PREDICTING THE SUITABILITY OF HABITAT IN SOUTHEAST IDAHO FOR PYGMY RABBITS

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Abstract: A geographic information system (GIS) model was developed for pygmy rabbit (Brachylagus idahoensis) habitat in southeastern Idaho. Areas of potential use by pygmy rabbits were determined from appropriate vegetation and geological classes in a GIS analysis. Sites most likely to be occupied within potential vegetation and geologic habitat were determined by including appropriate slope and aspect measurements. Randomly selected areas within and outside of predicted areas were searched for pygmy rabbit sign. This resulted in a 57% probability of predicting areas occupied by pygmy rabbits and a 100% probability of predicting areas not occupied. Our model may be useful in identifying areas unsuitable for pygmy rabbits and it is a useful first step in identifying appropriate habitat for the pygmy rabbit, potentially throughout their range.

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Pygmy rabbits are unique among leporids in that they rely on big sagebrush (Artemisia tridentata) for food. The pygmy rabbit has had a limited distribution within sagebrush areas of the Great Basin and adjacent intermountain areas including the Snake River Plain in southern Idaho (Katzner 1994). An isolated population also occurs in eastcentral Washington (Lyman 1991, Washington Department of Fish and Wildlife 1995). However, pygmy rabbits historically have had a greater distribution than they do today (Weiss and Verts 1984, Washington Department of Fish and Wildlife 1995).

The primary cause for the reduction in range is considered to be habitat loss. Across much of the historic range, sagebrush-steppe has been converted to cropland or has been used for livestock grazing. Grazing continues to be the dominant use on sagebrush-steppe lands (West 1983). Overgrazing can potentially break down shrub cover, lead to loss of native grasses and forbs, and lead to invasions of annual species such as cheatgrass (Bromus tectorum; Washington Department of Fish and Wildlife 1995). These changes could make an area unsuitable for pygmy rabbits. In addition, shrub cover is often manually or chemically reduced to improve forage production for livestock. This degradation and conversion of sagebrush lands has been extensive. For example, only about 60% of the original shrub-steppe remains in Washington (Dobler 1992). Unfortunately, it is unknown how much suitable habitat may remain in the other parts of this species' range. For this reason, the pygmy rabbit is considered a species of special concern by the U.S. Fish and Wildlife Service.

We took the first step in developing a conservation management plan for this species by assessing the current status of available habitat in a portion of its range. We developed a GIS predictive model for a 2,000-km² sagebrush-steppe area in southeastern Idaho to calculate what percentage of suitable habitat remains and identify these areas for possible conservation efforts.

STUDY AREA

The study was conducted on the Idaho National Engineering and Environmental Laboratory (INEEL), located on the upper Snake River Plain in southeastern Idaho. Mean annual precipitation for the INEEL was 22 cm, most of which falls during winter and early summer. Snow cover usually persisted for at least 4 to 5 months. Temperature can range from −44°C in winter to 38°C in summer.

The surface of the INEEL was gently rolling with some basalt flows and a few volcanic
buttes. The subsurface was made up of basalt from past lava flows. Most of the soil was derived from older silicic volcanic and paleozoic rocks from the surrounding mountains (McBride et al. 1978). In the southern portion of the INEEL, soils tended to be gravely to rocky, while in the northern portion the soil was made up of lake and aeolian deposits composed mainly of unconsolidated clay, silt, and sand (Kramer et al. 1992). Soil depth on the INEEL varied from a few centimeters to the more recent or exposed flows to several meters in low lying areas. Accumulation was also greater on leeward sides of lava ridges and on alluvial fans. The native vegetation at the INEEL consisted of a sagebrush dominated shrub overstory with an understory of perennial grasses and forbs (Anderson et al. 1996).

METHODS
We used GIS modeling to develop a map depicting levels of potential habitat suitability for pygmy rabbits. We first performed a spatial analysis, based on known locations of pygmy rabbit burrow sites, on 4 thematic map layers: vegetation, surface geology, slope, and aspect. A predictive map incorporating overlays of these 4 layers was produced to display areas of potentially suitable habitat for pygmy rabbits. The accuracy of this predictive model was field tested by verifying the presence or absence of pygmy rabbits at randomly selected sites predicted to be used or not used by pygmy rabbits.

