observations (black) and survey locations that could have detected the species (gray).

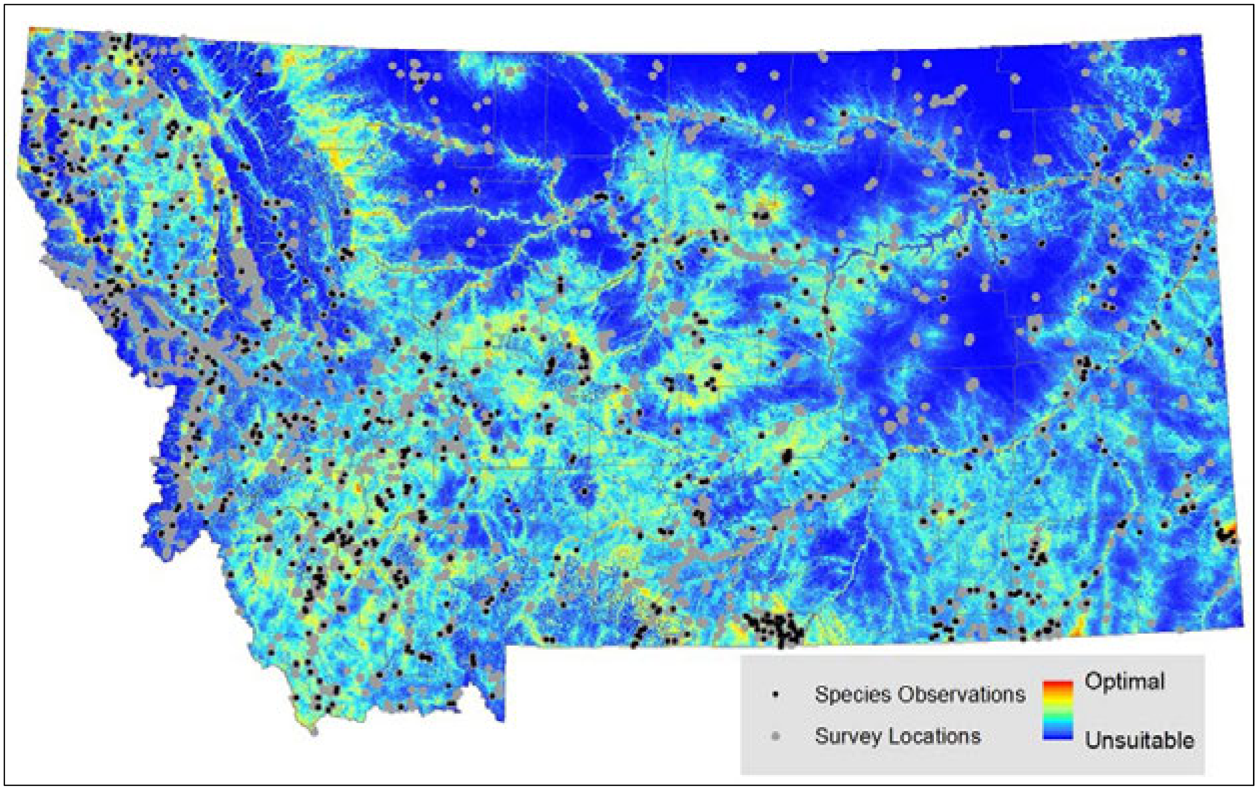


Figure 8. Model output classified into habitat suitability classes.

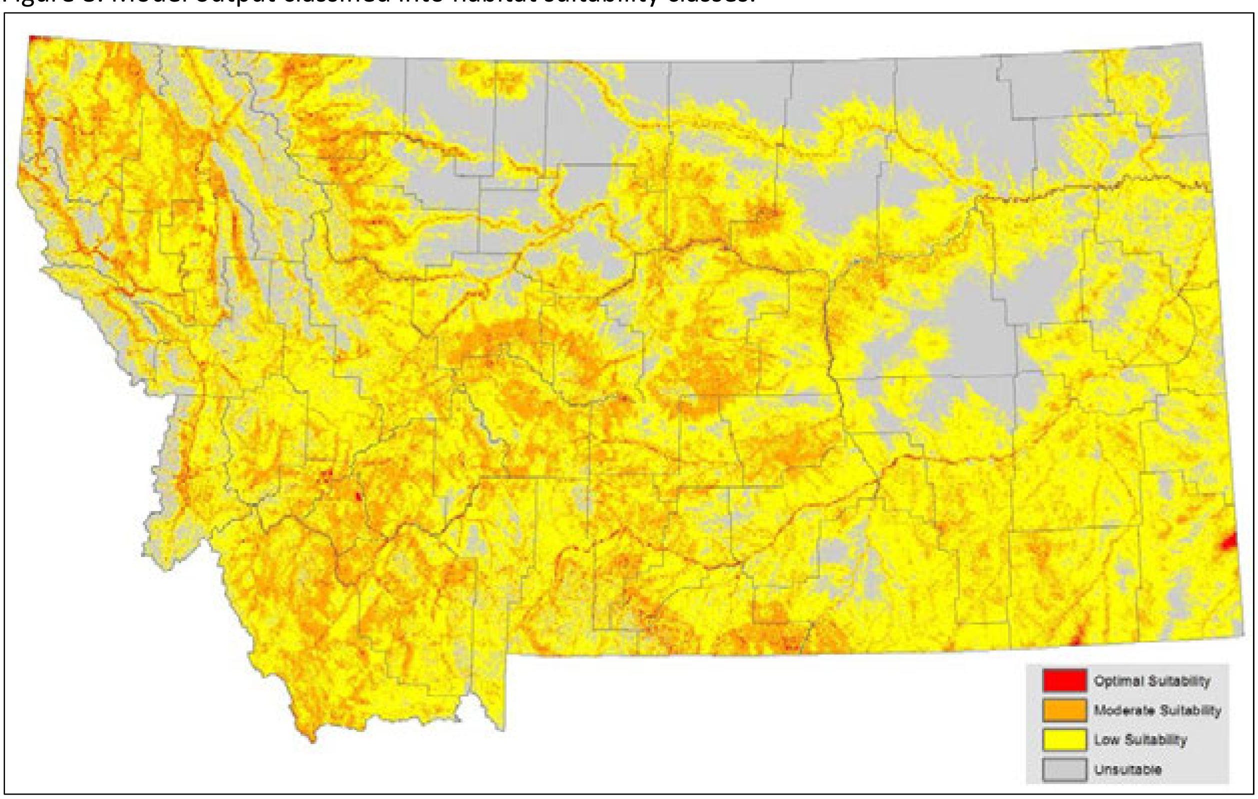
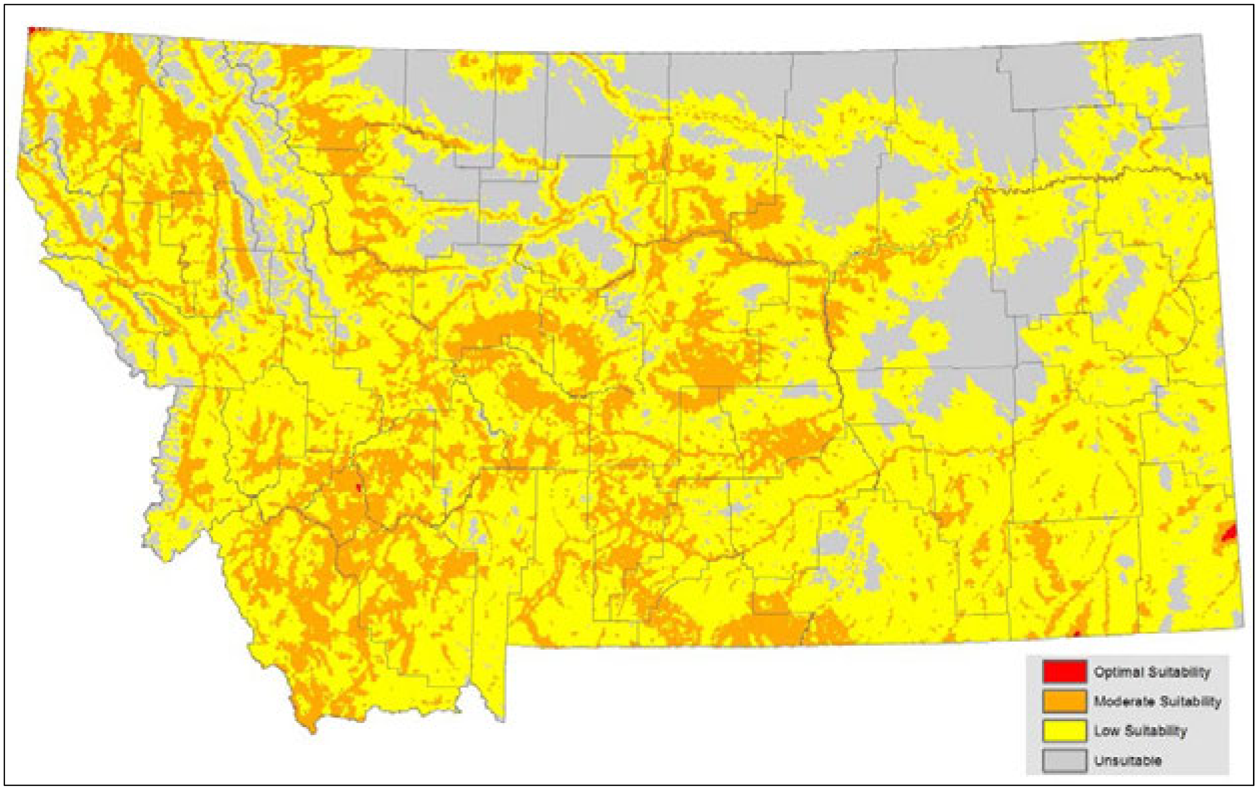


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Long-eared Myotis

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	47
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	44
Montane Sagebrush Steppe	5455	Common	43
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	41
Rocky Mountain Lodgepole Pine Forest	4237	Common	30
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	29
Big Sagebrush Steppe	5454	Common	29
Open Water	11	Common	26
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	26
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	24
Great Plains Floodplain	9159	Common	23
Great Plains Badlands	3114	Common	21
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	19
Great Plains Riparian	9326	Common	19
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	15
Post-Fire Recovery	8505	Common	13
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	12
Alpine-Montane Wet Meadow	9217	Common	12
Recently burned forest	8501	Common	10
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	9
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	9
Insect-Killed Forest	8700	Common	8
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	6
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	6
Great Plains Sand Prairie	7121	Common	6
Aspen Forest and Woodland	4104	Common	5
Great Plains Wooded Draw and Ravine	4328	Common	4
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	3
Mountain Mahogany Woodland and Shrubland	4303	Common	2
Mat Saltbush Shrubland	5203	Common	2
Great Plains Shrubland	5262	Common	2
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	2
Greasewood Flat	9103	Common	2
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	1
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Emergent Marsh	9222	Common	1
Rocky Mountain Subalpine-Montane Fen	9234	Common	1
Shale Badland	3139	Common	0

Table 5: Ecological Systems Associated with Long-eared Myotis

Ecological System	Code	Association	Count[a]
Great Plains Cliff and Outcrop	3142	Common	0
Active and Stabilized Dune	3160	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Low Sagebrush Shrubland	5209	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Great Plains Prairie Pothole	9203	Common	0
Great Plains Open Freshwater Depression Wetland	9218	Common	0
Great Plains Closed Depressional Wetland	9252	Common	0
Great Plains Saline Depression Wetland	9256	Common	0
Other Roads	28	Occasional	67
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	8
Recently burned grassland	8502	Occasional	7
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	5
Harvested forest-tree regeneration	8601	Occasional	4
Developed, Open Space	21	Occasional	3
Railroad	25	Occasional	3
Quarries, Strip Mines and Gravel Pits	31	Occasional	3
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	3
Harvested forest-grass regeneration	8603	Occasional	3
Low Intensity Residential	22	Occasional	2
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	2
Recently burned shrubland	8503	Occasional	2
Harvested forest-shrub regeneration	8602	Occasional	1
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Burned Sagebrush	8504	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 687 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

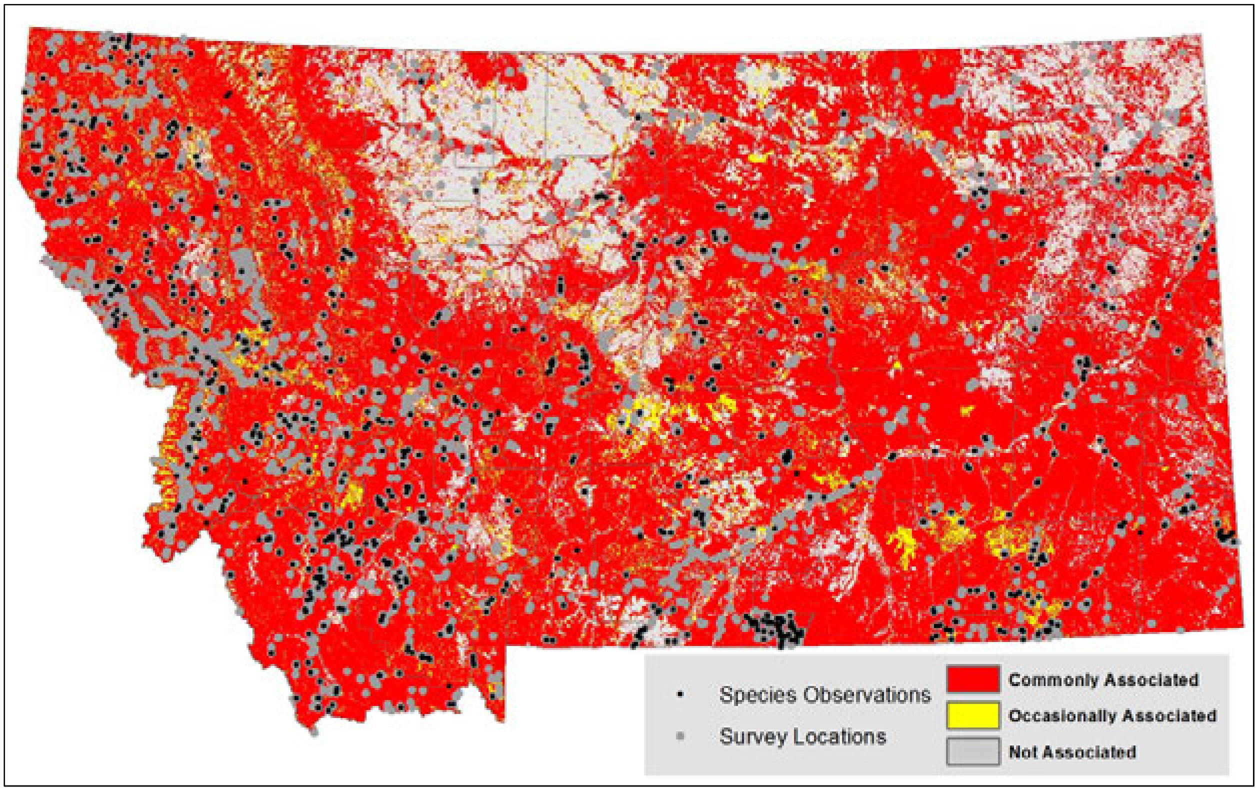
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	309,122.0 km^2
Area of Commonly Associated ES	281,643.0 km^2
Area of Occasionally Associated ES	27,479.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	97.2%
Commonly Associated ES AVI[a]	80.8%
Occasionally Associated ES AVI[a]	16.4%

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

Figure 10. Deductive model output classified into habitat associations.



Little Brown Myotis (*Myotis lucifugus*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S3 (Species of Concern)
Global Rank: G3

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 12, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 12, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Little Brown Myotis active season habitat suitability at larger spatial scales across Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with appear to adequately represent the amount of suitable habitat for Little Brown Myotis across the species' known summer range in Montana. However, the inductive model output is recommended for informing survey and management decisions because of the availability of information on habitat suitability classes.

Suggested Citation: Montana Natural Heritage Program. 2017. Little Brown Myotis (*Myotis lucifugus*) predicted suitable habitat models created on October 12, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	1,624
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	1,446
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	853
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	37.1%	contwinrad	2.1%
contstrmed	11.1%	contvrm	2.1%
catgeol	9.5%	contsumrad	2.0%
contslope	5.7%	contewasp	1.7%
catsoiltemp	5.1%	catsoilord	1.5%
contwinpcp	4.6%	contfrsted	1.5%
contndvi	4.0%	conttmin	1.3%
contnsasp	3.9%	contprecip	0.6%
contddays	2.8%	contelev	0.6%
conttmax	2.7%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.106
Moderate Logistic Threshold[b]	0.394
Optimal Logistic Threshold[c]	0.803
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	316,049.0 km^2
Area of predicted low suitability habitat within modeled range	236,851.4 km^2
Area of moderate suitability habitat within modeled range	75,547.0 km^2
Area of predicted optimal habitat within modeled range	3,650.6 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	98.4%
Moderate AVI[a]	65.0%
Optimal AVI[a]	11.8%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	1.637 ± 1.153
Training AUC[c]	0.812
Test AUC[d]	0.793

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 4.487, 1.863 and 0.438, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

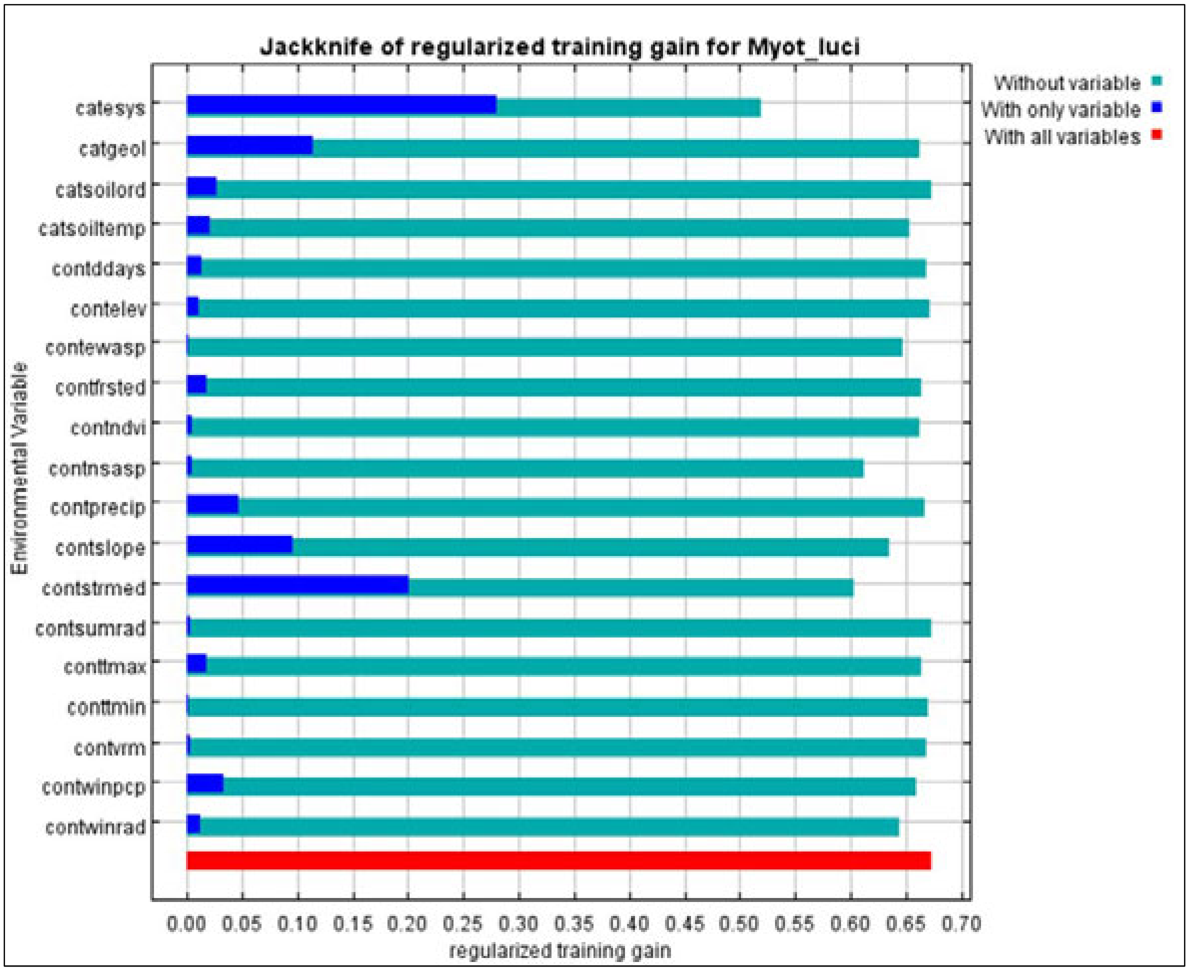
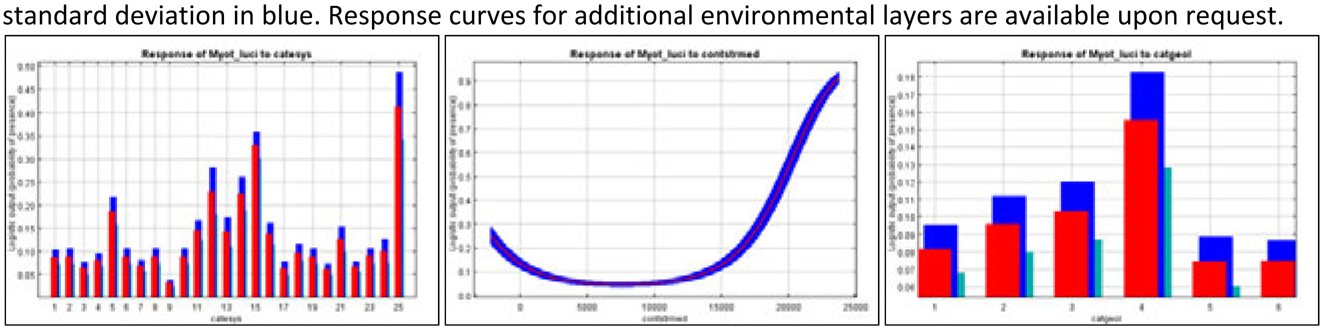


