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Pygmy rabbits (*Brachylagus idahoensis*) in Oregon and Washington are a sagebrush (*Artemisia tridentata spp*.) obligate species of concern because of declining populations and extirpation from much of their range. Efforts are underway to establish a captive bred population of the Columbia Basin pygmy rabbit in Washington state for reintroduction into the wild. We developed a resource selection model based on soil and vegetation characteristics of occupied pygmy rabbit habitat at Hart Mountain National Antelope Refuge in Oregon. Data collected in Oregon were used to quantify relationships of pygmy rabbits with their habitat. Using logistic regression and Akaike's Information Criterion (AICc) to identify the best model, we determined that big sagebrush height and soil percent sand content were the two habitat characteristics most predictive of occupied pygmy rabbit burrow locations. The model indicated that the odds ratio of an occupied pygmy rabbit burrow occurrence increased with an increase in percent sand content of soils and big sagebrush height. We then applied the resource selection model using a two-step approach. We first used a Geographic Information System (GIS) to determine broad scale areas of suitable habitat for the potential reintroduction of pygmy rabbits at Hanford Reach National Monument in Washington, and then collected data on the

ground to determine the best suitable habitat. Using GIS procedures, we found approximately 8500 ha of potential habitat at Hanford Reach National Monument. Field data collected within the potential habitat were used to further define 3035 ha as the most suitable habitat for pygmy rabbits. Lands that currently support pygmy rabbits, or areas identified as potential habitat in Washington, can be used to prioritize management or restoration efforts for pygmy rabbits and their habitats.

# Development and Application of a Resource Selection Model for Pygmy Rabbits

by
Jennifer K. Meisel

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Jennifer K. Meisel, Author

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## CONTRIBUTION OF AUTHORS

Dr. Richard A. Schmitz was involved in the design, analysis and writing of each manuscript.

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## Chapter 1

## Introduction

Pygmy rabbits (*Brachylagus idahoensis*) are a sagebrush obligate species found in big sagebrush habitats (*Artemisia tridentata spp.*) in the Great Basin and Intermountain West (Green and Flinders 1980a, WDFW 1995, Gabler et al. 2001, USDOI 2003) of Idaho, Montana, Wyoming, Utah, Nevada, California, Oregon and Washington (Figure 1.1). Pygmy rabbits depend on big sagebrush for thermal and hiding cover, and for a large portion of their diet. Pygmy rabbits consume up to 99% big sagebrush in winter, and 51% big sagebrush and 49% native perennial grasses and forbs in the spring and summer months (Green and Flinders 1980a). Weiss and Verts (1984) found that pygmy rabbits inhabit areas of deep, loose soils and that soil characteristics were important in distinguishing areas occupied by pygmy rabbits from unoccupied areas. Pygmy rabbits are one of two rabbits in North America that dig their own burrows (WDFW 1995, USDOI 2003); therefore, soils are an important component of their habitat requirements. Pygmy rabbits are geographically widespread throughout sagebrush habitats in the Great Basin and Intermountain West (Green and Flinders 1980a, Weiss and Verts 1984, USDOI 2003). However, because of their specific habitat requirements, they are patchily distributed on the landscape. Their patchy distribution and heavy reliance on sagebrush make pygmy rabbits especially vulnerable to habitat fragmentation, overgrazing and sagebrush eradication (Holechek 1981, Katzner and Parker 1998).

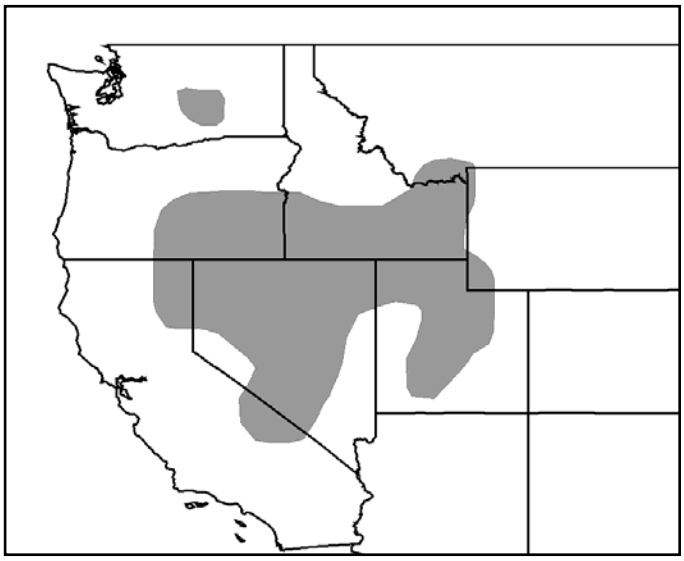

Figure 1.1: Current range wide distribution of pygmy rabbits in the western United States. After the "Washington State Recovery Plan for the Pygmy Rabbit" (WDFW 1995).

Throughout the arid west, natural and human caused disturbances have altered sagebrush habitats used by pygmy rabbits and other sagebrush obligate species. These disturbances include: conversion of suitable habitat for agriculture and urban development, invasion of non-native plant species, intensive livestock grazing, and an increase in the frequency and size of wildfires. Together these disturbances have caused a steady decline in the acreage and integrity of big sagebrush habitats throughout the western United States, resulting in their designation as one of the most endangered habitats in North America (Knick et al. 2003).

Pygmy rabbits in Oregon and Washington are a species of concern because of declining populations and extirpation from portions of their range. Populations of pygmy rabbits are known to exist on Hart Mountain National Antelope Refuge, Oregon, in stands of mountain and basin big sagebrush (*Artemisia tridentata*

*vaseyana, Artemisia tridentata tridentata*); however, their population status and distribution are poorly known. The Columbia Basin population of pygmy rabbits in Washington state is considered a distinct population segment because it has been separated from the rest of the species' range for at least 7,000 years (USDOI 2003). The historic range of pygmy rabbits in eastern Washington included portions of Hanford Reach National Monument (Monument) in Benton, Adams, Franklin, and Grant counties, along with land in Lincoln and Douglas counties (Gahr 1993, WDFW 1995). The Columbia Basin population of pygmy rabbits experienced a dramatic decrease from 1997 to 2001 (USDOI 2003, WDFW 2003), which prompted the United States Fish and Wildlife Service (USFWS) to list this distinct population as endangered in 2003 (USDOI 2003).

In 1995 the Washington Department of Fish and Wildlife (WDFW) released the "Washington State Recovery Plan for the Pygmy Rabbit" which described recovery strategies for pygmy rabbits in Washington (WDFW 1995). This plan describes the initiation and implementation of a captive breeding program for the Columbia Basin pygmy rabbit. The objectives of the recovery plan were to manage habitat to protect pygmy rabbits, develop a captive population, and to reintroduce members of the captive population into suitable habitat in eastern Washington (WDFW 1995, 2001, 2003). The survival of pygmy rabbits in Washington currently relies on the recovery of viable populations through successful reintroduction into suitable habitat.

The research presented in this thesis examines which habitat characteristics are most important in describing pygmy rabbit habitat in Oregon, and uses that information to identify suitable lands for the potential reintroduction of pygmy rabbits

on Hanford Reach National Monument in Washington. We located and sampled habitat characteristics in occupied and unoccupied pygmy rabbit habitat on Hart Mountain National Antelope Refuge (Hart Mountain) in Oregon to develop a model of resource selection and to document the distribution of pygmy rabbits on the refuge. The model of resource selection was based on soil and vegetation characteristics from occupied and unoccupied pygmy rabbit habitat. We then applied the resource selection model to lands at Hanford Reach National Monument in eastern Washington using a two-step approach to determine areas of suitable habitat for pygmy rabbits. First we applied the model using a Geographic Information System (GIS) to identify broad scale areas of potential habitat. We then collected data on the ground within the potential habitat for a fine scale application of the model to identify more specific areas of the most suitable pygmy rabbit habitat.

We studied pygmy rabbits in Oregon because the known population of pygmy rabbits in Washington had declined precipitously, and rabbits no longer exist in the wild. Climate and vegetation conditions in Oregon were also similar to those in Washington. Studies were conducted outside of Washington to thoroughly understand and measure potential types and characteristics of habitat that may be suitable for pygmy rabbits. Identifying potential pygmy rabbit habitat could be an important step towards protecting sagebrush habitats from disturbances and further degradation. Lands that currently support pygmy rabbits, or areas identified as potential habitat in Washington, can be used to prioritize management or restoration efforts for pygmy rabbits.

This thesis contains two chapters prepared for submission to peer reviewed journals, along with an introduction chapter, and summary conclusions. Chapter 2 discusses resource selection modeling for pygmy rabbits based on occupied and unoccupied habitat measured at Hart Mountain National Antelope Refuge in Oregon. Chapter 3 discusses the application of the resource selection model using GIS analyses and on the ground measurements at Hanford Reach National Monument in Washington to determine the best suitable habitat for pygmy rabbits.

# Chapter 2

## Development of a Resource Selection Model for Pygmy Rabbits at Hart Mountain National Antelope Refuge, Oregon

Jennifer K. Meisel, Richard A. Schmitz

**ABSTRACT**

Pygmy rabbits (*Brachylagus idahoensis*) are a sagebrush obligate species that inhabit areas of big sagebrush (*Artemisia tridentata spp*.) in the Great Basin and Intermountain West. Because of their rarity on the landscape and unknown distribution across Hart Mountain National Antelope Refuge (Hart Mountain), Oregon, we were interested in locating and defining the habitat characteristics around occupied pygmy rabbit burrows. Vegetation and soils data were collected from occupied burrow locations and adjacent unoccupied locations to develop a resource selection model of pygmy rabbit habitat. Data were then used to quantify relationships of pygmy rabbits with their habitat. We used logistic regression and Akaike's Information Criterion (AIC) with the additional bias term for small sample size (AICc) to identify the best approximating model. Sagebrush height and percent sand content of soil were the two habitat characteristics most predictive of where occupied pygmy rabbit burrows were located. The model indicated that the odds ratio of an occupied pygmy rabbit burrow occurrence increased with an increase in percent sand content and sagebrush height. This model can be used to predict additional areas of pygmy rabbit habitat on Hart Mountain to further define the distribution of pygmy rabbits on the refuge, and also has the potential to be applied to other areas of the Great Basin and Columbia Basin to predict pygmy rabbit habitat. Identifying pygmy rabbit habitat could be an important step towards protecting sagebrush habitats from disturbances and further degradation.

