# Determining Suitable Habitat for American Marten (*Martes americana*) using a Geographic Information System (GIS)

**Final Report**
Professional Services Contract# 80-516-00-04484

Submitted to:
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*New Mexico Department of Game and Fish*
*One Wildlife Way*
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August 15, 2009

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## Introduction

Martens are small carnivorous mammals that live in old growth spruce-fir forests and prey primarily on small mammals. They are considered habitat specialists preying primarily on members of the *Clethrionomys* (vole) genus. Martens require forests that have complex physical structures near the forest floor because they provide denning areas and cover, as well as an environment that is suitable for prey animals (Buskirk, 1998). They are active all winter and are well adapted to burrowing in snow in search of prey. The mountains of northern New Mexico are at the southern end of their range. Populations in the American west are generally considered to be fragmented. This is due in large part to the discontinuous forest coverage in the western states as well as human encroachment on their habitat (Gibilisco 1994). Fragmentation of Marten habitat is likely more pronounced in New Mexico since there are not many large contiguous areas of spruce-fir forest.

Martens are listed in the New Mexico Comprehensive Wildlife Conservation Strategy as a species of greatest conservation need (SGCN) and are listed by the State of New Mexico as a threatened species.

## Purpose

The data generated by this project will allow the Department to have better information upon which to base field surveys for future research. This project will provide NMDGF with two valuable datasets: potential marten habitat and an occurrence database.

Previously NMDGF did not have reliable up-to-date data representing potential Marten habitat. The potential habitat data will allow NMDGF biologists and others to focus their survey efforts in areas that they would not have otherwise inventoried. Recent field efforts have been restricted to a few well known locations. However, highly suitable habitat exists in other portions of the northern Sangre de Cristo range as well as the San Juan Mountains neither of which has been surveyed recently. In the future this dataset could be used to estimate the total number of individuals on the landscape.

With this project we also compiled all the known sightings of Marten that NMDGF had collected. Most of these were in the form of hard copy field notes. The digital and spatially enabled sightings data will be easier to maintain, backup and utilize in future research endeavors.

## Methodology

### Modeling approach:

The marten sighting locations and a sample of random point locations (as a control) were intersected with predictor variable data layers. The intersection of these data sets associated predictor variable values with marten sighting locations and random points. We then used these associations in a binary logistic regression analysis to produce a model which weights predictor variable values by their effectiveness in distinguishing marten locations from random locations. With the results from the logistic regression, a formula was derived which calculated the probability of marten occurrence for any given location based on the predictor variable values.

By using this probability formula in the Raster Calculator of ArcGIS along with our array of predictor variable layers, we produced a final predictive raster that classified marten habitat categories from non-suitable to highly suitable.

A first generation model was generated in December 2008. This was based on preliminary sightings data and preliminary habitat data. This was intended to be used by Brian Long (NMDGF contractor) to locate different areas to conduct winter surveys in. Surveys are conducted in winter so that marten tracks can be located in the snow. Unfortunately high elevation snow fall started late creating a shortened survey season. The season yielded no new sightings from which to improve the model. We therefore looked for better data to use in the model. The following methodology applies to the final modeling effort.

**Marten occurrence mapping:**

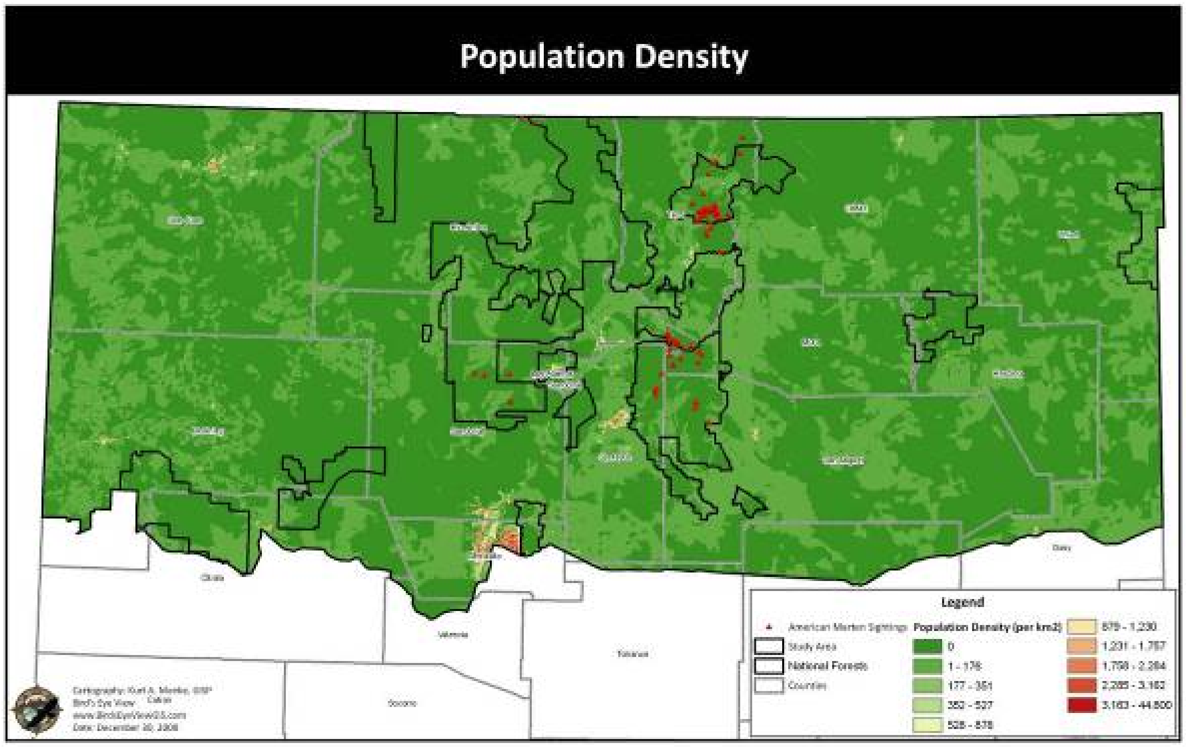
A thorough search was performed for existing marten occurrence records. This included material provided by the New Mexico Department of Game and Fish (NMDGF), a search in the Mammal Networked Information System (http://manisnet.org/), and records maintained by Brian Long (contractor to NMDGF). When possible these points were mapped via coordinates obtained by global positioning units (GPS). However, many points supplied by Brian Long were mapped by heads up digitizing points marked onto topographic maps of varying scales or from verbal descriptions based on geographic features. In total 96 sightings were mapped. Seventy four of the sightings were heads up digitized with the remainder being mapped from GPS coordinates. The source for each sighting was recorded in the attribute table of the resulting ESRI shapefile.