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

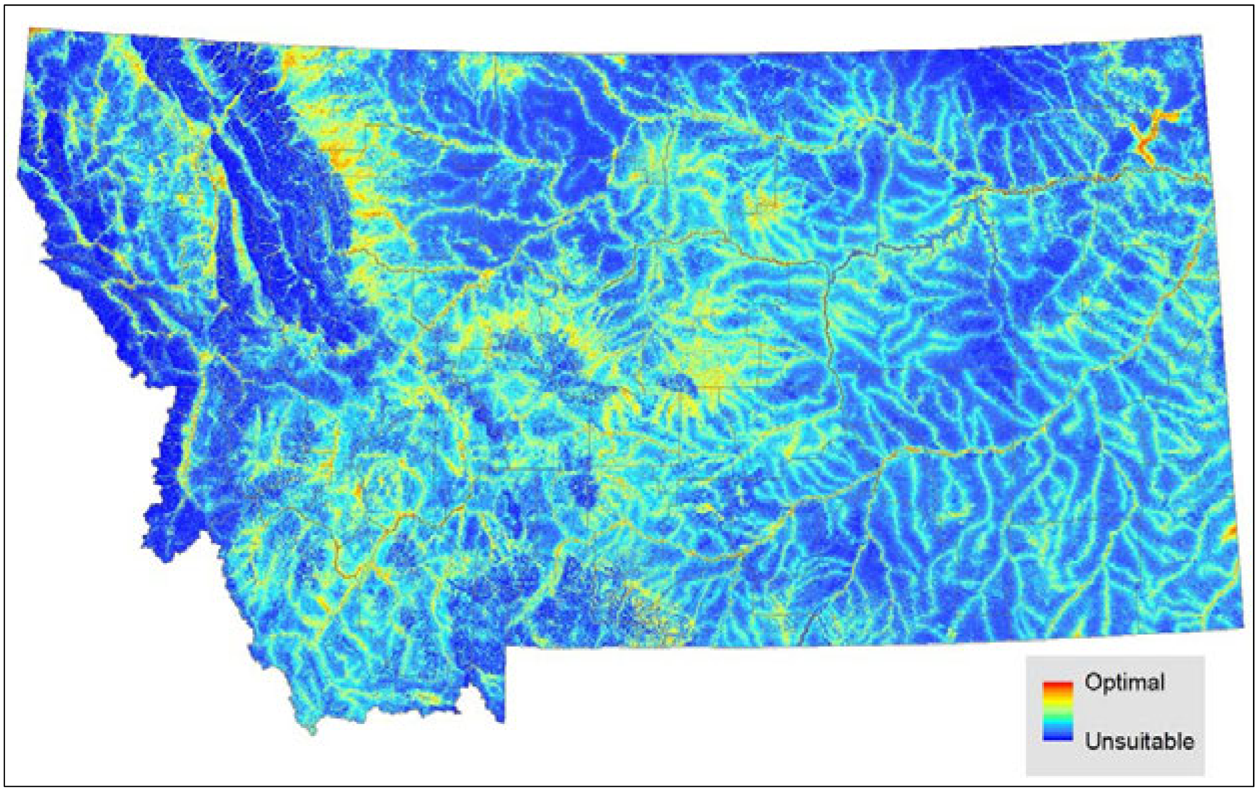


Figure 4. Standard deviation in the model output across the averaged models.

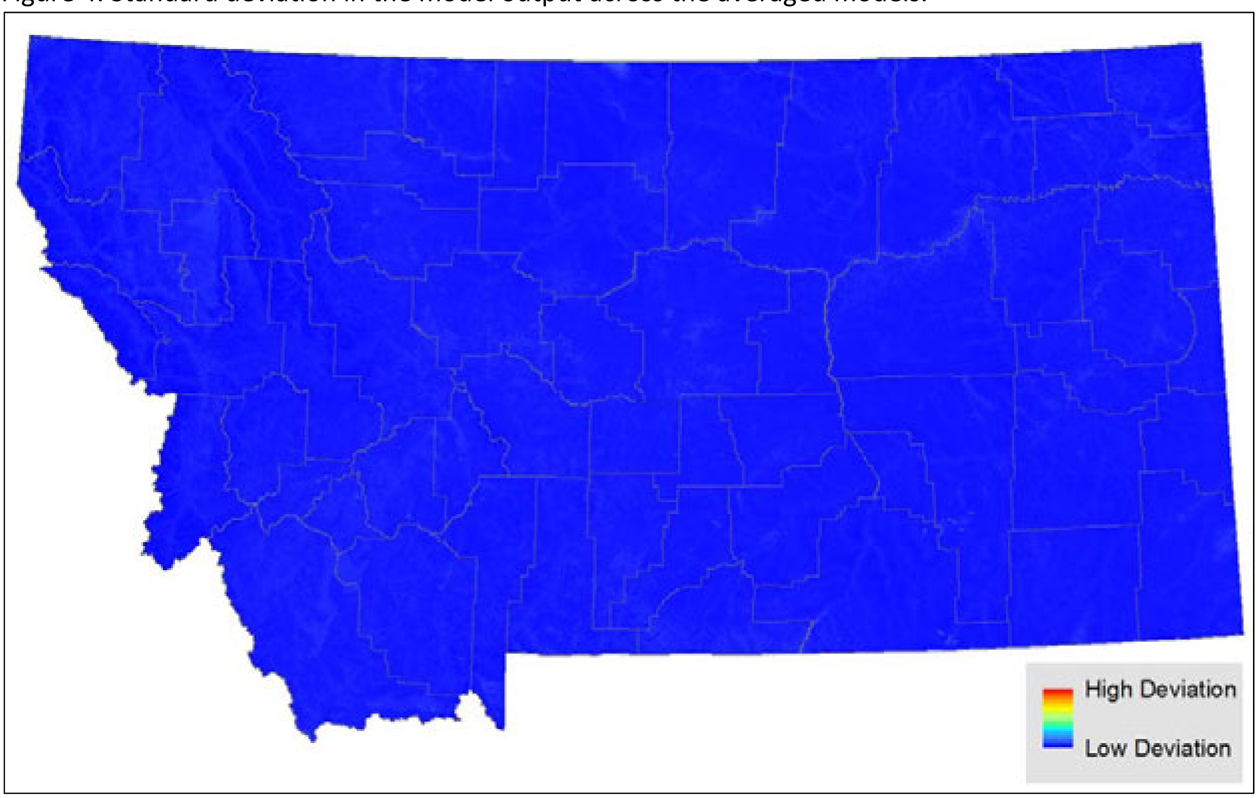


Figure 5. Continuous habitat suitability model output with the 853 observations used for modeling.

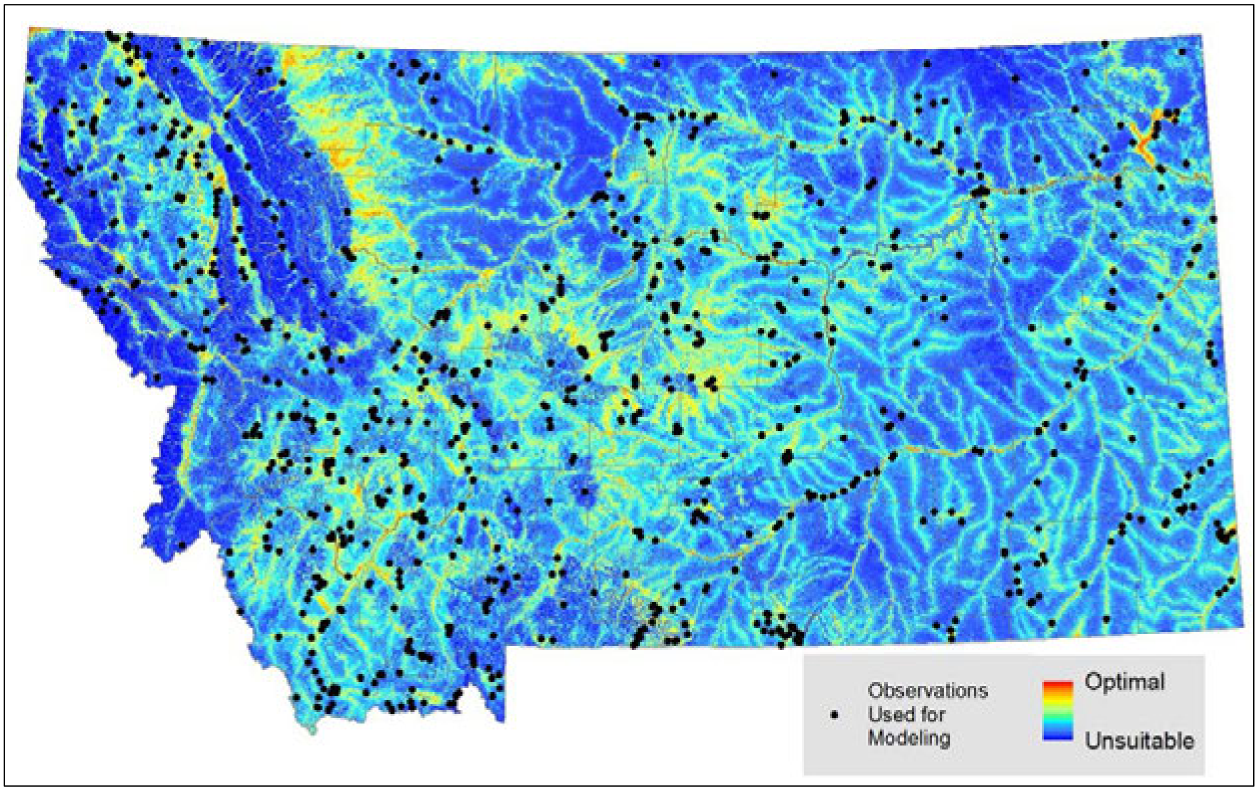


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

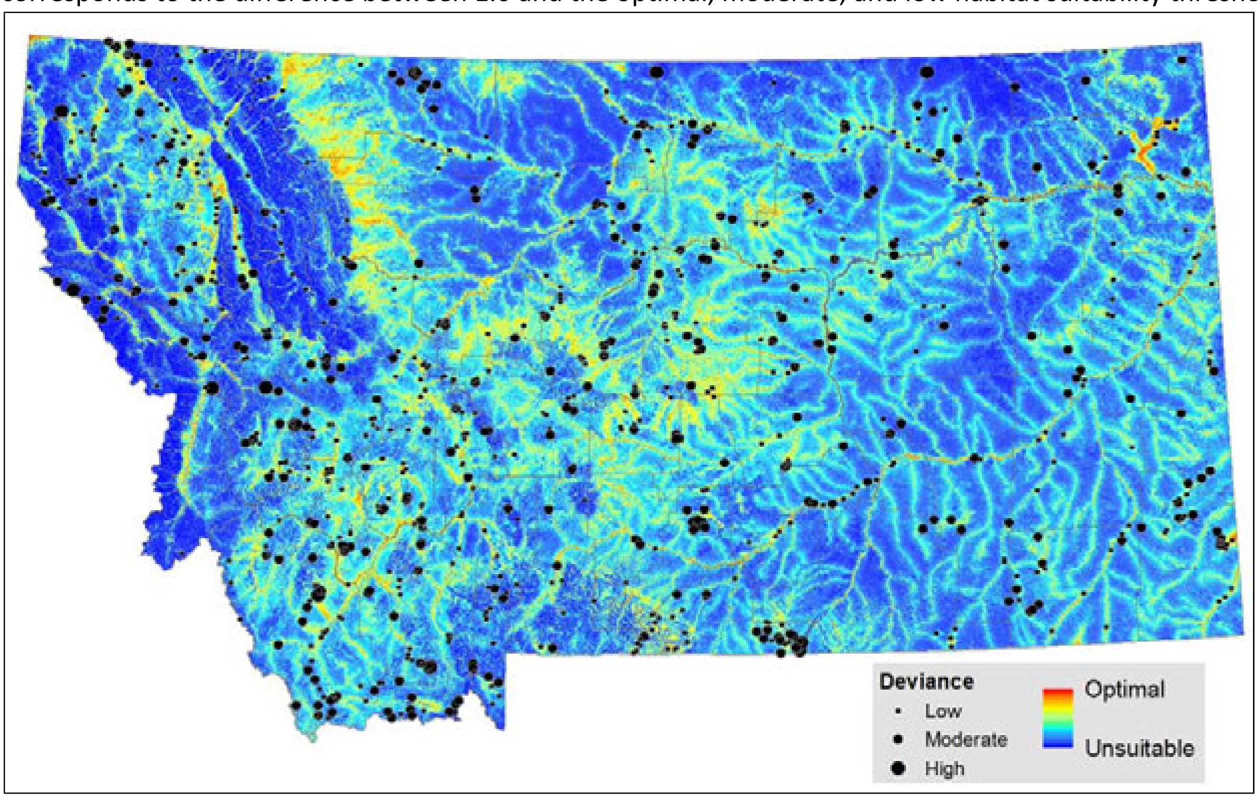


Figure 7. Continuous habitat suitability model output with all 1,624 observations (black) and survey locations that could have detected the species (gray).

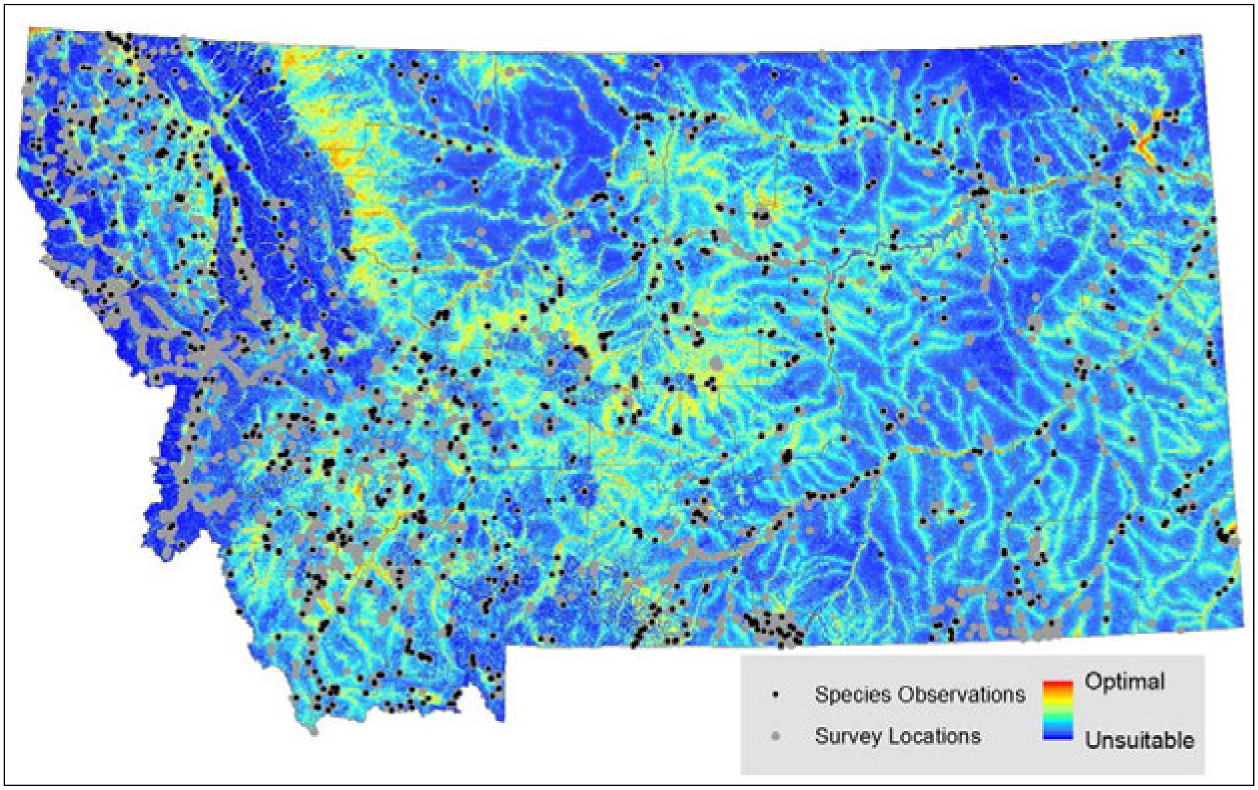


Figure 8. Model output classified into habitat suitability classes.