## INTRODUCTION

Pygmy rabbits (*Brachylagus idahoensis*) are a sagebrush obligate species that inhabit areas of tall dense big sagebrush (*Artemisia tridentata spp*.) in the Great Basin and Intermountain West (Orr 1940, Severaid 1950, Green and Flinders 1980b). In many areas of the arid west, natural and human-caused disturbances have altered sagebrush habitats used by pygmy rabbits and other sagebrush obligate species. These disturbances include: conversion of suitable habitat for agriculture and urban developments, invasion of non-native plant species, livestock grazing, and an increase in the frequency and size of wildfires. Lands cleared for agriculture were concentrated in areas with deep, fertile soils (Connelly et al. 2004), which were also likely lands suitable for pygmy rabbits.

Disturbances such as wildfires and overgrazing by livestock cause alterations that make habitat unsuitable for pygmy rabbits or may fragment populations. Historically wildfires were small and infrequent, and were important in creating a mosaic of shrub and grassland communities (Knick 1999). However, the invasion of non-native annual grasses, specifically cheatgrass (*Bromus tectorum*), has caused a change in the fire regime (Young and Evans 1973, USDOI 2002). Today wildfires can be large and catastrophic, and have a greater chance of affecting pygmy rabbit populations.

Siegel (2002) concluded from her study of pygmy rabbit use in grazed and ungrazed habitat in Washington, that livestock grazing may be detrimental to pygmy rabbits. Grazing reduces large amounts of grasses and forbs in an area, which can reduce pygmy rabbit forage (Siegel 2002). Together, disturbances such as increased wildfire frequency and intensity, intensive livestock grazing, invasion of non-native

annual grasses and conversion for agricultural purposes have caused a decline in the acreage and integrity of sagebrush habitats throughout the western United States, resulting in their designation as among the most endangered habitats in North America (Knick et al. 2003).

Pygmy rabbits are geographically widespread throughout their range in sagebrush habitats in the Great Basin and Intermountain West (Green and Flinders 1980a, Weiss and Verts 1984, USDOI 2003). However, because of their specific habitat requirements, they are rare and patchily distributed on the landscape. Pygmy rabbits depend on big sagebrush for a large portion of their diet and for thermal and hiding cover. Their diet consists of up to 99% big sagebrush in winter, and 51% big sagebrush and 49% native perennial grasses and forbs in the summer months (Green and Flinders 1980a). Besides relying almost exclusively on sagebrush for their diet, pygmy rabbits need deep loose soils to dig their own burrows (Green and Flinders 1980a). Soil characteristics were important in distinguishing areas occupied by pygmy rabbits from unoccupied areas in Oregon (Weiss and Verts 1984). Weiss and Verts (1984) examined soil depth, strength of surface and subsurface soils and found all of these measures to be greater at sites occupied by pygmy rabbits.

Extensive stands of big sagebrush exist throughout southeast and south-central Oregon. This big sagebrush habitat has remained fairly intact, and has not been completely converted and fragmented by human uses. Hart Mountain National Antelope Refuge (Hart Mountain) in south-central Oregon contains pristine big sagebrush habitat that has been protected from development and disturbances by humans for over 70 years. Hart Mountain is a 112,500 ha wildlife refuge that was set aside in the 1930's for the protection of pronghorn antelope (USDOI 1996).

Populations of pygmy rabbits are known to exist on Hart Mountain, however, their population status and distribution are poorly known.

The purpose of this study was to locate occupied pygmy rabbit burrows and occupied habitat on Hart Mountain, to document pygmy rabbit distribution on the refuge, and to develop a model of resource selection (Manly et al. 2002) based on vegetation and soils characteristics of pygmy rabbit habitat. We developed a resource selection model that identified the most important habitat characteristics pygmy rabbits may select for when choosing burrow locations. This habitat model may be used to identify additional areas of potential pygmy rabbit habitat at Hart Mountain and other areas in the Great Basin and Intermountain West with similar habitat types.

**STUDY AREA**

Hart Mountain National Antelope Refuge is located in south-central Oregon in Lake County. Hart Mountain is a fault block ridge that rises to an elevation of 2460 meters. The west side rises 900 meters from the floor of the Warner Valley as rugged cliffs, and steep slopes. The east side of the mountain descends slowly to the sagebrush habitats typical of southeast Oregon and the Northern Great Basin. Big sagebrush and low sagebrush (*Artemisia arbuscula*) are the dominant shrubs, with bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus spp*.), curlleaf mountain mahogany (*Cercocarpus ledifolius*), and snowberry (*Symphoricarpos spp*.) also occurring where conditions allow. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is dominant over the driest portion of the refuge in the north and eastern regions. Basin big sagebrush (*Artemisia tridentata tridentata*) occurs in small

patches predominantly near riparian areas and in valley bottoms with deep soils, and mountain big sagebrush (*Artemisia tridentata vaseyana*) occurs in the higher elevations on the western hills of the refuge. Hart Mountain also contains a number of perennial streams and their associated riparian habitats, along with playa lakes, aspen stands, grassy meadows and a remnant stand of ponderosa pine (*Pinus ponderosa*). Mean annual precipitation is 30 cm, January mean minimum temperature is -9 to -11º C, and the July mean maximum temperature is 27 to 30º C (Franklin and Dyrness 1973). Hart Mountain supports over 300 wildlife species, including sage grouse (*Centrocercus urophasianus*), pronghorn antelope (*Antilocarpa americana*), bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), pygmy rabbits (*Brachylagus idahoensis*), jack rabbits (*Lepus spp.*), and many species of birds.

**METHODS**

We located occupied pygmy rabbit burrows by searching areas of big sagebrush on Hart Mountain National Antelope Refuge. We then identified unoccupied locations adjacent to the occupied burrows and measured habitat characteristics at both occupied burrows and unoccupied locations. Vegetation and soils characteristics around occupied burrows and in unoccupied locations were compared using logistic regression analyses to determine which habitat characteristics were associated with occupied pygmy rabbit burrows.

**Determining Sampling Locations**

To locate as many occupied burrows as possible and document all potential centers of pygmy rabbit activity on Hart Mountain, we conducted searches in big sagebrush habitats to locate occupied pygmy rabbit burrows. All searches were conducted on the ground and we began by identifying centers of pygmy rabbit activity. We first searched in locations of past pygmy rabbit activity, then searched additional areas of tall, dense big sagebrush thought to contain pygmy rabbits. Because pygmy rabbits are rare on the landscape, we focused our searches in locations of tall dense big sagebrush that were likely to contain pygmy rabbits based on literature descriptions (Green and Flinders 1980b, Weiss and Verts 1984, WDFW 1995) and prior knowledge of pygmy rabbit habitat. We searched for signs of recent pygmy rabbit activity, including: fecal pellet groups, evidence of fresh digging, and rabbit sightings. Once in areas of pygmy rabbit activity, we intensified our searches for occupied burrows. Areas searched and locations of occupied burrows were recorded with a handheld Trimble GeoXM™ (Trimble Navigation Limited, Westminster, Colorado, USA) GPS (Global Positioning System) unit.

At burrows where recent sign of pygmy rabbit use was detected (fresh fecal pellet groups or fresh digging) but no rabbits were seen, we used remote infrared 35-mm cameras (Trail Timer Co. St. Paul, Minnesota, USA) to confirm that pygmy rabbits were using the burrows (Cutler and Swann 1999). Cameras were placed on the ground next to the burrow entrance, usually under a shrub, and held in place by wooden stakes. Cameras were checked every 3-5 days to ensure proper function and to collect film. To correctly distinguish pygmy rabbits from cottontail rabbits (*Sylvilagus spp*.) in the photos, we looked for the characteristic brown tail of pygmy

rabbits, cinnamon coloring of the legs and underside, or the abundance of white hairs in the ears (Bailey 1936, Green and Flinders 1980a).

After occupied burrows were located, we set up a rectangular 100-$m^2$ plot to measure habitat characteristics centered around each burrow. Locations for unoccupied plots were randomly selected and referenced to the position of the occupied plots. We walked a random distance (50-500 m) and direction (0-360 degrees) from the occupied plot and set up a 100-$m^2$ plot in the unoccupied habitat. If sign of pygmy rabbit activity (fecal pellets or burrows) was detected in the randomly chosen location, the above method was repeated until an unoccupied location was found. The minimum distance measurement was based on an approximate home range radius of 30 m for pygmy rabbits (Green and Flinders 1980a, Katzner and Parker 1997).

**Measuring Habitat Characteristics**

Methods for determining plot size, plot set up, and data collection were based on those used by the Washington Department of Fish and Wildlife (WDFW) (Romain-Bondi 2003). We collected information using these methods to produce data that were compatible with information collected at various sites in Washington by WDFW so that data can be standardized across a large geographic area.

Sampling plots were rectangular in shape with dimensions of 15 m X 6.67 m, for a total sampling area of 100$m^2$. Plots were centered around an occupied burrow or in a randomly determined location in unoccupied habitat. Both vegetation and soils characteristics were measured within the occupied and unoccupied plots.

We used the line-point intercept method to measure percent canopy cover (Herrick et al. 2005) of all sagebrush, forb and grass species encountered within each plot. A total of 150 points were sampled in each plot, and the total number of "hits" for each species was divided by 150 to obtain the percent canopy cover for that species. Sagebrush height was measured in increments of 10 cm using a 2-section, 2.5 cm X 2-m collapsible pole (Nudds 1977, Griffith and Youtie 1988). Measurements for sagebrush height were taken from each of the four cardinal directions at a distance of 15 m and averaged.

We recorded soils information from each plot because soil structure has been shown to be one of the most important factors that determines pygmy rabbit habitat (Weiss and Verts 1984). Soil samples were collected from the top 30 cm of the soil surface within 1 $m^2$ surrounding a burrow entrance in the occupied plot, and from the center 1 $m^2$ of the unoccupied plots. A particle size analysis using the hydrometer method (Buol et. al 2003) was conducted at Oregon State University's Soil Science Physical Characterization Lab to determine the percent sand, silt and clay for each plot.

Data collected around occupied burrows and in unoccupied plots included; percent canopy cover of all grass, forb and shrub species, sagebrush height, and a soil sample to determine the percent sand, silt and clay content.

