1998

A GIS model for identifying potential black-tailed prairie dog habitat in the northern Great Plains shortgrass prairie

Jonathan Proctor
The University of Montana

A GIS MODEL FOR IDENTIFYING POTENTIAL BLACK-TAILED PRAIRIE DOG HABITAT IN THE NORTHERN GREAT PLAINS SHORTGRASS PRAIRIE

by

Jonathan Proctor

B.S. Wittenberg University, 1990

presented in partial fulfillment of the requirements

for the degree of

Master of Science

The University of Montana

1998

Approved by:

____
Chairperson

____
Dean, Graduate School

6-2-98
____
Date

Proctor, Jonathan D., M.S., May 1998 Environmental Studies

A GIS Model for Identifying Potential Black-tailed Prairie Dog Habitat in the Northern Great Plains Shortgrass Prairie (56 pp.)

Director: Len Broberg

Four habitat variables were analyzed in relation to prairie dog colony locations on the Charles M. Russell and UL Bend National Wildlife Refuges using an ARC/INFO Geographic Information System (GIS). A classification tree and a logistic regression statistical program searched for patterns between prairie dog presence and: 1) vegetation, 2) slope, 3) soil texture, and 4) soil depth. The dataset consisted of a complete census of the study site — 488,695 pixels of 30m x 30m, each coded with the above information. Both tests found vegetation and slope to correlate well with prairie dog presence. Soil texture correlated only minimally, and soil depth did not appear to be a significant factor.

A model was developed with six habitat categories based on the classification tree results, which split the data into the following categories based on the probability of prairie dog presence within each combination of variables: 1) higher biomass vegetation with gentle slopes; 2) higher biomass vegetation with steeper slopes and non-clay-loam soils; 3) higher biomass vegetation with steeper slopes and clay-loam soils; 4) low biomass vegetation with steeper slopes; and 5) low biomass vegetation with gentle slopes. This model was applied to the study site, and found that 85.1% of prairie dog pixels fell within the four potential habitat categories (categories 2 through 5). The model was then extrapolated to south Phillips County, Montana. In this case, categories 2 and 3 were combined by removing the soil variable. All known prairie dog town locations (mapped between 1979 and 1997) were overlaid on this habitat category map, and 94.5% of prairie dog pixels fell within the three potential habitat categories (categories 2,3, and 4). For both maps, most towns centered on the preferred habitat category, with presence in less suitable categories occurring primarily in relation to these towns.

Management implications for the study site and south Phillips County are discussed, with special consideration given to identifying core prairie dog habitat areas and their relation to the future of the prairie dog ecosystem and the ongoing black-footed ferret reintroduction program.

Preface

This thesis began as a semester project undertaken for Predator Project, an environmental group in Bozeman, Montana that works to conserve and restore ecosystem integrity by protecting predators and their habitats. While prairie dogs are not generally thought of as predators, they are essential for the survival of several predators, including the black-footed ferret—the most endangered mammal in North America. A healthy, viable ferret population will necessitate a dramatic increase in occupied prairie dog habitat across the Great Plains. In fact, numerous species now in peril—such as the swift fox, the western burrowing owl, the mountain plover, and the ferruginous hawk— would benefit greatly from such an increase. This thesis offers one method of improving prairie dog ecosystem management in eastern Montana, if only we create the political will to do so.

I thank my advisor and committee, Len Broberg, Colin Henderson, and Tom DeLuca; the EVST program; Predator Project; the Ecology Center, Bill Haskins, and Tim Bechtold; Environmental Systems Reserach Inc. for donating the ARC/INFO GIS programs; Steve Forrest and Craig Knowles for their knowledge of this issue; Jim Robison-Cox and Doug Helms at Montana State University for their help with the statistics; John Grensten with BLM, Phillips Resource Area; and Randy Matchett with the Charles M. Russell National Wildlife Refuge.

Table of Contents

Abstract....p. ii

Preface....p. iii

List of Tables....p. v

List of Figures....p. vi

Introduction....p. 1

Chapter 1: Study Site Description....p. 7

Chapter 2: Methods....p. 10

Chapter 3: Results....p. 19

Chapter 4: Discussion....p. 27

Chapter 5: Management Implications....p. 33

Appendices

Appendix A: Montana Prairie Dog Management Guidelines....p. 37

Appendix B: Vegetation Classifications....p. 44

Appendix C: Classification Tree Models....p. 51

Literature Cited....p. 53

CMR Study Site Map....pocket

South Phillips County Study Site Map....pocket

List of Tables

Table 2.1: Categories of the Four Habitat Variables Tested for Significance with Prairie Dog Locations.. p. 11

Table 2.2: Slopes Observed on Prairie Dog Towns in Prior Studies throughout the Northern and Central Great Plains.. p. 13

Table 2.3: Biomass Ratings for MNDVI Category Values.............................. p. 18

Table 3.1: Prairie Dog Presence (%) Versus Vegetation Categories.................... p. 19

Table 3.2: Prairie Dog Presence (%) Versus MNDVI Categories...................... p. 20

Table 3.3: Prairie Dog Presence (%) Versus Slope Categories......................... p. 20

Table 3.4: Prairie Dog Presence (%) Versus Soil Texture Categories................. p. 21

Table 3.5: Prairie Dog Presence (%) Versus Soil Depth Categories................... p. 21

Table 3.6: Prairie Dog and Area Percentages for the Five Habitat Categories in the North Study Site.. p. 22

Table 3.7: Prairie Dog and Area Percentages for South Phillips County.............. p. 26

List of Figures

Figure 0.1: Historic Prairie Dog Distribution.. p. 2

Figure 1.1: Study Site Location.. p. 8

Figure 2.1: Phillips County Prairie Dog Colony Complex and Black-footed Ferret Reintroduction Areas.. p. 16

Figure 3.1: Classification Tree for North Dataset...................................... p. 22

Figure 3.2: Revised Classification Tree.. p. 25

Introduction

Biology and Distribution

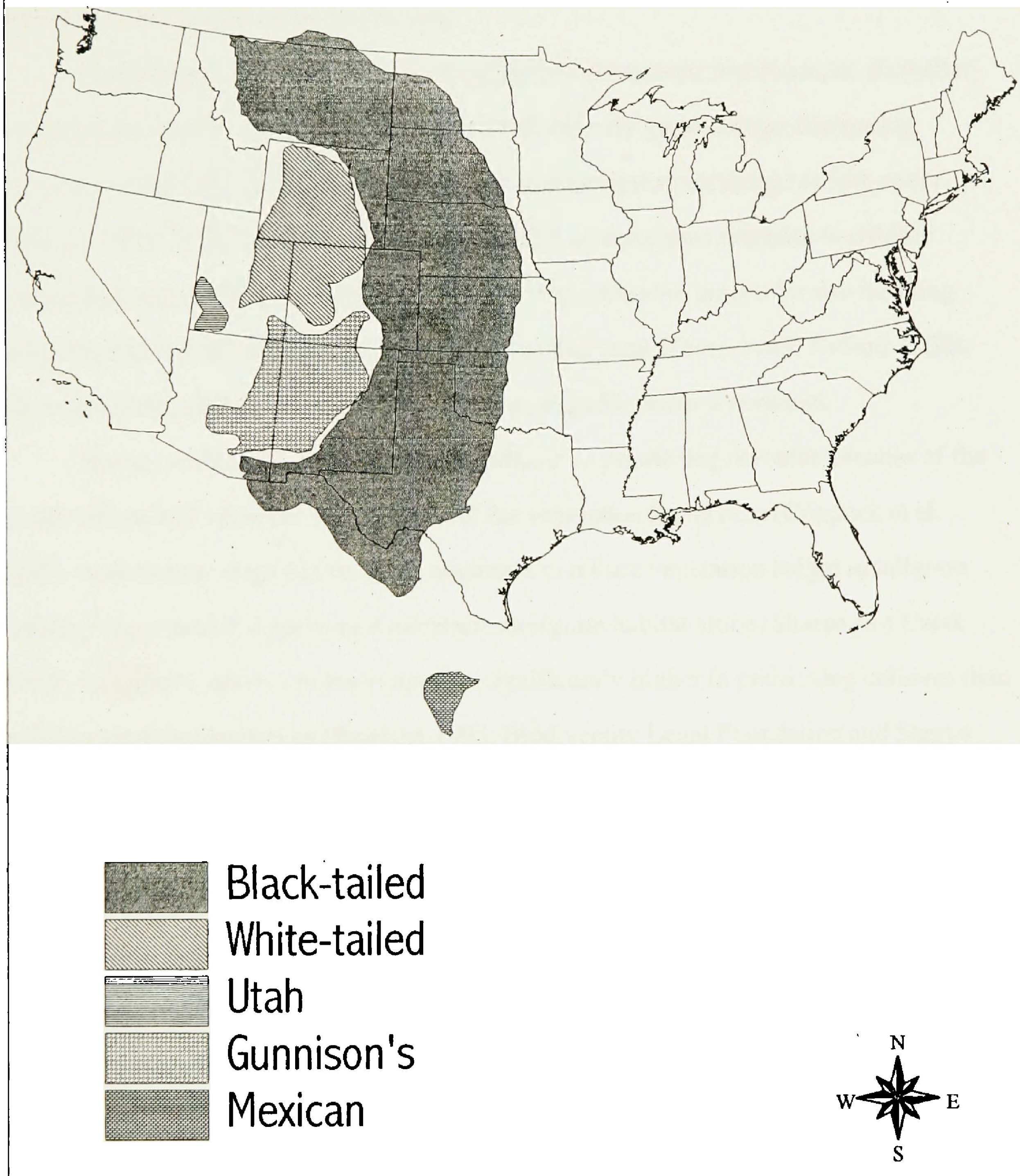
The black-tailed prairie dog (*Cynomys ludovicianus*) is a large, colonial, burrowing rodent of the squirrel family (*Sciuridae*) found on the short- and mixed-grass prairies of the Great Plains region of North America (Figure 0.1). At one time the prairie dog may have been the most abundant mammal in the region (Koford 1958), possibly numbering as many as 5 billion individuals (Seton 1929). Black-tailed prairie dogs historically occupied a significant portion of the Great Plains, estimated between a minimum of 2.8 percent and up to 20 percent of the region (Flath and Clark 1986, Summers and Linder 1978). Estimates of total area occupied range from 100 million acres to 700 million acres (Knowles and Knowles 1994, Seton 1929, Anderson et al. 1986, Cully 1989).