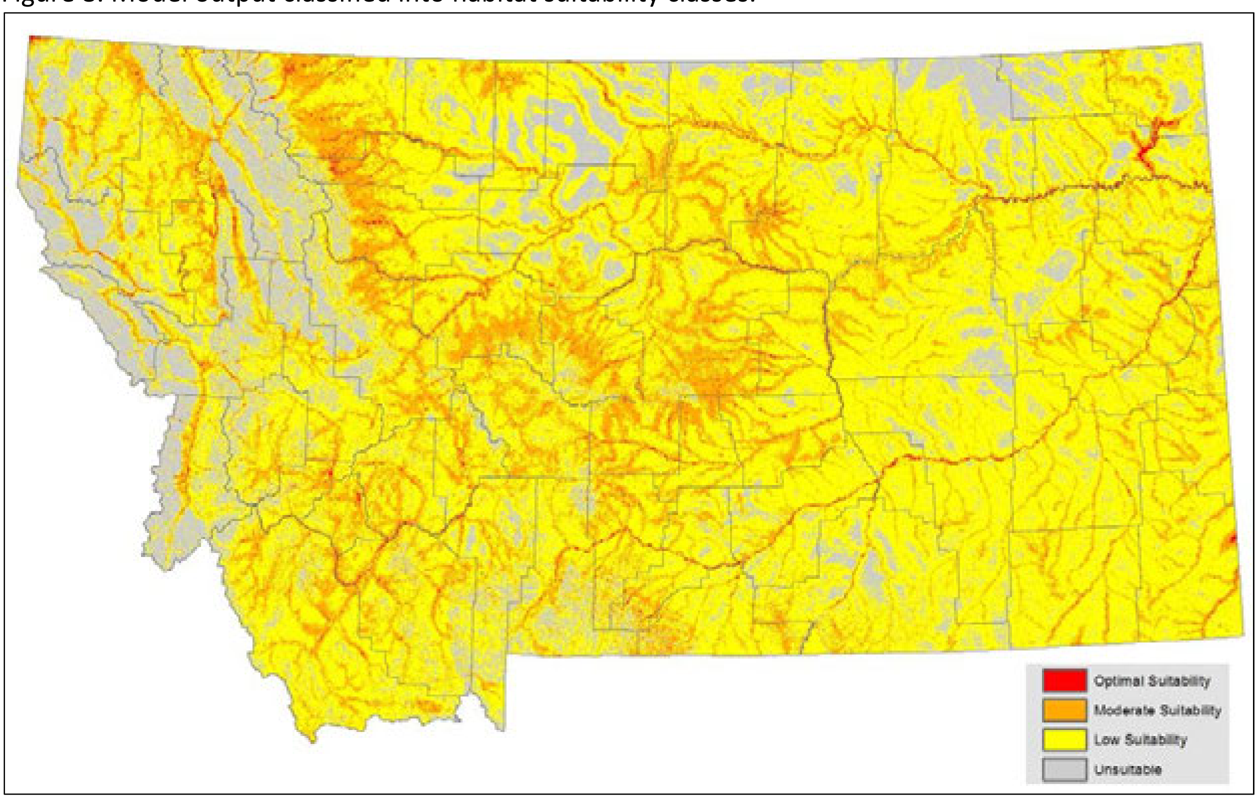
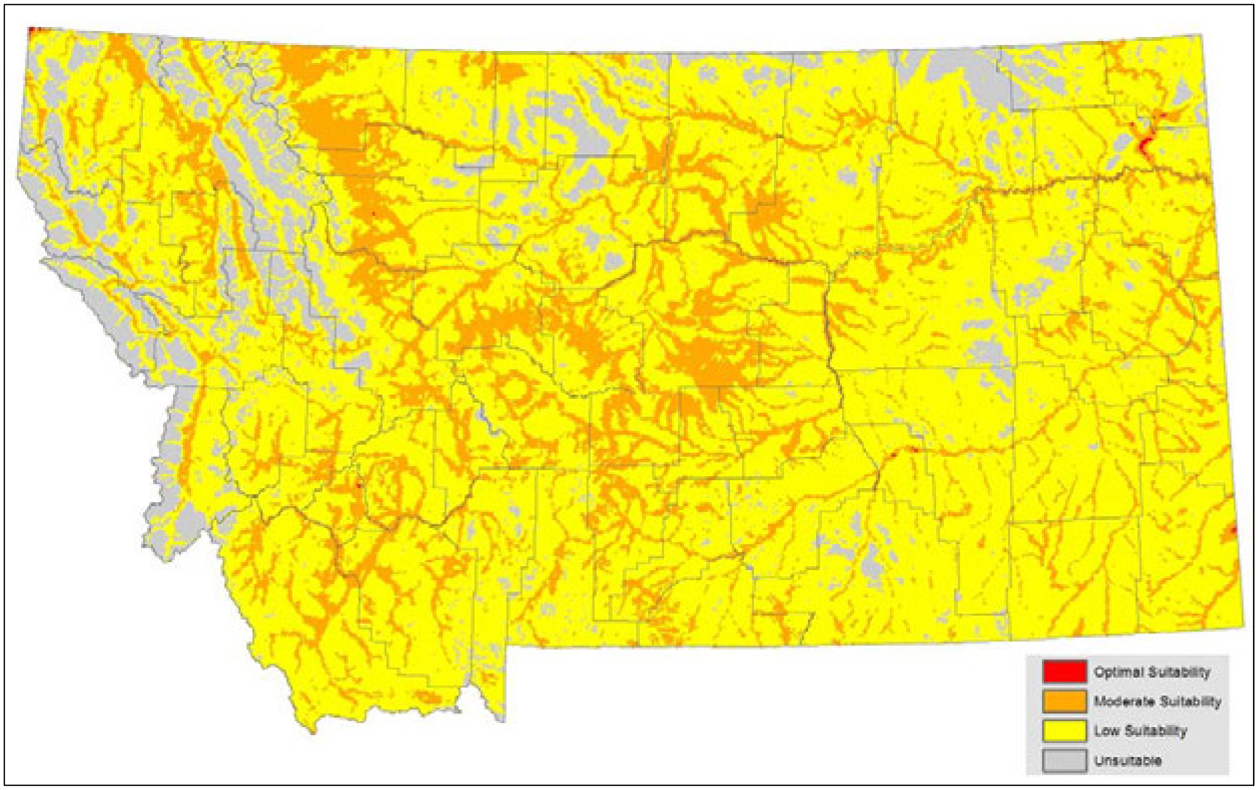


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Little Brown Myotis

Ecological System	Code	Association	Count[a]
Great Plains Mixedgrass Prairie	7114	Common	68
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	66
Open Water	11	Common	56
Big Sagebrush Steppe	5454	Common	43
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	42
Great Plains Floodplain	9159	Common	36
Great Plains Riparian	9326	Common	36
Montane Sagebrush Steppe	5455	Common	35
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	25
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	22
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	20
Rocky Mountain Lodgepole Pine Forest	4237	Common	20
Great Plains Badlands	3114	Common	19
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	18
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Common	14
Alpine-Montane Wet Meadow	9217	Common	14
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	12
Insect-Killed Forest	8700	Common	12
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Common	10
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	9
Great Plains Sand Prairie	7121	Common	9
Developed, Open Space	21	Common	7
Aspen Forest and Woodland	4104	Common	7
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	7
Great Plains Wooded Draw and Ravine	4328	Common	7
Recently burned forest	8501	Common	7
Post-Fire Recovery	8505	Common	7
Low Intensity Residential	22	Common	6
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	5
Great Plains Shrubland	5262	Common	5
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	4
Mountain Mahogany Woodland and Shrubland	4303	Common	4
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	3
Harvested forest-tree regeneration	8601	Common	3
Greasewood Flat	9103	Common	3
Great Plains Closed Depressional Wetland	9252	Common	3
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Common	2
Harvested forest-grass regeneration	8603	Common	2
Great Plains Open Freshwater Depression Wetland	9218	Common	2
Emergent Marsh	9222	Common	2

Table 5: Ecological Systems Associated with Little Brown Myotis

Ecological System	**Code**	**Association**	**Count[a]**
Great Plains Cliff and Outcrop	3142	Common	1
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	1
Harvested forest-shrub regeneration	8602	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	1
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Rocky Mountain Subalpine-Montane Fen	9234	Common	1
Great Plains Saline Depression Wetland	9256	Common	1
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Big Sagebrush Shrubland	5257	Common	0
Mixed Salt Desert Scrub	5258	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Great Plains Prairie Pothole	9203	Common	0
Other Roads	28	Occasional	89
Major Roads	27	Occasional	21
Introduced Upland Vegetation - Annual and Biennial Forbland	8403	Occasional	20
Cultivated Crops	82	Occasional	10
Commercial/Industrial	24	Occasional	6
Interstate	26	Occasional	4
Quarries, Strip Mines and Gravel Pits	31	Occasional	3
Pasture/Hay	81	Occasional	3
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	3
Introduced Riparian and Wetland Vegetation	8406	Occasional	3
Recently burned grassland	8502	Occasional	3
Railroad	25	Occasional	2
Recently burned shrubland	8503	Occasional	2
Mat Saltbush Shrubland	5203	Occasional	1
Burned Sagebrush	8504	Occasional	1
High Intensity Residential	23	Occasional	0
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Low Sagebrush Shrubland	5209	Occasional	0
Introduced Upland Vegetation - Shrub	8402	Occasional	0
Introduced Upland Vegetation - Annual Grassland	8404	Occasional	0
Introduced Upland Vegetation - Perennial Grassland and Forbland	8405	Occasional	0
Coal Bed Methane	32	Occasional	0
Gas and Gas Storage	33	Occasional	0
Injection	34	Occasional	0
Oil and Oil and Gas	35	Occasional	0
Wind Turbine	40	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 853 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

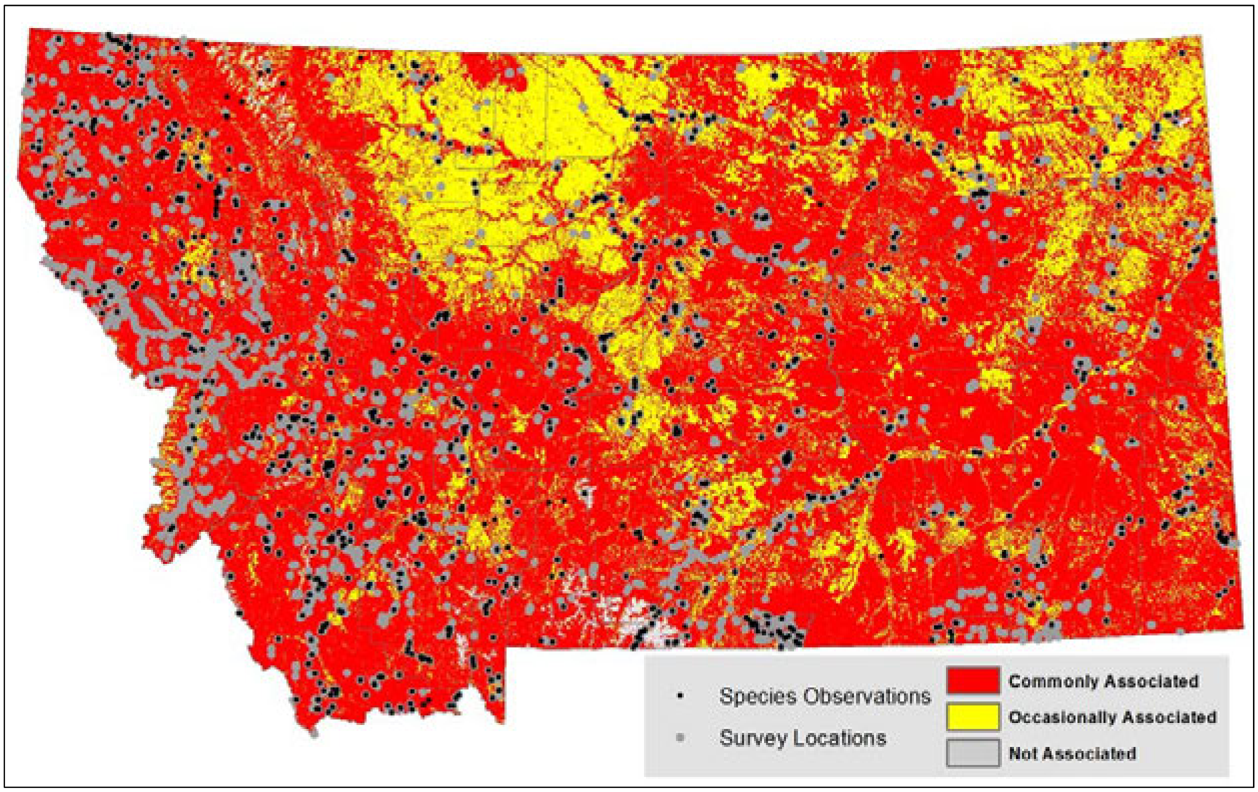
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	376,964.0 km^2
Area of Commonly Associated ES	285,374.0 km^2
Area of Occasionally Associated ES	91,591.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	99.8%
Commonly Associated ES AVI[a]	78.1%
Occasionally Associated ES AVI[a]	21.7%

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

Figure 10. Deductive model output classified into habitat associations.



Fringed Myotis (*Myotis thysanodes*)
Predicted Suitable Habitat Modeling

Distribution Status: Migratory Summer Breeder
State Rank: S3 (Species of Concern)
Global Rank: G4

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 12, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 12, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across the species' known active season range in Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Fringed Myotis active season habitat suitability at larger spatial scales across the species' known active season range in Montana. Evaluation metrics indicate a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across the species' known active season range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with overpredict the amount of active season suitable habitat for Fringed Myotis across the species' known active season range in Montana. Use of the inductive model output is recommended for informing survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Fringed Myotis (*Myotis thysanodes*) predicted suitable habitat models created on October 12, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01090

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	184
Location Data Selection Rule 1	Records with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	156
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	79
Season Modeled	Entire state, Year-round
Number of Model Background Locations	42,310

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	29.6%	contnsasp	3.2%
contprecip	13.2%	catgeol	2.5%
contfrsted	12.3%	contwinrad	1.3%
contvrm	10.2%	contewasp	0.7%
conttmin	7.1%	contddays	0.6%
contelev	4.6%	conttmax	0.3%
catsoilord	3.9%	contsumrad	0.2%
contstrmed	3.6%	contslope	0.0%
contwinpcp	3.3%	contndvi	0.0%
catsoiltemp	3.3%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.038
Moderate Logistic Threshold[b]	0.225
Optimal Logistic Threshold[c]	0.605
Area of entire modeled range (percent of Montana)	268,336.81 km^2 (70.5%)
Total area of predicted suitable habitat within modeled range	125,937.4 km^2
Area of predicted low suitability habitat within modeled range	94,435.4 km^2
Area of moderate suitability habitat within modeled range	27,543.7 km^2
Area of predicted optimal habitat within modeled range	3,958.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	93.7%
Moderate AVI[a]	67.1%
Optimal AVI[a]	36.7%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	2.336 ± 2.130
Training AUC[c]	0.929
Test AUC[d]	0.887

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 6.519, 2.980 and 1.007, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

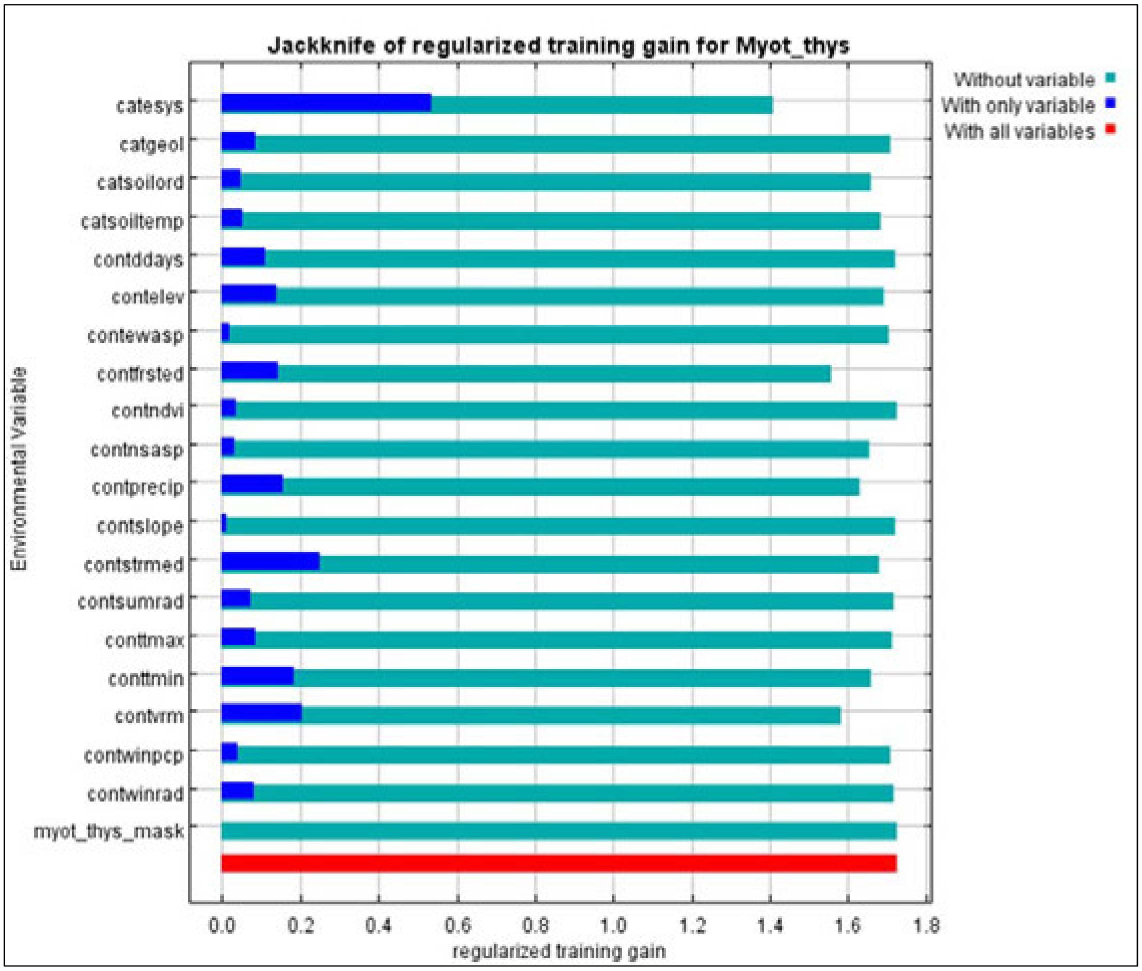
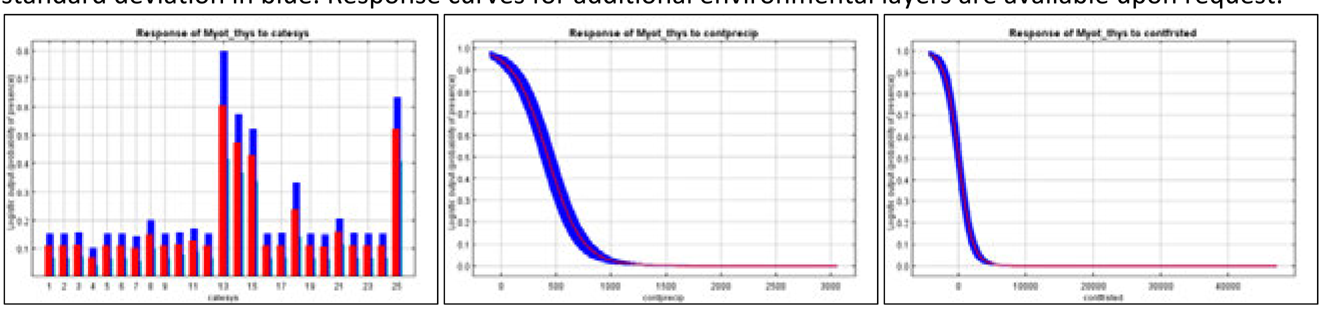


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

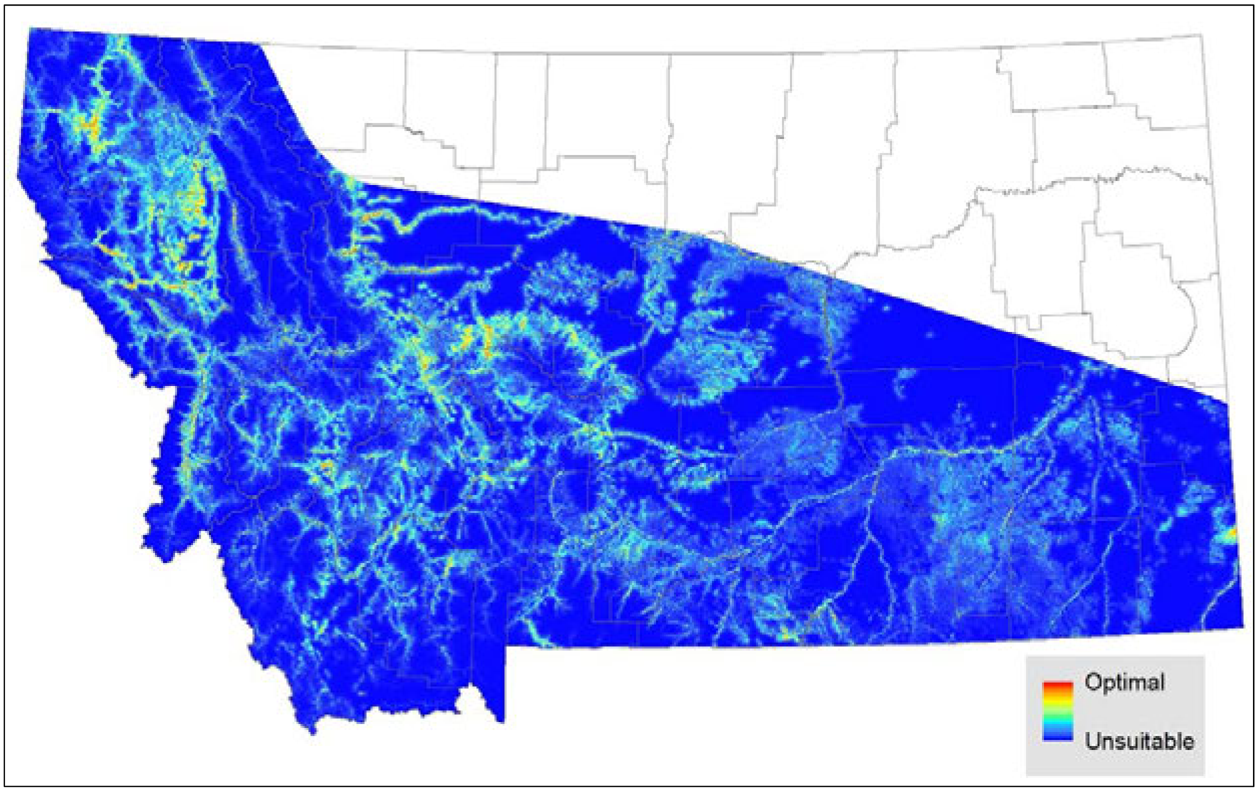


Figure 4. Standard deviation in the model output across the averaged models.