**Habitat data:**

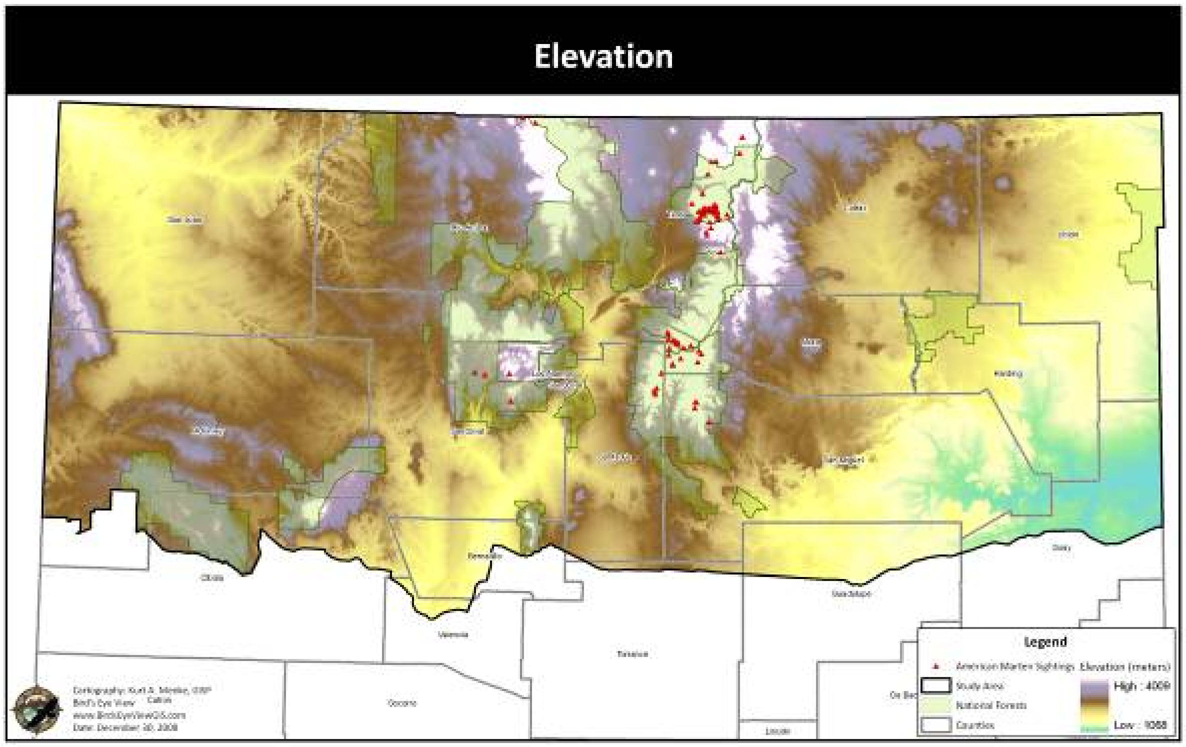
A study area was generated roughly equal to the northern third of New Mexico and encapsulating all the marten occurrence data. This was generated by dissolving Game Management Unit boundaries 1 – 11 and 41 – 58.

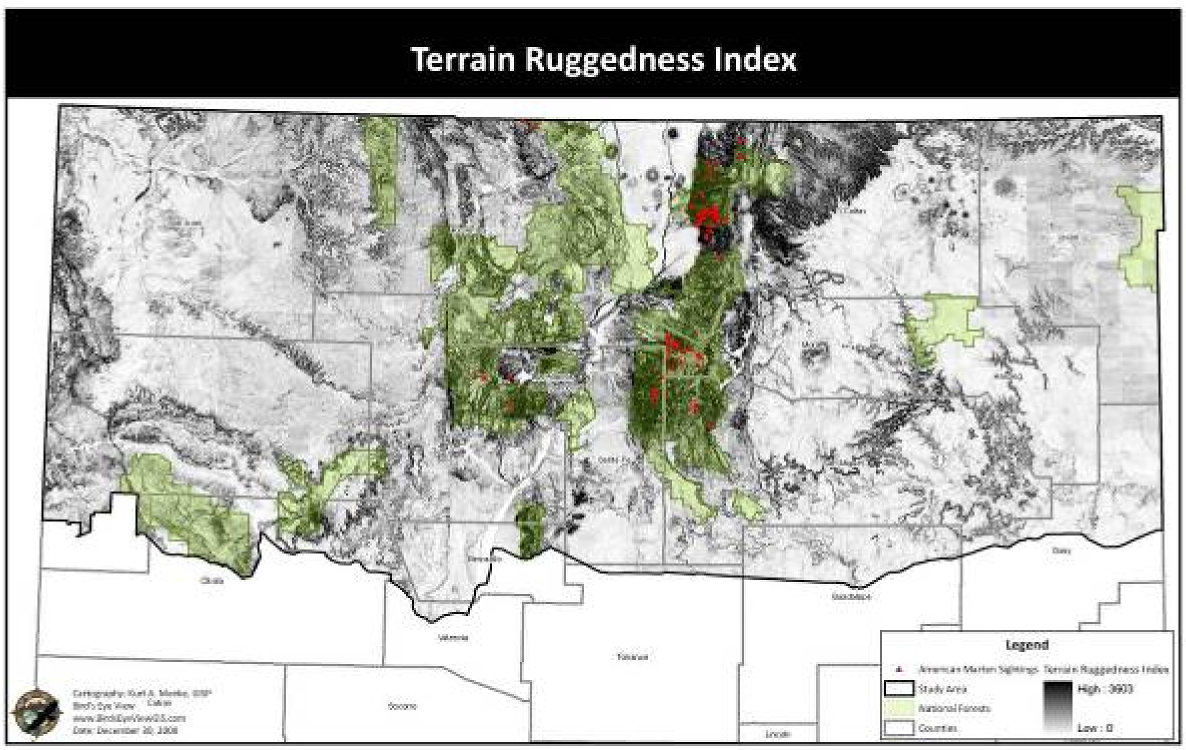
Data potentially relevant to determining marten habitat were collected. These included population by block, elevation, roads, landcover and vole (*Microtus sp*.) sightings. All data were projected to Universal Transverse Mercator (UTM), zone 13, datum NAD83 and clipped to the study area boundary.

The population data was obtained from the 2000 US Census Factfinder website (http://factfinder.census.gov/home/saff/main.html?_lang=en) by block. The area of each polygon was calculated in hectares using ArcGIS 9.3 with the XTOOLS extension. A field was created and calculated to the area in square kilometers. Then a field generated and calculated to density (persons per square kilometer). The vector dataset was rasterized to a 30 meter resolution Arc/Info grid.