The black-tailed prairie dog is distinguished from the three species of white-tailed prairie dogs by its geographic range (the others do not occur on the Great Plains), its more colonial nature, and its reddish-brown fur and black-tipped tail. It occurs at elevations ranging from 915 to 1,830 meters and digs extensive burrow systems with large mounds 15-20 cm high. Black-tailed prairie dog densities average 15/ha, with a range of 5-33/ha (Fagerstone and Ramey 1996).

Interactions with the Environment

Black-tailed prairie dogs (referred to through the rest of this study as simply "prairie dogs") create and provide important or essential habitat conditions (e.g., food, shelter) for several wildlife species of the Great Plains ecosystem, and thus are central figures in the plant and wildlife ecology of this region. Prairie dogs directly influence the success of

Historic Prairie Dog Distribution



several species that are now in jeopardy, including the black-footed ferret (endangered), mountain plover (candidate species), ferruginous hawk (sensitive), swift fox (candidate species), and western burrowing owl (sensitive) (Knowles and Knowles 1994; Biodiversity Legal Foundation and Sharps 1994). The decline of these species has been attributed to the decline of the prairie dog.

Prairie dogs also change their surrounding environment. For example, they alter vegetative processes by maintaining vegetation in an early growth stage, decreasing vegetative height, increasing bare ground, and increasing the percentage of forb cover (Koford 1958). This provides a diversity of habitat on the plains essential to wildlife species that depend on these conditions. Prairie dogs also alter long-term soil-building processes through bioturbation, or mixing of soil horizons (Thorp 1949; Koford 1958), which is a fundamental process in the formation of mollic surface horizons.

Bison, pronghorn, and cattle prefer grazing on prairie dog colonies because of the greater nutritional value per unit biomass of the vegetation found here (Coppock et al. 1983), while prairie dogs rely on these ungulates to reduce vegetation height in tallgrass regions, where prairie dogs cannot maintain shortgrass habitat alone (Sharps and Uresk 1990). In general, species richness appears significantly higher in prairie dog colonies than in the surrounding landscape (Reading 1993; Biodiversity Legal Foundation and Sharps 1994).

Human Manipulation

Due to their vast number and extent, prairie dogs must have greatly affected the structure and function of the Great Plains region. Despite such importance, humans have historically placed a negative value on prairie dogs, and since the early 1900s have been largely responsible for reducing the area occupied by prairie dogs by an estimated 90 to 98 percent or more throughout North America (Flath and Clark 1986, Miller et al. 1994). In Eastern Montana, for example, the prairie dog currently occupies an estimated 0.17 percent of the landscape (Knowles 1995). These reductions are due to habitat destruction, poisoning, sport shooting, and the recent spread of sylvatic plague (Biodiversity Legal Foundation and Sharps 1994, Wuerthner 1997).

Public land agencies—including the U.S. Bureau of Land Management, U.S. Forest Service, and state land and wildlife management agencies—continue to manage prairie dog populations at numbers which are a fraction of historic levels (USFS 1986; USBLM 1992). Although prairie dogs still number a few million in isolated pockets scattered across much of their historic range, this severe reduction has essentially removed the disturbance function of the prairie dog on the grasslands, and numerous species that require such disturbances have subsequently plummeted in numbers.

If we wish to ensure the long-term viability of the entire prairie dog ecosystem, we must identify and protect the remaining habitat and locate unoccupied potential habitat in which restoration efforts may occur. Protection of the remaining 1-2% of fragmented prairie dog towns alone may not be enough to maintain the entire prairie dog ecosystem, including its disturbance function. For example, too few prairie dog complexes have been identified to date to ensure the successful reintroduction of the black-footed ferret (Reading et al., 1997).

Purpose and Objectives

The purpose of this study is to provide a methodology for creating habitat maps outlining suitable black-tailed prairie dog habitat on lands in the northern Great Plains shortgrass prairie at a scale that wlll help identify regional potentials for prairie dog ecosystem recovery, including the needs of associated species. The specific objectives of this study are to: a) identify the habitat variables associated with prairie dog towns on the Charles M. Russell and UL Bend National Wildlife Refuges (CMR); b) create a GIS model based on these associations; and c) apply the model to neighboring regions.

By combining existing vegetative, slope, and soil data with a Geographic Information System (GIS), prairie dog habitat maps outlining varying degrees of suitability can be created for large areas. Such maps are more coarse in scale than detailed maps that depend on extensive site-specific measurements (i.e., vegetation height), but maps at this scale may prove invaluable for identifying wildlife corridors, core reserves, and isolated colonies. This information may be used to outline critical wildlife habitat and/or develop plague management plans. Also, public land agency wildlife budgets may prohibit analysis at greater levels of detail.

A procedure for determining suitabe prairie dog habitat is also needed to implement the Montana Prairie Dog Management Guidelines (Appendix A). These guidelines call for site-specific management plans that describe the occupied and potential ranges of prairie dogs in the planning area. A detailed map is also suggested. Mapping methodologies to rapidly assess habitat suitability are, therefore, key to successful implementation of these guidelines.

In order to delineate suitable prairie dog habitat as a subset of the total landscape, first it must be shown that prairie dogs selectively "choose" from the resources available to them. Several studies imply such resource selection. For example, Clippinger (1989) developed a habitat suitability index model for prairie dogs and Tepley et al. (1990) used this information to produce a GIS model of potential and preferred prairie dog habitat, but the variables on which these studies are based remain untested. Reading (1993) studied a set of variables with a GIS and found prairie dog occupancy on smaller slopes, one soil association (Elloam soils), and BLM ownership to be significantly greater than expected. He suggests analyzing vegetation, shooting impacts, proximity to other colonies, and associations with heavy livestock use and adding this to his data to create a predictive model of prairie dog colony expansion.

This study utilizes Reading's (1993) slope factor, drops the ownership factor (as not pertinent to the goals of this thesis), and alters the soil factor to allow its use across areas with various soil associations by focusing on the aspects of soil thought to be important to prairie dog presence instead of simply identifying this factor by the taxonomic name (i.e., "soil depth greater than 60 inches, clay-loam texture" is more explanatory than "Elloam soil"). It also includes Reading's suggestion of a vegetation factor analysis, but does not add the other suggestions for the following reasons: 1) vegetation information was created from satellite imagery for all of eastern Montana. The vegetation classifications inherently include all factors that impact vegetation enough to alter its biomass or species composition, including the impacts from livestock grazing or prairie dog occupancy. This is especially true given that the data is so recent and vegetation has remained relatively constant in this area over the past several decades; 2) shooting does not occur within the Refuge; and 3) adding proximity to other colonies as a factor would have significantly complicated the process, and the importance of this factor can be inferred from the final maps.

Chapter 1: Study Site Description

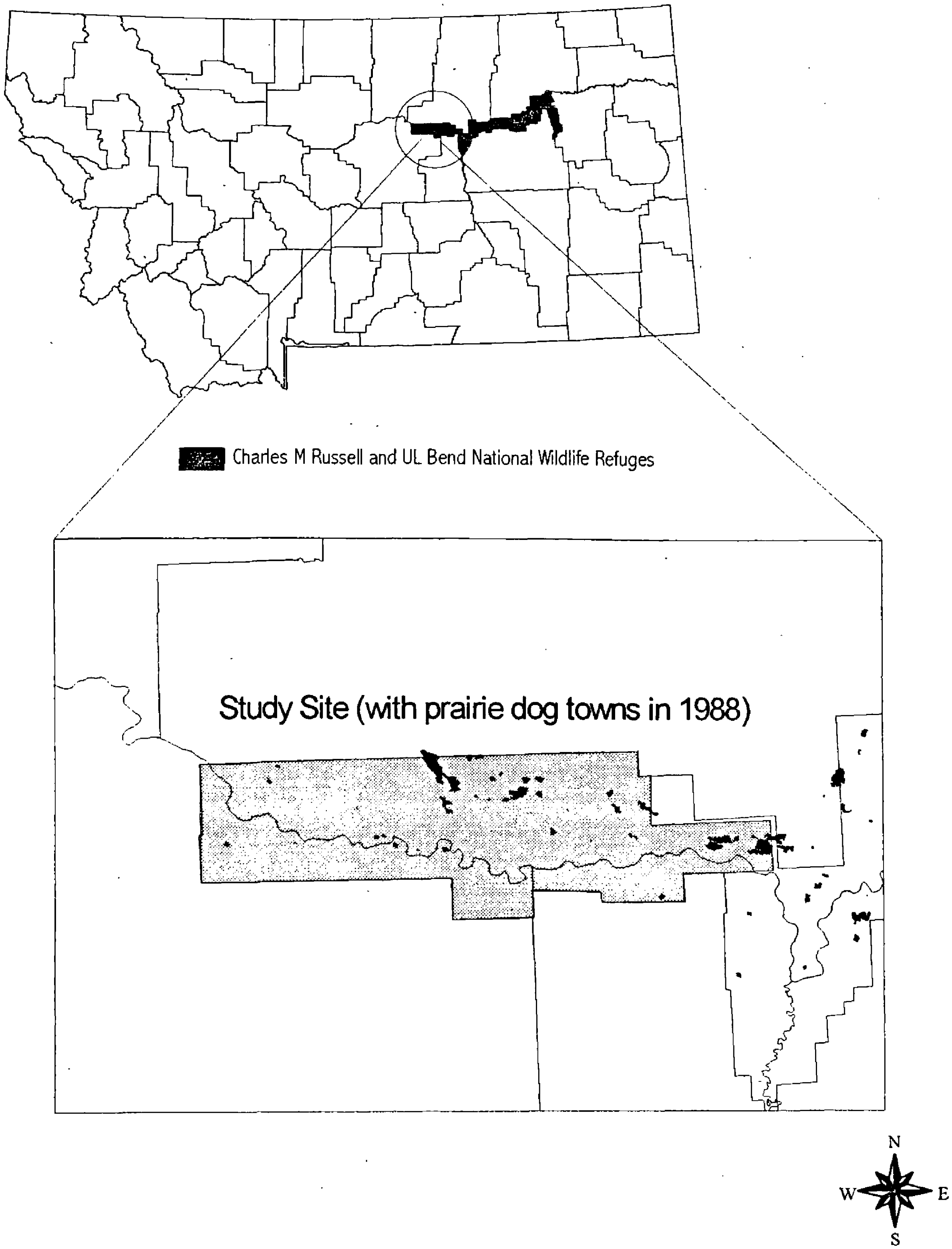
Geographic Description

The Charles M. Russell and UL Bend National Wildlife Refuges (hereafter referred to as CMR) encompass 1,094,301 acres of land and water, 760,000 acres of which are federal lands. Within the refuge's boundary are also Fort Peck Reservoir, state lands, and private lands. The study site consists of approximately 236,233 acres of land (369 square miles) within the CMR. This area lies in the western-most portion of the CMR including those areas of the refuge that fall within the following 7 1/2 minute topographic quadrangles: Grand Island, Bell Ridge West, Bell Ridge East, Sagebrush Reservoir, Blizzard Reservoir, Lake Reservoir, Karsten Coulee, Pea Ridge, Mitchell Crossing, Hessler Ridge, Carter Coulee, Kepple Bottom, Hanson Flat, Dry Coulee, Chain Buttes, and Locke Ranch (Figure 1.1). Excluded from study within these areas are those lands known to be unsuitable habitat (i.e., forested lands, water, steep slopes). This leaves 148,766 acres (233 square miles) which were included in the study.