**Statistical Analysis**

Resource selection models (Manly et al. 2002) were developed for the habitat characteristics measured at occupied burrow locations and in unoccupied plots to determine which characteristics pygmy rabbits were selecting for when choosing

burrow locations. A set of *a priori* models was chosen as working hypotheses using the variables recorded in occupied and unoccupied pygmy rabbit habitat. We used Akaike's Information Criterion (AIC) with the additional bias correction term for small sample sizes (AICc) to select the best approximating model (Burnham and Anderson 2002). Logistic regression (PROC GENMOD, SAS Institute Inc. 2003) was used to fit the model of resource selection where habitat characteristics for occupied plots were compared to habitat characteristics for the unoccupied plots. Vegetative and physical measures collected in each plot were used as the explanatory variables, and the response was 1 for occupied burrows and 0 for unoccupied locations. Logistic regression allowed us to determine how the odds of an active burrow being present change as a function of the explanatory variables. This study is considered retrospective because we collected samples based on each level of the response variable (occupied and unoccupied) (Ramsey and Schafer 2002), and the explanatory variables subsequently represented important habitat characteristics.

A Wilcoxon Rank sum test (Ramsey and Schafer 2002) was used to determine if there were significant differences between the means of percent canopy cover for the most commonly occurring plant species in plots around occupied burrows and in unoccupied plots. We accepted $P < 0.05$ as being significant.

*Model Development*

When developing models of resource selection, we combined the percent canopy cover data for individual plant species into their respective functional groups (i.e. big sagebrush, annual grasses, perennial grasses and forbs). By combining data for each species into functional groups, we were able to significantly reduce the

number of potential variables to be considered in the model selection process. Anderson and Burnham (2002) suggest limiting the model set to a few *a priori* models rather than using the full set of potential models, and to keep the number of *a priori* models less than the sample size, as limiting the model set would decrease the possibility of spurious results.

We used six habitat characteristics to develop a set of *a priori* models (Table 2.1). Since data were collected in 2004 and 2005, we also included a variable to determine if the yearly variation in data collection would influence model selection. Pearson correlation coefficients for each of the seven variables were examined using the PROC CORR procedure in SAS v. 9.1 to determine if any variables were correlated (SAS Institute Inc. 2003). Variables having correlation coefficients greater than 0.5 were not included in the same model. We consulted the existing literature (Green and Flinders 1980a, 1980b; Weiss and Verts 1984, Gabler et al. 2001) on pygmy rabbits, and along with expertise gained from working in pygmy rabbit habitat, we used these seven variables to develop a set of models describing the relationship of pygmy rabbits with their habitat.

Table 2.1. Seven variables used to develop *a priori* models of resource selection from data collected at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| Canopy Cover | Soils | Other |
|---|---|---|
| big sagebrush (%)<br>perennial grass (%)<br>annual grass (%)<br>forbs (%) | sand (%) | sagebrush height (cm)<br>time (0-1) |

The importance of soils and big sagebrush characteristics are well documented for pygmy rabbits (Weiss and Verts 1984, WDFW 1995, Gabler et al. 2001, USDOI 2003). Therefore, we developed models using the knowledge that pygmy rabbits are strongly associated with percent sand in the soil, sagebrush height and percent canopy cover of big sagebrush. We considered quadratic terms (Ramsey and Schafer 2002) for percent sand, sagebrush height, and percent canopy cover of big sagebrush for habitat associations that may be non-linear. We modeled two-way interactions among percent sand, sagebrush height, and percent canopy cover of big sagebrush because looser soils, or soils with a high percent sand content, may have an effect on big sagebrush height and percent canopy cover. The four other variables included in developing candidate models were percent canopy cover of perennial grasses, annual grasses, forb species, and time. Only the main effects for these four variables were examined in combination with the main effects of percent sand, percent canopy cover of big sagebrush, and sagebrush height.

*Model Selection*

We used an Akaike's Information Criterion (AIC), with the additional bias correction term for small sample sizes (AICc), to select the best approximating model (Burnham and Anderson, 2002);

$$AICc = -2[\log(L(\theta))] + 2K + 2K(K+1)/(n-K-1)$$

Where $\log(L(\theta))$= the maximum log likelihood value of the parameters in the model; K is the number of estimable parameters in the approximating model; and n is the sample size (Burnham and Anderson 2002).

Competing models were those with a difference in AICc values (Δ AICc) of less than two units, and were considered of equal importance (Burnham and Anderson 2002). Parameter estimates for the best approximating model were exponentiated and the results were reported as the log odds ratios (Keating and Cherry 2004).

## RESULTS

We searched over 1100 ha of big sagebrush habitat thought to contain pygmy rabbits at Hart Mountain in the spring of 2004. During the summers of 2004 and 2005, we measured habitat characteristics around 45 occupied burrows and in 45 adjacent unoccupied plots for a total sample size of 90. We found that the locations of occupied burrows were not tightly clustered across the landscape, and were generally found in either Wyoming big sagebrush or mountain big sagebrush habitat. Because of the distance between occupied burrows, we never encountered sign of pygmy rabbit activity when locating the unoccupied plots.

### Burrow Attributes

We found the greatest abundance of occupied burrows in the northeast portion of Hart Mountain National Antelope Refuge which contains Wyoming big sagebrush stands characteristic of the northern Great Basin and generally flat topography (Figure 2.1). We found 28 of the occupied burrows (n=45) in a large contiguous stand of Wyoming big sagebrush. Fifteen occupied burrows were located in mountain big sagebrush habitat near Hart Mountain headquarters, and a single occupied burrow was found in a small isolated clump of mountain big sagebrush in

the south-central portion of the refuge. One burrow was located in basin big sagebrush near a creek bottom (Rock Creek) in the northeast portion of the refuge.

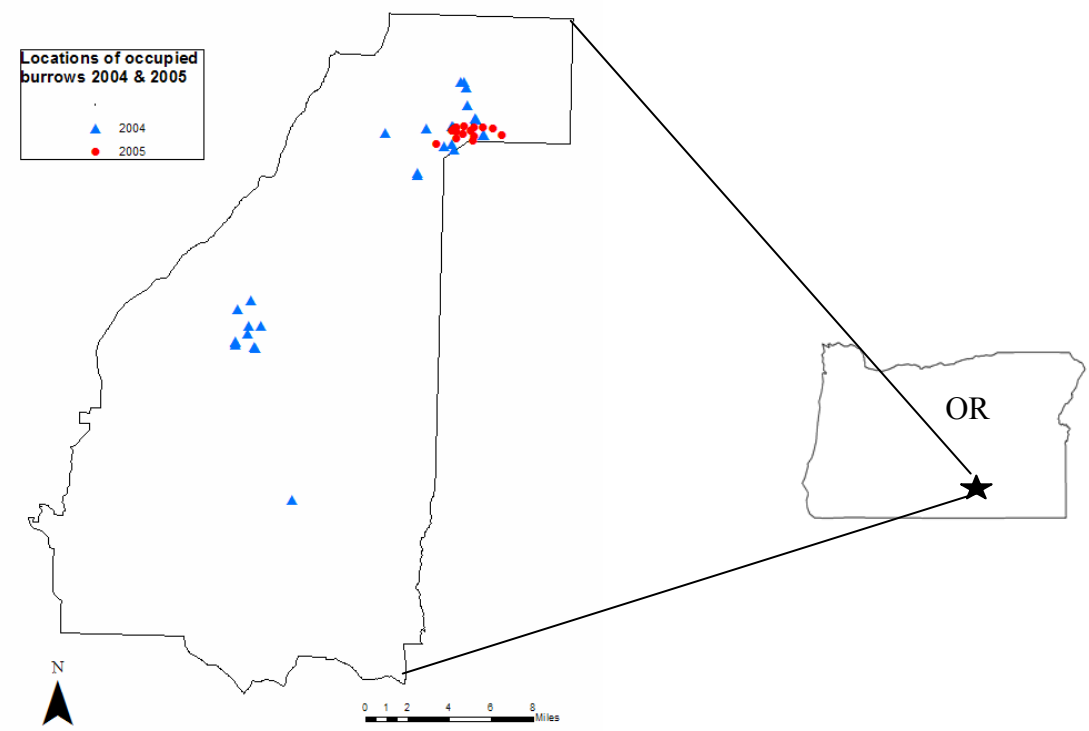


Figure 2.1: Locations of 45 occupied pygmy rabbit burrows on Hart Mountain National Antelope Refuge, OR that were sampled to obtain habitat characteristics. Triangles represent occupied burrows sampled in 2004 and circles represent burrows sampled in 2005.

Squirreltail (*Elymus elymoides*), prairie junegrass (*Koeleria macrantha*), Sandberg bluegrass (*Poa secunda*), Thurber needlegrass (*Achnatherum thurberianum*) and cheatgrass (*Bromus tectorum*) were the most commonly occurring grasses in occupied and unoccupied plots (Table 2.2). Great Basin woolystar, (*Eriastrum sparsiflorum*), tansy mustard (*Descurainia spp*.), slender phlox, (*Pholx gracilis*), were the most commonly occurring forbs in occupied and unoccupied plots.

Table 2.2: Mean percent canopy cover values and standard errors for the most commonly occurring plant species found at occupied pygmy rabbit burrows (n=45) and unoccupied plots (n=45) at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| Species | % Canopy Cover Occupied | SE | % Canopy Cover Unoccupied | SE |
|---|---|---|---|---|
| GRASSES | | | | |
| Perennial | | | | |
| *Elymus elymoides* | 4.35 | 0.54 | 3.30 | 0.42 |
| *Poa secunda** | 5.41 | 0.68 | 7.25 | 0.72 |
| *Koeleria macrantha* | 2.33 | 0.24 | 1.72 | 0.17 |
| *Achnatherum thurberianum* | 1.93 | 0.14 | 3.50 | 0.47 |
| Annual | | | | |
| *Bromus tectorum* | 5.98 | 1.29 | 2.39 | 0.41 |
| FORBS | | | | |
| Annual | | | | |
| *Eriastrum sparsiflorum* | 2.63 | 0.27 | 2.39 | 0.27 |
| *Descurainia spp.* | 1.12 | 0.06 | 1.01 | 0.06 |
| *Pholx gracilis*[#] | 1.68 | 0.16 | 1.25 | 0.13 |

# 2005 data only
* Wilcoxon-rank sum test indicated means of differences between occupied and unoccupied plots were significantly different ($P<0.05$)

The data for percent canopy cover of individual species was combined into functional groups (perennial grass, annual grass and forbs), and used for the six habitat variables in the resource selection models (Table 2.3).