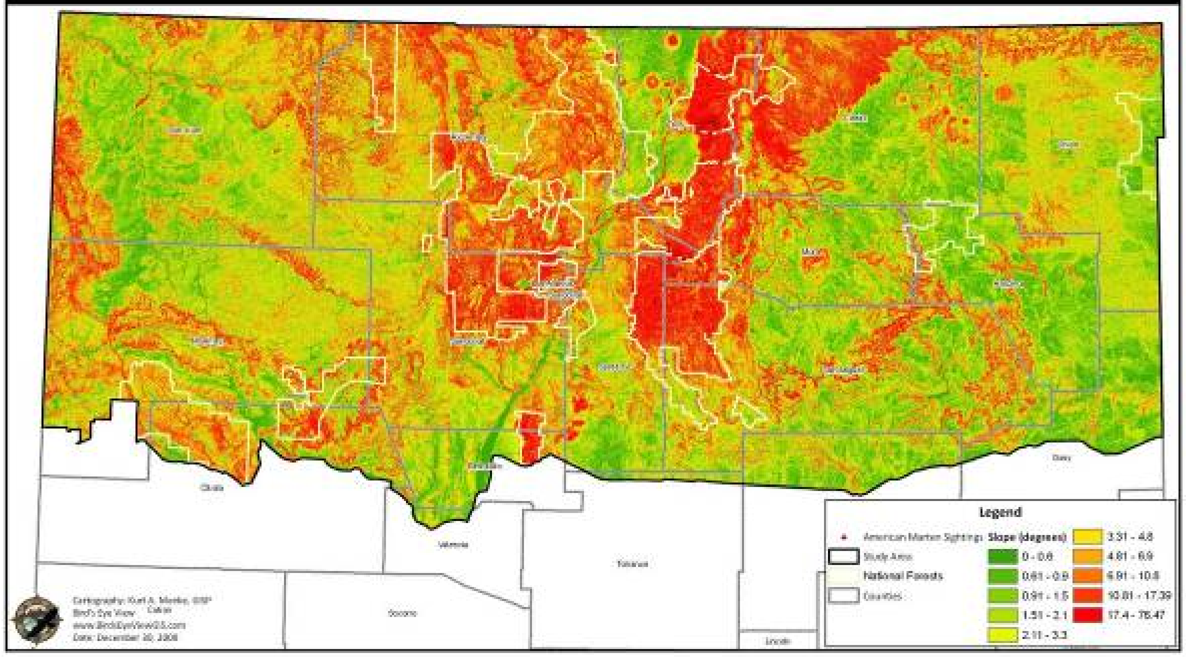



The elevation data was obtained from the Resource Geographic Information System (RGIS) website (http://rgis.unm.edu). The original source was the USGS National Elevation Dataset. The elevation data had a 30 meter resolution. From this dataset slope, aspect and terrain ruggedness were derived using ArcGIS 9.3 Spatial Analyst.

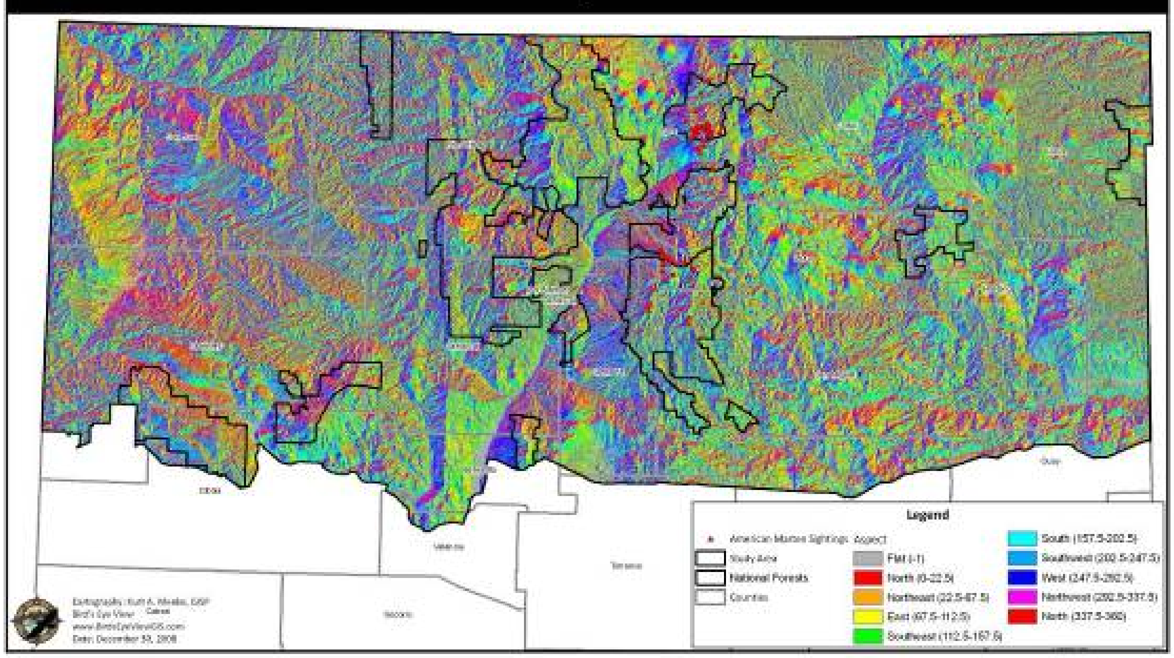

Elevation
Legend
American Marten Sightings
Elevation (meters)
Study Area
National Forests
Counties
High : 4009
Low : 1068


Terrain Ruggedness Index
Legend
American Marten Sightings
Terrain Ruggedness Index
Study Area
National Forests
Counties
High : 3603
Low : 0