Three main landforms dominate the study site: uplands, breaks, and floodplains. Elevation ranges from 2,000 feet above sea level to 3,200 feet. The Missouri River bisects the refuge and study site, carving 500- to 1000-foot-deep valleys. Floodplains have been submerged by Fort Peck Lake through all but the western edge of the refuge (this area is included in the study site). Uplands consist of rolling prairies dissected by intermittent streams. Breaks lie adjacent to the Missouri River in a band 2-10 miles wide, and make up approximately 40-50 percent of the land within the CMR (USFWS 1985).

The CMR receives 12-13 inches of precipitation per year, about 70 percent occurring from April-September. Runoff often exceeds 50 percent due to the heavy-textured soils. Temperatures range from an average low in January of 0 degrees Fahrenheit

Study Site Location



to average highs in the 80s in summer. Lightning storms in late summer often result in wildfires. Soil moisture is rapidly lost in summer due to high temperatures, low humidity, and regular winds (USFWS 1985).

The CMR contains 179 soil mapping units, about 50 of which fall within the study site (Knowles 1982). Most soils are fine textured. Some of the dominant soils in this area include Ashber, Bascovy, Harlem, Marvan, and Neldore clays; Gerdrum and Elloam clay loams; and Phillips loam. All soils are classified as well drained.

Study Site Selection

Besides numerous general descriptions from early travelers of the plains, virtually no historic prairie dog data exists from which a “natural” prairie dog ecosystem can be described. The Charles M. Russell and UL Bend National Wildlife Refuges (CMR) best approximate "natural" prairie dog habitat in eastern Montana because: 1) prairie dogs have been relatively free from human control efforts since 1964, longer than any other area of eastern Montana (Knowles 1982). As a result, they have been able to expand to occupy what is thought to be a large percentage of their suitable habitat; 2) this area is part of a relatively large and biologically important prairie dog complex (Reading et al., 1997); and 3) accurate prairie dog distribution data is available.

Chapter 2: Methods

Hypotheses

The following research hypotheses were examined: black-tailed prairie dogs select: 1) short- to medium grassland cover types more than expected; 2) slopes of 0-8% more than expected; 3) soils ranging in texture from clay to loam more than expected; and 4) soils with depths greater than 60 inches more than expected.

The results of studies designed to address these hypotheses were used to create a model of prairie dog habitat categories based on selected variables and cutoff levels, and apply these habitat categories to the CMR study site. The model was then extrapolated to adjacent south Phillips County, Montana to create a second map of prairie dog habitat categories across a much greater area.

Variables

Vegetation, slope, and soil were considered to be the factors affecting prairie dog resource selection. The research hypotheses consisted of the subsets of each factor which prairie dogs are presumed to prefer. These factors and cutoff levels were selected after a thorough review of related studies, expert interviews, and spot checks of several black-tailed prairie dog colony locations (see "sources of variation" section below for a thorough defense of these assumptions). Factors were also chosen for their ease of collection (e.g., vegetation height does not need to be measured in the field) and for their applicability throughout the region.

Each factor was divided into several subsets as follows, with the research hypothesis subsets in bold print (see Appendix B for a further explanation of vegetation categories):

Table 2.1: Categories of the Four Habitat Variables Tested for Significance with Prairie Dog Locations. Research hypothesis subsets are in bold print.

1st Variable: Vegetation. 23 categories fall within the study site:

3111 - Non-native Grass	3362 - Juniper and Sagebrush/Grass
3115 - CRP Lands	3510 - Mesic Shrub-grassland associations
3130 - Very Low Cover Grasslands	3520 - Xeric Shrub-grassland associations
3140 - Low Cover Grasslands	3530 - Tree-grassland Associations
3150 - Low/Moderate Cover Grasslands	**7100** - Dry Salt-flats
3160 - Moderate/High Cover Grasslands	7300 - Rock-dominated sites
3210 - High Cover Grasslands	7600 - Badlands
3309 - Silver Sage	7602 - Grass Badlands
3310 - Salt-Desert Shrub	7603 - Mixed Shrub/Grass Badlands
3311 - Greasewood	7604 - Missouri Breaks
3350 - Big Sagebrush Steppe	**7800** - Mixed Barren Sites
3361 - Greasewood and Big Sagebrush	

2nd Variable: Slope. 5 categories:

1 = 0-2% **2 = 2-4%** **3 = 4-8%** 4 = 8-15% 5 = 15-25%

3rd Variable: Soil Texture. 5 categories:

0 = Rock **1 = Clay** **2 = Clay-loam** **3 = Silt** **4 = Loam**
5 = Sand

4th Variable: Soil Depth. 5 categories:

0 = 0-10" 1 = 10-20" 2 = 20-40" 3 = 40-60" **4 = 60" and up**

All areas classified as urban, agricultural, forestlands, water, riparian, or alpine in the vegetation category were eliminated from consideration, as were all areas with slopes greater than 25%. This was done because in general, prairie dogs do not inhabit these areas (Hall 1981), although they may on occasion inhabit undeveloped areas within urban areas or agricultural areas that have been abandoned. Also, by removing these unlikely categories from consideration, the remaining possibilities would be more accurately defined as being suitable or not.

Soil was characterized by three attributes: depth, texture, and drainage class. These soil attributes were chosen because they are believed to be the factors important to burrow construction (Osborn 1942, Koford 1958), and because they can be applied to other regions regardless of the specific soil types because soil surveys contain these factors for individual soils. Drainage class was dropped from the final analysis due to the fact that all soils within the study site were classified as well drained.

Sources of Variation

Vegetation: Black-tailed prairie dogs inhabit short- and mixed-grass prairies in the semi-arid plains (Clippinger 1984; Reid 1954), and are able to spread into tallgrass prairie following heavy grazing by ungulates (Osborn 1942; Schaffner 1926). Vegetation height in prairie dog colonies ranges from 7 to 13 cm (Agnew et al. 1986) and up to 64 cm (Clark et al. 1982). This vegetation height is necessary for visibility which allows protection from predators (Hoogland 1981). In short- and mixed-grass prairie, prairie dogs alone are able to maintain this vegetation height. However, in tallgrass prairie, prairie dogs rely on ungulates to reduce vegetation height; if ungulates are absent, prairie dog colonies will be reduced in size and eventually eradicated (Osborn and Allen 1949). A rare prairie dog town has been found in a Cottonwood stand or shinnery savanna, but this is only on the edge of large towns when severe overgrazing has occurred (Reid 1954; Osborn 1942). Sagebrush is not a complete barrier to prairie dog dispersal, as they can progressively invade and cut these plants (Reid 1954), although they are still dependent on livestock to graze any tallgrasses in the area (Osborn 1942). They seem to prefer disturbed areas (Koford 1958; Knowles 1982). Old fields are especially attractive to prairie dog habitation (Reid 1954), and prairie dogs thrive in overgrazed areas (Koford 1958).

Grassland vegetation is also essential for food requirements. Stomach exams of prairie dogs in Montana have found 98.6% vegetative content (Kelso 1939). Stomach and fecal exams of prairie dogs in South Dakota found five major grasses: western wheatgrass, blue grama, buffalo grass, sixweeks fescue, and tumblegrass (Wydeven and Dahlgren 1982). These species and others (including hairy grama, hairy triodia grass, and sand dropseed) have been identified in several studies as species consumed by prairie dogs

(Knowles 1982; Clippinger 1984). All of these species are found in short- and mid-grass prairie (MT GIS lab 1995).

Slope: Black-tailed prairie dogs prefer flat areas or gentle slopes, possibly due to the greater ability to detect predators. Several studies have measured slopes on prairie dog towns. The findings are listed in the following table:

Table 2.2: Slopes Commonly Observed on Prairie Dog Towns in Prior Studies throughout the Northern and Central Great Plains.

Study	Location	Slopes on prairie dog towns
Reid (1954)	SW North Dakota	<25-30%
Sheets (1970)	South Dakota	<35-45 degrees
Koford (1958)	South Dakota	<22%
Clippinger (1984)	Rocky Mtn. Arsenal, CO	<20%
Tileston/Lechleitner (1966)	Colorado	<10%
Knowles (1982)	CMR Wildlife Refuge, MT	0-12%
Dalsted (1981)	Wind Cave Nat'l Park, SD	<9%

One additional study found that prairie dog colonies are located on flatter terrain than are randomly located polygons (Reading 1993).

Soil: Cover may be the most important requirement for prairie dogs; soil provides this requirement. Black-tailed prairie dogs require well-drained soils that are capable of retaining water for burrow stability. They occur in most all soil textures ranging from clays to sandy loams (Proctor 1995; Reid 1954; Sheets 1970; Knowles 1982); however, very sandy soils are avoided (Osborn 1942; Reid 1954; Knowles 1982). They are also attracted to disturbed soils, such as livestock watering sites and old homesteads, possibly due to the lower vegetation height and/or greater ease of burrow construction (Knowles 1982).