Table 2.3. Mean values, standard errors, and ranges for six habitat variables used in model selection process from plots with occupied burrows (n=45) and unoccupied plots (n=45) at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| | Variable | Mean | SE | Range of values |
|---|---|---|---|---|
| Occupied | SAND | 50.16 | 1.05 | 35.00 - 66.30 |
| | HEIGHT | 0.65 | 0.04 | 0.23 - 1.43 |
| | SG_COVER | 21.75 | 1.20 | 1.30 - 36.00 |
| | PER_GRASS | 7.45 | 1.03 | 0.00 - 27.33 |
| | AN_GRASS | 3.34 | 1.08 | 0.00 - 29.33 |
| | FORBS | 4.20 | 1.62 | 0.00 - 72.70 |
| Unoccupied | SAND | 45.52 | 1.19 | 15.00 - 61.25 |
| | HEIGHT | 0.32 | 0.02 | 0.00 - 0.63 |
| | SG_COVER | 13.80 | 1.25 | 0.00 - 38.67 |
| | PER_GRASS | 10.13 | 0.96 | 1.33 - 25.99 |
| | AN_GRASS | 0.66 | 0.26 | 0.00 - 8.70 |
| | FORBS | 2.53 | 0.48 | 0.00 - 15.30 |

SAND = percent sand in soil sample
HEIGHT = average sagebrush height (meters)
SG_COVER = percent canopy cover of big sagebrush
FORBS = percent canopy cover of all forb species
AN_GRASS = percent canopy cover of all annual grass species
PER_GRASS = percent canopy cover of all perennial grass species

**Results of Model Selection**

We developed a set of 86 models using seven explanatory variables, which were combinations of the six habitat variables plus the time variable. The set of 86 models included the null model (no variables) and the global model (all seven variables). The best approximating model, with the lowest AICc value, included average sagebrush height, percent sand content in the soil and percent canopy cover of big sagebrush. There was one competing model containing average sagebrush height and percent sand content in the soil (Table 2.4). The top 16 models included average sagebrush height and percent sand content in the soil, indicating that these two variables are extremely important determinants of occupied burrows.

Table 2.4. Top 16 models, null model, global model and model with YEAR variable showing AICc values, ΔAICc values and k (number of estimable parameters in the approximating model) from model selection procedure using data collected at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| model rank | model | k | AICc | ΔAICc |
|---|---|---|---|---|
| 1 | SAND + HEIGHT + SG_COVER | 4 | 74.642 | 0.000 |
| 2 | SAND + HEIGHT | 3 | 76.092 | 1.450 |
| 3 | SAND + HEIGHT + FORBS + SG_COVER | 5 | 76.716 | 2.074 |
| 4 | SAND + HEIGHT + AN_GRASS + SG_COVER | 5 | 76.757 | 2.115 |
| 5 | SAND + HEIGHT + PER_GRASS + SG_COVER | 5 | 76.776 | 2.134 |
| 6 | SAND + HEIGHT + FORBS | 4 | 77.944 | 3.302 |
| 7 | SAND + HEIGHT + PER_GRASS | 4 | 78.058 | 3.416 |
| 8 | SAND + HEIGHT + AN_GRASS | 4 | 78.071 | 3.429 |
| 9 | SAND + HEIGHT + AN_GRASS + PER_GRASS + SG_COVER | 6 | 78.905 | 4.263 |
| 10 | SAND + HEIGHT + PER_GRASS + FORBS + SG_COVER | 6 | 78.926 | 4.284 |
| 11 | SAND + HEIGHT + AN_GRASS + FORBS + SG_COVER | 6 | 78.974 | 4.332 |
| 12 | SAND + HEIGHT + AN_GRASS + PER_GRASS | 5 | 79.971 | 5.329 |
| 13 | SAND + HEIGHT + AN_GRASS + FORBS | 5 | 80.091 | 5.449 |
| 14 | SAND + HEIGHT + AN_GRASS + SG_COVER | 5 | 80.091 | 5.449 |
| 15 | SAND + HEIGHT + AN_GRASS + PER_GRASS + FORBS + SG_COVER | 7 | 81.205 | 6.563 |
| 16 | SAND + HEIGHT + AN_GRASS + PER_GRASS + FORBS | 6 | 82.073 | 7.431 |
| 21 | (global model) | 8 | 83.315 | 8.673 |
| 73 | (null model) | 1 | 126.812 | 52.173 |
| 76 | TIME | 2 | 128.904 | 54.262 |

SAND = percent sand in soil sample
HEIGHT = average height of sagebrush
SG_COVER = percent canopy cover of big sagebrush
FORBS = percent canopy cover of all forb species
AN_GRASS = percent canopy cover of all annual grass species
PER_GRASS = percent canopy cover of all perennial grass species
TIME = 2004 and 2005

The parameter estimates for percent sand and sagebrush height were both positive, therefore, we can present the results as how the odds ratios of finding a burrow at a given location increase with an increase in the explanatory variables (average sagebrush height and percent sand).

Consequently, for every 0.1 meter increase in sagebrush height, the odds ratio of finding an occupied burrow increases by a factor of 2.33 times (95% CI 1.59-3.80) after accounting for percent sand and percent cover of sagebrush (Table 2.5). Also, for every 1 percent increase in sand, the odds ratio of finding an occupied burrow increases by a factor of 1.18 times (95% CI 1.06-1.34) after accounting for sagebrush height and percent sagebrush cover (Table 2.5). Percent canopy cover of big sagebrush, contributed little to the final model, and had a 95% confidence interval for the parameter estimate that included zero (Table 2.5). Therefore, the percent sand content in the soil and average sagebrush height were sufficient to describe the habitat around occupied pygmy rabbit burrows.

Table 2.5. Parameter estimates, 95% confidence intervals, standard errors, and odds ratios for average sagebrush height, percent sand, and percent sagebrush cover in the top model of resource selection determined from data collected at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| Parameter | Parameter Estimate | SE | 95 % Confidence Interval for the parameter estimate | odds ratio[a] |
|---|---|---|---|---|
| intercept | -13.1543 | 3.4042 | -20.7746, -7.2287 | |
| SAND | 0.1665 | 0.0587 | 0.0620, 0.2956 | 1.18 |
| HEIGHT | 8.4951 | 2.1917 | 4.6849, 13.3653 | 2.33[b] |
| SG_COVER | 0.0787 | 0.042 | -0.0021, 0.1654 | 1.08 |

a = odds ratio ($e^{ß}$) = odds of selection increase or decrease by this factor for each unit increase in the explanatory variable
b = odds ratio calculated for 0.1 meter increase rather than 1 meter increase so that odds ratios are reported on similar scales
SAND = percent sand in soil sample
HEIGHT = average height of sagebrush
SG_COVER = percent canopy cover of big sagebrush

## DISCUSSION

We found that sagebrush height and soil percent sand content were the two habitat characteristics most predictive of occupied pygmy rabbit burrow locations. Pygmy rabbits have been found to inhabit areas of tall, dense sagebrush cover (Orr 1940, Severaid 1950, Green and Flinders 1980b) and are dependent on sagebrush for food and shelter (Green and Flinders 1980b). We found that the odds ratios of finding a pygmy rabbit burrow increased as sagebrush height increased, supporting the finding by Green and Flinders (1980b) that pygmy rabbits prefer taller big sagebrush. Weiss and Verts (1984) found an average sagebrush height of 84.4 cm (±5.8 cm) for their study areas in Oregon, and Katzner and Parker (1997) found an average sagebrush height of 55.2 cm (±3.7cm) for their study areas in Wyoming. Pygmy rabbits may prefer to inhabit these taller stands of sagebrush because they provide hiding cover from predators. Pygmy rabbits may be more susceptible to predators because they are slower moving than other rabbits in the Leporidae family and are vulnerable in open habitats (Weiss and Verts 1984, Gabler et al. 2001).

Weiss and Verts (1984) also found that pygmy rabbits inhabit areas of deep, loose soils, and soil characteristics were important in distinguishing areas occupied by pygmy rabbits from unoccupied areas. Similarly we found that the odds ratio of finding a pygmy rabbit burrow increased with increasing percent sand. Loose soils can be found in areas with a greater sand content, and digging would be easier for pygmy rabbits in sandy soils. Brady and Weil (2002) describe sandy soils as less aggregated and having larger pores, therefore, they are less likely to cohere and become hard.

Our finding that sagebrush height and percent sand best describe occupied pygmy rabbit habitat were consistent with those of others. Sagebrush height and percent sand were both included in a habitat suitability model created by Gabler et al. (2001) which used data from occupied burrows, unoccupied areas, active areas and non-use areas to describe pygmy rabbit habitat. Also, Weiss and Verts (1984) reported that pygmy rabbits were found in areas with greater sagebrush height and coarser soil texture.

Tall clumps of big sagebrush are known to be predictive of pygmy rabbit occurrence (Orr 1940, Katzner and Parker 1997, Gahr 1993, Gabler et al. 2001). We found pygmy rabbit burrows in taller clumps of mountain big sagebrush near refuge headquarters. In addition, we found that pygmy rabbit burrows were most abundant in a large and contiguous stand of Wyoming big sagebrush in the northeast portion of Hart Mountain. This area of Wyoming big sagebrush covers approximately 19,830 ha and has a relatively uniform height over the entire area. There are no big sagebrush clumps that are considerably taller, which is inconsistent with the literature and what we presumed was typical habitat for pygmy rabbit burrows. We suspect that taller clumps of big sagebrush in this area of Wyoming big sagebrush are not necessarily predictive of pygmy rabbit occurrence. Pygmy rabbits may construct burrows in greater abundance in this area because of the large expanse of big sagebrush with few roads that is free from human and livestock grazing disturbances. Bailey (1936) reports that pygmy rabbits are locally abundant, but only where the conditions are most favorable, as may be the case with this Wyoming big sagebrush habitat where the majority of our occupied burrows were found.

Of the big sagebrush subspecies, Wyoming big sagebrush tends to be the least dense because it grows on warmer drier sites (Rosentreter 2004). Mountain and basin big sagebrush form thicker denser stands and are typically found in areas with greater moisture content and deeper soils (Rosentreter 2004). Since there was no visual difference in height or density of the Wyoming big sagebrush in the area where we found the greatest pygmy rabbit burrow abundance, soils may be of even greater importance in distinguishing areas occupied by pygmy rabbits. This presents a problem, because most digital soils information that is available for public lands is at a scale too coarse to detect small areas of soil that pygmy rabbits seem to be seeking when constructing burrows. This coarse scale for soils data may be helpful in accurately predicting occupied pygmy rabbit use areas, but may not accurately determine specific areas where they are constructing burrows. Coarse scale soils data may be used to predict general areas of occupied pygmy rabbit habitat, but we recommend on the ground surveys at a finer scale to locate the more specific burrow locations.