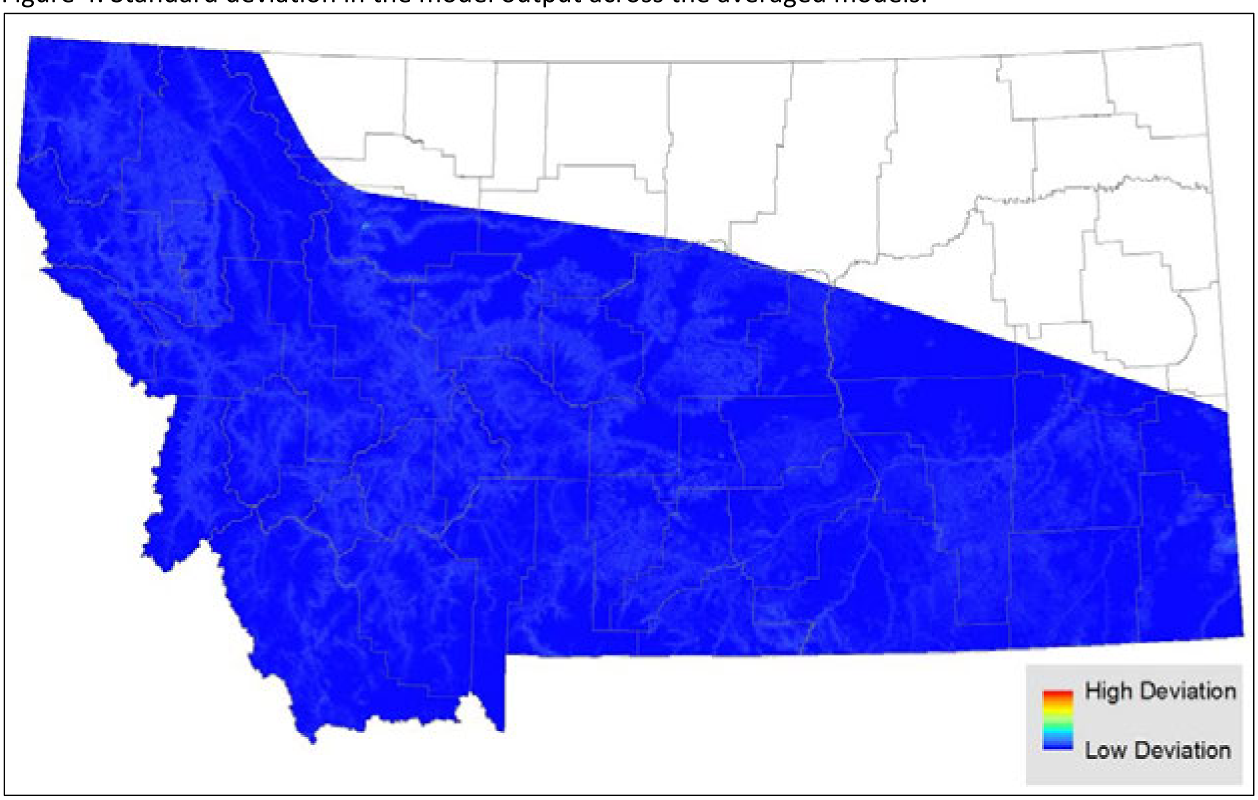


Figure 5. Continuous habitat suitability model output with the 79 observations used for modeling.

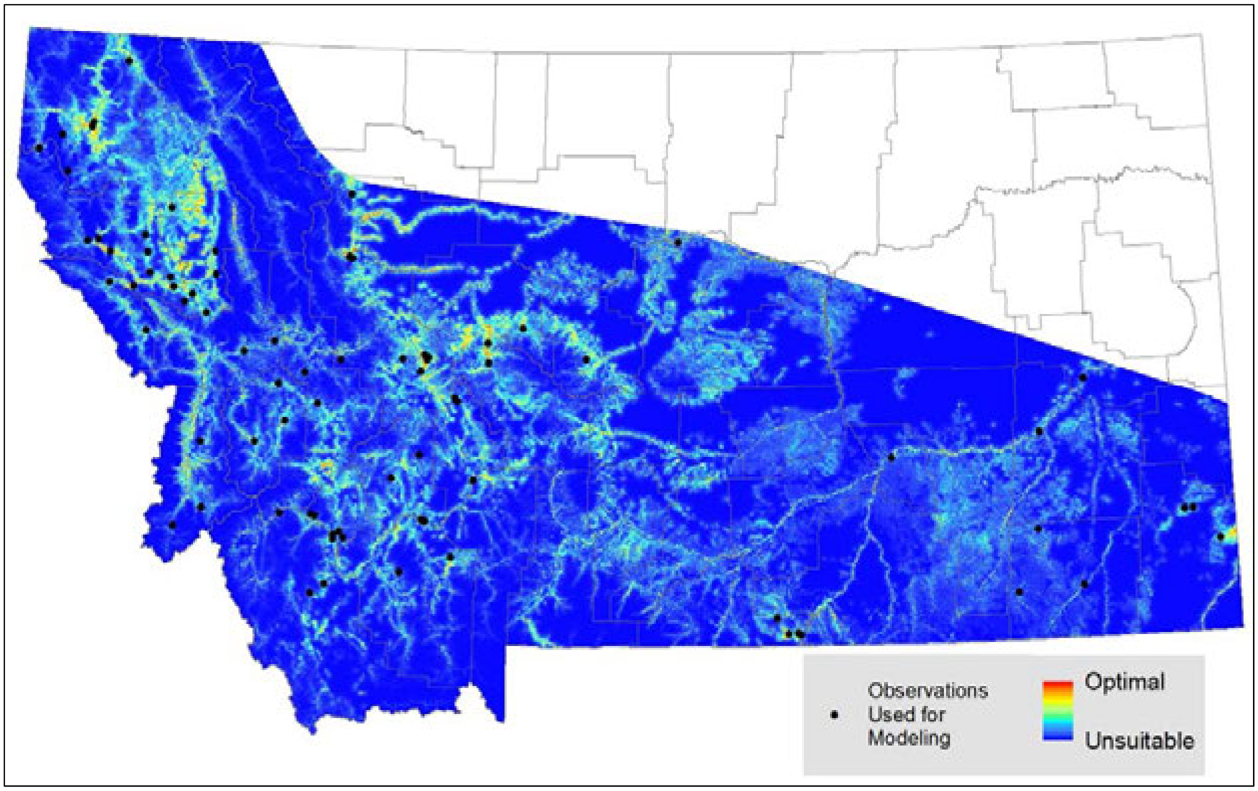


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

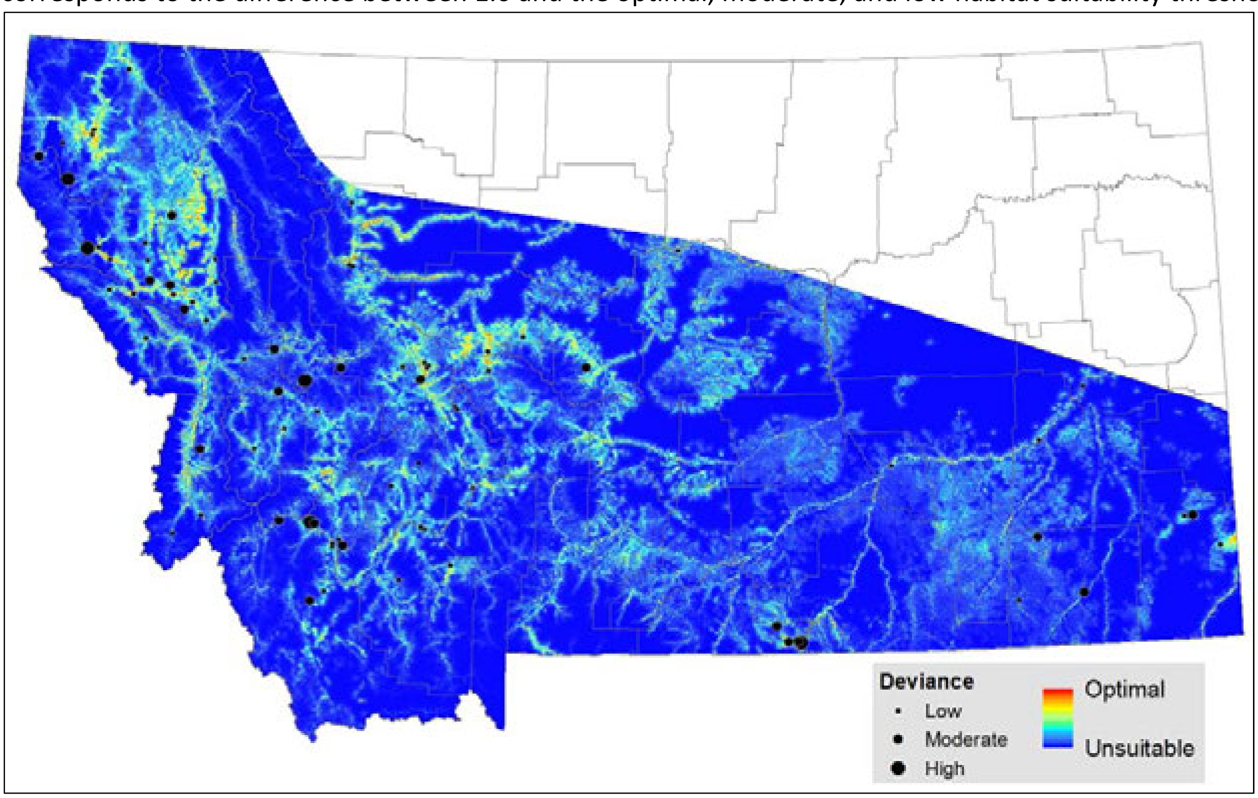


Figure 7. Continuous habitat suitability model output with all 184 observations (black) and survey locations that could have detected the species (gray).

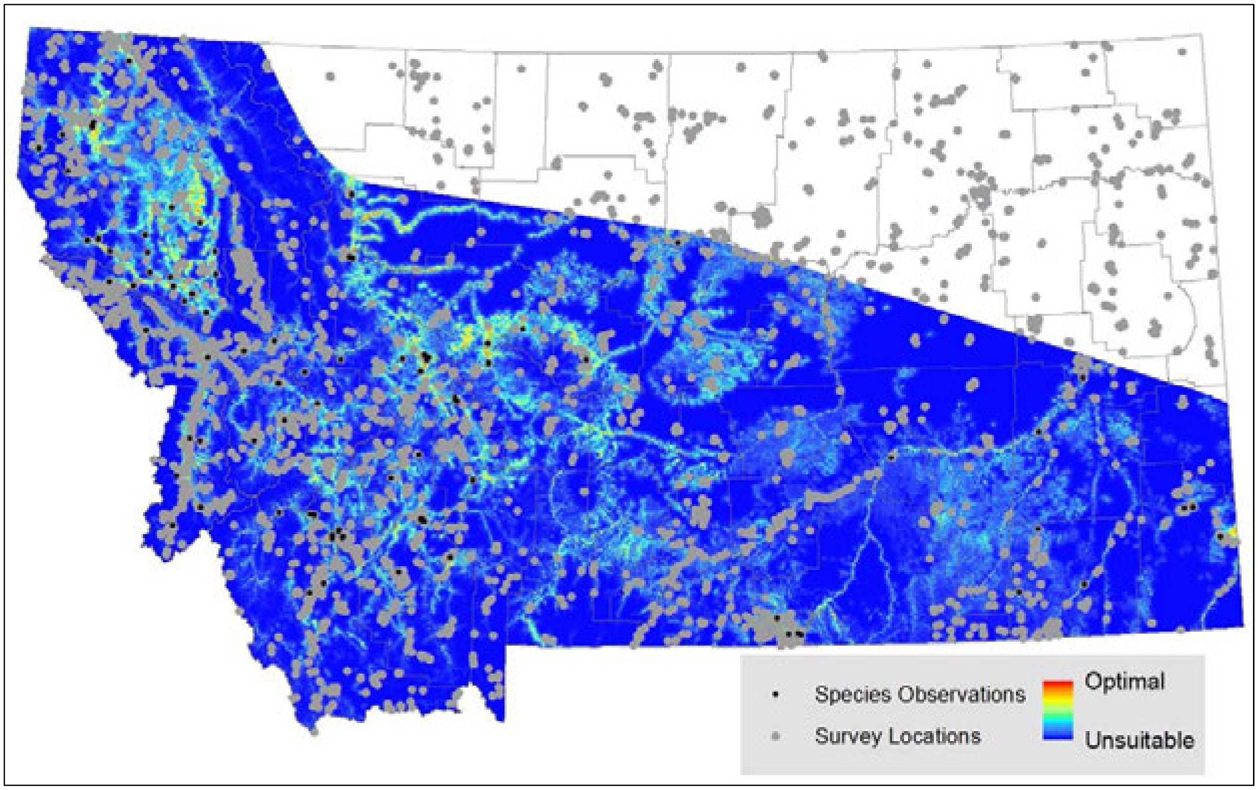


Figure 8. Model output classified into habitat suitability classes.

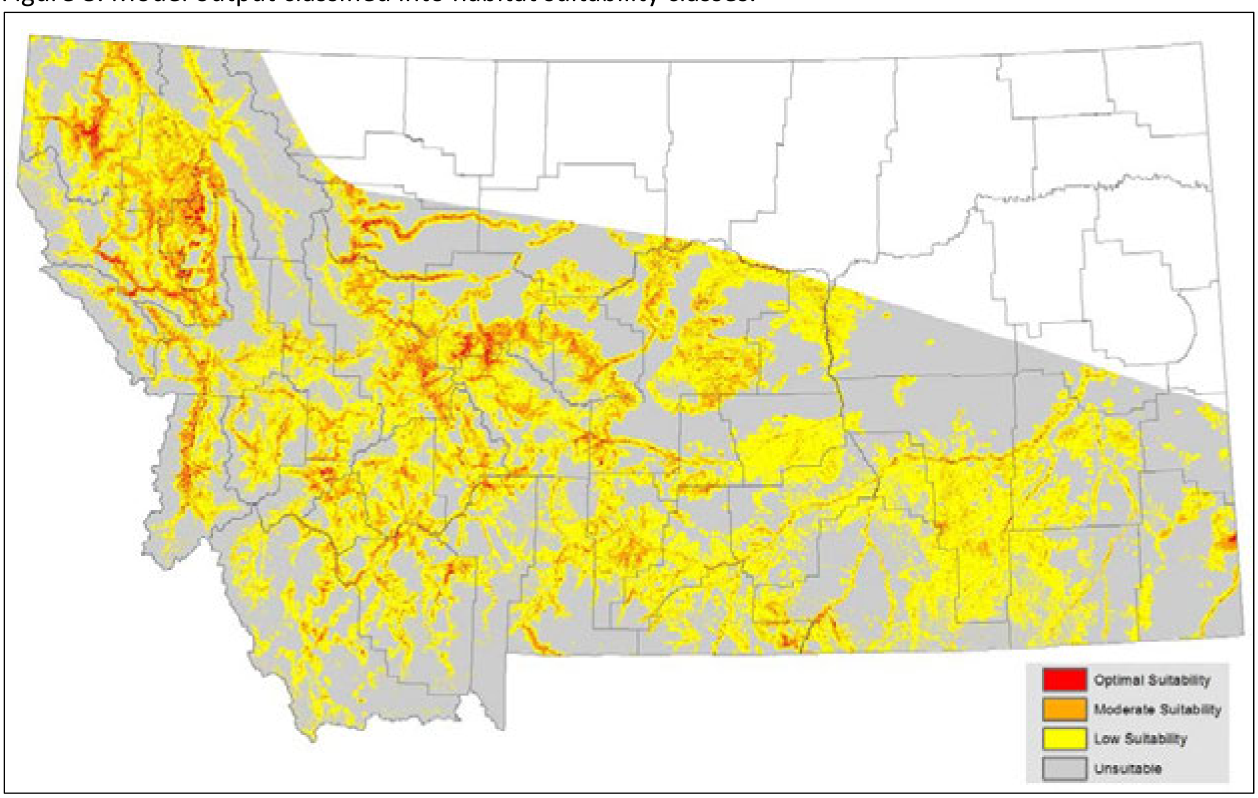
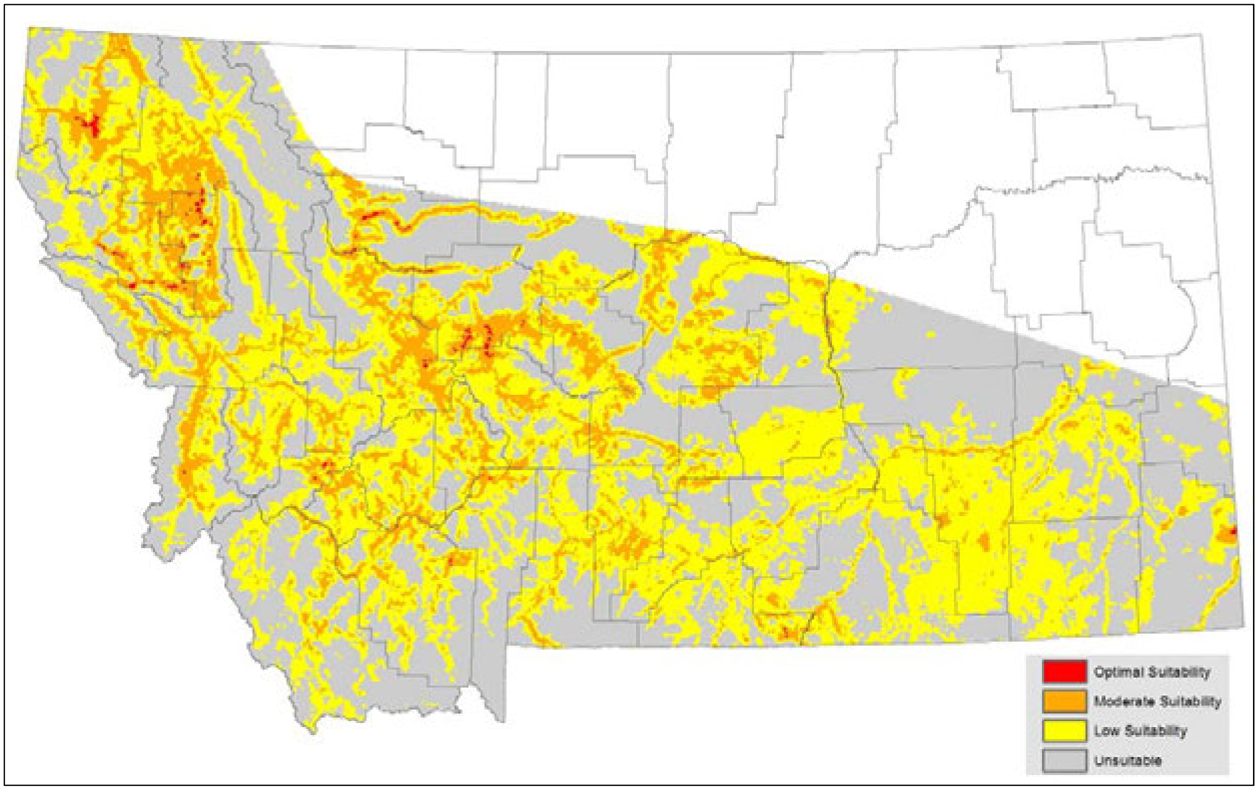