Burrow construction requires soil of sufficient depth. Sheets (1970) excavated 18 burrows and found their depths to range from 3 to 14 feet (7' mean, 8.5' median). Only 3 burrows were less than 60 inches. Also, soils with depths less than 5 feet are classified as poorly drained. However, prairie dogs have been observed to burrow through soft bedrock such as shale (Knowles 1982).

Data Collection

Soil information was derived from the Natural Resource Conservation Service (NRCS). The soil survey for Phillips County has yet to be published. A GIS soil map of Phillips County (north study site) was created from scanned images provided by NRCS which were cleaned up by removing dangling nodes and connecting missing segments using a PC Arc/Info version 3.5 program (ESRI 1996). A GIS soil map of Fergus and Petroleum Counties (south study site) was created by photographing the published NRCS paper surveys, scanning the negatives with a Polaroid slide scanner, and then digitizing the scanned images with an Arcview 3.0 program for Microsoft Windows (ESRI 1996).

Each soil polygon was then coded by three categories: depth, texture, and drainage class, and each of these categories was divided into the classes listed in Table 2.1. The polygons were then converted to 30 x 30 meter pixels to match the vegetative data, and a separate layer was created for both soil depth and for soil texture.

Vegetative data for eastern Montana was provided by the Montana Wildlife Spatial Analysis Lab. The Lab classified the vegetation in the scene which covers the study area from satellite imagery taken in 1991. A vegetation code key was created for this purpose. Each pixel was classified within this key based on its reflective properties (Appendix B).

All pixels labeled with vegetation categories which are not capable of being inhabited by prairie dogs were dropped from this analysis (i.e., forested areas, water). Of the categories that were left, 23 fall within the study site (6 grassland categories, 7 shrubland categories, 3 shrub-grassland complex categories, and 7 barren land categories).

Slope data was derived from 30 x 30 meter USGS Digital Elevation Models (DEMs). This information was condensed into the categories listed in Table 2.1. These categories were chosen because they match NRCS soil information and because differences at smaller slopes may be more crucial for predicting suitable habitat than differences at larger slopes. All areas with slopes over 25% were dropped from analysis because in general these slopes fall outside of the range of prairie dogs.

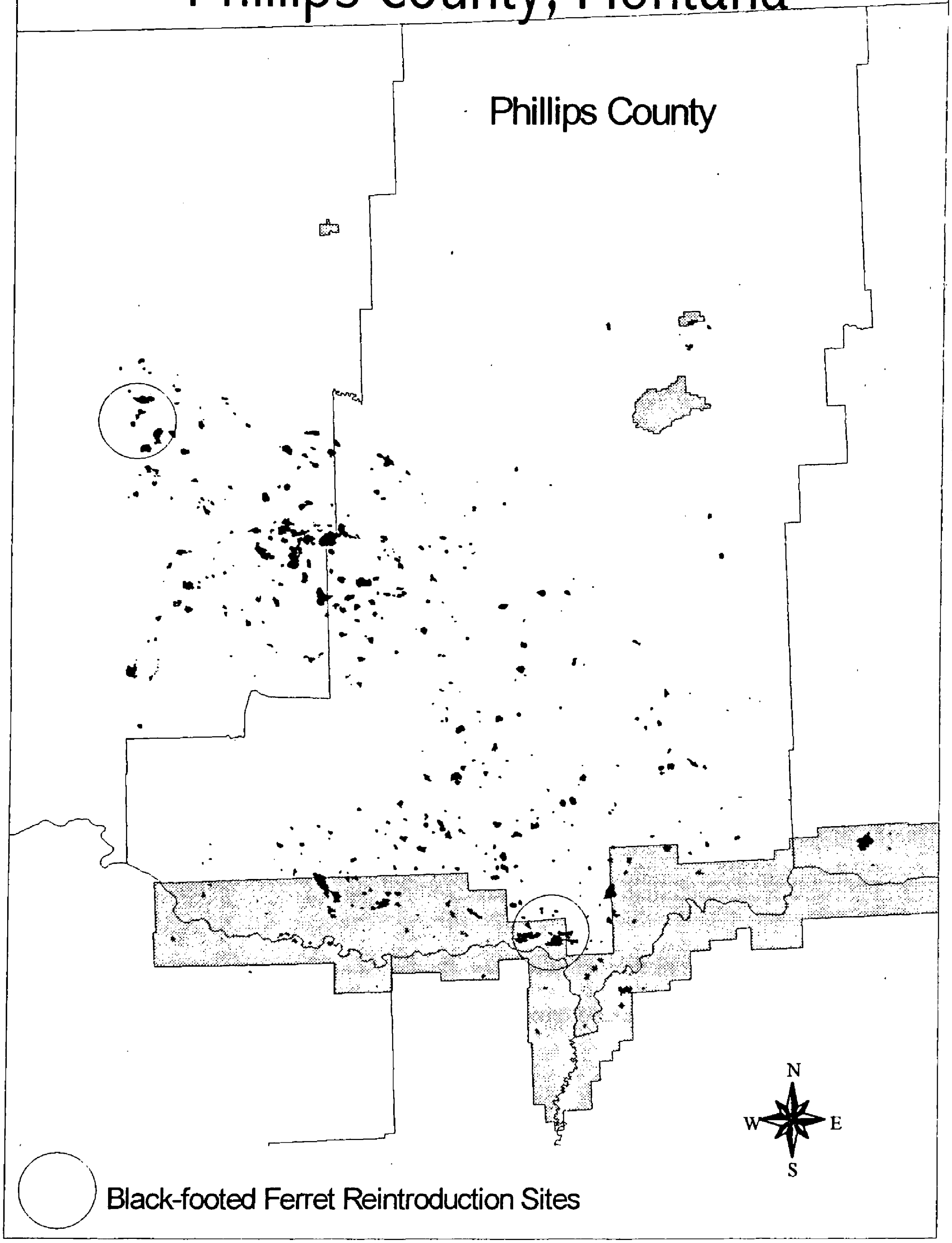
Prairie dog locations on the CMR—as well as on neighboring BLM lands and the Fort Belknap Indian Reservation—have been accurately located and mapped recently using a Global Positioning System (GPS). Surveys done before GPS was available were originally mapped by hand on 7.5 minute topographic maps, but have since been digitized from the mapped locations. The CMR prairie dog town locations were mapped in 1979, 1984, 1988, and 1995 by CMR employees. These maps were combined to create a map of maximum-known occupied prairie dog area. This combined data map was then used for the CMR study site map (Figure 1.1). The south Phillips County map combined these prairie dog town locations with town locations mapped in 1994 on the Fort Belknap Indian Reservation, and town locations mapped in 1988, 1993, 1995, 1996, and 1997 in south Phillips County (Figure 2.1).

The CMR study site was divided by the Missouri River into two sections for analysis. The prairie dog populations south of the river may not have recovered fully from the days of poisoning (Knowles, pers. comm. 1998), and thus the results of this area may not be as revealing as those north of the river. The south data was used only to check inferences made from the north dataset. The north study area included 488,695 pixels of data, and the south study area contained 180,520 pixels of data.

An Arc/Info Geographic Information System version 7.1.1 for Windows (ESRI 1997) was used to create a separate map layer for each factor. The scale for all maps is 1:24,000, and the minimum mapping unit (MMU) for all maps is 30 x 30 meters. Maps are in NRIS format (Albers projection, in meters).

Layers representing soil depth, soil texture, slope class, vegetation class, and prairie dog presence/absence were then overlaid, excluding all pixels known to be unsuitable for prairie dog occupancy (i.e., water, bedrock, forests, steep slopes). A

Prairie Dog Colony Complex
Phillips County, Montana



dataset for each remaining 30 x 30 meter pixel was then created. The number of pixels included in this analysis totaled 669,215, which equals an area of 602 square kilometers (233 square miles), or 60,229 hectares (148,766 acres). All pixels with the same combination of these five variables were then grouped and tallied. The north dataset contained 517 unique combinations, and the south dataset contained 316.

Data Analysis

Two steps of data analysis occurred. First, a classification tree (S-Plus version 3.4, StatSci, 1996) was computed for the north and south datasets using all available variables (vegetation, slope, soil texture, soil depth, and prairie dog presence/absence) to find which variables seem to be most strongly associated with prairie dog presence. Because classification trees are known to over-fit the data, a subset of the data was used to cross-validate the results in order to estimate how large a model was needed.

Second, a logistic regression model (S-Plus version 3.4, StatSci, 1996) further analyzed the datasets to explain the variation between available and occupied habitat. A new vegetation-related classification with 5 categories (as opposed to 23) was created based on biomass to facilitate analysis. This reclassification was done in the following manner: the vegetation information for each pixel contained not only a vegetation category but also a value based on the Modified Normalized Differenced Vegetation Index (MNDVI). This commonly-used value—a ratio between the red band and near infrared band—correlates well with biomass (Nemani et al. 1993). Therefore, 5 MNDVI categories were delineated based on the breaks in the MNDVI values that were used to classify grassland vegetation categories in the original development of the vegetation code key as outlined in Appendix B (Table 2.3).

Table 2.3: Biomass Ratings for MNDVI Category Values. MNDVI — or Modified Normalized Differenced Vegetation Index — is a ratio between the red band and near infrared band; each vegetation pixel is assigned an MNDVI value.

Category	MNDVI numeric value	Biomass
1	-4 to 14	very low
2	15-25	low
3	26-53	low/moderate
4	54-100	moderate/high
5	101 and up	high

Each pixel was reclassified based on its MNDVI value, and a new dataset was created by replacing the vegetation code column with the biomass column. In this analysis, 188 unique combinations occurred in the north dataset and 147 occurred in the south dataset. In addition to using this data for logistic regression analysis, a second classification tree was also computed based on this new dataset.

Chapter 3: Results

Summary Tables

Summary tables of prairie dog presence as a function of the categories show that prairie dogs in the study site are associated with certain vegetation types, MNDVI values, slopes, soil depths, and soil textures. Both vegetation and MNDVI tables are listed because each was used in the statistical tests: one classification tree used the vegetation data, and logistic regression and a second classification tree used the MNDVI data.

Table 3.1: Prairie Dog Presence (%) Versus Vegetation Categories in the CMR Study Site. The first row is the percentage of each category occupied by prairie dog pixels; the second row is the percentage of total prairie dog pixels that falls within each category; the third row is the percentage of the total study site that falls within the category.