Because this model is in agreement with other studies of pygmy rabbit habitat (Green and Flinders 1980b, Weiss and Verts 1984, Gabler et al. 2001), we feel confident that it could be used to identify additional areas of occupied pygmy rabbit habitat on Hart Mountain. Although the information in our model is strongest for Hart Mountain, the model may be used in combination with other tools to identify potential habitat for pygmy rabbits in other areas of the Great Basin and/or Columbia Basin in Washington where pygmy rabbits are listed as an endangered species (USDOI 2003). This model contains two habitat characteristics that are easily measured in the field, and we reduced the number of variables in the model selection process with

hopes of creating a model that can be applied to a large area, requiring minimal effort in the field.

**Management Considerations**

Based on our findings, a large population of pygmy rabbits may inhabit the 19,830 ha of Wyoming big sagebrush in the northeast portion of Hart Mountain National Antelope Refuge. From the number of occupied burrows we located in a small area, there is potential for this contiguous stand of Wyoming big sagebrush to support many more rabbits and burrows. Additional surveys in winter of 2005 by refuge staff located over 99 occupied burrows in a 1035 ha (4 square mile) area adjacent to our burrow locations found in 2004 (R. Huddleston-Lorton, personal communication). Future research should be conducted in this area of Wyoming big sagebrush to account for all pygmy rabbit burrows and document the population status on Hart Mountain which is not currently known. Information on pygmy rabbit habitat use will be important in the future as big sagebrush habitats continue to decline due to conversion and fragmentation by human activities, overgrazing by livestock, noxious weed invasions and wildfires.

We attempted to keep our model of resource selection simple by only including measures we hypothesized to have the most explanatory power in our model selection process. This was necessary to formulate a model that can be easily applied and interpreted and used by land managers to predict pygmy rabbit habitat. The final model in our regression analysis was a simple model with two variables that describe occupied pygmy rabbit habitat. Also, percent sand content in the soil and

sagebrush height were easily measured in the field and results were obtained fairly quickly.

This information is useful for management decisions regarding prescribed burns, grazing plans or other disturbances that may alter sagebrush cover and soils in pygmy rabbit habitat. Managers may want to consider limiting these activities and prevent uncontrolled disturbances (i.e. catastrophic wildfire and noxious weeds) in areas occupied by pygmy rabbits to preserve their remaining habitat and to ensure their persistence. Identifying occupied pygmy rabbit habitat could be an important step towards protecting sagebrush habitats from disturbances and further degradation.

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# Chapter 3

## Identifying Suitable Habitat for the Reintroduction of Pygmy Rabbits at Hanford Reach National Monument, Washington

Jennifer K. Meisel, Richard A. Schmitz

**ABSTRACT**

Pygmy rabbits (*Brachylagus idahoensis*) in Oregon and Washington are a big sagebrush (*Artemisia tridentata spp.*) obligate species of concern because of declining populations and extirpation from much of their range. Efforts are underway by the Washington Department of Fish and Wildlife to establish a captive bred population of the Columbia Basin pygmy rabbit for reintroduction into the wild. We used a resource selection model developed from occupied pygmy rabbit habitat at Hart Mountain National Antelope Refuge in Oregon to determine suitable habitat for the potential reintroduction of pygmy rabbits at Hanford Reach National Monument (Monument) in Washington. We used a two-step approach to apply this model to vegetation and soils data. We first used GIS (Geographic Information System) procedures for a coarse scale application of the resource selection model, and identified approximately 8500 ha of potential pygmy rabbit habitat. We then collected data on the ground within the 8500 ha for a finer scale application of the model. The fine scale application was used to identify 3035 ha considered as the best suitable habitat. Locations identified as the best suitable habitat on the Monument may be critical to the survival of the Columbia Basin population of pygmy rabbits. Identifying potential pygmy rabbit habitat could be an important step towards protecting big sagebrush habitats from disturbances and further degradation. Areas identified as potential pygmy rabbit habitat on the Monument can be used to prioritize management efforts for pygmy rabbits.

## INTRODUCTION

A number of disturbances, natural and human caused, have altered and fragmented big sagebrush (*Artemisia tridentata spp*.) habitats used by pygmy rabbits (*Brachylagus idahoensis*) and other sagebrush obligate species throughout much of their range. Pygmy rabbits are vulnerable to habitat fragmentation, overgrazing by livestock and sagebrush eradication (Holechek 1981, Katzner and Parker 1998) because they rely heavily on big sagebrush for a large portion of their diet and for thermal and hiding cover. Because of these specific habitat requirements and the alteration of big sagebrush habitats, pygmy rabbits are becoming increasingly rare on the landscape.

Pygmy rabbits belong to the family Leporidae, and are the smallest rabbits in North America (Green and Flinders 1980a, WDFW 1995, USDOI 2003). It is well documented that they inhabit areas of tall, dense big sagebrush (Orr 1940, Severaid 1950, Green and Flinders 1980b, Katzner and Parker 1997, Gabler et al. 2001) and are dependent on big sagebrush for food and shelter (Green and Flinders 1980b). Weiss and Verts (1984) also determined that pygmy rabbits inhabit areas of deep, loose soils and that soil characteristics were important in distinguishing areas occupied by pygmy rabbits from unoccupied areas. Pygmy rabbits are one of two rabbits in North America which dig their own burrows (WDFW 1995, USDOI 2003); making soils an important component of their habitat requirements. Pygmy rabbits are geographically widespread throughout the Great Basin and Intermountain West (Green and Flinders 1980a, Weiss and Verts 1984, USDOI 2003), and are patchily distributed in big sagebrush landscapes.

In Washington state 75% of the big sagebrush habitat occurring in loamy soils has been converted to agriculture and other land uses (Knick et al. 2003). Much of the remaining big sagebrush habitat in central Washington exists on the US Army's Yakima Training Center and the Department of Energy's Hanford Site, which includes Hanford Reach National Monument (Monument).

Disturbances such as overgrazing and wildfires cause alterations that may fragment or create unsuitable habitat for pygmy rabbits. Fragmentation of big sagebrush habitats can influence pygmy rabbit populations because of the rabbit's limited dispersal capabilities over areas without big sagebrush cover (Weiss and Verts 1984). Historically, wildfires in the sagebrush ecosystem were small and infrequent, and were important in creating a mosaic of shrub and grassland communities (Knick 1999). Today, the number and frequency of wildfires in sagebrush ecosystems has increased as a result of the invasion by non-native annual grasses, specifically cheatgrass (*Bromus tectorum*) (Young and Evans 1973, USDOI 2002). It is estimated that over 50% of native sagebrush communities have non-native grasses in the understory, or have been completely converted to annual grasslands (Knick et al. 2003). Therefore, wildfires may have a greater chance of affecting pygmy rabbit populations in vulnerable sagebrush habitats.

Siegel (2002) concluded from her study of pygmy rabbit use in grazed and ungrazed habitat in Washington, that livestock grazing may be detrimental to pygmy rabbits. Livestock grazing reduces large amounts of grasses and forbs in an area, which can directly affect pygmy rabbits by reducing their forage (Siegel 2002). Together, disturbances such as increased wildfire frequency and intensity, intensive livestock grazing, invasion of non-native annual grasses, and conversion for

agricultural purposes have caused a decline in the acreage of sagebrush habitats throughout the western United States, resulting in their designation as among the most endangered habitats in North America (Knick et al. 2003).

Pygmy rabbits in Oregon and Washington are a sagebrush obligate species of concern because of declining populations and extirpation from much of their range within the Columbia Basin and the western United States. Historically, pygmy rabbits were widespread in sagebrush habitats of eastern Oregon and Washington, an area that covered over 14.8 million ha (Franklin and Dyrness 1973). The historic range of pygmy rabbits in eastern Washington included portions of Hanford Reach National Monument (Monument) in Benton, Adams, Franklin, and Grant counties, along with land in Lincoln and Douglas counties (Gahr 1993, WDFW 1995) (Figure 3.1).

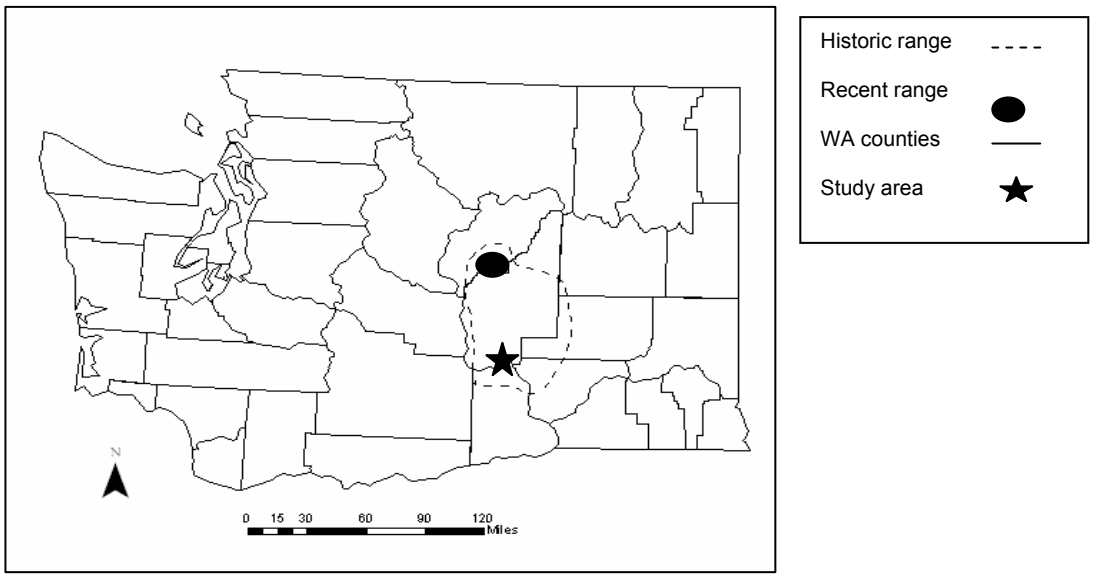


Figure 3.1: Most recent and historic range of pygmy rabbits in Washington state. The dashed line represents the historic range of pygmy rabbits, and the circle represents the most recent location of pygmy rabbits at Sagebrush Flat in Douglas County. The star represents the location of the study area on Hanford Reach National Monument, Washington.