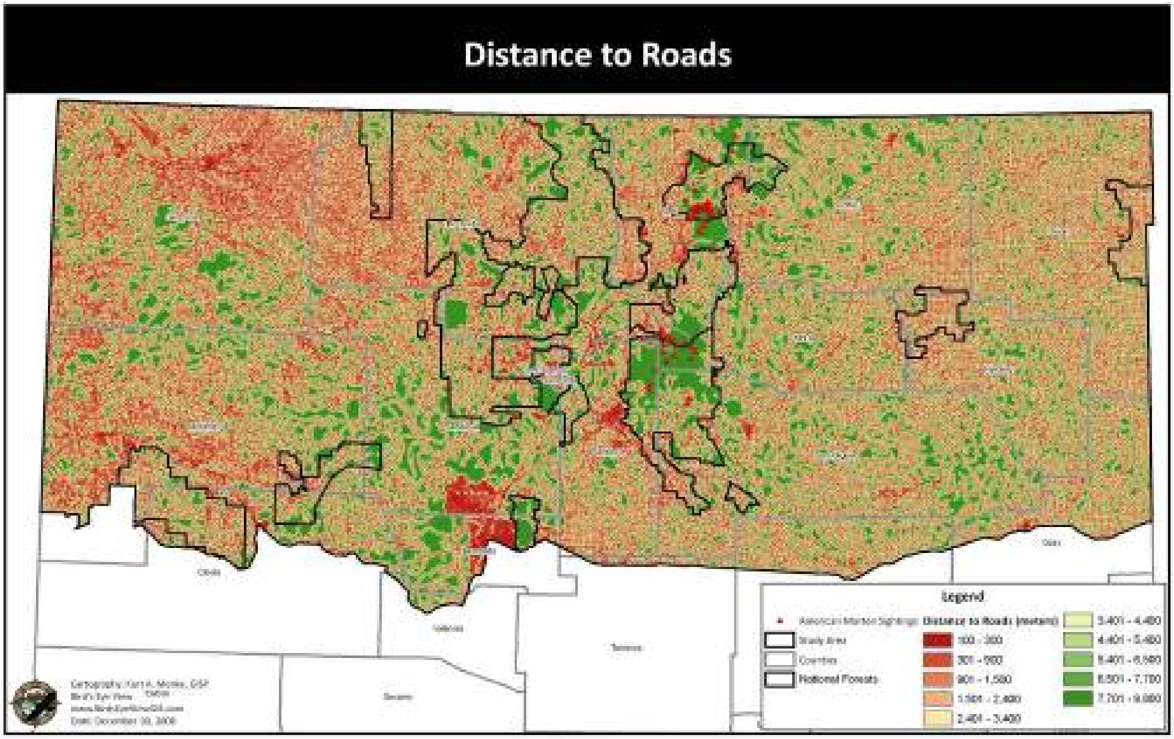
# Slope



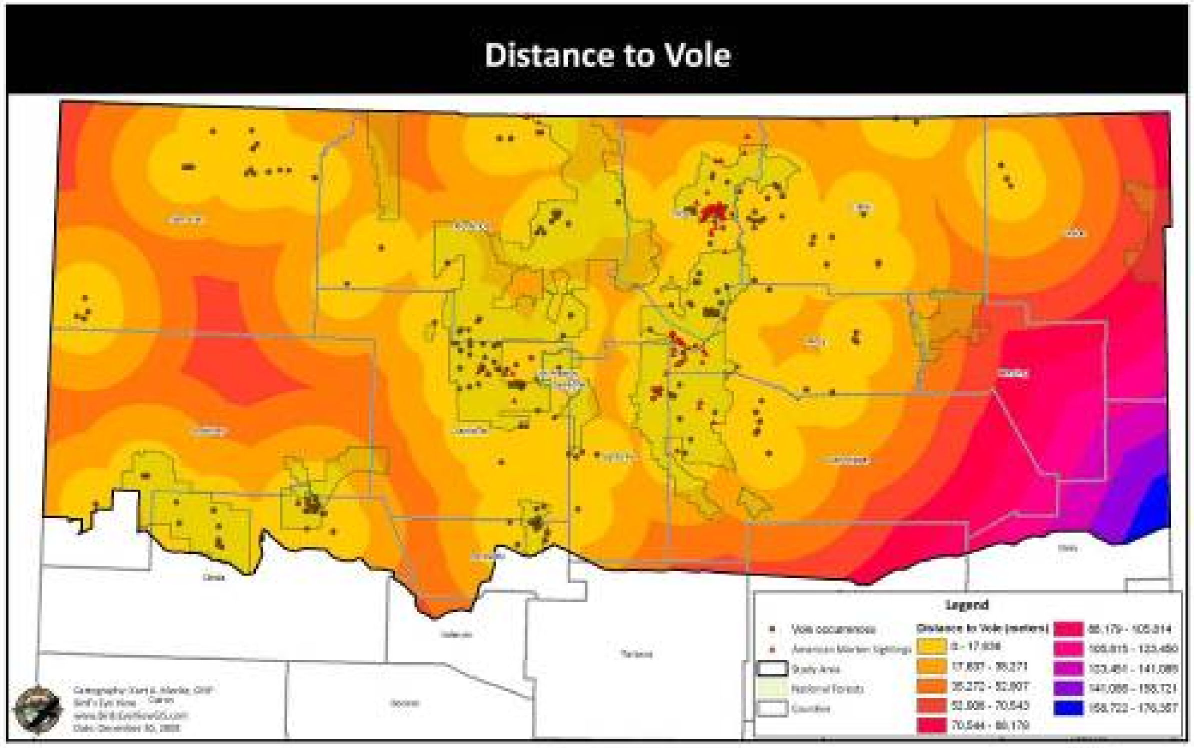

# Aspect



Roads were obtained from the U.S. Census 2008 TIGER shapefiles website (http://www2.census.gov/cgi-bin/shapefiles/national-files). Distance to roads was calculated using the Euclidean Distance function in Spatial Analyst at a 30 m resolution.



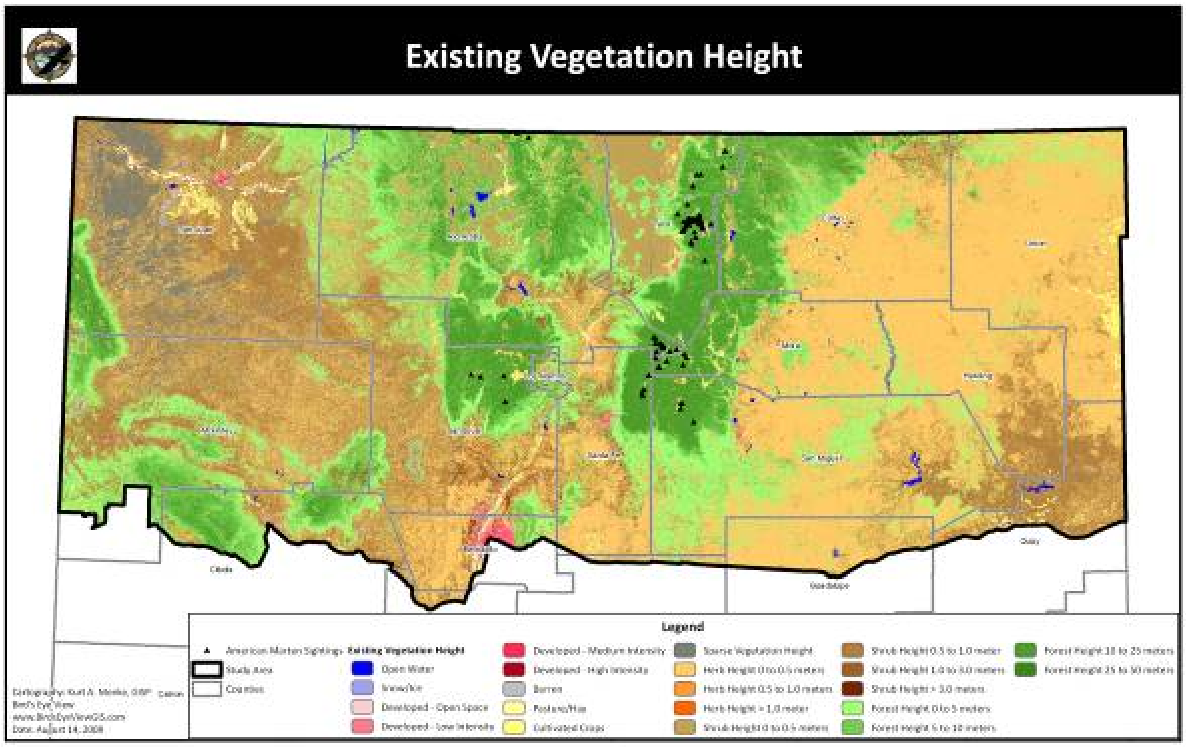

Vole sighting records were mapped via GPS coordinates. Once clipped to the study area this dataset included 1,650 vole occurrence records ranging in time from 1952 to 2007. A distance to vole dataset was then derived using the Euclidean Distance function in Spatial Analyst at a 30 meter resolution.