Vegetation Code

	3111	3115	3130	3140	3150	3160	3210	3309
% area with PD	0	4	51.7	6.6	3.8	2	6.3	1.3
% total PD	0	0.4	29.6	8.7	6.0	2.4	3.4	0.1
% total area	0.2	0.5	2.6	6.0	7.2	5.4	2.5	0.5

	3310	3311	3350	3361	3362	3510	3520	3530
% area with PD	60.4	3.4	8.4	4.1	7.7	0	1.2	0.5
% total PD	4.8	10.8	11.3	1.3	14.7	0	0.8	0.1
% total area	0.4	14.6	6.2	1.5	8.8	0.0	2.9	1.3

	7100	7300	7600	7602	7603	7604	7800	overall
% area with PD	93.8	0	0	0	0.6	0	75.8	4.6
% total PD	1.0	0	0	0	1.8	0	2.8	100
% total area	0.1	0.0	0.5	0.0	13.6	25.3	0.2	100

Table 3.2: Prairie Dog Presence (%) Versus MNDVI Categories. Row categories are as in Table 3.1.

	MNDVI					
	1	2	3	4	5	Overall
% area with PD	27.3	7.3	1.5	0.1	0.0	4.6
% total PD	43.8	37.6	16.5	0.4	0.0	98.3
% total area	7.3	23.6	50.3	17.1	1.7	100

Table 3.3: Prairie Dog Presence (%) Versus Slope Categories. Row categories are as in Table 3.1.

	Slope Class					
	1	2	3	4	5	Overall
% area with PD	44.1	20.6	2.0	0.05	0.0	4.6
% total PD	12.4	71.1	16.0	0.5	0.0	100
% total area	1.3	15.8	36.7	45.2	1.1	100

Table 3.4: Prairie Dog Presence (%) Versus Soil Texture Categories. Row categories are as in Table 3.1.

	Soil Texture Class						
	0	1	2	3	4	5	Overall
% area with PD	0.1	2.5	24.0	0.0	4.6	0.0	4.6
% total PD	0.1	46.7	51.4	0.0	1.2	0.0	99.4
% total area	3.40	85.57	9.81	0.0	1.22	0.0	100

Table 3.5: Prairie Dog Presence (%) Versus Soil Depth Categories. Row categories are as in Table 3.1.

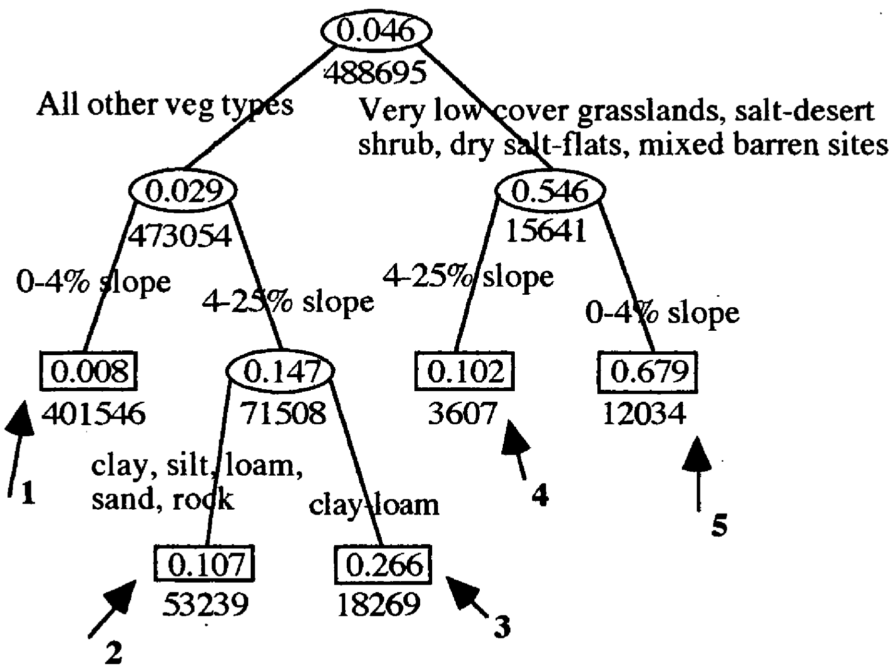
	Soil Depth Class					
	0	1	2	3	4	Overall
% area with PD	0.1	0.4	8.3	0.0	12.1	4.6
% total PD	0.1	5.2	6.7	0.0	88.2	100.2
% total area	3.4	59.5	3.7	0.0	33.4	100

Classification Tree

Classification tree analysis revealed a strong pattern between vegetation category and slope with prairie dog presence/absence. A weaker association with soil texture was also noted. No association was noted with soil depth. Plots of predictive deviance against model size suggest that trees with no more than six leaves are needed or should be used for these datasets, so further splits were avoided. If an association does exist with soil depth, it occurs beyond this cutoff level.

Figure 3.1: Classification Tree for North Dataset. Numbers within ovals and rectangles are the proportions of pixels at each branch with prairie dog presence. Numbers below ovals and rectangles are the number of pixels with that branch's unique combination of variables (i.e., the right branch of the first split has prairie dogs on 54.6% of its 15,641 pixels).

North Dataset



(Bold numbers refer to habitat categories)

Table 3.6: Prairie Dog and Area Percentages for the Five Habitat Categories in the North Study Site.

Habitat Category	% of area with PD	% of total PD	% of total area
1	0.8	14.8	82.2
2	10.7	25.4	10.9
3	26.6	**21.7**	**3.7**
4	10.2	1.7	0.7
5	67.9	**36.5**	**2.5**
Overall	4.6	100.1	100

For the north dataset, the classification tree found that prairie dogs tend to select: (1) four specific vegetative categories more than expected. The classification tree separated vegetation codes 3130 (very low cover grasslands), 3310 (Salt-Desert shrub), 7100 (dry salt-flats), and 7800 (mixed barren sites) — referred to throughout the rest of the text as the preferred vegetation — from the other 19 categories. This suggests that prairie dogs are associated with these four vegetation types; (2) slopes of 0-4% more than expected. The classification tree separated slopes of 0-4% from slopes of 4-25%, suggesting that slopes greater than 4% are not a significant factor associated with prairie dog presence; and (3) clay-loam soils more than expected. Only clay-loam soils were separated as a significant factor of prairie dog presence, and only then in cases of less-desired vegetation types and small slopes.

The south dataset contains less information due to the lower percentage of prairie dog towns (0.7% versus 4.5% in the north), however, this classification tree also found vegetation type and slope to be the significant factors, although in reverse order. The first split for the south separated slopes 0-4% from the steeper slopes, and the second split separated very low cover grasslands (3130) from the other vegetation types (no types 7100 or 7800 were observed, and all 452 sites with vegetation code 3310 had an absence of prairie dogs).

Table 3.4 shows a preference for soil depths greater than 60" (category 4), but this preference was not strong enough for the classification tree to separate within the chosen level of confidence.

Logistic Regression

Logistic regression results using MNDVI were similar to the classification tree model in that slope was the single most important variable with MNDVI being second and soil texture (in the north dataset only) coming in third. For the north dataset, slope accounted for 32% of the overall variation, and MNDVI accounted for 19% of the variation (for the south dataset, the amounts are 20.5% and 6% respectively).

A second classification tree based on MNDVI was created for comparison with the logistic regression results. This test similarly found slope to be most important, MNDVI to be second, and soil texture (in north dataset only) to be third.

CMR Study Site Habitat Map

The north dataset classification tree habitat category model (Figure 3.1) was applied to the CMR study site to create a habitat map outlining six habitat suitability categories, the sixth habitat category being areas excluded from the study (Map 1). Category 5 contains prairie dogs on 67.9% of pixels and represents the preferred habitat (Table 3.7). With a 26.6% occupancy rate, category 3 represents potential prairie dog habitat. Categories 2 and 4 have almost identical occupancy rates at 10.7% and 10.2% respectively, also representing potential habitat. With only 0.8% occupancy, category 1 represents unsuitable habitat. Areas excluded from the study contained no prairie dogs and are therefore also unsuitable.

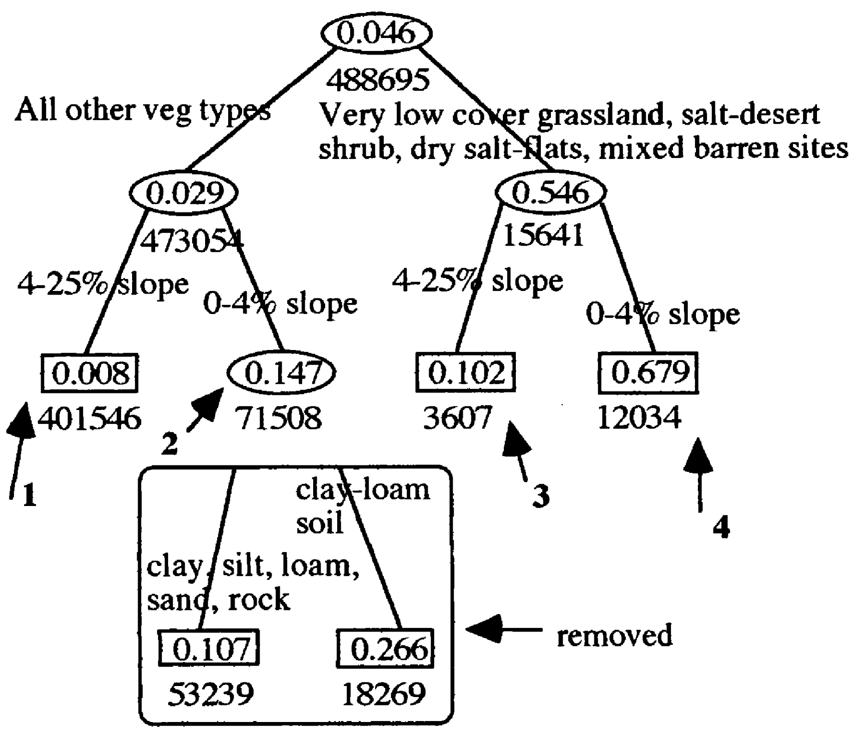
Within the study site, 19,370 acres fall within categories 2-5. This equals about 17.83% of the total area (this figure does not include the unsuitable areas excluded from the study). In comparison, only 2,672 acres, or 2.46% of the study site, fall within the preferred habitat category 5. If these categories are considered potential prairie dog habitat, then the north dataset had prairie dogs on 21.8% of potential habitat prior to the recent plague-related decline.