The Columbia Basin population of pygmy rabbits in Washington experienced a dramatic decrease from six known populations in 1997 to one in 2001 (WDFW 2003, USDOI 2003). This decrease prompted the United States Fish and Wildlife Service (USFWS) to emergency list this distinct population as federally endangered in 2001, with a final ruling as endangered in 2003 (USDOI 2001, USDOI 2003). The Columbia Basin pygmy rabbit was listed as a Washington state threatened species in 1990, and upgraded to endangered status in 1993 (WDFW 1995). The last known population of pygmy rabbits in Washington existed on land at Sagebrush Flat in Douglas county (WDFW 2004) (Figure 3.1). Surveys conducted by the Washington Department of Fish and Wildlife (WDFW) in winter 2004 failed to locate pygmy rabbits at Sagebrush Flat. As a result, there are no known populations of pygmy rabbits in the wild in Washington state (WDFW 2004).

The survival of the Columbia Basin pygmy rabbit in Washington currently relies on the recovery of viable populations through successful reintroduction into suitable habitat; however, suitable habitat must first be identified. Because there are no pygmy rabbits in the wild in Washington state, we developed a resource selection model (Manly et al. 2002) for pygmy rabbits by sampling occupied and unoccupied pygmy rabbit habitat at Hart Mountain National Antelope Refuge (Hart Mountain) in Oregon (Meisel 2006). We found that sagebrush height and percent sand content were the two most important factors that pygmy rabbits were selecting for when choosing burrow locations. The model indicated that the odds ratio of an occupied pygmy rabbit burrow occurrence increased with an increase in percent sand content and sagebrush height.

Studies were conducted outside of Washington in known pygmy rabbit habitat to thoroughly understand and measure all possible types and characteristics of habitat that may be suitable for pygmy rabbits. The model in Oregon was developed in vegetation and climate conditions similar to those at Hanford Reach National Monument in Washington where we applied the model. Hart Mountain contains Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) habitats similar to those at Hanford Reach National Monument. Hart Mountain also supports areas of mountain big sagebrush (*Artemisia tridentata vaseyana*) and basin big sagebrush (*Artemisia tridentata tridentata*). Hanford Reach National Monument does not support mountain big sagebrush and has little basin big sagebrush habitat. However, White et al. (1982) found that pygmy rabbits do not select sagebrush at the subspecies level, and showed no preference of basin big sagebrush over mountain big sagebrush. Weiss and Verts (1984) also noted that the distribution of pygmy rabbits in Oregon was not dependent on the specific subspecies of big sagebrush.

The objective of this study was to apply the resource selection model for pygmy rabbits that was developed in Oregon (Meisel 2006) to lands at Hanford Reach National Monument to create spatially explicit maps identifying the best potential pygmy rabbit habitat. Locations with the highest probability of use on the Monument were considered as the areas most suitable for the potential reintroduction of pygmy rabbits.

## STUDY AREA

The Hanford Reach National Monument covers approximately 78,900 ha in south-central Washington in Adams, Benton, Franklin, and Grant counties. The

Monument surrounds the US Department of Energy's Hanford Site. For this study, we focused on the North Slope of the Monument which contains the largest contiguous tract of big sagebrush habitat (Figure 3.2). This area includes portions of Saddle Mountain National Wildlife Refuge and the Wahluke Unit of the Monument totaling 36,420 ha and is within the historic range of pygmy rabbits in Washington state. Average annual precipitation is approximately 17.7 cm, with January average temperature of -0.1 º C, and July average temperature of 24.6 º C (Hoitink et al. 2003). The Monument has a number of qualities that make it a candidate for the possible reintroduction of pygmy rabbits. The Hanford Site was established by the U.S. Government in the 1940's as a national security area for the production of weapons-grade plutonium; however, large tracts of land were used as protective buffer zones and remained undisturbed. These buffer zones preserved a biological and cultural resource setting unique in the Columbia Basin region. The diversity of habitats, along with the abundance of big sagebrush that have remained intact from years of protection may contain suitable pygmy rabbit habitat.

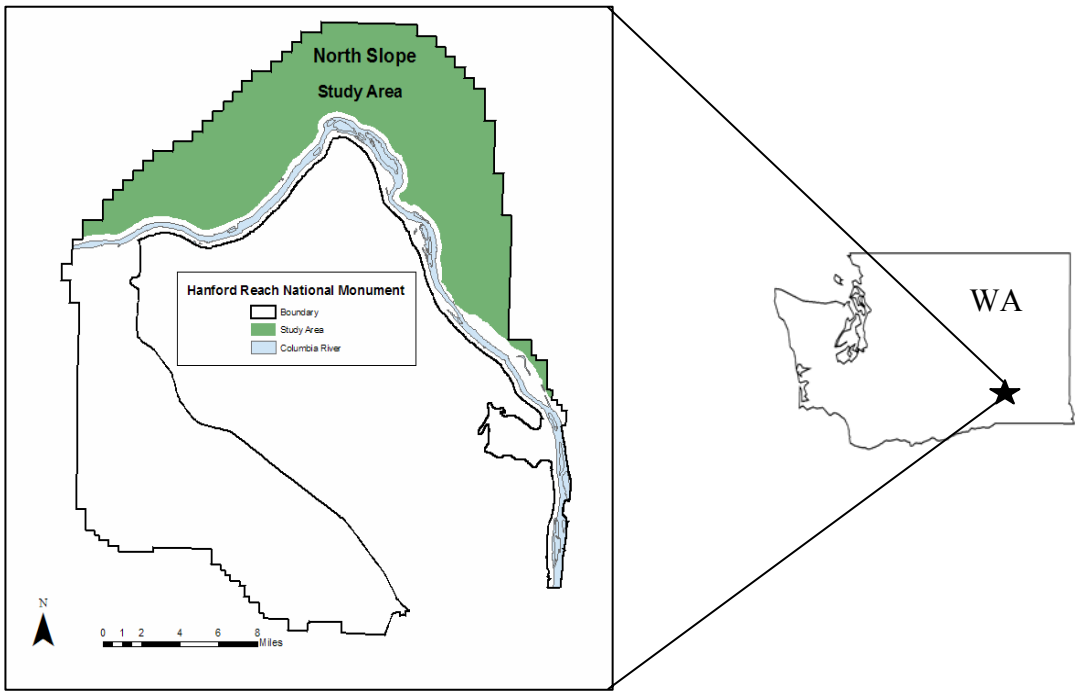


Figure 3.2: Study area on the North Slope of Hanford Reach National Monument, Washington.

## METHODS

We used a two-step approach to develop a map depicting potential pygmy rabbit habitat by applying the resource selection model to the North Slope of Hanford Reach National Monument. We first performed a coarse scale application of the model using vegetation and soils data in a Geographic Information System (GIS) (Environmental Systems Research Institute, Redlands, CA, USA). We selected the appropriate soils and vegetation conditions as defined by the resource selection model (Meisel 2006) and overlaid the vector files to produce a coarse scale map of potential pygmy rabbit habitat. We then refined the coarse scale map by collecting data from random points within areas identified by the GIS. Habitat measures collected at each random point were used to calculate odds ratios for the resource

selection model. Those areas with the highest odds ratios were then identified as the best potential pygmy rabbit habitat.

**Coarse Scale Identification of Potential Habitat**

We used GIS coverages for soils and vegetation for the initial application of the resource selection model. We created the soils data set from the Soil Survey Geographic (SSURGO) database for Grant and Franklin counties in Washington (USDA 1994). The SSURGO data base contains the most detailed level of soil geographic data developed by the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) (J. Doolittle, personal communication). Soil maps in the SSURGO data base duplicate the original soil survey maps at scales ranging from 1:12,000 to 1:63,360 (with minimum delineation size of 0.6 to 16 ha, respectively) (J. Doolittle, personal communication).

Using a soil textural triangle (Buol et. al 2003), we determined the range of percent sand content for all soil types found on the North Slope (Table 3.1). We classified each of the soil types according to the percent sand content, and then selected those areas having percent sand content within the range of data for occupied burrows at Hart Mountain using a GIS. The range of percent sand in the soils at Hart Mountain was 30-66%; however, we expanded this range to include percent sand values up to 90% based on findings in Idaho (Gabler et al. 2001). The percent sand content at occupied burrows and in active pygmy rabbit areas in Idaho contained 81 and 87% sand respectively (Gabler et al. 2001).

Table 3.1: Range of percent sand values for soil types on the North Slope, Hanford Reach National Monument, WA.

| soil type | range of percent sand |
|---|---|
| silt loam | 10-50% |
| clay loam | 30-65% |
| loam | 35-65% |
| sandy loam | 50-90% |
| loamy sand | 80-95% |
| sand | 90-100% |

The vegetation GIS layer was delimited specifically for the North Slope of Hanford Reach National Monument using aerial photos, infrared aerial photos and extensive ground truthing to classify vegetation types (Salstrom and Easterly 2004). All shrub and grass species in the study area were recorded in the classification process. Big sagebrush height was identified by the resource selection model as an important predictor of active pygmy rabbit burrows; however, GIS layers depicting sagebrush height were not available, consequently, we selected areas with big sagebrush as the dominant cover type in the absence of measures for big sagebrush height.

The soil and vegetation coverages were overlaid using a GIS, and the resulting map showed areas of potential pygmy rabbit habitat. Only those areas classified as having big sagebrush cover and fitting the range of soils defined by the resource selection model were further considered as potential pygmy rabbit habitat.

**Fine Scale Identification of Potential Habitat**

To apply the model at a finer scale, we placed random points within the areas of potential pygmy rabbit habitat identified by the GIS. We used Hawth's Analysis Tools for ArcGIS (Beyer 2004) to generate 250 random points within the area

identified as potential pygmy rabbit habitat by the coarse scale identification using the GIS. We then transferred the UTM (Universal Transverse Mercator) coordinates for the random points into a Trimble Geo XM™ GPS (Global Positioning System) unit (Trimble Navigation Limited, Westminster, Colorado, USA) and navigated to each point in the field. Sagebrush height measurements were taken and a soil sample was collected at each random point. Sagebrush height was measured using a two-section, 2.5 cm X 2-m collapsible pole (Nudds 1977, Griffith and Youtie 1988). We measured sagebrush height from a distance of 15 m in each of the four cardinal directions and averaged the values. A soil particle size analysis, using the hydrometer method, was conducted to determine the percent sand, silt and clay for each point (Buol et. al 2003). Samples were analyzed at Oregon State University's Soil Science Physical Characterization Lab.