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Fringed Myotis

Ecological System	Code	Association	Count[a]
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	12
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	8
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	5
Montane Sagebrush Steppe	5455	Common	5
Open Water	11	Common	4
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	4
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	3
Great Plains Floodplain	9159	Common	3
Great Plains Riparian	9326	Common	3
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	2
Big Sagebrush Steppe	5454	Common	2
Post-Fire Recovery	8505	Common	2
Alpine-Montane Wet Meadow	9217	Common	2
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	1
Rocky Mountain Lodgepole Pine Forest	4237	Common	1
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	1
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	1
Mountain Mahogany Woodland and Shrubland	4303	Common	1
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	1
Recently burned forest	8501	Common	1
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	1
Insect-Killed Forest	8700	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen Forest and Woodland	4104	Common	0
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Great Plains Wooded Draw and Ravine	4328	Common	0
Big Sagebrush Shrubland	5257	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	0
Emergent Marsh	9222	Common	0
Other Roads	28	Occasional	8
Railroad	25	Occasional	2
Great Plains Mixedgrass Prairie	7114	Occasional	1
Harvested forest-tree regeneration	8601	Occasional	1

Table 5: Ecological Systems Associated with Fringed Myotis

Ecological System	Code	Association	Count[a]
Greasewood Flat	9103	Occasional	1
Developed, Open Space	21	Occasional	0
Low Intensity Residential	22	Occasional	0
Great Plains Badlands	3114	Occasional	0
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Mat Saltbush Shrubland	5203	Occasional	0
Mixed Salt Desert Scrub	5258	Occasional	0
Great Plains Shrubland	5262	Occasional	0
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	0
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	0
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	0
Great Plains Sand Prairie	7121	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Recently burned grassland	8502	Occasional	0
Great Plains Open Freshwater Depression Wetland	9218	Occasional	0
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	0
Great Plains Closed Depressional Wetland	9252	Occasional	0
Great Plains Saline Depression Wetland	9256	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 79 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

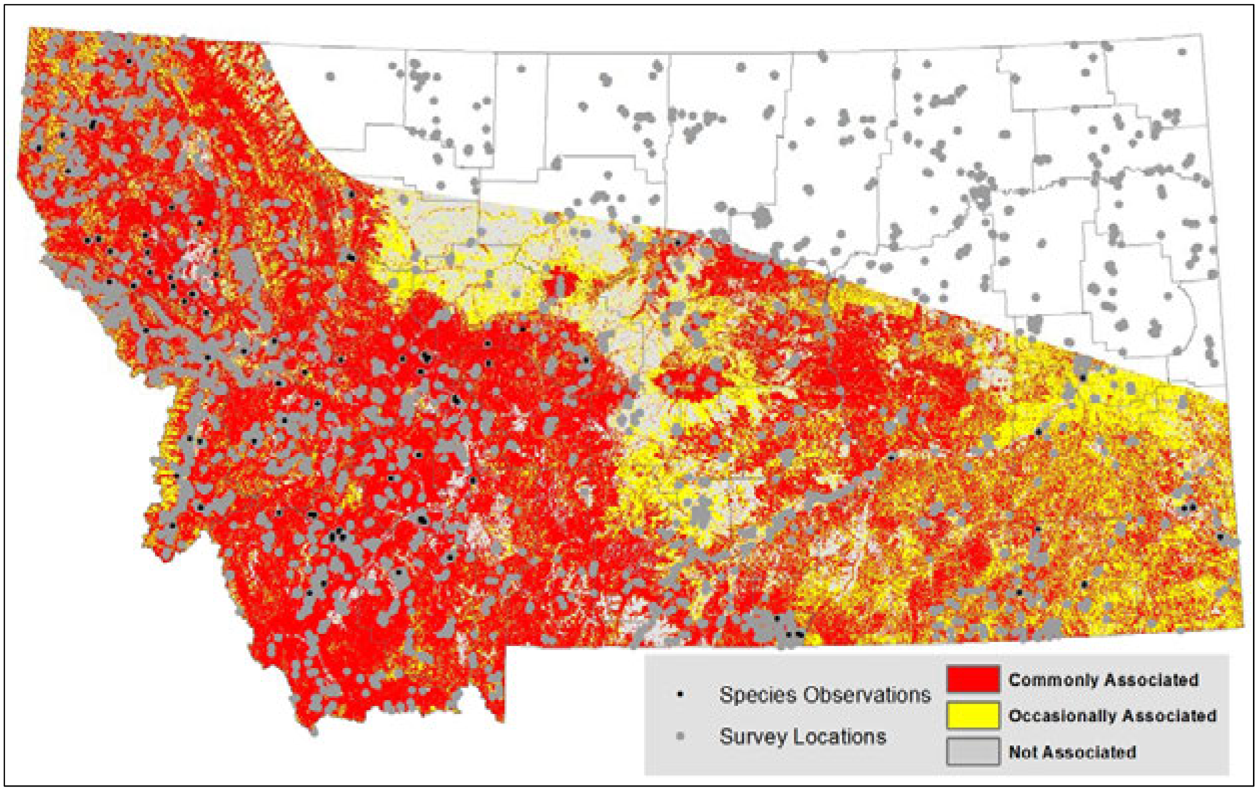
Measure	Value
Area of entire modeled range (percent of Montana)	268,336.81 km^2 (70.5%)
Area of Commonly and Occasionally Associated ES	229,114.0 km^2
Area of Commonly Associated ES	157,737.0 km^2
Area of Occasionally Associated ES	71,377.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	97.5%
Commonly Associated ES AVI[a]	81.0%
Occasionally Associated ES AVI[a]	16.5%

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

Figure 10. Deductive model output classified into habitat associations.



Long-legged Myotis (*Myotis volans*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S4
Global Rank: G4G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 11, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 11, 2017

Inductive Model Goal: To predict the distribution and relative suitability of active season habitat at large spatial scales across Montana.
Inductive Model Performance: It is important to note that this model may not adequately reflect important travel or roosting habitats for the species due to the focus on standing water bodies and stream corridors of most mist net and acoustic survey efforts. However, the model does a good job of reflecting the distribution of Long-legged Myotis active season habitat suitability at larger spatial scales across Montana. Evaluation metrics suggest a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species during the active season across Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with likely greatly overpredict the amount of active season suitable habitat for Long-legged Myotis across Montana. Use of the inductive model output is recommended to inform survey and management decisions.

Suggested Citation: Montana Natural Heritage Program. 2017. Long-legged Myotis (*Myotis volans*) predicted suitable habitat models created on October 11, 2017. Montana Natural Heritage Program, Helena, MT. 16 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMACC01110

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	286
Location Data Selection Rule 1	Records during summer with <= 1000 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	234
Location Data Selection Rule 2	No overlap in locations within 1000 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	179
Season Modeled	Summer
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	13.5%	contddays	4.3%
catsoiltemp	9.8%	contstrmed	3.7%
contwinpcp	9.1%	contslope	3.2%
contndvi	8.8%	contelev	3.1%
contvrm	8.6%	contwinrad	2.8%
contnsasp	6.1%	catgeol	1.9%
contfrsted	6.1%	contsumrad	1.9%
catsoilord	5.1%	contprecip	1.8%
conttmin	4.6%	contewasp	1.1%
conttmax	4.5%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.046
Moderate Logistic Threshold[b]	0.247
Optimal Logistic Threshold[c]	0.666
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	185,307.3 km^2
Area of predicted low suitability habitat within modeled range	128,098.5 km^2
Area of moderate suitability habitat within modeled range	51,391.5 km^2
Area of predicted optimal habitat within modeled range	5,817.3 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	96.7%
Moderate AVI[a]	73.7%
Optimal AVI[a]	25.1%
Average Testing Deviance ($\bar{x}$ ± sd)[b]	2.077 ± 1.762
Training AUC[c]	0.923
Test AUC[d]	0.889

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 6.145, 2.796 and 0.813, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

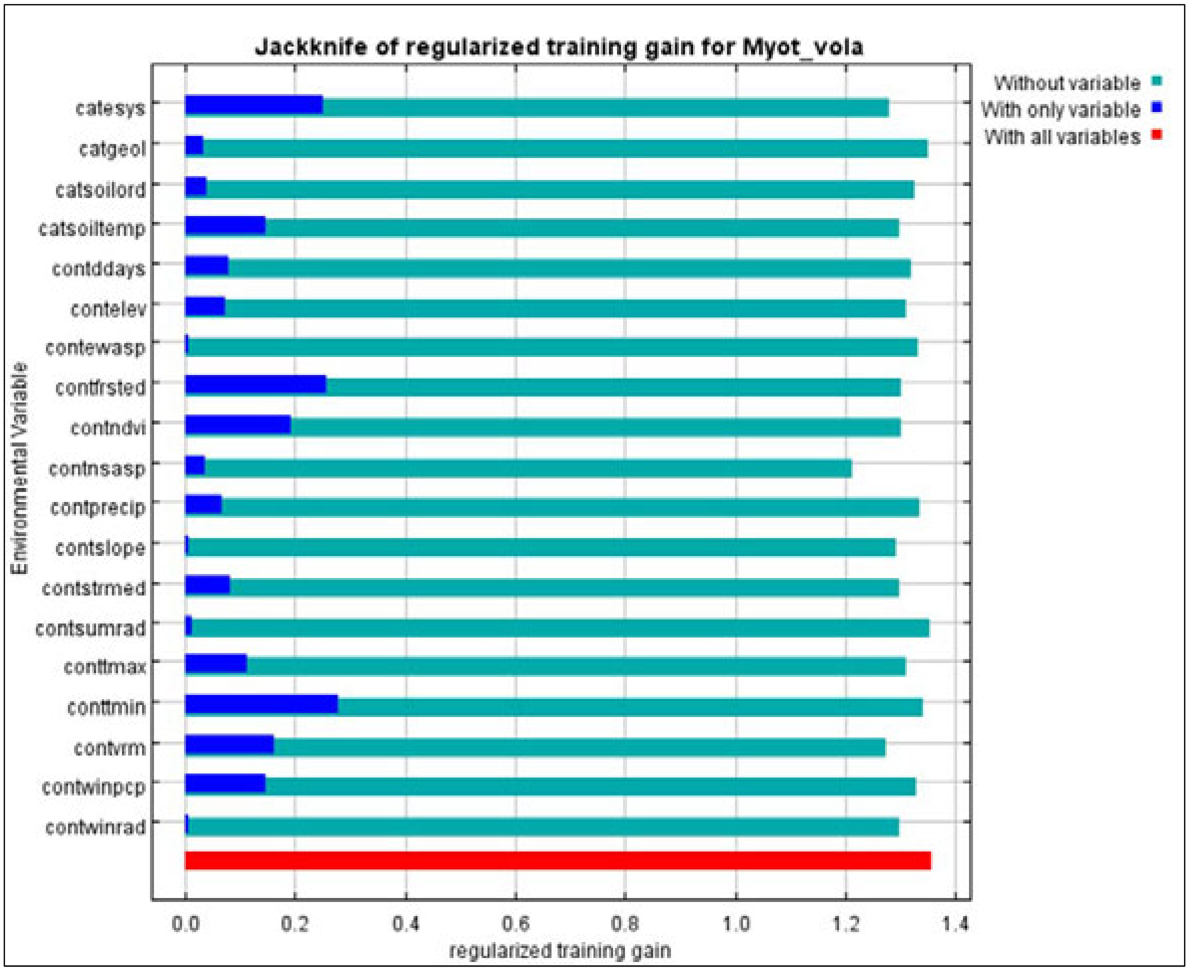
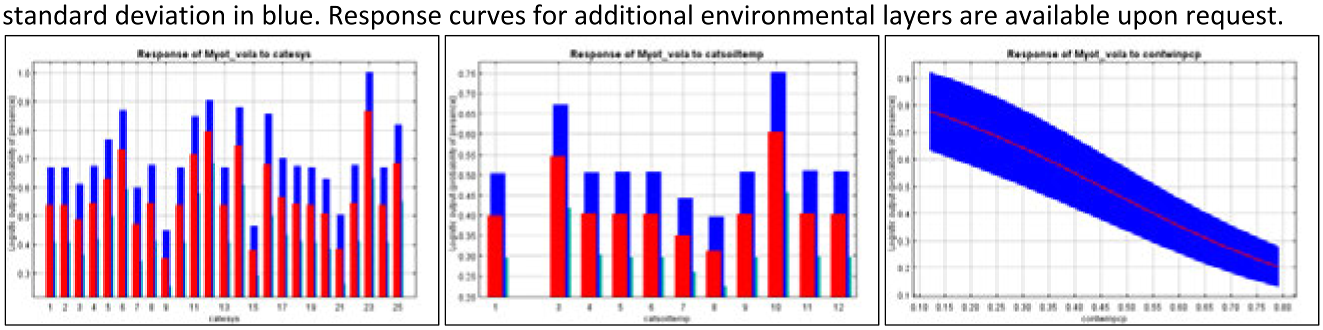


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

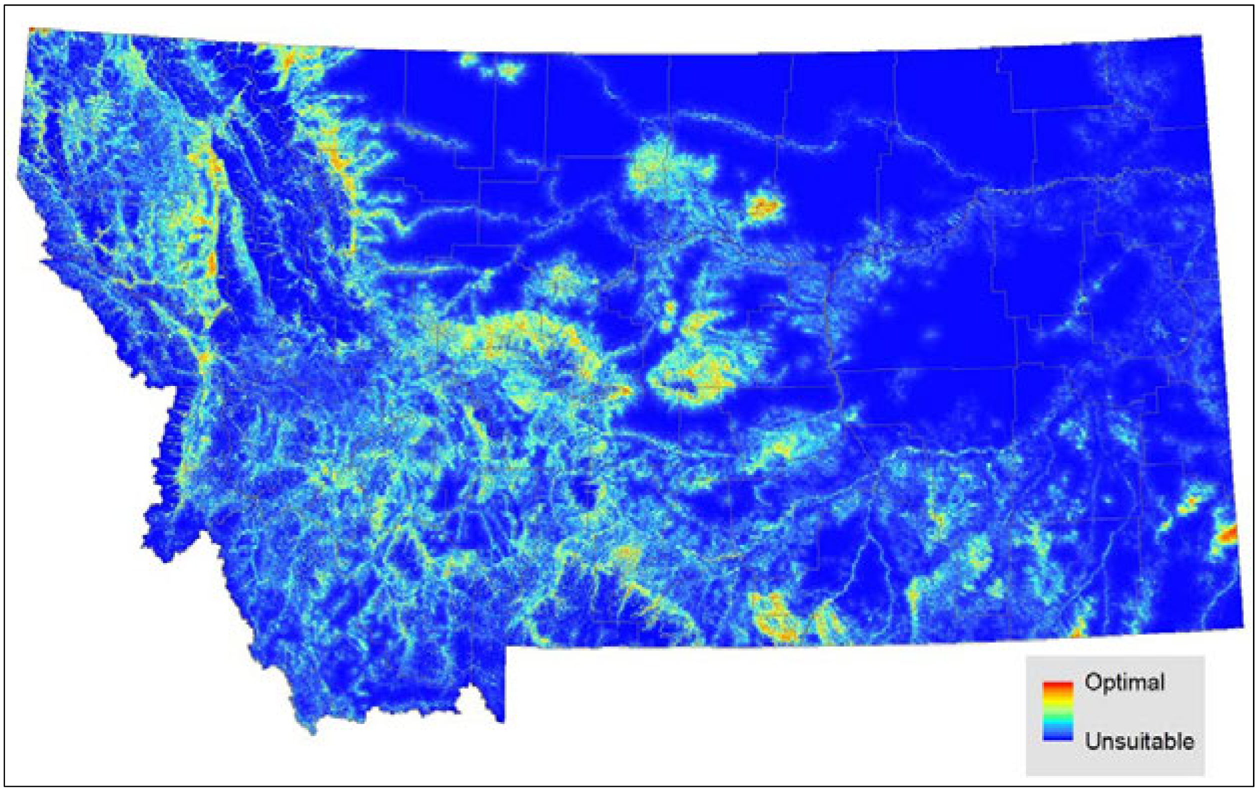


Figure 4. Standard deviation in the model output across the averaged models.