South Phillips County Habitat Map

The model was also applied to south Phillips County (Map 2). Only one vegetation category (7601—shrub badlands) occurred in south Phillips County that did not occur in the study site and represents a minute percentage of the total area (well less than one percent). These areas are labeled "unclassified" .

This new map necessitated removing the split separating categories 2 and 3 because the soil texture variable that separates these categories is not available for Phillips County (Figure 3.2). The colors between the study site map and the south Phillips County map correlate, although pink now represents both the pink and yellow categories from the CMR study site map.

Figure 3.2: Revised Classification Tree (for use in the south Phillips County study site and other areas without digitized soil data).



(Bold numbers refer to habitat categories)

Total potential habitat within south Phillips County equals 1,137,853 acres. Of this total, 143,748 acres fall within the preferred category 4. The maximum extent of prairie dogs between 1979 and 1997 totaled only 34,255 acres, or 3% of potential habitat.

The categories in which prairie dogs were located were similar to the findings in the CMR study site. The largest single percentage of all prairie dogs occurred in category 2 (a combination of two categories in the CMR study site). Second was preferred category 4 (Table 3.7).

Table 3.7: Prairie Dog and Area Percentages for South Phillips County

Category	% of area with PD	% of total PD	% of total area
1	0.4	3.3	17.8
2	2.0	57.7	56.8
3	3.3	0.3	0.2
4	8.7	**36.5**	**8.2**
Unclassified	0.0	0.0	0.0
Unsuitable	0.3	2.1	17.0
Overall		99.9	100

Chapter 4: Discussion

Variables

Prior studies found a high correlation between prairie dog presence and certain soil associations (Knowles 1982, Reading and Matchett 1997). However, when the individual soil factors were studied in conjunction with slope and vegetation factors, soil depth was not found to be a factor while soil texture was only a minor factor. It is likely that the results from prior studies are due to correlations that these soil associations have with gentle slopes and certain vegetation types.

Aspect and slope position may also factor in prairie dog presence/absence, as they affect soil texture, moisture retention, and vegetation. Prairie dogs may also prefer south-facing slopes for increased direct sunshine in the winter months. Reading (1993), however, tested the aspect hypothesis and found that random locations did not differ significantly from prairie dog colony locations. Although prairie dogs may in fact prefer certain aspect and slope positions, it is likely that these preferences are a result of other variables already considered in this study — soil texture and depth, and vegetation type and height.

For the vegetation factor, statistical tests analyzed both the MNDVI value (biomass) and vegetation code. Vegetation code is of greater use in defining areas suitable for prairie dogs than MNDVI because prairie dogs are known to be associated with areas of low biomass (MNDVI correlates with biomass), but whether this is a factor which they select in colonizing an area or whether this is a result of their presence is not clear. It could be in fact that prairie dogs prefer areas with greater biomass, but their presence over time results in the low biomass values associated with these towns. A correlation with specific vegetation categories, however, would aid in identifying suitable habitat regardless of its exact biomass at any specific point in time.

Choosing the Model

Because results between the classification tree tests and the logistic regression test were similar and validated each other, and because of the greater simplicity of the classification tree — which is easier to interpret and use than logistic regression coefficients — the classification tree model was used to define prairie dog habitat. The classification tree model is also preferable to the logistic regression model because the former can be used for either vegetation code or MNDVI value, while the latter can only interpret MNDVI value. And, as explained above, the classification tree model with vegetation codes is preferable for use over the model using MNDVI codes because of the confusion whether biomass is a cause or effect of prairie dog presence.

Interpreting the Maps

These maps may be used to predict where future expansion of prairie dog colonies is most likely to occur, either independently or through reintroduction efforts. They may also aid in comprehending the current situation by outlining how much suitable habitat a certain area contains, and the percentage of this suitable habitat that is currently occupied. They also outline areas where management efforts should be concentrated for the greatest benefit.

CMR map: The vast majority of prairie dog towns are centered on or at least occur partially within category 5 (preferred vegetation and 0-4% slopes), which strongly suggests the importance of this category as preferred prairie dog habitat (this category also contains the largest single percentage of prairie dogs). When pixels with prairie dog presence fall within categories 2, 3, or 4, they often occur at the edges of towns that center on category

5. These categories (2, 3, and 4) therefore appear to be suitable habitat to varying degrees and primarily as a result of their association with category 5.

With a 26.6% occupancy rate, category 3 (secondary vegetation, 0-4% slopes, and clay-loam soils) appears to be a secondary category of preference. Category 2 (secondary vegetation, 0-4% slopes, and other soil textures), however, contains a larger number of prairie dog pixels than category 3 because it covers a larger area, even though it has a lower occupancy rate (10.7%).

With a 10.2% occupancy rate, category 4 (preferred vegetation and 4-25% slopes) is of limited importance here due to the small area it represents. The limiting factor for this category may be that the four preferred vegetation types (3100, 3310, 7100, and 7800) rarely occur on slopes greater than 4%.

With only a 0.8% occupancy rate, category 1 is of little value to prairie dog habitat except where it borders existing towns within the other categories. Even though this category covers the majority of the study area (82%), only two small prairie dog towns occur solely within category 1. These are located along the banks of the Missouri River, possibly attributable to a factor not considered (assumed to be due to concentrated human impacts, which seem to attract prairie dogs).

Finally, no prairie dog towns occur within the areas excluded from study. This appears to justify the assumptions made in rejecting these areas as suitable habitat.

South Phillips County Map: When the model was extrapolated to the neighboring region, the same patterns occurred. Most towns centered on the preferred category (in this case, renumbered as 4) and in several cases stopped at this category's boundaries. Also, a minimal percentage of the unsuitable category 1 contained prairie dogs. In this map, however, the majority of the area is considered potential habitat, as opposed to the study site (included in this larger map) in which the majority of the area was unsuitable. This shows the relative value of the region as prairie dog habitat. The geographic patterns of preferred habitat (denoted as red on this map) are easily located within the region.

Curiously, a large area of preferred habitat contains relatively few prairie dog towns (located due south of Malta and southeast of the "U.S. Highway 191" label on the map). This area is primarily private land, however, and may have been poisoned on a more regular basis than public land. A much greater extent of prairie dog towns (both in number and in size) occurs on the same habitat type to the immediate west of this area on the Fort Belknap Indian Reservation, possibly due to differences in poisoning programs.

This map shows clear patterns of core areas of preferred prairie dog habitat and potential connecting corridors amidst a larger pattern of semi-potential and unsuitable habitat. This information could be used to prioritize management of certain areas to benefit the larger prairie dog ecosystem.

Applying the Results Elsewhere

According to this model, the ideal prairie dog habitat — or the habitat most associated with existing prairie dog towns on the North CMR study site — consists of very low cover grasslands or salt-desert shrub vegetation and slopes of 0-4%. From the classification table data, further preference is seen for MNDVI levels below a value of 14 (corresponding wih very low biomass), slopes below 2%, clay loam soils, and soil depths greater than 60". Although this model is meant to gain a coarse scale picture of a region for the relative value of specific locations, these preferences may be used to identify site-specific locations with these values for site-specific prairie dog potential.

The results of this study are most accurately applied to the Northern Great Plains shortgrass prairie ecoregion. Factors change as one moves out of this region (e.g., slope appears to be more restrictive for prairie dog occupancy further south). This model may be applied across all of eastern Montana to create prairie dog habitat suitability maps with at least the five categories now available, and all six categories in areas where NRCS soil surveys have been digitized. Similar tests should be conducted in relatively natural prairie dog ecosystems in other ecoregions to create more accurate models for these regions. Few areas exist; Theodore Roosevelt National Park in North Dakota and Badlands National Park in South Dakota are two possibilities.

Limitations

The results of these studies do not reveal directly why prairie dogs select or avoid certain factors, but rather tabulates the degree to which these factors are associated with existing prairie dog towns within the North CMR study site. If the model is applied elsewhere, it must be assumed that this new location does not contain significant areas with conditions not found in the original study site that may invalidate the model. For example, over 80% of the study site contained clay soils, and no sandy soils were identified; large regions of coarse-textured soils may therefore not be an appropriate area in which to apply the model because these soils may in fact prohibit prairie dog colonization, even if the area falls in the preferred category (i.e., a mixed-barren site with 0-4% slope).

When this model was extrapolated to south Phillips County, prairie dog town patterns fit the model well, adding to the model's credibility. This larger area, however, contained nearly identical vegetation and soil information — only one very minor additional vegetative code was encountered, and soils were similarly deep, well-drained, and fine-textured. For application in other areas, vegetation should be similar to the 23 codes found within the study site, and soils should be fine-textured.

One common theme between the four vegetative codes that correlate well with prairie dog presence — 3130 (very low cover grasslands), 3310 (Salt-Desert shrub), 7100 (dry salt-flats), and 7800 (mixed barren sites) — is their low biomass. Clearly, prairie dogs exist within areas with relatively low biomass. Whether the vegetative component of preferred category 5 represents shortgrass species versus any species with low vegetative height is a question that deserves more consideration. Could the other suitable categories

(2, 3, and 4) be reclassified as category 5 by, for example, heavy livestock grazing? And is species composition in fact important for the prairie dog diet, or is vegetation height the real issue? The data collected in this study is unable to resolve these issues. Before relying on the model for site-specific prairie dog reintroductions, a review of site vegetation characteristics independent of prairie dogs should be done to independently evaluate reintroduction success.

The model will, at the very least, outline the areas most similar to existing prairie dog towns. Whether species composition or height is the similar factor, these areas are likely to be suitable for prairie dog habitatation at this point in time, since the vegetative classification takes into consideration all influences that may alter vegetation height or composition.

Chapter 5: Management Implications

This model for predicting potential prairie dog habitat may be used to develop and/or improve prairie dog ecosystem management plans for lands in eastern Montana. Below are some examples, beginning with the study site itself.