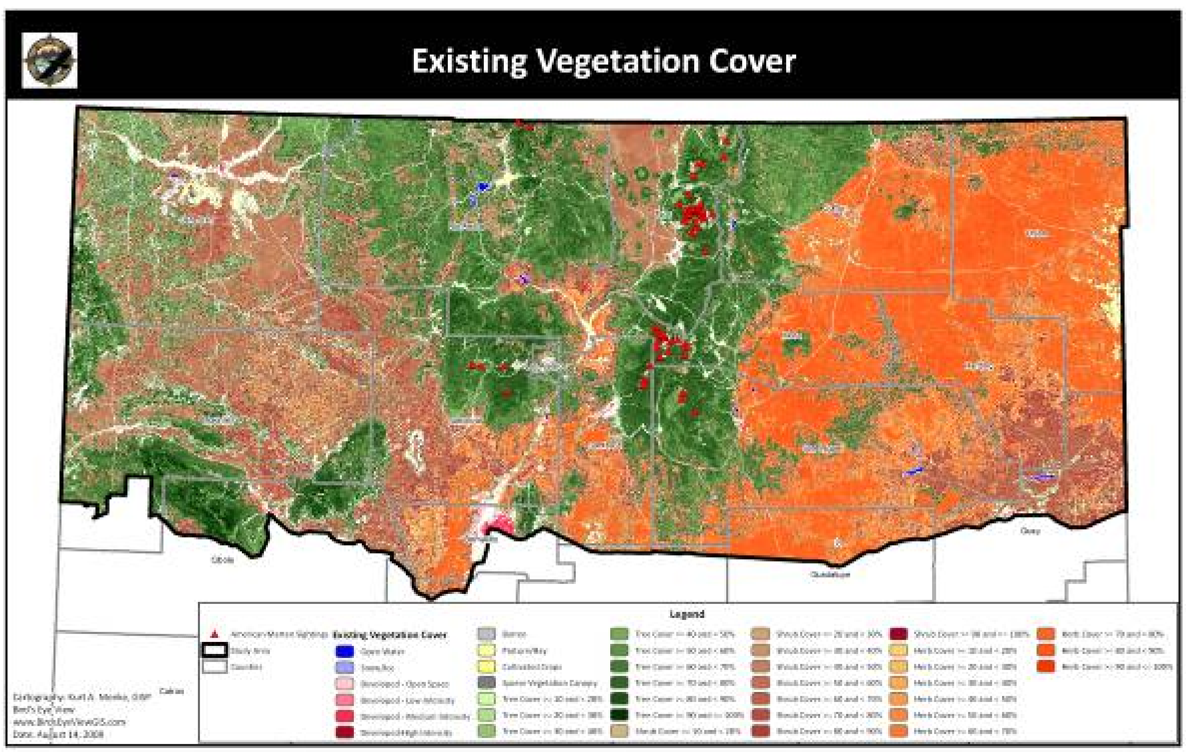



Existing Vegetation Height and Existing Vegetation Cover were obtained from the Landscape Fire and Resource Management Planning Tools Project (http://www.landfire.gov/ ) (LandFire). LandFire s a five-year, project including the U.S. Department of Agriculture Forest Service and U.S. Department of the Interior. The project aims to produce consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States.

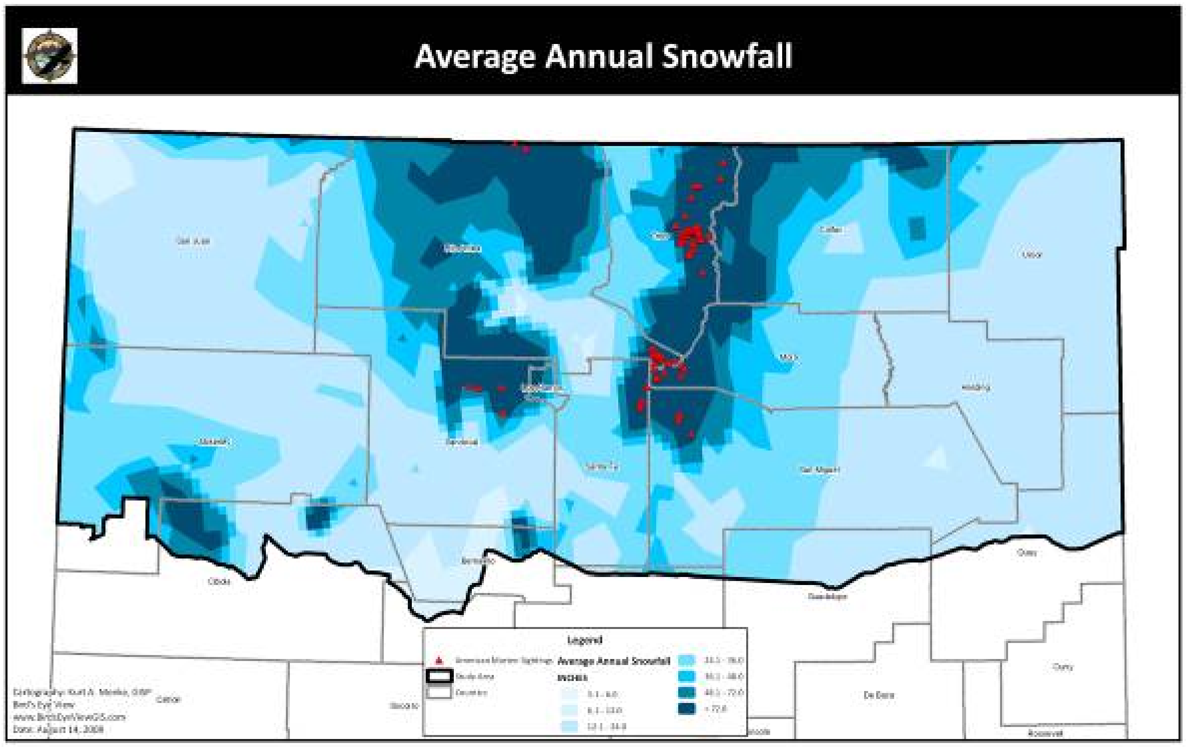
Vegetation height represents the average height of the dominant vegetation for a 30-m grid cell. The Canopy Height layer was generated using a predictive modeling approach that related Landsat imagery and spatially explicit biophysical gradients to calculated values of average dominant height from field training sites.