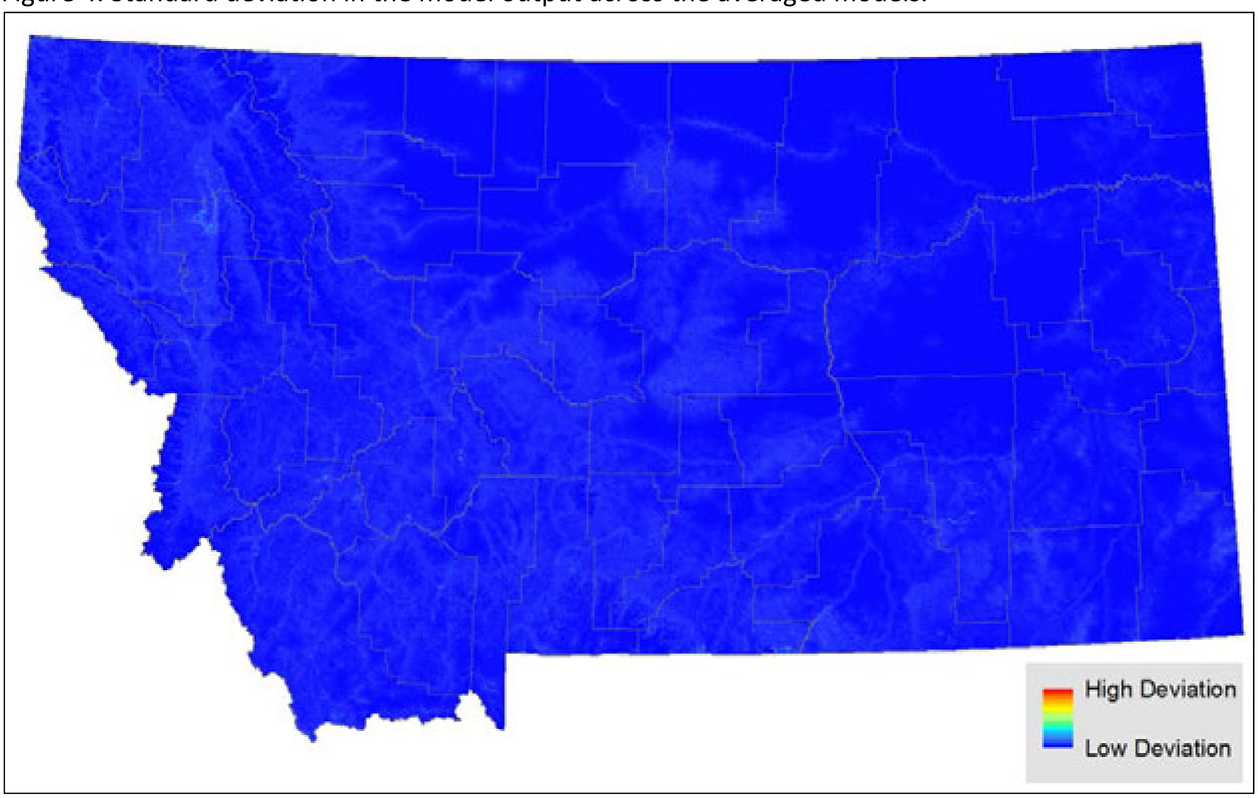


Figure 5. Continuous habitat suitability model output with the 179 observations used for modeling.

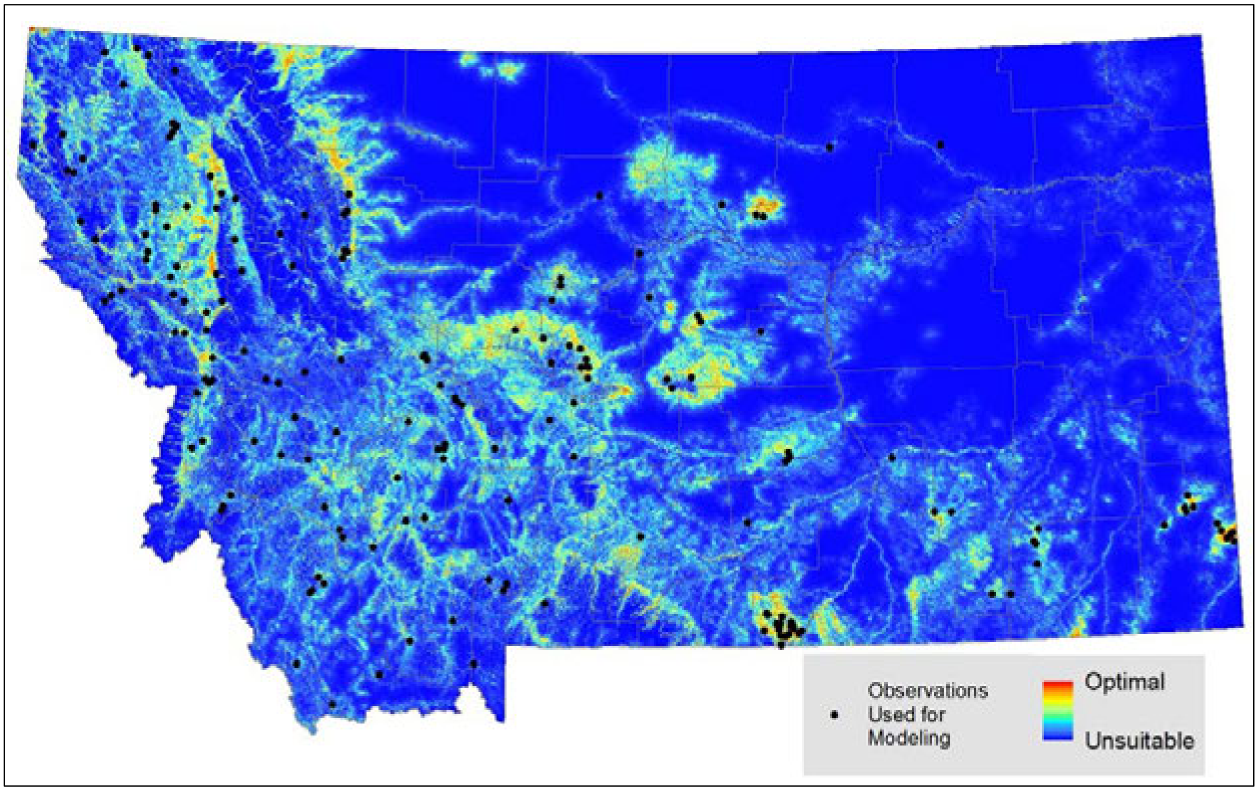


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

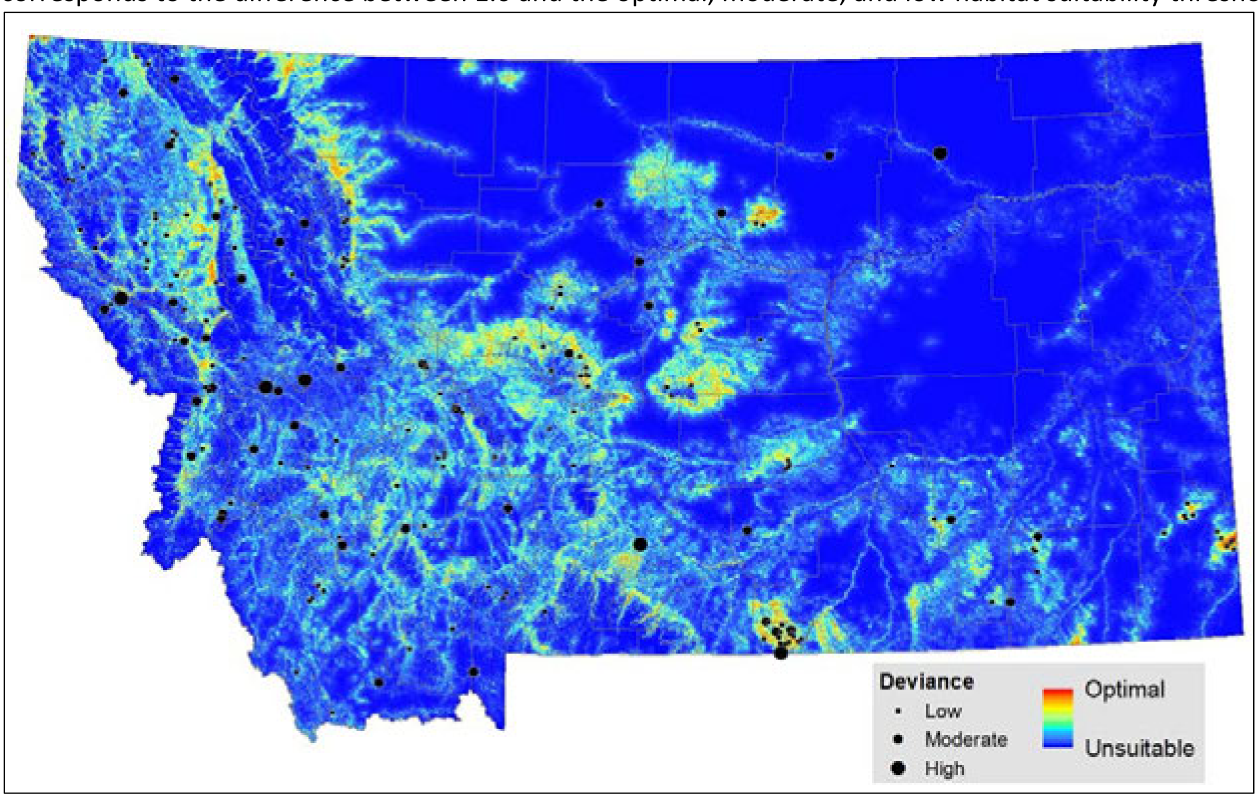


Figure 7. Continuous habitat suitability model output with all 286 observations (black) and survey locations that could have detected the species (gray).

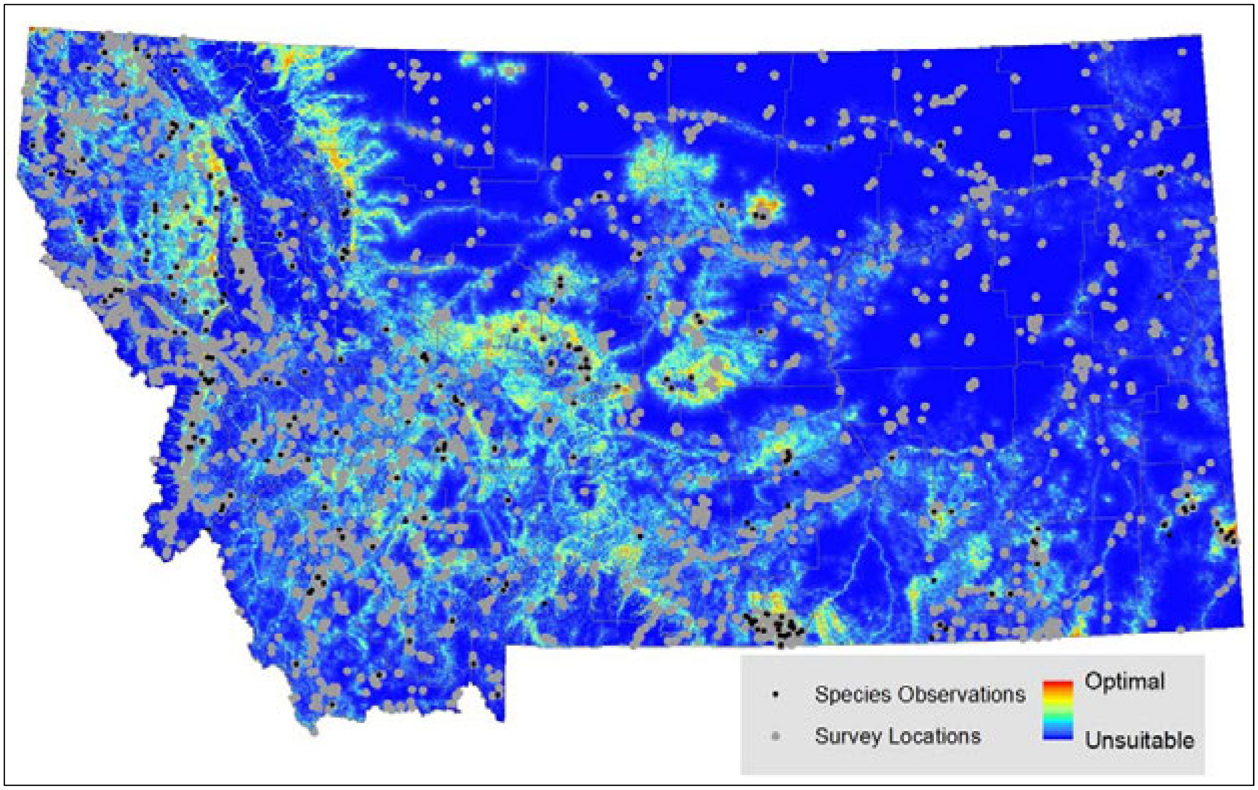


Figure 8. Model output classified into habitat suitability classes.

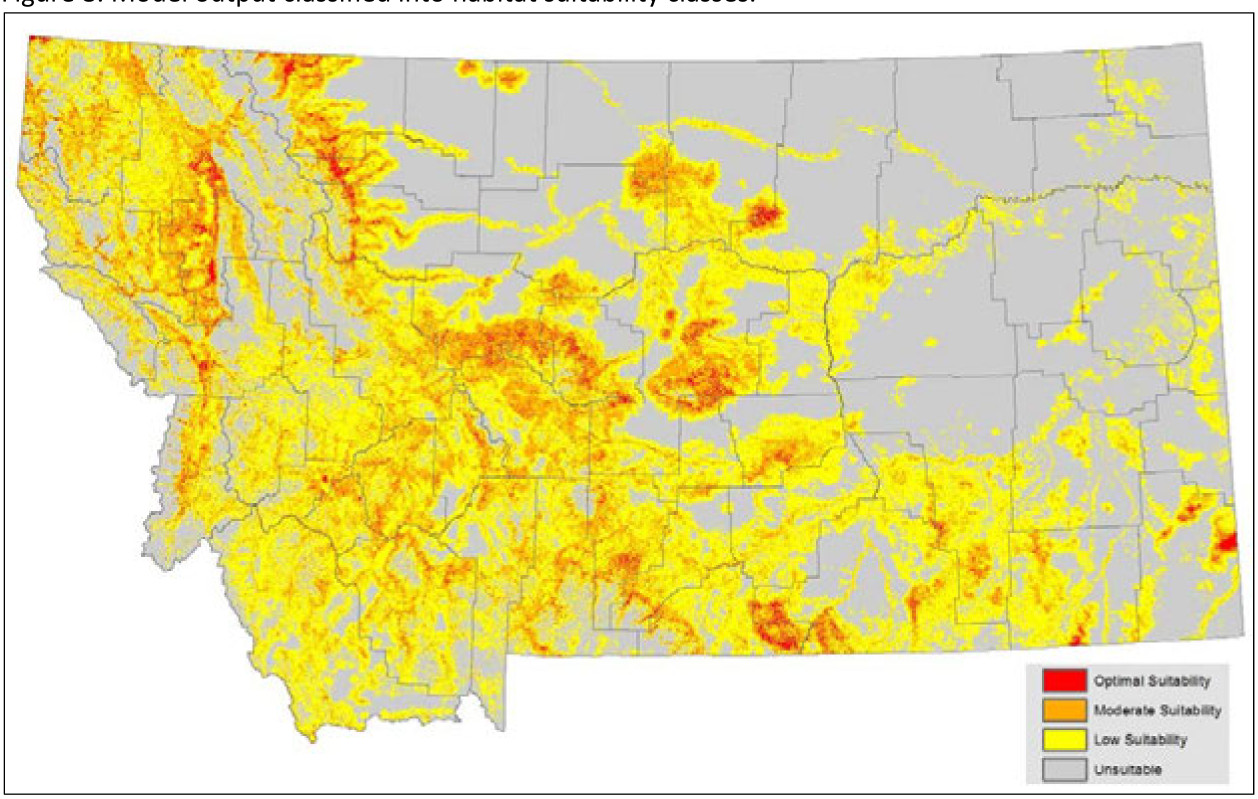
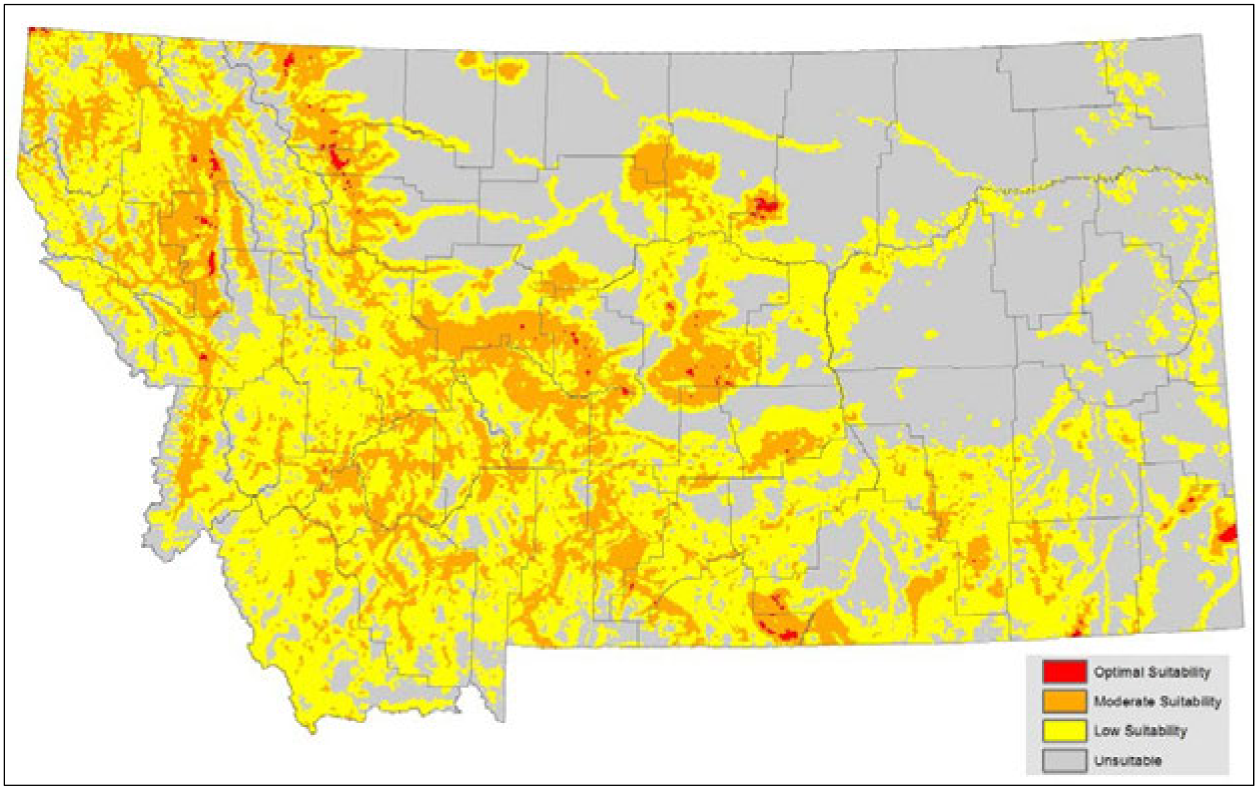


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Long-legged Myotis

Ecological System	Code	Association	Count[a]
Rocky Mountain Lower Montane, Foothill, and Valley Grassland	7112	Common	16
Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	4232	Common	11
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	10
Rocky Mountain Montane Douglas-fir Forest and Woodland	4266	Common	8
Great Plains Riparian	9326	Common	8
Rocky Mountain Mesic Montane Mixed Conifer Forest	4234	Common	7
Montane Sagebrush Steppe	5455	Common	7
Rocky Mountain Lodgepole Pine Forest	4237	Common	6
Rocky Mountain Ponderosa Pine Woodland and Savanna	4240	Common	6
Big Sagebrush Steppe	5454	Common	6
Post-Fire Recovery	8505	Common	6
Open Water	11	Common	4
Great Plains Ponderosa Pine Woodland and Savanna	4280	Common	4
Rocky Mountain Foothill Limber Pine - Juniper Woodland	4236	Common	3
Recently burned forest	8501	Common	3
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	3
Insect-Killed Forest	8700	Common	3
Aspen Forest and Woodland	4104	Common	2
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	4242	Common	2
Great Plains Wooded Draw and Ravine	4328	Common	2
Rocky Mountain Montane-Foothill Deciduous Shrubland	5312	Common	2
Great Plains Floodplain	9159	Common	2
Rocky Mountain Cliff, Canyon and Massive Bedrock	3129	Common	1
Mountain Mahogany Woodland and Shrubland	4303	Common	1
Rocky Mountain Foothill Woodland-Steppe Transition	5426	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Alpine-Montane Wet Meadow	9217	Common	1
Great Plains Cliff and Outcrop	3142	Common	0
Wyoming Basin Cliff and Canyon	3173	Common	0
Aspen and Mixed Conifer Forest	4302	Common	0
Big Sagebrush Shrubland	5257	Common	0
Rocky Mountain Lower Montane-Foothill Shrubland	5263	Common	0
Rocky Mountain Conifer Swamp	9111	Common	0
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	0
Emergent Marsh	9222	Common	0
Other Roads	28	Occasional	33
Great Plains Mixedgrass Prairie	7114	Occasional	4
Harvested forest-tree regeneration	8601	Occasional	2
Developed, Open Space	21	Occasional	1