Improve management on the CMR

The CMR developed a set of goals and objectives based on the laws, orders, and policies that guide its management (Executive Order 7509 and the National Wildlife Refuge System Administration Act of 1966). Wildlife objective 8 is to "Maintain viable prairie dog towns totaling no less than 5,000 acres and no more than 10,000 acres on suitable areas with sizes and patterns desirable for black-footed ferrets. Minimize conflicts with adjacent landowners" (USFWS 1985). The study site map outlines these suitable areas and identifies areas where future prairie dog colonies are most likely. The maps also show where suitable habitat exists near private land. These areas may be managed to prevent prairie dog colonization by, for example, removing livestock grazing which leads to shorter vegetation height and thereby increases the potential for prairie dog colonization.

Wildlife objective 2 is to "Maintain habitat for and reintroduce a minimum of six pairs of black-footed ferrets on six or more prairie dog towns when animals are available," and objective 11 is to "Reintroduce...swift fox into suitable habitat" (USFWS 1985). Ferrets are now being reintroduced and need more prairie dog towns to ensure a viable future. Swift fox may be reintroduced in the future if/when ferret reintroduction succeeds. Because swift fox densities are highest in areas with extensive prairie dog towns, prairie dog maps may also aid in this effort. Finally, because prairie dog towns in this area are important habitat for mountain plovers (a candidate species), prairie dog habitat maps may help define the potential of the CMR for mountain plover habitat.

Beginning in the summer of 1997, the CMR and private individuals began relocating prairie dogs onto plagued-out towns in an attempt to reestablish these areas for the benefit of the black-footed ferret reintroduction program and for mountain plover recovery. The study site map may help to identify appropriate translocation areas, especially areas that have not been occupied by prairie dogs in the recent past.

The prairie dog habitat map shows that, prior to plague in 1992, much of the primary habitat was occupied. Comparing habitat suitability on the CMR to neighboring areas in south Phillips County, it is clear that the CMR contains relatively little habitat, and the two main habitat areas that do exist are geographically separated from each other. For improved management of the black-footed ferret recovery program, the BLM lands with much greater suitability should play a greater role in this effort.

Improve management in the BLM's Phillips Resource Area

The Judith Valley Phillips Resource Management Plan states that "BLM, in cooperation with the FWS and MDFWP, would maintain the existing prairie dog habitat and distribution on BLM land within the 7 km Complex based on a 1988 survey" (USBLM 1992). In 1988, BLM lands within the 7 km Complex contained 12,346 acres of prairie dog towns. Between 1991 and 1996, sylvatic plague ran through the area and wiped out 70% of the prairie dog complex. The BLM has initiated a voluntary shooting ban on BLM lands, but the number of prairie dogs in the area remains far below plan objectives. An action plan to address how the BLM will return prairie dogs to 1988 levels will be developed in the first half of 1998, and the habitat map of south Phillips County may aid in developing a successful plan.

Improve black-footed ferret reintroduction

The prairie dog habitat map may be used to identify the best locations within south Phillips County in which to encourage or reestablish prairie dogs to create such corridors. Areas should be identified which would connect towns crucial to black-footed ferret recovery and reduce conflicts with adjacent private landowners.

The CMR and BLM may also use these maps to identify locations in which to establish or reestablish prairie dog towns to connect the ferret reintroduction site in the UL Bend area with the Manning Corral prairie dog town (recently wiped out by plague).

Develop a plague management plan

Although plague is not fully understood, it is thought that a diverse pattern of connected colonies of varying sizes as well as isolated colonies of various sizes is the best condition to ensure the future of prairie dogs and associated species. This model may identify isolated towns, and locate suitable areas in which to promote new isolated towns which may survive future plague epidemics.

Develop prairie dog ecosystem management plans

Other areas of significant prairie dog habitat on public lands exist in eastern Montana, such as the Tongue River Valley. But the agencies which manage these lands (Custer National Forest and BLM's Powder River Resource Area) do not have such plans.

Outline a prairie dog ecosystem conservation strategy

Conservation biologists have promoted such strategies for conserving numerous wildlife species and habitat. Prairie dog habitat may be outlined with this model and used as the basis for a conservation strategy as proposed in general terms by Noss and Cooperrider (1994) and specifically to the prairie dog ecosystem by Wuerthner (1997). Such a strategy is needed to ensure the long-term viability of the entire prairie dog ecosystem including the several dependent species in jeopardy as well as the overall ecosystem functions provided by significant numbers of prairie dogs.

When the vegetation map of eastern Montana is completed, the model can be used to identify significant areas of preferred habitat on public lands throughout the state. These areas could then form the "core reserves" necessary for such a proposal.

An absolute minimum of 10 such core reserves must be identified nation-wide in order to attain the goals of the black-footed ferret recovery program (USFWS 1988). Development of these core reserves should also consider other species' needs. Because this study site and its larger prairie dog colony complex has been identified as nationally significant for prairie dogs, black-footed ferrets, and mountain plovers (Knowles 1995, Reading 1993, Olson and Edge 1985), this area should constitute one such core reserve.

Appendix A: Montana Prairie Dog Management Guidelines

May 1988
Prepared by the Montana Black-footed Ferret Working Group

(selected pages only)

Goals of the Guidelines

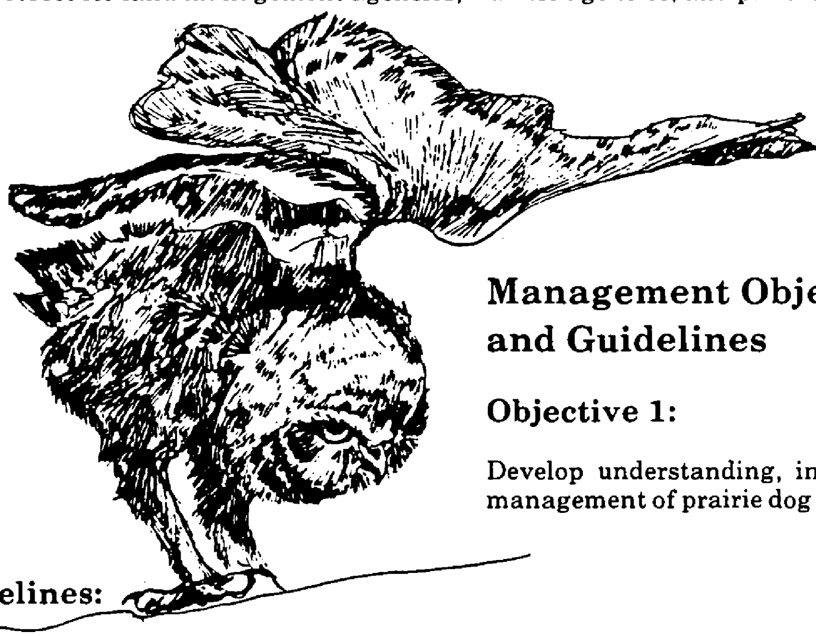
1. Inform public and private land managers in Montana of the role of the prairie dog ecosystem.

2. Assist land managers in developing long-term management objectives for prairie dog ecosystems including those for associated species that may be threatened, endangered, or of special concern.

3. Help managers identify potential problems for prairie dog populations in Montana and offer recommendations to avoid or resolve conflicts.

4. Ensure that managers consider the biology and needs of associated species in developing prairie dog management plans.

5. Establish a framework for a reliable prairie dog ecosystem and associated species management protocol for land management agencies, wildlife agencies, and private landowners.



Management Objectives and Guidelines

Objective 1:

Develop understanding, interest, and support for management of prairie dog ecosystems in Montana.

Guidelines:

1. Land managers and the public should understand the role of the prairie dog in Montana's natural history, and citizens should be encouraged to participate in establishing management priorities for prairie dog ecosystems in the state.

2. The public's interest, understanding, and knowledge of the prairie dog ecosystem and its economic importance in Montana should be determined.

3. Consumptive and non-consumptive uses of prairie dog ecosystems within established management plans should be presented in public information programs.

4. Booklets and posters about the prairie dog ecosystem should be developed for use in elementary and agriculture curricula. These should be distributed to specific groups and made available to the general public.

Objective 2:

Maintain prairie dog ecosystems to ensure adequate habitats for the continued existence of threatened, endangered, and associated species.

Guidelines:

1. Ensure that high quality habitat is managed to prevent irreversible declines in endangered and threatened species, and species of special concern, including: black-footed ferret, swift fox, ferruginous hawk (*Buteo regalis*), golden eagle (*Aquila chrysaetos*), mountain plover and burrowing owl. For example, recovery of the black-footed ferret requires the establishment of several secure ferret populations throughout its potential range. Thus, identifying, evaluating, and managing prairie dog complexes for reintroduction of ferrets in Montana is necessary for recovery of this endangered species. Habitat management guidelines for the black-footed ferret have been published (Forrest et al. 1985) and should be referred to when developing management and reintroduction plans for ferrets.

2. Many other species of wildlife occur in close association with prairie dogs. In striving for stable ecosystems, managers should maintain habitat to ensure the functional role of each species within that ecosystem.

Objective 3:

Identify standards and techniques for managing prairie dog populations in Montana.

Guidelines:

1. Develop site-specific prairie dog management plans wherever an intentional change in distribution or abundance of prairie dogs is proposed. Such actions may vary from extensive management plans on public lands to private landowner decisions. This could include actions to maintain, eliminate, or increase the size of prairie dog colonies. Recommended procedures for developing these plans are contained in Appendix I which also has a planning and action matrix to be used for selecting specific management techniques, based upon associate species and conflict value ratings.

2. When management objectives involve the use of rodenticides to reduce or eliminate prairie dogs, only recommended methods and materials registered by the Environmental Protection Agency and the Montana Department of Agriculture (MDA) can be used. Acceptable methods, materials, recommendations and use restrictions may change. Therefore, periodic contacts with the MDA or U.S. Department of Agriculture, Animal and Plant Health Inspection Service must be made. Management techniques for grazing, range improvements, and sport shooting should also be integrated into a prescription for prairie dog management.

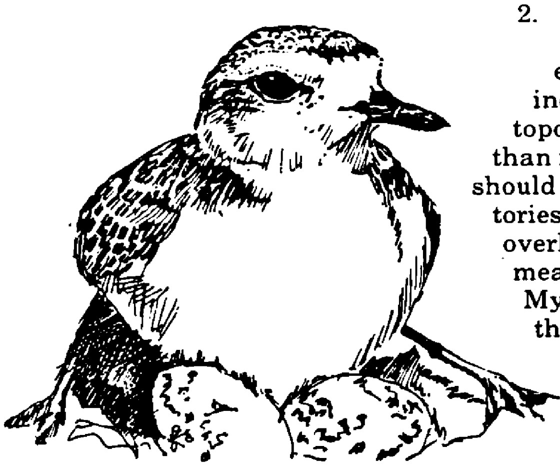
3. Public land managers should establish cooperative prairie dog management programs with private landowners or lessees. This is particularly important where prairie dogs inhabit public lands immediately adjacent to privately-owned lands.