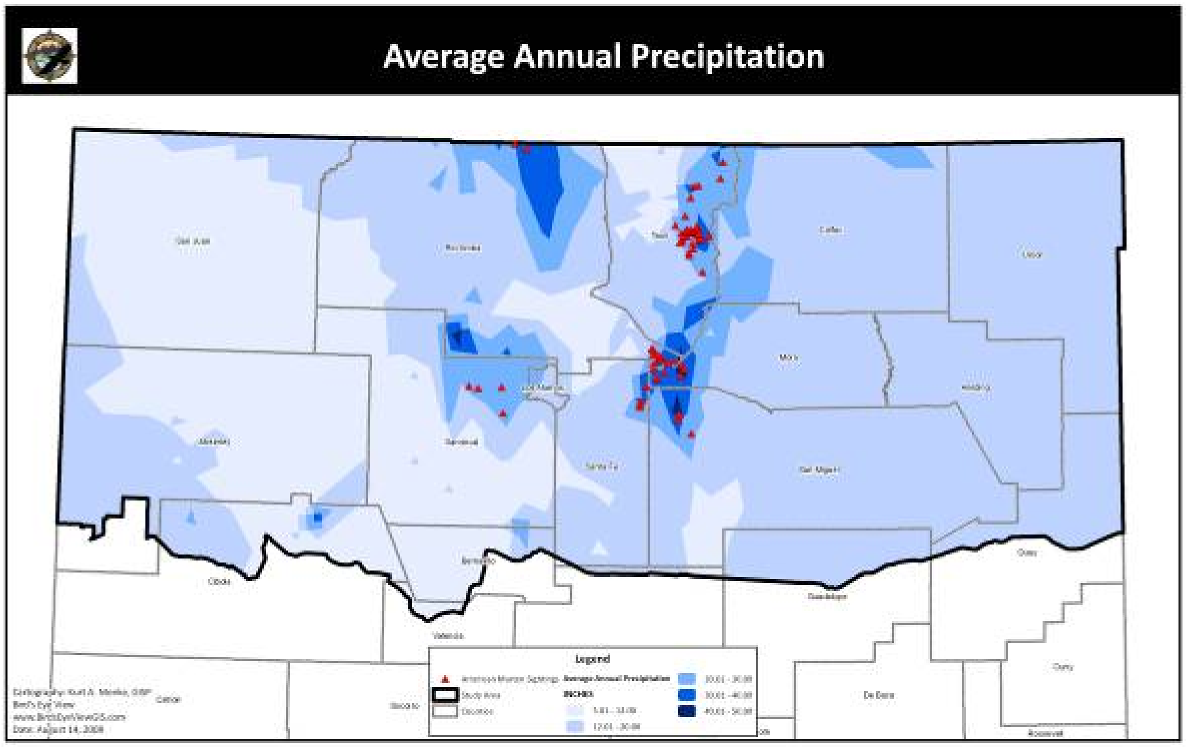
Vegetation cover represents the average percent cover of existing vegetation for a 30-m grid cell. The Existing Vegetation Cover layer was generated using a predictive modeling approach that related Landsat imagery and spatially explicit biophysical gradients to calculated values of average canopy cover from field training sites and digital orthophoto quadrangles.

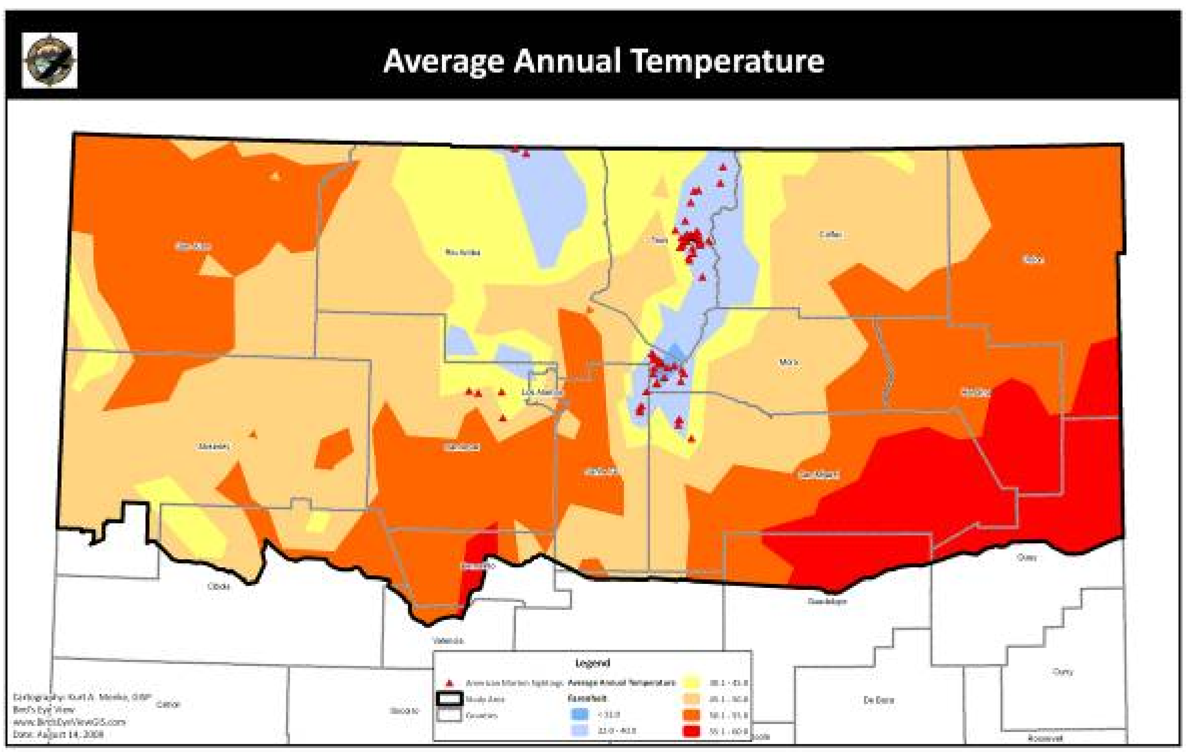

Existing Vegetation Height
Legend
American Marten Sightings
Study Area
Counties
Existing Vegetation Height
Open Water
Snow/Ice
Developed - Open Space
Developed - Low Intensity
Developed - Medium Intensity
Developed - High Intensity
Barren
Pasture/Hay
Cultivated Crops
Sparse Vegetation Height
Herb Height 0 to 0.5 meters
Herb Height 0.5 to 1.0 meters
Herb Height > 1.0 meter
Shrub Height 0 to 0.5 meters
Shrub Height 0.5 to 1.0 meter
Shrub Height 1.0 to 3.0 meters
Shrub Height > 3.0 meters
Forest Height 0 to 5 meters
Forest Height 5 to 10 meters
Forest Height 10 to 25 meters
Forest Height 25 to 50 meters
Cartography: Kurt A. Menke, GISP
Bird's Eye View
www.BirdsEyeViewGIS.com
Date: August 14, 2008


Existing Vegetation Cover
Legend
American Marten Sightings
Study Area
Counties
Existing Vegetation Cover
Open Water
Developed - Open Space
Developed - Low Intensity
Developed - Medium Intensity
Barren
Pasture/Hay
Cultivated Crops
Sparse Vegetation Canopy
Cartography: Kurt A. Menke, GISP
Bird's Eye View
www.BirdsEyeViewGIS.com
Date: August 14, 2008