We inserted the values for percent sand and sagebrush height collected at each random point into the equation for the resource selection model to calculate the odds ratio of finding an active pygmy rabbit burrow. Those areas with the highest odds ratios were identified as the best potential pygmy rabbit habitat. Data collected for the resource selection model were considered retrospective because we collected samples based on each level of the response variable (occupied and unoccupied) (Ramsey and Schafer 2002), and the explanatory variables represented important habitat characteristics. Our results are presented as the odds ratios, which are the odds that a pygmy rabbit burrow is present. In this case, we do not have pygmy rabbits or burrows present; however points with the highest odds ratios represent areas most likely to support pygmy rabbit burrows.

## RESULTS

### Coarse Scale Identification of Potential Habitat

The coarse scale GIS analysis of vegetation and soils data resulted in an area of approximately 8500 ha of potential pygmy rabbit habitat on Hanford Reach National Monument (Figure 3.3). A large area of potential habitat was uniformly spread across the northern portion of the study site. The southeastern corner of the study area also contained a large continuous portion of potential habitat. The southwest section of the study area did not contain large polygons of potential habitat.

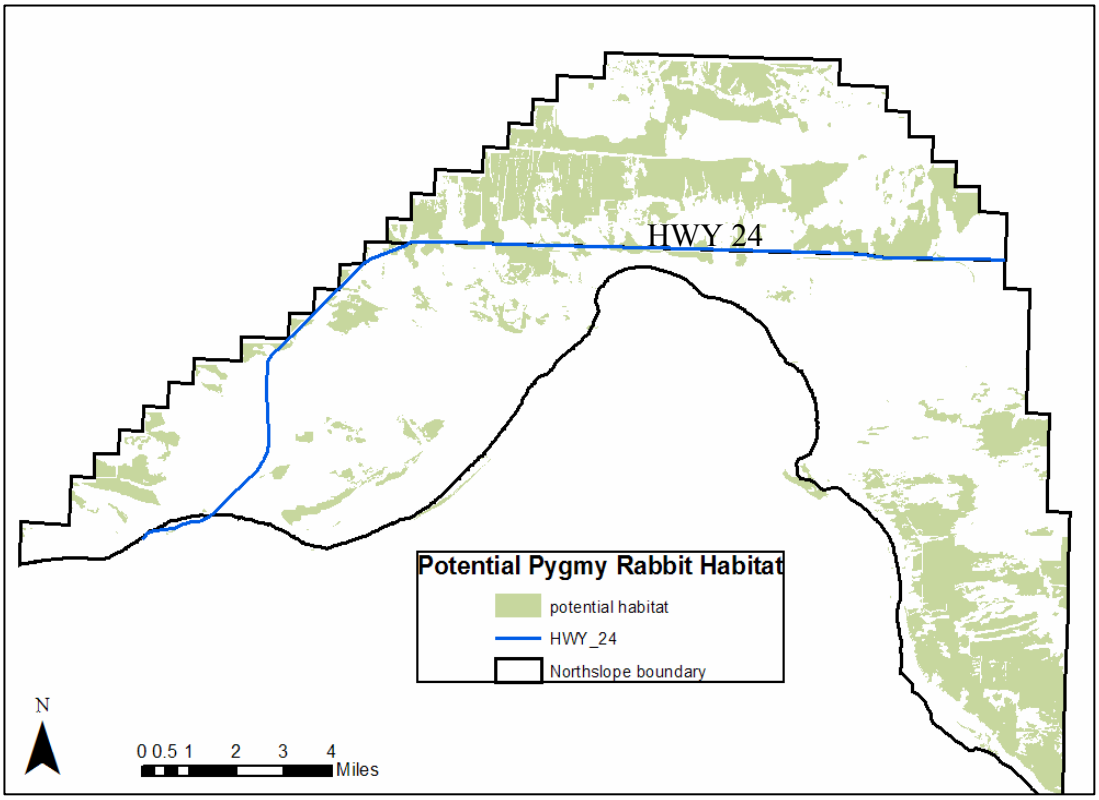


Figure 3.3: Shaded areas representing 8500 ha (21,000 acres) of potential pygmy rabbit habitat at Hanford Reach National Monument, Washington, determined by a coarse scale GIS analysis.

**Fine Scale Identification of Potential Habitat**

Data were collected from 237 of the 250 random points within the 8500 ha of potential habitat identified by the GIS. We did not collect data from all 250 points because a wildfire on August 7-9, 2005 burned the area containing the remaining 13 points. The range of calculated odds ratios for the 237 points was 0.50-4.34. As the odds ratios increased, there was a greater likelihood of an area to support pygmy rabbit burrows. Therefore, we can consider points with odds ratios greater than 1.5 as being areas more likely to support active pygmy rabbit burrows than those areas with odds ratios less than 1.5. The area in the southeast corner of the study area contains the greatest concentration of points with the highest odds ratios (Figure 3.4). This area in the southeast corner contains approximately 3035 ha of potential pygmy rabbit habitat identified using the coarse scale GIS technique. Many random points in this area contain odds ratios greater than 1.5; therefore we can consider the vicinity of the 3035 ha as the best potential pygmy rabbit habitat. There are two additional concentrations of points in the northern section of the study area (north of State Highway 24) that represent marginal habitat. These areas are considered marginal because they contain points with high odds ratios, but are not large enough to be considered as potential sites for reintroduction.

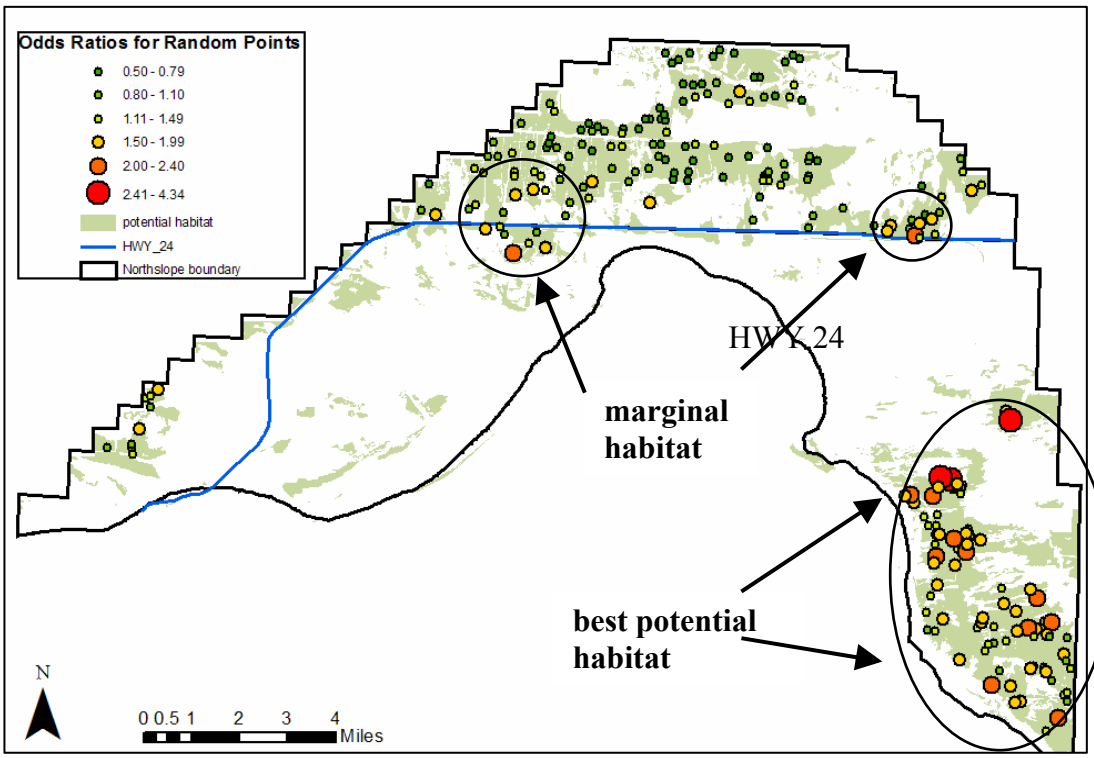


Figure 3.4: Calculated odds ratios of 237 random points on the North Slope of Hanford Reach National Monument, Washington. Points with odds ratios greater than 1.5 represent the best potential pygmy rabbit habitat and are displayed as the larger yellow, orange and red circles.

## DISCUSSION

We determined that the 3035 ha in the southeast corner of the Monument contains the best potential pygmy rabbit habitat on Hanford Reach National Monument in Washington. There were 36,420 ha considered in our study area, and 8500 ha or 23% of the area was predicted as potential habitat by the GIS. Only 3035 ha or 8% of the total area was more precisely identified as the best potential habitat suitable for reintroduction by ground truthing the area identified by the GIS. A large portion of the remaining big sagebrush habitat in the Columbia Basin, including areas on Hanford Reach National Monument, has been converted to annual grassland (cheatgrass) or contains big sagebrush cover with an understory of cheatgrass due to

disturbances such as wildfire and intensive grazing. This area has a history of heavy livestock grazing, and along with multiple wildfires, these disturbances have reduced big sagebrush cover and resulted in the invasion of cheatgrass, thus reducing the amount of habitat that could be considered potential pygmy rabbit habitat.

Most of the potential pygmy rabbit habitat identified by the GIS north of State Highway 24 was not identified as suitable habitat through the fine scale application of the model. We speculate this land was not identified as suitable habitat because much of the area consists of sparse big sagebrush interrupted by large patches of cheatgrass, rather than having a large continuous patch of big sagebrush. The area identified as the best potential habitat in the southeast corner of the Monument contains large continuous areas of big sagebrush, with native grasses and forbs in the understory.

Sampling habitat at a finer scale should be considered when locating potential pygmy rabbit habitat because pygmy rabbits seem to select burrow locations on a scale smaller than can be identified in a GIS. Gabler et al. (2000) used a GIS to create a model for predicting the suitability of habitat for pygmy rabbits in southeast Idaho and recommended that further analysis of the habitat on a finer scale is necessary to determine if an area is indeed suitable for pygmy rabbits. We followed these recommendations by taking the analysis one step further and identified potential pygmy rabbit habitat at a finer scale. Refining the search area identified through the GIS analysis by collecting data on the ground allowed us to predict those areas on the Monument that most closely resemble occupied pygmy rabbit habitat at Hart Mountain National Antelope Refuge.