Locating and Recording Burrow Sites
We surveyed the approximately 650 km of widely distributed dirt roads (Fig. 1) on the INEEL during the winters of 1994–95 and 1995–96, and also during the spring of 1996 for existing pygmy rabbit burrows. When snow cover was present, the roads were driven to locate pygmy rabbit tracks. When tracks were found they were followed to burrow sites. When there was no snow cover, roads were driven and areas off the roads were systematically searched for burrows. Most roads on the INEEL consist of dirt 2-tracks that did not differ from the surrounding vegetation and were extensively distributed in all possible habitat types. Thus, any road bias due to the types and placement of roads was considered minimal. In addition to surveying the roads, 3 earlier study areas (Wilde et al. 1976, Wilde 1978, Fisher 1979) were relocated and searched. When burrows were found, the locations were recorded in UTM coordinates with either a Trimble® Geoeplorer or a Trimble® Basic Plus Global Positioning System (Trimble Navigation Limited, Sunnyvale, California, USA) and then differentially corrected.

Creating a GIS Predictive Model
Development of the predictive model was limited by the map overlays available: vegetation, geology, slope, and aspect. Vegetation, slope, and aspect are known to be important in the suitability of a site for pygmy rabbits (Green 1978, Wilde 1978, Weiss and Verts 1984, Gahr 1993, Katznner 1994). Soil structure and texture are also considered important (Weiss and Verts 1984, soil conservation service) but no maps were available. As soil characteristics are often influenced by underlying geologic structure, we used an available geologic map to incorporate
some aspect of the physical substrate. We did not have a priori information as to which of these layers may be more important to pygmy rabbits selection and thus, gave them equal weight in our analysis.

The raster vegetation map was developed from 2 Landsat satellite images from May 1987 and August 1989 (Kramber et al. 1992), and was comprised of 11 vegetation classes, with a pixel size of $30 \times 30$ m. The map was extensively ground checked and corrected in 1990 (Anderson et al. 1996). The geologic map (scale of 1: 100,000), consisting of 14 surficial-deposit classes, 6 basaltic-lava flow and rhyolitic-rock classes, and 34 rhyolitic-and basaltic-rock classes (Kuntz et al. 1990), was digitized in vector format and then converted to a raster image ($30 \times 30$ m pixel size) in IDRISI (Eastman 1992). The slope and aspect layers were previously developed from a USGS Digital Elevation Model (DEM) of the INEEL.

A point vector file was created from the locations of all burrow sites discovered during the road surveys. This vector file was separately overlain on the vegetation, geologic, slope, and aspect layers, and a spatial analysis was performed to determine the vegetation, geologic, slope, and aspect classes containing burrows. The 4 layers were reclassified into boolean images (Eastman 1992), which displayed only those classes in each layer where burrows occurred. The 4 boolean images of vegetation, geologic, slope, and aspect were overlain with ARC/INFO® software (Environmental Systems Research Institute, Redlands, California, USA) and the resulting map displayed areas where potentially appropriate vegetation, geologic, slope, and aspect characteristics existed for pygmy rabbits on the INEEL. This map displayed areas where pygmy rabbit burrows were most likely to be located with respect to the 4 habitat characteristics.

Testing the GIS Predictive Model

Once areas of potentially suitable pygmy rabbit habitat were identified, the accuracy of the model was tested. First, 60 random locations were chosen, 30 within areas of potential habitat use and 30 outside potential habitat. The number of sites chosen was determined by manpower restrictions. To select the 60 locations, a grid was established across an INEEL map at 1,000-m intervals to match major UTM ticks. Three hundred random numbers acted as the east–west UTM ticks and 300 additional random numbers served as the north–south UTM ticks. The 2 sets of 300 numbers were then paired in order of their selection to obtain a full set of 300 random UTM locations. The first randomly selected 30 locations that fell inside potential habitat were chosen as the predicted sites and the first 30 locations that fell outside potential habitat were chosen as the predicted non-use sites. To account for errors in the accuracy of digitized data in the original map layers and possible GPS navigational errors in the field, only sites at least 200 m inside or outside the predicted habitat boundaries were selected.