Table 5: Ecological Systems Associated with Long-legged Myotis

Ecological System	Code	Association	Count[a]
Low Intensity Residential	22	Occasional	1
Great Plains Badlands	3114	Occasional	1
Rocky Mountain Subalpine Deciduous Shrubland	5326	Occasional	1
Rocky Mountain Subalpine-Upper Montane Grassland	7113	Occasional	1
Rocky Mountain Subalpine-Montane Mesic Meadow	7118	Occasional	1
Great Plains Sand Prairie	7121	Occasional	1
Recently burned grassland	8502	Occasional	1
Railroad	25	Occasional	0
Shale Badland	3139	Occasional	0
Rocky Mountain Subalpine Woodland and Parkland	4233	Occasional	0
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	4243	Occasional	0
Rocky Mountain Poor Site Lodgepole Pine Forest	4267	Occasional	0
Mat Saltbush Shrubland	5203	Occasional	0
Mixed Salt Desert Scrub	5258	Occasional	0
Great Plains Shrubland	5262	Occasional	0
Introduced Riparian and Wetland Vegetation	8406	Occasional	0
Greasewood Flat	9103	Occasional	0
Great Plains Open Freshwater Depression Wetland	9218	Occasional	0
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	0
Great Plains Closed Depressional Wetland	9252	Occasional	0
Great Plains Saline Depression Wetland	9256	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 179 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

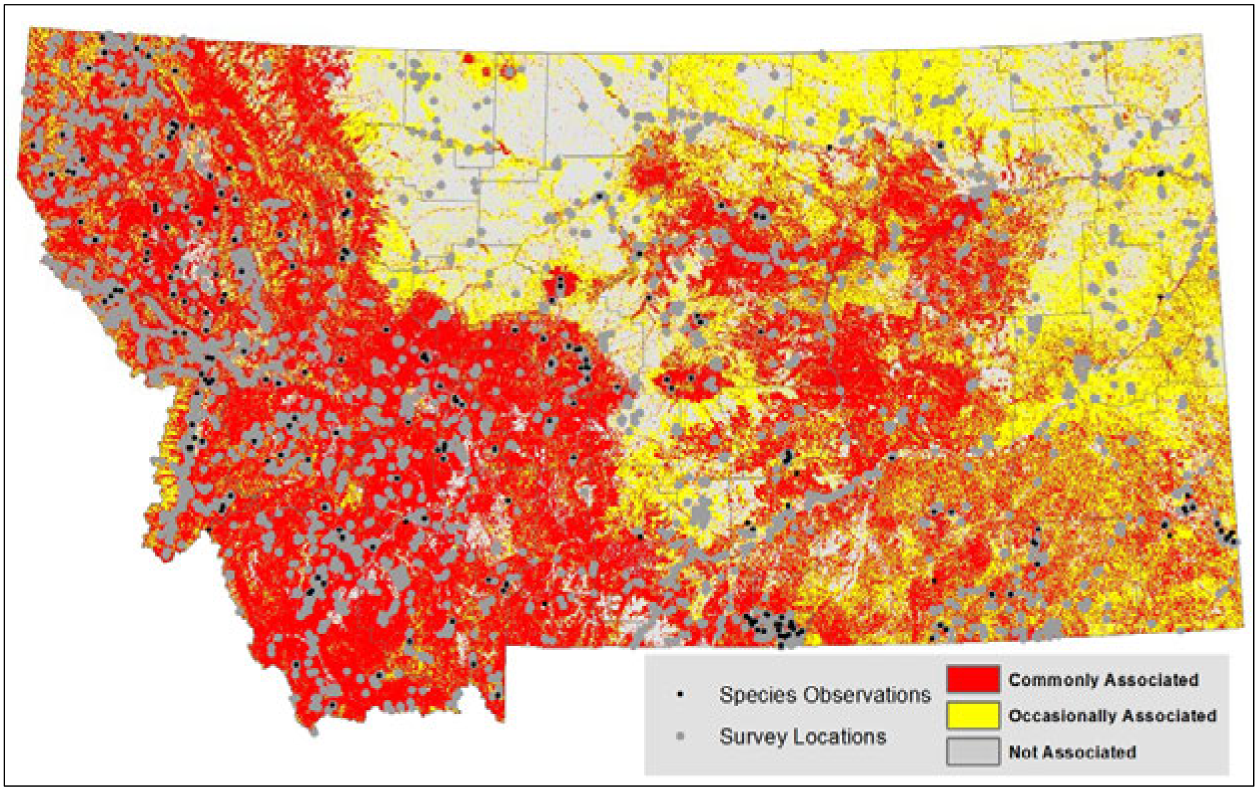
Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	297,664.0 km^2
Area of Commonly Associated ES	180,243.0 km^2
Area of Occasionally Associated ES	117,421.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	96.7%
Commonly Associated ES AVI[a]	70.4%
Occasionally Associated ES AVI[a]	26.3%

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

Figure 10. Deductive model output classified into habitat associations.



Beaver (*Castor canadensis*)
Predicted Suitable Habitat Modeling

Distribution Status: Resident Year Round
State Rank: S5
Global Rank: G5

Modeling Overview

Created by: Bryce Maxell & Braden Burkholder
Creation Date: October 7, 2017
Evaluator: Bryce Maxell
Evaluation Date: October 7, 2017

Inductive Model Goal: To predict the distribution and relative suitability of general year-round habitat at large spatial scales across the species' known range in Montana.
Inductive Model Performance: The model does a good job of representing the distribution of Beaver general year-round habitat suitability at larger spatial scales across the species' known range in Montana. Evaluation metrics indicates a good model fit and the delineation of habitat suitability classes is well-supported by the data.

Deductive Model Goal: To represent the ecological systems commonly and occasionally associated with this species year-round, across the species' known range in Montana.
Deductive Model Performance: Ecological systems that this species is commonly and occasionally associated with do a reasonably good job of representing the amount of suitable habitat across the species' known range in Montana. However, the inductive model is recommended for informing survey and management decisions. Low AVI evaluations are a result of the fact that smaller riparian habitats the species is dependent on are sometimes poorly mapped in the land cover layer.

Suggested Citation: Montana Natural Heritage Program. 2017. Beaver (*Castor canadensis*) predicted suitable habitat models created on October 7, 2017. Montana Natural Heritage Program, Helena, MT. 15 p.

Montana Field Guide Species Account: http://fieldguide.mt.gov/speciesDetail.aspx?elcode=AMAFE01010

Table 1: Model Data Selection Criteria and Summary

Location Data Source	Montana Natural Heritage Program Databases
Total Number of Records	2,756
Location Data Selection Rule 1	Records with <= 1600 meters of locational uncertainty
Number of Locations Meeting Selection Rule 1	2,670
Location Data Selection Rule 2	No overlap in locations within 800 meters in order to avoid spatial autocorrelation
Observation Records used in Model (Locations Meeting Selection Rules 1 & 2)	613
Season Modeled	Year-round
Number of Model Background Locations	60,000

Inductive Model Results

Table 2: Environmental Layer Contributions to Model Fit

Layer ID	Percent Contribution[a]	Layer ID	Percent Contribution[a]
catesys	44.7%	contddays	1.6%
catsoiltemp	11.7%	contnsasp	1.4%
catgeol	8.4%	conttmax	1.2%
contslope	7.4%	contewasp	1.1%
contstrmed	4.5%	contelev	0.9%
contsumrad	4.0%	contwinrad	0.7%
catsoilord	4.0%	contprecip	0.5%
contndvi	3.6%	contvrm	0.3%
contfrsted	2.0%	conttmin	0.3%
contwinpcp	1.8%		

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

Table 3: Habitat Suitability Thresholds

Measure	Value
Low Logistic Threshold[a]	0.048
Moderate Logistic Threshold[b]	0.273
Optimal Logistic Threshold[c]	0.631
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Total area of predicted suitable habitat within modeled range	201,688.6 km^2
Area of predicted low suitability habitat within modeled range	162,650.1 km^2
Area of moderate suitability habitat within modeled range	31,190.8 km^2
Area of predicted optimal habitat within modeled range	7,847.7 km^2

[a] The logistic threshold between unsuitable and low suitability as determined by Maxent which balances data omission error with minimizing predicted suitable area. This is a conservative threshold that should encompass nearly all potentially suitable habitat for a species.
[b] The logistic threshold value where the percentage of test observations above the threshold is what would be expected if the observations were randomly distributed across logistic value classes (Hirzel et al. 2006). This is equivalent to a null model. When sample sizes are small, it may be undetermined.
[c] The logistic threshold where the percentage of test observations above the threshold is 10 times higher than would be expected if the observations were randomly distributed across logistic value classes. When sample sizes are small, it may be undetermined.

Table 4: Evaluation Metrics

Metric	Value
Low AVI[a]	95.9%
Moderate AVI[a]	79.4%
Optimal AVI[a]	46.9%
Average Testing Deviance ($\bar{x} \pm sd$)[b]	1.682 ± 1.855
Training AUC[c]	0.931
Test AUC[d]	0.916

[a] Absolute Validation Index: The proportion of test locations that fall above the low, moderate, or optimal logistic threshold.
[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 6.057, 2.600 and 0.920, respectively. Deviances for individual test locations are plotted in Figure 6.
[c] 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.
[d] The same metric described in c, but calculated for test observations.

Figure 1. Jackknife assessment of contribution by individual environmental layers to training gain.

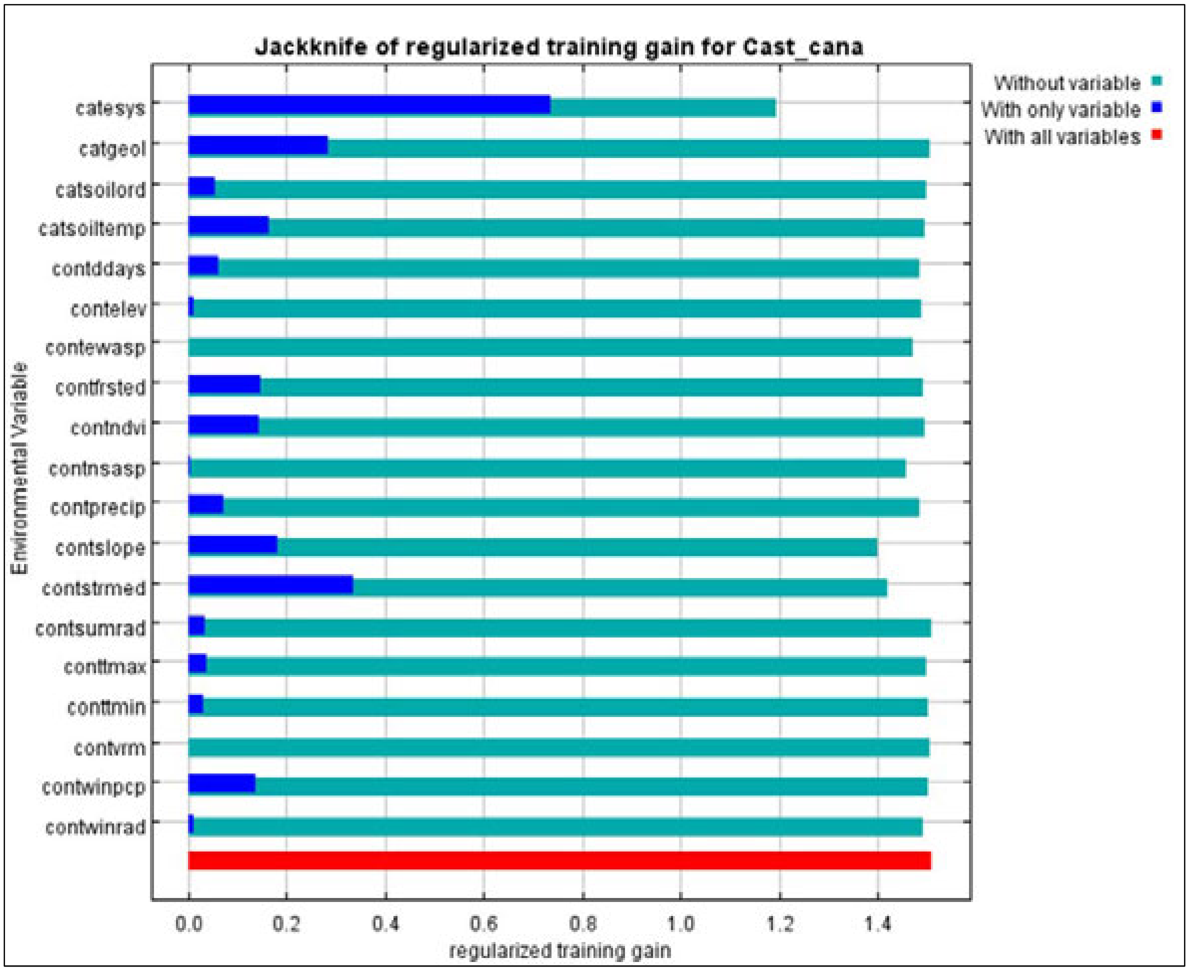
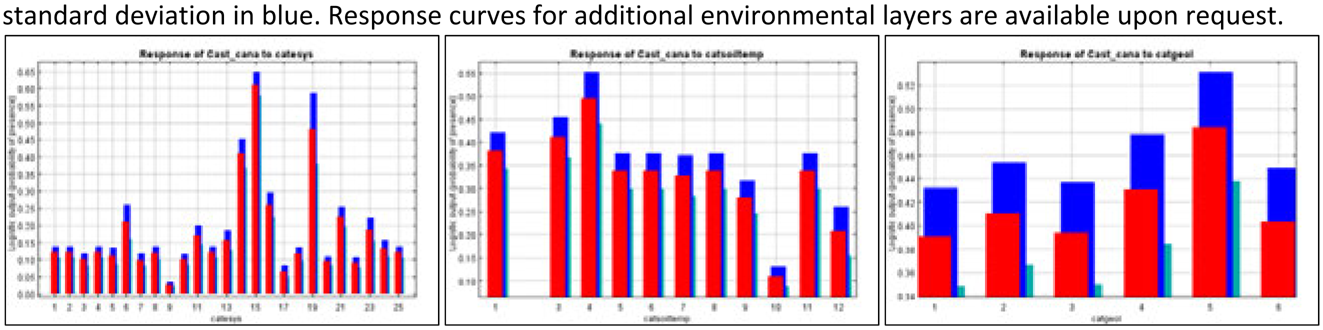


Figure 2. Response curves for the top three contributing environmental layers, mean value in red, +/- one standard deviation in blue. Response curves for additional environmental layers are available upon request.



Inductive Model Map Outputs

Figure 3. Continuous habitat suitability model output (logistic scale).

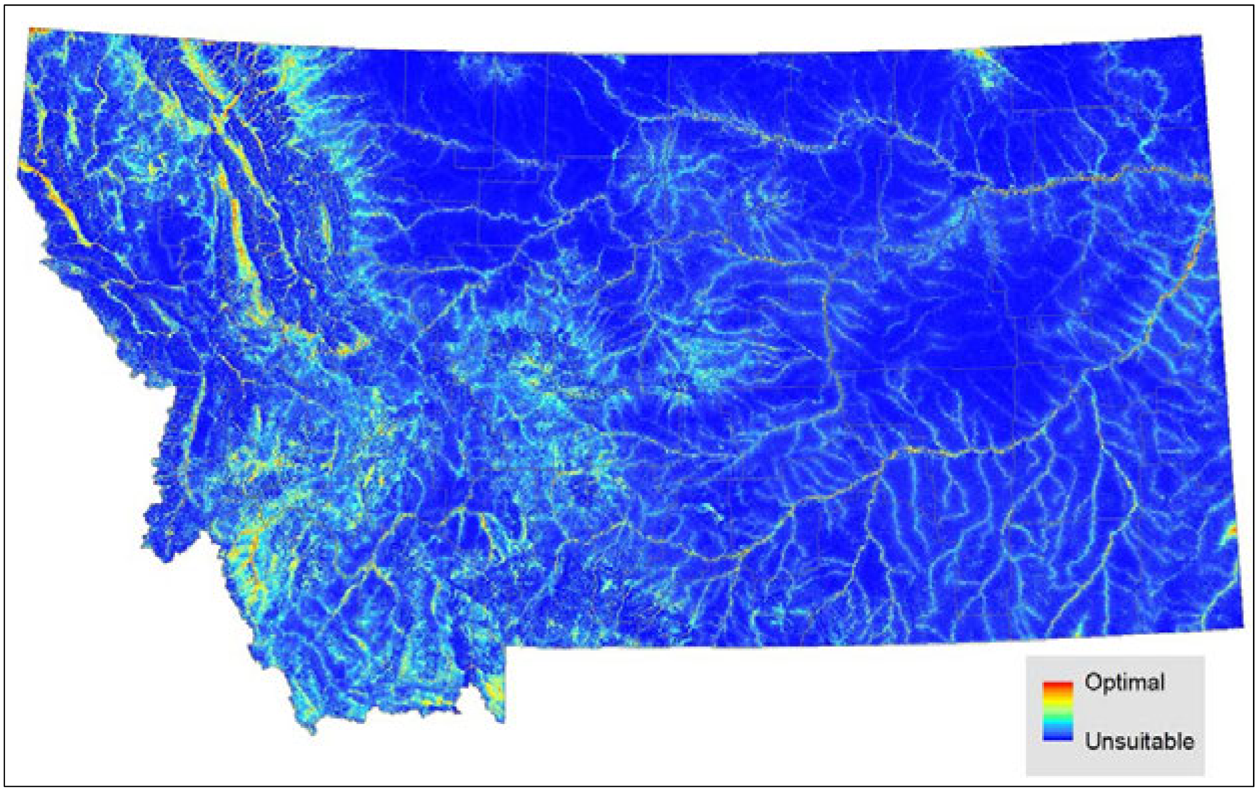


Figure 4. Standard deviation in the model output across the averaged models.