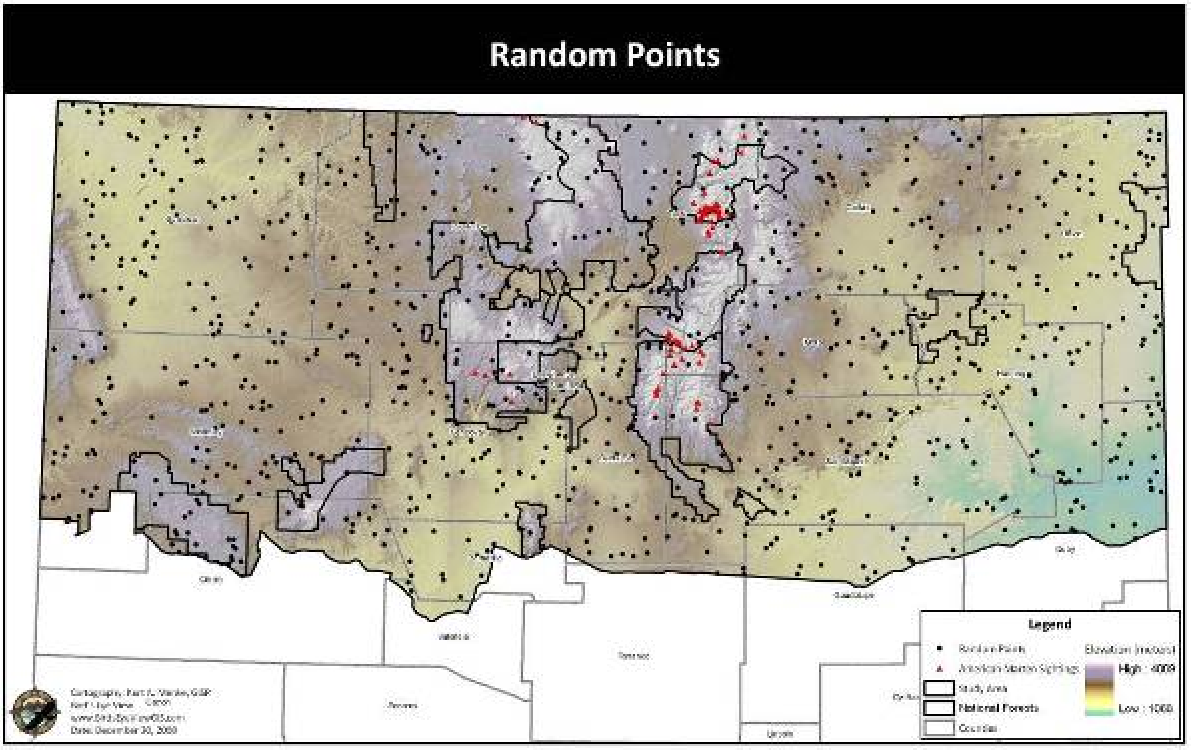
Climatic data was obtained from the National Climatic Data Center which is within the National Oceanic and Atomospheric Administration (NOAA) (http://hurricane.ncdc.noaa.gov/cgi-bin/climaps/climaps.pl). National data representing average annual snowfall, temperature and precipitation were downloaded and converted to raster data with a 30 meter resolution.




Average Annual Precipitation
Legend
Average Annual Precipitation
Study Area
Cartography: Kurt A. Menke, GISP
Bird's Eye View
www.BirdsEyeViewGIS.com
Date: August 14, 2008


Average Annual Temperature
Legend
Average Annual Temperature
Cartography: Kurt A. Menke, GISP
Bird's Eye View
www.BirdsEyeViewGIS.com
Date: August 14, 2008

For analysis purposes 1,000 random points were generated within the study area boundary using the Hawth's Tools extension to ArcGIS.




**Statistical Methods:**

Both the marten occurrence points and the random points were intersected with each the habitat datasets: population density, elevation, aspect, slope, terrain ruggedness, distance to roads, existing vegetation height, existing vegetation cover, climatic data and distance to vole using Hawth's Tools. These data were then exported into Microsoft Excel. The Microsoft Excel datasheet was then imported into SPSS version 17.0 (copyright 24 August, 2008 - SPSS Inc. Chicago, Illinois) to conduct a logistic regression. The logistic regression produces the mathematical combination of habitat variables that are best for predicting marten occurrence (i.e. the marten habitat model).

To evaluate the quality and accuracy of our model, we used several methods:

(a) We first randomly selected 70% of our random points and 70% of our marten occurrence points to build the habitat model, leaving 30% of our points to test the accuracy of the resulting model.

(b) Initially we used the forward stepwise method of model building to construct the model. Then we used the backward stepwise method to check for agreement between the models resulting from each method. Agreement between the models indicates the robustness of the models.

(c) To further evaluate the quality of the model, we saved: (1) predicted probabilities, (2) studentized residuals, and (3) Cook's influence values. Studentized residuals were then squared to produce the variable "changes in deviation". We then constructed two graphs, changes in deviation versus predicted probability and Cook's influence versus predicted probability. These graphs allow us to visually assess the suitability of the model as well as identify data points that may be having a disproportionate effect on the model.

(d) Finally, we saved the Hosmer-Lemeshow goodness of fit values and the Nagelkerke $R^2$ values for evaluation. These two variables provide additional information regarding the quality and accuracy of our model.

The initial logistic regression equation was in terms of logodds that a given combination of habitat variables would indicate a random point rather than a marten location. In order to convert these results into an equation that would give us the probability that a particular combination of habitat variables would indicate a suitable marten location, we first converted logodds of random occurrence to *odds* of random occurrence by exponentiating ($e^{\text{logodds}}$ = odds) Then we converted odds of random occurrence to probability of random occurrence (probability = odds/(1+odds). Finally, we subtracted the probability of random occurrence from 1 to obtain the probability of marten occurrence (probability of marten occurrence = 1 – probability of random occurrence).

**Statistical Results:**

Three of the seven input variables were relevant in distinguishing marten points from random points, elevation, terrain ruggedness and distance to vole, in the resulting equation: LogOdds = -55.103 + (0.005 * elevation) + (0.013 * terrain ruggedness index) + (0.00001 * distance to vole) + (0.374 * existing vegetation height).

This habitat model was robust and accurate as indicated by the following:

(a) Ninety-three percent of the marten occurrence records used to test the model were correctly identified by the model. Ninety seven percent of the total number of test points were correctly identified by the model.

(b) Both the forward stepwise method and the backward stepwise method produced the same model.