To test the GIS predictive model, the 60 random areas were located on the ground and searched during the summer of 1996 to determine presence or absence of pygmy rabbits. A Trimble® Geoeplorer or a Trimble® Basic Plus GPS unit was used to navigate to each selected site. Because the average home range size of pygmy rabbits during spring and summer is approximately 13 ha (Gahr 1993), a $360 \times 360$ m (~13 ha) grid was established and centered around each location. North-south transects at 30-m intervals were searched for pygmy rabbit sign. The probability level of correctly predicting use areas was expressed as a percentage of the number of sites containing sign to the total number of sites (30). For non-use areas, it was the percentage of sites found not to contain pygmy rabbit burrows or sign.

RESULTS

One hundred and one burrow sites were found as a result of the road surveys, 26 of which were active at the time of discovery. Based on the spatial analysis of the vegetation map, all burrow sites were located within 3 vegetation classes: sagebrush-steppe on lava, sagebrush-steppe off lava, and sagebrush–winterfat (Eurotia lanata). From the spatial analysis of the geologic map, burrow sites were located in 7 different geologic classes. Four of the classes were surficial deposits and included alluvial deposits of Pinedale age (upper Pleistocene) along mainstreams (QMP), younger fan alluvium (upper Pleistocene; QFY), playa deposits (Holocene to upper Pleistocene; QP), and Eolian sand (Holocene to upper Pleistocene; QES). The 3 other classes (QBB, QBC, QBD) were basaltic lava flows and pyroclastic deposits ranging in age from 15,000–200,000 (QBB),
200,000–400,000 (QBC), and 400,000–730,000 (QBD) years.

Based on the spatial analysis of the aspect layer, 32% of burrow locations had no aspect. Sixty-eight percent of burrow locations had aspects ranging from 300 to 360° and 0 to 120° with a mean of 38.7°. From the spatial analysis of the slope layer, burrow locations had slopes ranging from 0.0 to 25%, with a mean of 8.6%. Because of computer memory constraints, it was not possible to create modified boolean images using the full range of slopes and aspects. Therefore, aspects between 0 to 120° and between 300 to 360°, which include 84.5% of all the burrow locations, were selected to make up the modified aspect image. Slopes between 0 and 15%, which include 83.5% of all burrow locations, were selected to make up the modified slope image. In the final image, the slope, aspect, vegetation, and geologic layers overlapped on only 23.4% of the total area of the INEEL (Fig. 1). This image represents areas predicted most suitable for pygmy rabbits.

No pygmy rabbit sign was found at any of the 30 predicted non-use sites. Thus, based on this analysis, there was a 100% probability of predicting non-use areas. Of the 30 predicted pygmy rabbit sites, sign was found at 17 locations (57% probability of predicting use areas). Twelve of the 17 sites contained abandoned burrows with either old or fresh scat of pygmy rabbit. One of the 17 sites contained fresh scat but no burrows, and 3 other sites contained old scat with no burrows.

**DISCUSSION**

Others have investigated vegetation (Grinnell et al. 1930, Orr 1940, Severaid 1950, Green and Flinders 1980, Weiss and Verts 1984, Katzner 1994), slope, and aspect (Wilde 1978) characteristics at burrow systems of pygmy rabbits. Our study combines these 3 categories (vegetation, slope, and aspect) as well as the fourth of surficial geology, in a large scale GIS analysis. The result indicates that suitable habitat for pygmy rabbits on the INEEL consists of sagebrush-steppe or sagebrush–winterfat communities situated on lava flows older than 15,000 years in age and on alluvial deposits of upper Pleistocene, playa deposits, and eolian sand (>50%) deposits. Within these areas, pygmy rabbits construct burrows in locations with 0 to 49.7% slope and a mean orientation of 38.7°.

Our results for vegetation agree in general with the findings of others (Severaid 1950, Green and Flinders 1980, Weiss and Verts 1984, Soil Conservation Service 1991, Gahr 1993, Katzner 1994). Wilde (1978) also reported that pygmy rabbit burrows on the INEEL were in areas with a slope >5% and a northeast aspect. However, in contrast to ours and Wilde’s findings, 53% of pygmy rabbit burrow sites in Washington were on south-southeast or southwest aspects (Soil Conservation Service 1991). Pygmy rabbits can only dig burrows where the soil is sufficiently deep (Weiss and Verts 1984, Wilde 1978). Deeper soils on the INEEL are more common on northeast slopes as a result of the prevailing southwest winds. Perhaps in the Washington study site, sufficiently deep soils may have been more readily available and did not restrict site selection by pygmy rabbits. Thus, except for the differences in burrow aspect, our results match those of others. This concordance among the results of small scale studies indicates our larger scale model could be used to assess the suitability of habitat in most areas within pygmy rabbit range.