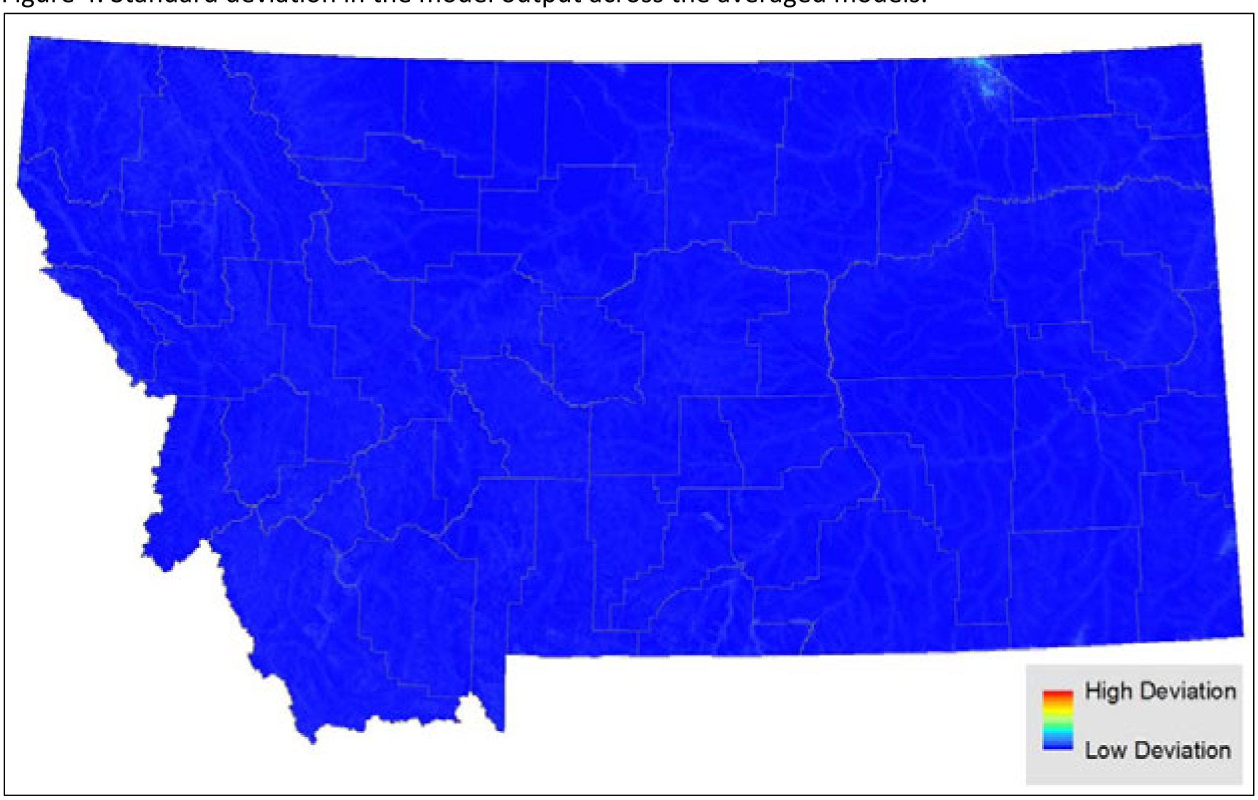


Figure 5. Continuous habitat suitability model output with the 613 observations used for modeling.

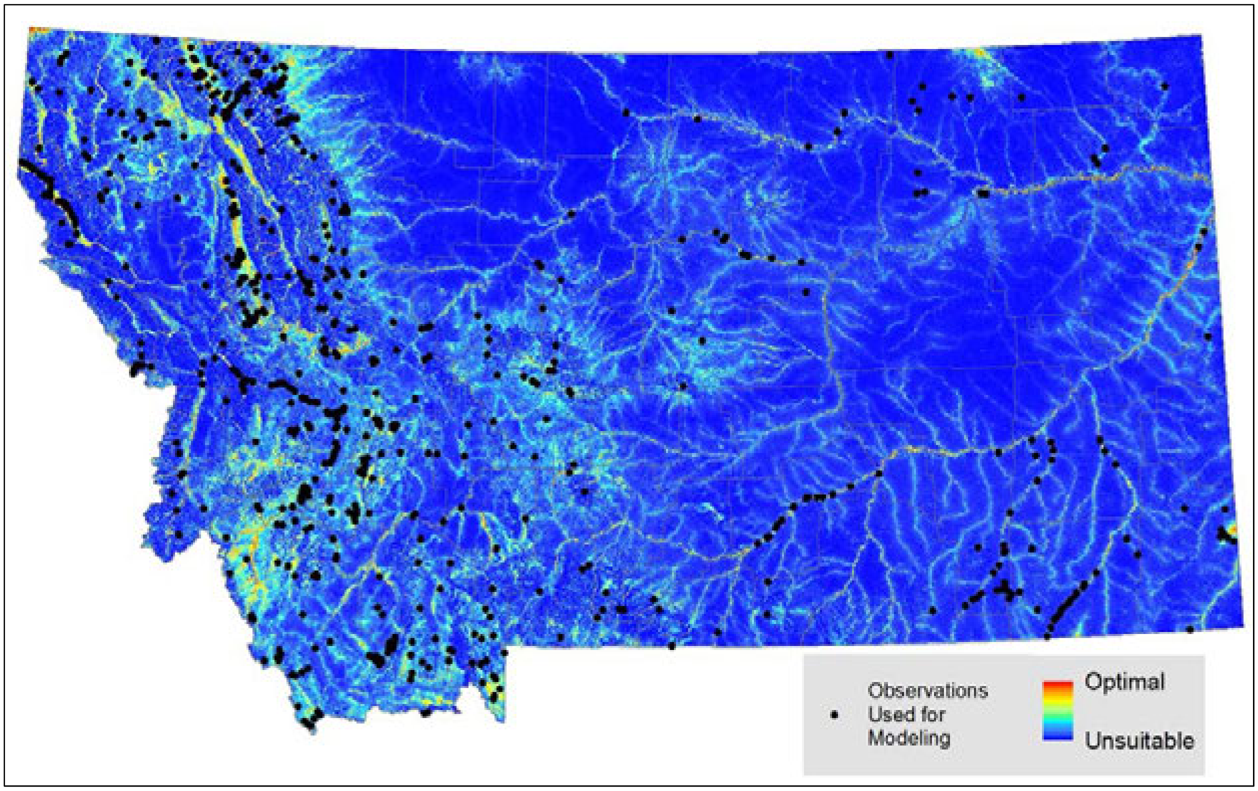


Figure 6. Continuous habitat suitability model output with relative deviance for each observation. Symbol size corresponds to the difference between 1.0 and the optimal, moderate, and low habitat suitability threshold.

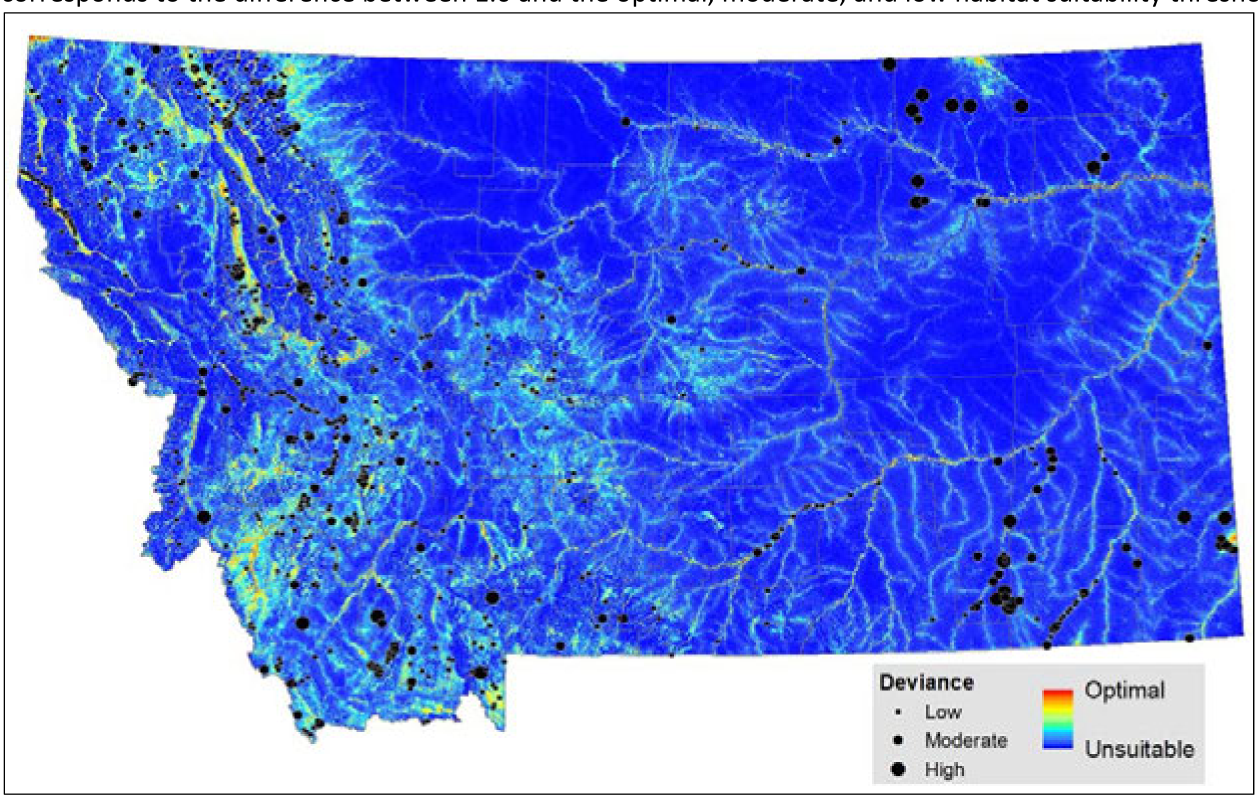


Figure 7. Continuous habitat suitability model output with all 2,756 observations (black) and survey locations that could have detected the species (gray).

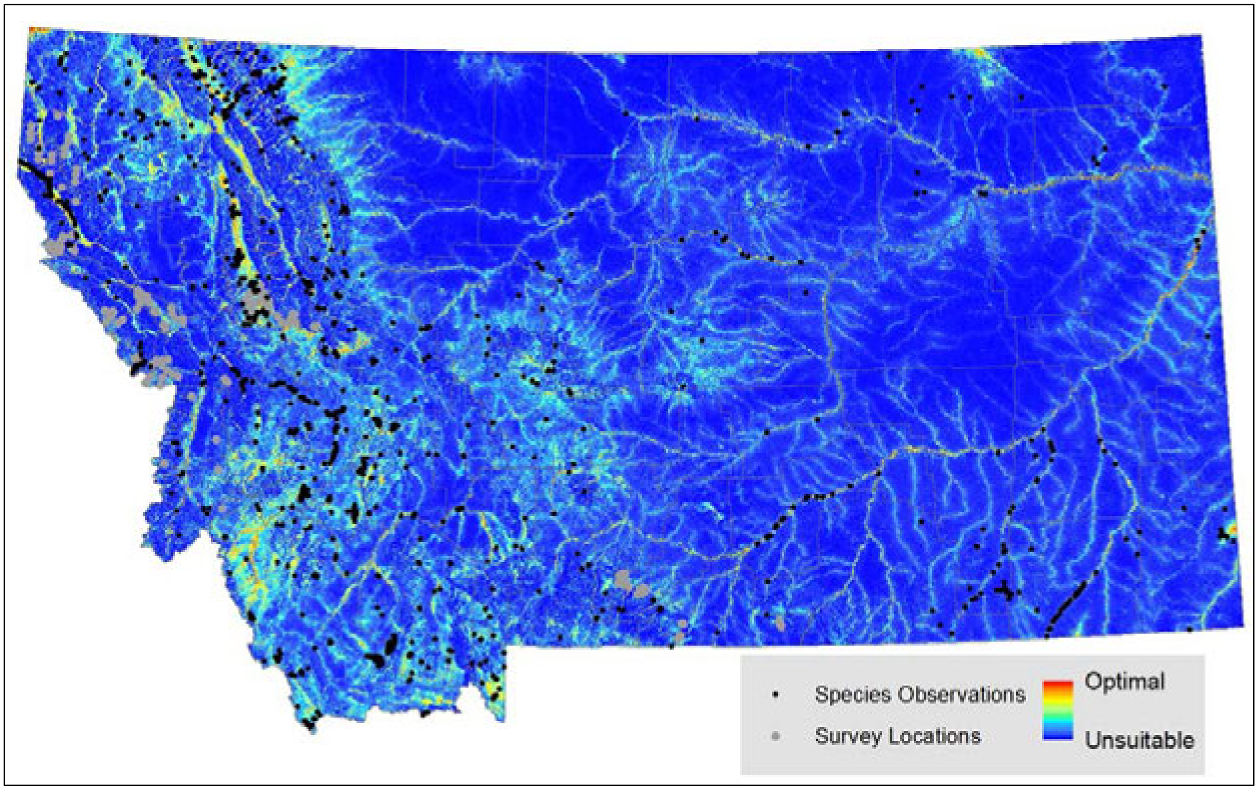


Figure 8. Model output classified into habitat suitability classes.

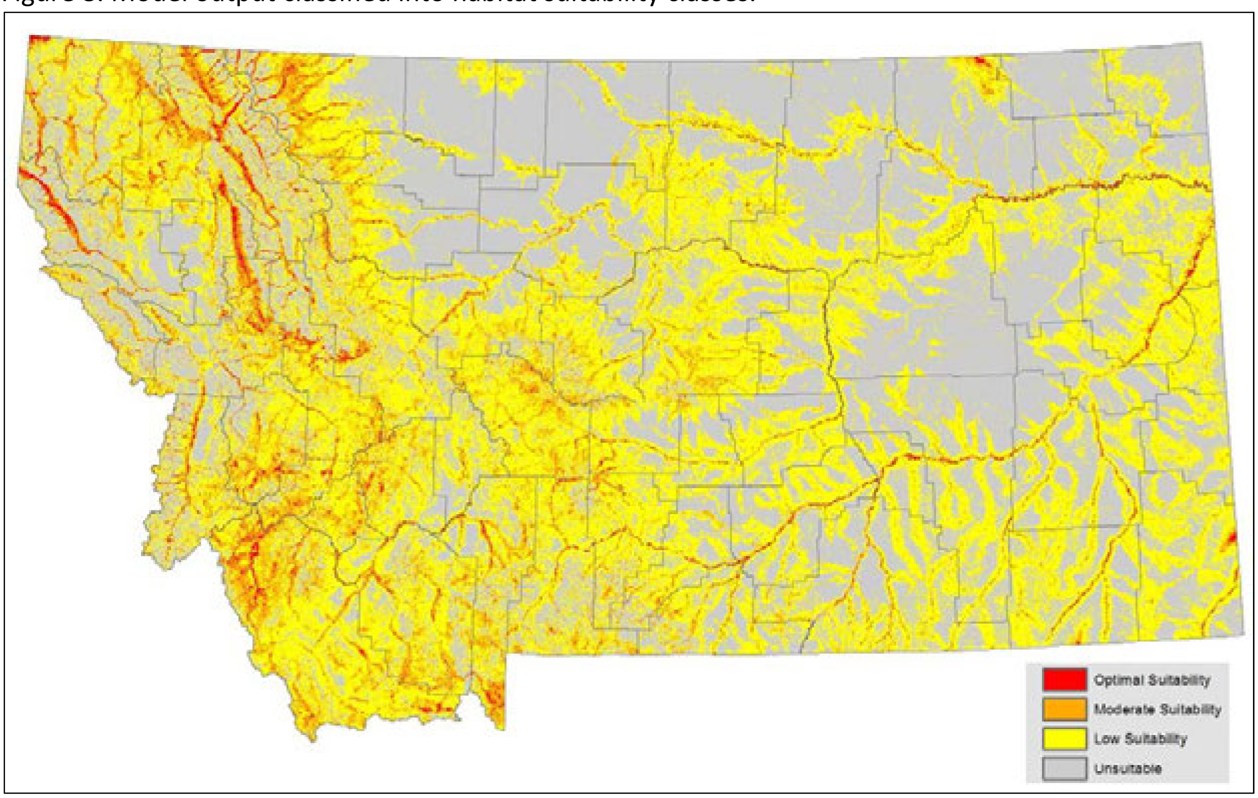
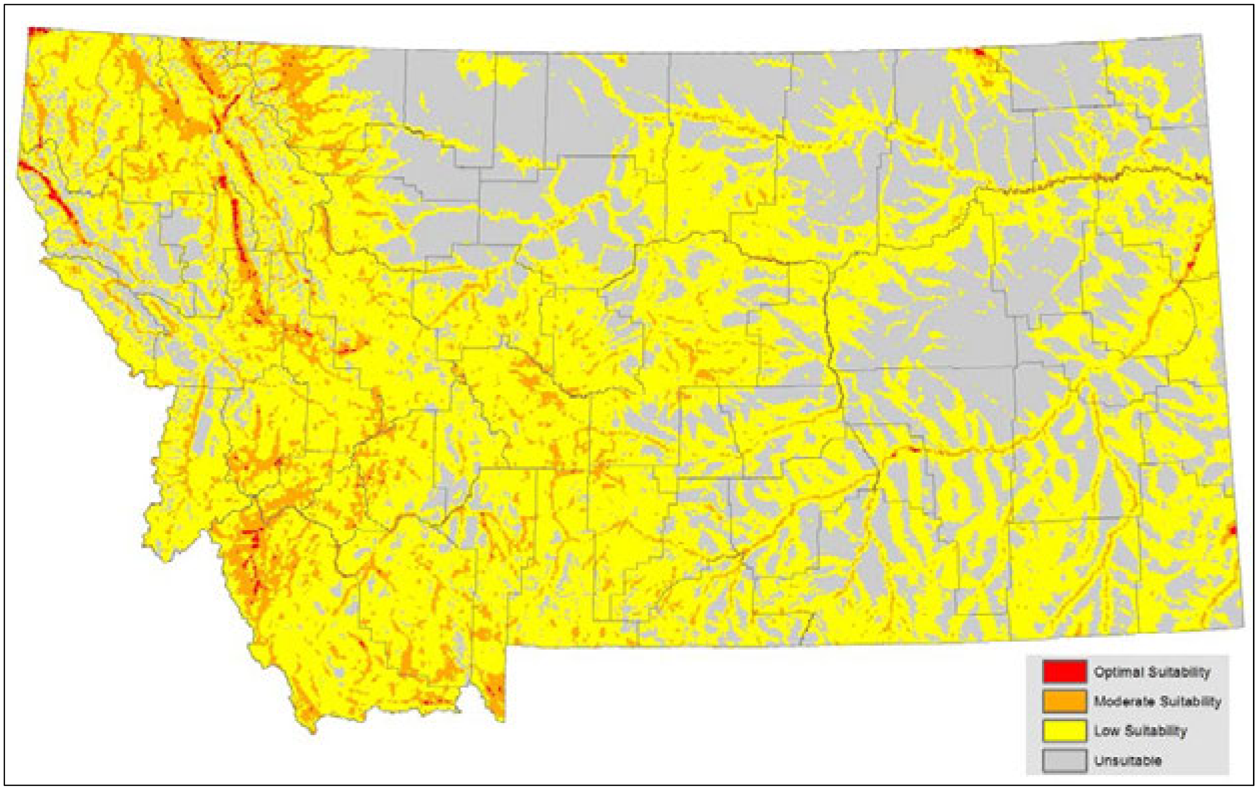


Figure 9. Model output classified into habitat suitability classes and aggregated into hexagon at a scale 259 hectares per hexagon. This is the finest scale suggested for management decisions and survey planning.



Deductive Model Results

Table 5: Ecological Systems Associated with Beaver

Ecological System	Code	Association	Count[a]
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	9155	Common	104
Open Water	11	Common	97
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	9156	Common	35
Alpine-Montane Wet Meadow	9217	Common	35
Great Plains Floodplain	9159	Common	18
Great Plains Riparian	9326	Common	7
Rocky Mountain Subalpine-Montane Riparian Woodland	9171	Common	2
Rocky Mountain Conifer Swamp	9111	Common	1
Rocky Mountain Subalpine-Montane Riparian Shrubland	9187	Common	1
Rocky Mountain Wooded Vernal Pool	9162	Common	0
Emergent Marsh	9222	Occasional	5
Rocky Mountain Subalpine-Montane Fen	9234	Occasional	5
Great Plains Open Freshwater Depression Wetland	9218	Occasional	1
Great Plains Wooded Draw and Ravine	4328	Occasional	0

[a] A count of the observation records intersecting each ecological system, based on the 613 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 patchy.

Table 6: Area of Range and Ecological System (ES) Classes

Measure	Value
Area of entire modeled range (percent of Montana)	380,494.42 km^2 (100.0%)
Area of Commonly and Occasionally Associated ES	19,234.0 km^2
Area of Commonly Associated ES	16,835.0 km^2
Area of Occasionally Associated ES	2,399.0 km^2

Table 7: Evaluation Metrics

Metric	Value
Commonly and Occasionally Associated ES AVI[a]	50.7%
Commonly Associated ES AVI[a]	48.9%
Occasionally Associated ES AVI[a]	1.8%

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

Figure 10. Deductive model output classified into habitat associations.