A common limitation of GIS data is that it provides information at a landscape scale which may be too coarse for assessing microhabitat or vegetation data (Mitchell et al. 2001) for animals that select habitat features on a fine scale. This was the case for our vegetation layer because it did not distinguish between continuous and sparse big sagebrush cover. Because of the disparity between the scale of the GIS data and the fine scale at which pygmy rabbits select habitat, we may have falsely predicted pygmy rabbit habitat in sparse big sagebrush areas using the GIS analysis. A more accurate GIS layer that distinguishes between sparse and continuous big sagebrush cover would be helpful to limit this problem in the future. Relying solely on GIS data to predict habitat eliminates the need for intensive field sampling and saves time and resources. However, for animals such as pygmy rabbits that select habitat on a fine scale, field sampling is necessary to correctly identify the best potential habitat.

The procedure of building a resource selection model using logistic regression analyses and applying the model using a GIS has successfully predicted suitable habitat for many other species. Gross et al. (2002) used logistic regression to develop habitat models from observations of mountain goats (*Oreamnos americanus*) in Colorado, and Carroll et al. (1999) used presence/absence data to build habitat models to predict fisher (*Martes pennanti*) distribution in southwest Oregon. Our study was most similar to a study performed by Niemuth (2003) using landscape characteristics surrounding active greater prairie chicken (*Tympanuchus cupido*) leks and unused points to develop a habitat model for identifying the suitability of landscapes in Wisconsin. Niemuth (2003) applied the model to digital landcover data for the entire state of Wisconsin to predict the suitability of landscapes for the translocation of greater prairie chickens.

The Washington Department of Fish and Wildlife (WDFW) is currently breeding pygmy rabbits in captivity with plans to release rabbits onto state land in fall of 2006 or spring 2007 (D. Hayes, personal communication). In 1995, the Washington Department of Fish and Wildlife published the "Washington State Recovery Plan for the Pygmy Rabbit" that described strategies to recover the species by increasing the extent and quality of available habitat, and protecting the population (WDFW 1995). The subsequent addenda to the plan in 2001 and 2003 describe the initiation and implementation of a captive breeding program for pygmy rabbits (WDFW 2001, 2003). The objectives of the captive breeding program were to develop a captive population to increase numbers, manage habitat to protect pygmy rabbits, and to eventually reintroduce members of the captive population into suitable habitat in eastern Washington (WDFW 1995, 2001, 2003). The 2003 Recovery Plan Update specifically states that habitat be managed for long-term protection of features that support pygmy rabbits and that areas be identified for reintroduction of the captive bred population (WDFW 2003). WDFW is seeking sites with a minimum of 5000 acres, or 2023 hectares, in which to reintroduce pygmy rabbits in Washington state (D. Hayes, personal communication). This study identifies an area of Hanford Reach National Monument in Washington that meets this minimum acreage requirement, and supports suitable habitat for pygmy rabbits which may be considered by WDFW as a potential reintroduction site in the future.

**Management Considerations**

We were able to identify an area in the southeast corner of Hanford Reach National Monument as the area most likely to support pygmy rabbits. This area

contains soils and sagebrush height values that are most similar to areas occupied by pygmy rabbits at Hart Mountain National Antelope Refuge in Oregon. The area identified as most suitable must be carefully managed if it is to be considered for reintroduction. Managers should attempt to protect the area from disturbances such as catastrophic wildfires and invasion by non-native plant species that may alter existing big sagebrush and soils. Protecting these lands from disturbances will be critical should rabbits be reintroduced into this area. Because cheatgrass is prevalent in this ecosystem, managers should explore options that limit or control the spread of cheatgrass into potential pygmy rabbit habitat. By controlling or reducing the amount of cheatgrass in an area, the risk of wildfire is also greatly reduced (Link et al. 2006).

The areas determined as marginally suitable by application of the resource selection model can be used to direct potential habitat restoration and rehabilitation efforts. These efforts should focus on creating pygmy rabbit habitat for the recovery of the endangered segment of the population. Efforts should focus on planting big sagebrush to fill in patchy or minimal big sagebrush cover in areas with suitable soils that are free of cheatgrass. Weiss and Verts (1984) suggest that pygmy rabbits may be reluctant or unable to cross open areas without big sagebrush; therefore, planting big sagebrush to create continuous cover would increase suitable habitat for pygmy rabbits.

The results of this study provide the information necessary to develop conservation and management guidelines for the potential recovery, through reintroduction, of pygmy rabbits in Washington. Locations identified as suitable for reintroduction on Hanford Reach National Monument may be critical to the survival of the Columbia Basin population of pygmy rabbits. These areas can be classified

as high quality big sagebrush habitat based on their understory components and their tall, dense cover of big sagebrush. This habitat may also be used by other big sagebrush dependent species, such as sage sparrow (*Amphispiza belli*), Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*) (Knick et al. 2003), sagebrush lizard (*Sceloporus graciosus*), and sagebrush vole (*Lammiscus curtatus*) (Paige and Ritter 1999). Identifying potential pygmy rabbit habitat could be an important step towards protecting sagebrush habitats from disturbances and further degradation. Areas identified as potential habitat in Washington can be used to prioritize management or restoration efforts for the benefit of pygmy rabbits.

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# Chapter 4

## Summary and Conclusions

Pygmy rabbit occurrence was best predicted by big sagebrush (*Artemisia tridentata spp*.) height and soil percent sand content at Hart Mountain National Antelope Refuge in south-central Oregon. These were the two habitat characteristics most predictive of occupied pygmy rabbit burrow locations. Pygmy rabbits are a sagebrush obligate species that rely on big sagebrush as their main food source, for thermal cover, and for hiding cover from predators (Green and Flinders 1980b, Gabler et al. 2001). Loose soils, or those with greater percent sand content, are important to pygmy rabbits because they dig their own burrows (Green and Flinders 1980a, WDFW 1995, USDOI 2003).

Big sagebrush height and soil percent sand content were used to identify suitable habitat for pygmy rabbits at Hanford Reach National Monument in Washington. Identifying suitable habitat for pygmy rabbits in Washington may be critical to the survival of the Columbia Basin population of pygmy rabbits because the suitable habitat may be used as a future reintroduction site.

We found pygmy rabbits and their burrows in the characteristic habitat described in the literature as tall, dense clumps of big sagebrush on Hart Mountain National Antelope Refuge, Oregon (Orr 1940, Severaid 1950, Green and Flinders 1980b, Gahr 1993, Gabler et al. 2001). We also found pygmy rabbits and burrows in a large contiguous stand of Wyoming big sagebrush with relatively even height and density, which contradicted the literature description of pygmy rabbit habitat. We suspect that pygmy rabbits inhabit this area because it is a large contiguous stand of big sagebrush that is free from human and grazing disturbances. Pygmy rabbits may

be selecting for small lenses of looser soils within the large area of Wyoming big sagebrush habitat in which to construct their burrows.

Our findings suggest that GIS data can be used to identify potential pygmy rabbit habitat at a coarse scale; however, sampling habitat on the ground at a finer scale is needed to identify the best potential pygmy rabbit habitat. Refining the search area identified through the GIS analysis by collecting data on the ground allowed us to predict those areas on Hanford Reach National Monument that most closely resemble occupied habitat at Hart Mountain National Antelope Refuge.

Big sagebrush habitats across the west that currently support populations of pygmy rabbits or areas identified as suitable habitat for pygmy rabbits should be regarded as a conservation priority. At a time when sagebrush habitats are rapidly declining, it is important that we maintain these intact sagebrush habitats for pygmy rabbits and other sagebrush obligate species.

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# Appendices

Appendix A: Locations of occupied pygmy rabbit burrows (n=45) on Hart Mountain National Antelope Refuge sampled in 2004 and 2005. Coordinates are in UTM (Universal Transverse Mercator) format, datum is NAD 27, zone 11N.

| Easting/Longitude | Northing/Latitude |
|---|---|
| 298155.729 | 4730620.282 |
| 297934.188 | 4730618.450 |
| 284866.364 | 4698376.806 |
| 294584.071 | 4723580.523 |
| 299672.771 | 4726475.193 |
| 297224.353 | 4727177.836 |
| 297449.890 | 4726986.779 |
| 299016.563 | 4727778.608 |
| 299075.131 | 4727702.054 |
| 297269.401 | 4727126.295 |
| 298298.300 | 4730140.244 |
| 299612.731 | 4726497.042 |
| 299036.558 | 4727728.417 |
| 298415.784 | 4728786.221 |
| 292128.596 | 4726615.253 |
| 281480.993 | 4711194.574 |
| 281608.142 | 4711748.302 |
| 282510.932 | 4711795.021 |
| 296614.106 | 4725621.743 |
| 280569.944 | 4710542.861 |
| 280549.291 | 4710460.585 |
| 280587.629 | 4710290.332 |
| 280738.291 | 4713031.685 |
| 281716.669 | 4713742.293 |
| 294559.304 | 4723382.737 |
| 297390.735 | 4725381.985 |
| 297189.082 | 4725802.675 |
| 295283.750 | 4726951.729 |
| 282121.747 | 4710078.538 |
| 282029.949 | 4710120.618 |
| 298152.632 | 4727162.533 |
| 297587.477 | 4727111.185 |
| 298882.832 | 4727105.007 |
| 298035.732 | 4726533.653 |
| 297524.105 | 4726236.243 |
| 297574.107 | 4726772.952 |
| 297252.475 | 4726806.530 |
| 297391.100 | 4727002.920 |
| 295989.963 | 4725805.304 |
| 298838.931 | 4726078.617 |
| 298905.274 | 4726412.446 |

Appendix A (Continued).

| Easting/Longitude | Northing/Latitude |
|---|---|
| 298658.793 | 4726858.567 |
| 301093.410 | 4726518.088 |
| 300415.346 | 4726964.098 |
| 299581.685 | 4727097.162 |

Appendix B: Mean values, standard errors, and ranges for percent sand, silt, and clay content in soil samples from plots with occupied burrows (n=45) and unoccupied plots (n=45) at Hart Mountain National Antelope Refuge, Oregon in 2004 and 2005.

| | Variable | Mean | SE | Range of values |
|---|---|---|---|---|
| Occupied | % Sand | 50.16 | 1.05 | 35.00 - 66.30 |
| | % Silt | 30.35 | 0.87 | 20.00 - 51.25 |
| | % Clay | 19.49 | 0.83 | 5.00 - 33.40 |
| Unoccupied | % Sand | 45.52 | 1.19 | 15.00 - 61.25 |
| | % Silt | 33.52 | 1.12 | 21.25 - 63.75 |
| | % Clay | 20.97 | 0.74 | 11.25 - 31.25 |