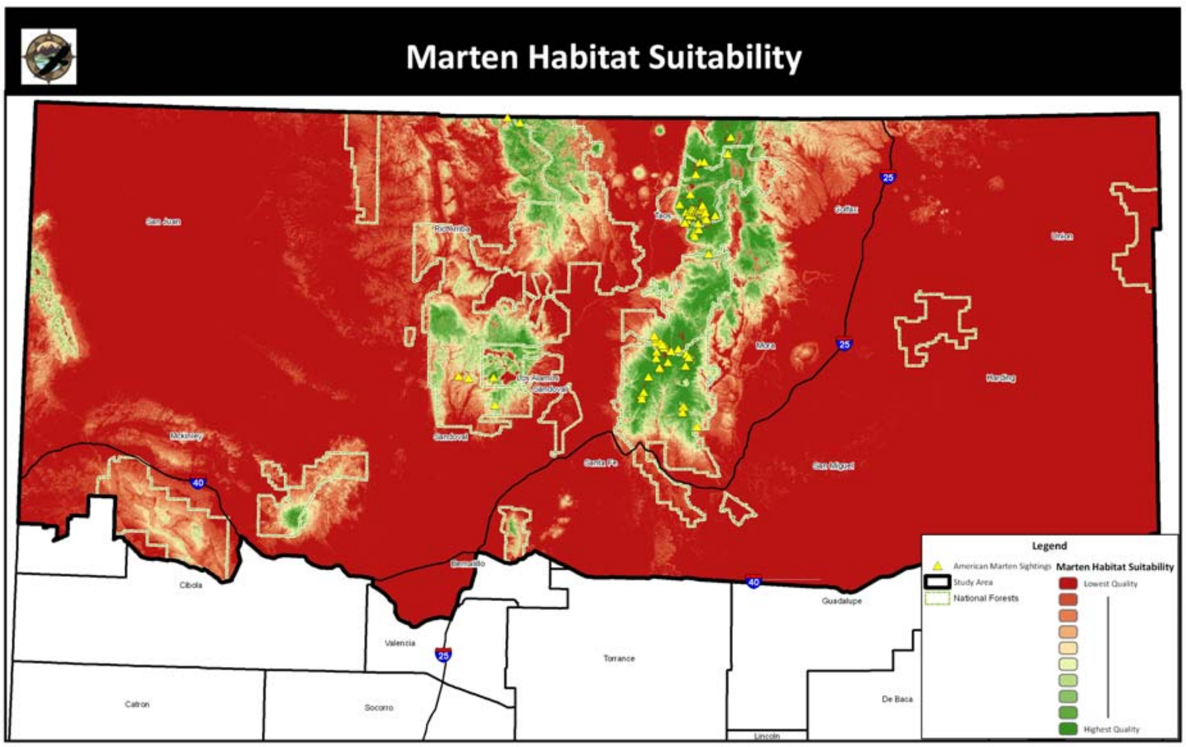
(c) Graphs of changes in deviation versus predicted probability and Cook's influence versus predicted probability indicated that the model was accurate with few points having a disproportionate effect on the model.

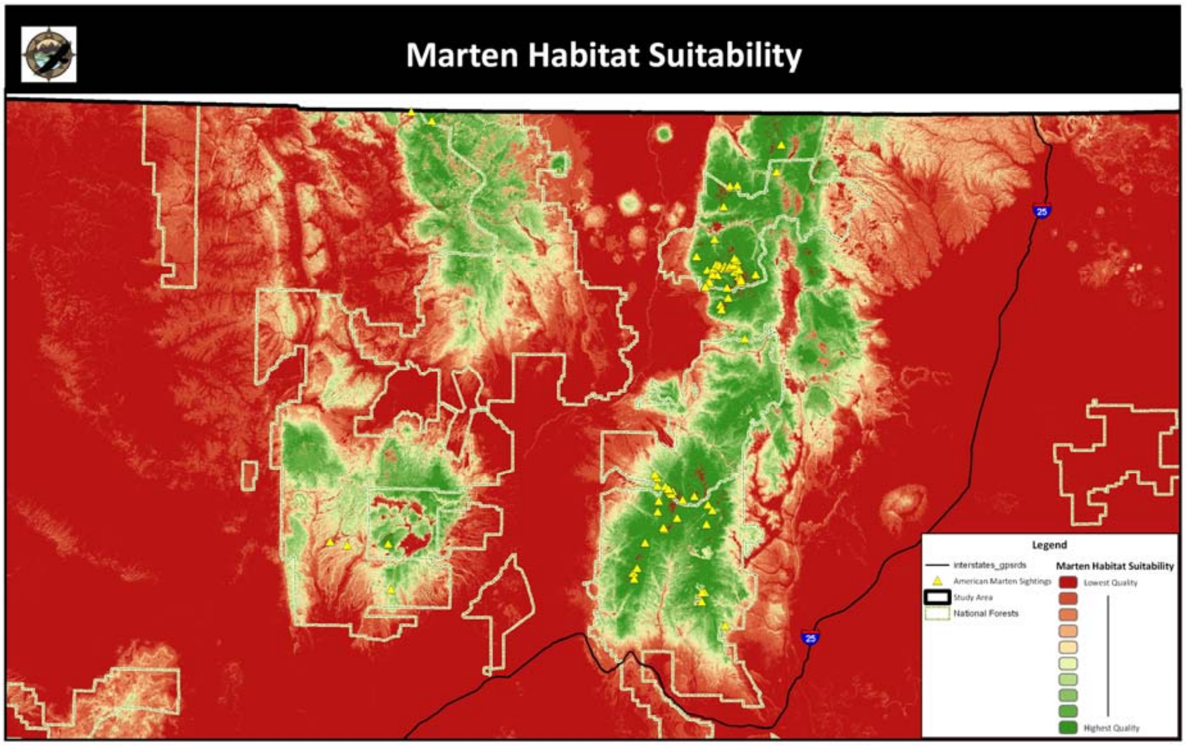
(d) The Hosmer-Lemeshow goodness of fit value for our model was 0.996. The further this value is from 0.05 the more accurately the model fits the data. The maximum possible value is 1.0. The Nagelkerke $R^2$ value also varies between zero and 1 and indicates how well the model fits the data.  The Nagelkerke $R^2$ value for our model was 0.797.  For ecological data, $R^2$ values above 0.50 are considered good, above0.75 considered excellent.

**Map Building:  Applying the logistic regression model to ArcGIS**

A habitat formula was generated from the logistic regression analysis and run in ArcGIS Raster Calculator:

> Probability  = 1 / (1 - Exp (-55.103 + (0.005 * [elevation]) + (0.013 * [terrain_ruggedness_index]) + (0.00001 * [distance_to_vole]) + (0.374 * [existing_vegetation_height])))






## Results

The marten habitat model produced for this final report is extremely accurate relative to most habitat models. The most suitable habitat is displayed in green in the above figure. The poorest habitat in red tones. The spatial *precision* of this model was increased over the mid-term report with data on vegetation height, which improved the fineness of spatial scale. Vegetation height data used in the model was ordinal scale data and not actual continuous scale vegetation height in meters. GIS climate data also improved the accuracy of initial models built since the mid-term report. Snow depth was particularly useful in predicting marten locations. However, the spatial coarseness of these data produced unrealistic habitat maps and these data were removed from subsequent model building. In summary, the distribution of martens in New Mexico can be accurately predicted from elevation, topographic ruggedness, the distribution of voles, and forest height (likely also a measure of forest complexity).

## Literature Cited


Buskirk S.W., & W.J. Zielinski. “American marten (*Martes americana*) ecology and conservation”. [Online] http://www.fs.fed.us/psw/rsl/projects/wild/zielinski/zielinski5.PDF 1998

Foreman, Dave et. al. *“New Mexico Highlands Wildlands Network Vision”*. The Wildlands Project. May 2003

Gibilisco, C.J. “*Distribution Dynamics of Modern Martes in North America.”* In: Buskirk, S.W., A.S. Harestad, M.G. Raphael, & R.A. Powell, editors. Martens, Sables, and Fishers, Biology and Conservation. Ithaca & London: Cornell University Press.1994.

Nowak, Ronald M. “*Walker’s Carnivores of the World.”* The Johns Hopkins University Press. 2005