Based on our GIS analysis, the probability of an area actually containing pygmy rabbits or sign was 57%. Stoms et al. (1992) proposed various factors regarding habitat maps that could be sources of uncertainty, and thus could affect the sensitivity of a GIS analysis. Some of these uncertainties likely contributed to our relatively low success in predicting suitable habitat. For example, although the predicted sites that had no pygmy rabbit sign were in sagebrush-steppe vegetation, based on the vegetation map of the INEEL (Kramber et al. 1992, Anderson et al. 1996), the map was not detailed enough to distinguish between sparse sagebrush cover and the greater cover required by pygmy rabbits (Gabler 1997, Green and Flinders 1980, Weiss and Verts 1984). Thus, 10 of the 13 predicted sites that contained no sign, consisted of dead and/or very short, sparse sagebrush. In addition, the vegetation map used was based on satellite images taken in 1987 and 1989. Temporal variability in climate in 7–9 years could cause significant changes within a local patch of vegetation (Anderson et al. 1996). Range fires can also alter the habitat dramatically; 13% of the habitat predicted as suitable was burned by fires in 1994, 1995, and 1996 (unpublished data). Thus, the use of updated images and possibly additional map layers (e.g., soil texture–depth)
could increase the sensitivity of our analysis in predicting suitable habitat for pygmy rabbits.

The probability of predicting non-use areas was 100%. Much of the area classified as non-use bordered the downstream portions of 2 rivers and was subject to flooding (Kuntz et al. 1990, Olson et al. 1995). Some of the non-use areas was also devoid of big sagebrush, and others contained lava flows <15,000 years old with only thin and discontinuous sand deposits (Kuntz et al. 1990). None of these factors are conducive to the construction and maintenance of burrows of pygmy rabbits (Wilde 1978, Green and Flinders 1980, White et al. 1982, Gabler 1997, Katzner and Parker 1997, Heady 1998).

Relative to conservation of pygmy rabbits, the GIS analysis indicates that large portions of what may seem like rabbit habitat may indeed not be suitable for their use. Although all of the 2,300 km² of the INEEL is considered within pygmy rabbit range, when we considered the specific vegetation, geologic, slope, and aspect characteristics, only 23% of the site (530 km²) was considered possible burrowing habitat, essential for this species. Of that area, based on our probability level of accuracy in predicting areas of use, only 60% (320 km²) had a good likelihood of actually having been occupied by pygmy rabbits. If our model is accurate and pygmy rabbits are the habitat specialists that research indicates (Green and Flinders 1980, Gabler 1997, Katzner and Parker 1997, Heady 1998), then large portions of native vegetation within what is currently depicted as pygmy rabbit range is likely not suitable habitat. If we also consider that much of the area within this range is being converted to farmland or being degraded by overgrazing (Dober 1992, Washington Department of Fish and Wildlife 1995), it may be imperative to the conservation of this species to identify those areas of the Great Basin that represent usable pygmy rabbit habitat.

**MANAGEMENT IMPLICATIONS**

Pygmy rabbits likely select areas for use on a smaller scale than can be completely provided for by this GIS model. This model, however, can be a very useful first step when trying to assess the suitability of an area for pygmy rabbits. Used alone, this model was very successful at identifying areas that are definitely unsuitable for pygmy rabbits. The ability to identify unsuitable areas in itself is of obvious importance in the management of a species. Our model can effectively eliminate those areas unsuitable for pygmy rabbits, enabling managers to concentrate their efforts and resources on those areas more likely to have pygmy rabbits. Once within predicted suitable habitat, as identified from the GIS map, further analysis of the habitat on a smaller scale (Gabler 1997) may be necessary to determine if an area is indeed suitable habitat for pygmy rabbits. What remains is a testing of this model in other parts of the range of pygmy rabbits to determine its applicability and—or adjustments that might need to be made (e.g., slope) in the criteria for the map layers.

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**LITERATURE CITED**


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