Objective 4:

Monitor prairie dog ecosystems to determine the status and trend of populations of prairie dogs, threatened and endangered species, and species of special concern.

Guidelines:

1. Prairie dog colonies that constitute potential or known habitats for threatened or endangered species or species of special concern should be identified, mapped, and monitored. Monitoring plans should be implemented and revised as needed or at least every 5 years. Accurate records should be maintained for each colony.



2. Prairie dog colonies containing greater than or equal to 4 burrows per acre, should be mapped at least once every 5 years on overlays of aerial photos (minimum 2 inch to the mile) or U.S. Geological Survey 7.5-minute topographic maps. Areas containing colonies with less than four burrows per acre are generally difficult to map and should be labeled as "scattered" for future reference or inventories. Initial and follow-up mapping should be done on overlays of the same map or photo which can then be measured to monitor changes in size (see Schenbeck and Myhre 1986). Follow-up mapping should be conducted at the same time of year as initial mapping efforts. When a colony is poisoned or abandoned as a result of natural causes (e.g., plague), it is very important that this information be retained for historical purposes. A yearly summary of field efforts should also be prepared.

3. The status of threatened or endangered species inhabiting prairie dog colonies should be documented annually. Monitoring plans should be developed for colonies occupied by black-footed ferrets and should follow "Handbook of Methods for Locating Black-footed Ferrets" (Clark et al. 1984). If other species associated with prairie dog colonies are identified as threatened or endangered in the future, the monitoring procedures for those species should be established accordingly.

4. Species of special concern should be monitored at least every 5 years. Situations will vary at different locations and with different species, thus systematic sampling methods should be devised for each species as needed. One method would be a system of linear transects 50 to 75 feet apart covering 100 percent of each colony.

5. All other prairie dog colonies should be located and periodically assessed to determine their status and trends.

6. Factors influencing the survival and dynamics of prairie dog colonies and complexes of colonies should be identified.

Objective 5:

Design research to find solutions to short and long-term biological and social problems related to prairie dog ecosystem management.

Guideline:

1. Identify prairie dog research needs and priorities in Montana. This may include basic or applied research. Monitoring methodologies are also needed to test the effectiveness of management actions.

APPENDIX

SITE-SPECIFIC PRAIRIE DOG MANAGEMENT PLAN

Introduction

Include any special background information as a basis for the management plan, particularly how it relates to existing land use plans. Identify the source of information used to develop the plan and the extent of site-specific prairie dog information. Identify the agencies and administrative units responsible for implementing the plan. Establish monitoring methods and schedules to evaluate the effectiveness of the plan.

Site Description

Include land ownership and land use patterns. Specifically identify all land owners included in the planning area. Provide a history and projection of habitat alterations with appropriate detail. Include a summary of habitat characteristics that might be important for prairie dog management.

History of Prairie Dog Use

Summarize what is known about prairie dog occurrence in the planning area. Include documented historical prairie dog colonies, control chronology and history.

Potential Conflicts

Identify and discuss management problems and potential conflicts for prairie dogs in the planning area.

Management Areas

Describe the occupied and potential range of prairie dogs in the planning area. Include a detailed map.

Situation Analysis

A. Describe Site Specific management objectives

B. Describe and analyze management options.

C. Identify and define variables used. An actual list of variables used on a test area follows. It will be necessary to consider different variables for each situation.

1. Colony size
2. Change in colony size
3. Number of species of special concern present
4. Unique attributes; largest town, snake den, mountain plover staging area, burrowing owl concentration, raptor staging area
5. Management treatments to date. See Planning and Action Matrix at the end of this document.
6. Years in shooting program
7. Existing developments; public road, windmill, stock pond, fish pond, oil well, Ducks Unlimited project, land exchange, air strip
8. Proposed development
9. Estimated rebound time.
10. Nearest neighbor colony
11. Number of colonies within 4 miles.

Management Direction

1. If existing information is inadequate to proceed with management recommendations, identify assumptions to replace information needs or gather the needed information.

2. Identify specific management direction for the planning area or specific sites and how that direction was selected. A planning/action matrix is provided at the end of this document to assist in this task.

Future Action Items

Identify what is needed for future management such as research, monitoring, habitat improvement, prioritization of land use, or a change in livestock stocking rates. Set preliminary time frames, budgets, and schedules.

Literature Cited

In addition to published information, cite file data, personal communications, and other sources of information.

Appendix B: Vegetation Classifications

Created by the Montana Wildlife Spatial Analysis Lab

Montana State Vegetation Code Key

September 1, 1997

This draft outline of the Montana State Vegetation Code Key delineates the vegetation code labels and their corresponding four-digit codes. The vegcode key has three levels: General Group, Parent Group, and Sub-code Group.

The species types and geographic/ecological descriptions are still being developed for the state of Montana. Two temporary species keys are: The Montana & Idaho Vegetation Key and the Custer & Pryor Mountains Vegetation Key. Thus this key does not contain the species types or geographic/ecological descriptions for each vegcode.

Please use the vegcode species form at the end of this key to provide input into the development of a final Montana Vegetation Code Species & Geographic/Ecological Limit Key.

The life form groups are broken out as follows:

1. Is the site Riparian or Upland?	
A. Is the site Forest dominated?	Forest Cover (FC) ≥ 10%
B. Is the site Shrub dominated?	FC < 10%, Shrub Cover (SC) ≥ 15%
C. Is the site Grass dominated?	FC < 10%, SC < 15%, Herbaceous Cover (HC) ≥ 15%
D. Is the site Barren or Rock?	FC < 10%, SC < 10% and HC < 10%
E. Is the site Alpine?	Vegetation above tree line
Special lifeform group association:	
F. Is the site Shrub/Grass dominated?	FC < 10%, SC & HC equal dominance

	General	**Parent**	**Sub-code**
URBAN—AGRICULTURAL LANDS			
1000-2999 (manually classified)			
Urban	1100		
Agricultural	2000		
Agriculture-Dry		2010	
Agriculture-Irrigated		2020	
GRASSLANDS 3100-3199			
Forest Cover <10%, Shrub Cover <15%, and Herbaceous Cover ≥15%			
Upland Grasslands	3100		
Altered Herbaceous		3110	
Non-Native grass			3111
CRP Lands			3115
Noxious Weeds			3121

	General	Parent	Sub-code
Very Low Cover Grasslands		3130	
Low Cover Grasslands		3140	
Low/Moderate Cover Grasslands		3150	
Moderate/High Cover Grasslands		3160	
High Cover Grasslands		3170	
Mesic Montane Parklands & Subalpine Meadows		3180	
SHRUBLANDS 3200-3499			
Forest Cover < 10%, Shrub Cover ≥ 15%			
Mesic Shrubs	3200		
Mixed Mesic Shrubs		3210	
Warm Mesic Shrubs			3212
Cold Mesic Shrubs			3213
Snowberry Shrub Communities		3250	
Buffalo Berry Communities		3260	
Smooth Sumac Communities		3270	
Xeric Shrubs	3300		
Mtn Mahogany		3301	
Skunkbrush Sumac		3303	
Bitterbrush		3304	
Silver Sage		3309	
Salt-Desert Shrub		3310	
Greasewood		3311	
Rabbitbrush		3312	
Creeping Juniper		3313	
Shadscale		3318	
Big Sagebrush Steppe		3350	
Mountain Big Sagebrush			3351
Wyoming Big Sagebrush Steppe			3352
Basin Big Sagebrush			3353
Black Sagebrush Steppe			3354
Low Sagebrush Steppe			3355
Tri-tip Sagebrush			3356
Xeric Mixed Shrubs		3360	
Greasewood and Big Sagebrush			3361
Juniper and Sagebrush/Grass			3362

	General	Parent	Sub-code
Shrub-Grassland Complexes 3500-3599			
Forest cover <10%, Shrub & grass cover co-dominant			
* Heterogenious polygons where life forms occur in patches throught the area			
Shrub-grasslands associations	3500		
Mesic Shrub-Grassland Associations		3510	
Xeric Shrub-Grassland Associations		3520	
Tree-Grassland Associations		3530	

FORESTLANDS 4000-4999

Forest Cover ≥ 10%

A. Is it Broadleaf or Conifer Dominated or Mixed Broadleaf/Conifer?
(Broadleaf > 66% Forest Cover; Conifer > 66% Forest Cover)

1. Is it a Very Low Cover Stand? (Forest Cover 10 - 20%)
2. Is it a Low - High Cover Stand? (Forest Cover > 20%)
   a. Is it a Single Species Stand? (one species > 66% Forest Cover)
   b. Is it a Two Species Stand? (Sum of two species ≥ 80% Forest Cover)
   c. Is it a Mixed Species Stand?

	General	Parent	Sub-code
Very Low Cover Stands 4000 - 4099			
Forest Savanna		4010	
Very Low Cover Forest		4020	
Broadleaf Forest 4100-4199			
Single Broadleaf Species	4100		
Aspen		4101	
Green Ash		4105	
Bur Oak		4106	
Basswood		4107	
Russian Olive (Silverwood)		4108	
Multiple Species Broadleaf Forest		4140	
Conifer Forest 4200-4299			
Single Conifer Species	4200		
Engelmann Spruce		4201	
Lodgepole Pine		4203	
Whitebark Pine		4204	
Limber Pine		4205	
Ponderosa Pine		4206	
Grand Fir		4207	
Subalpine Fir		4208	
Western Red Cedar		4210	
Western Hemlock		4211	

	General	Parent	Sub-code
Douglas-fir		4212	
Rocky Mtn Juniper		4214	
Western Larch		4215	
Utah Juniper		4216	
Alpine Larch		4217	
Two-conifer Species Stands	4220		
Douglas-fir/Lodgepole Pine		4223	
Douglas-fir/Grand Fir		4225	
Western Red Cedar/Grand Fir		4226	
Western Red Cedar/Western Hemlock		4227	
Western Larch/Lodgepole		4228	
Western Larch/Douglas-fir		4229	
Douglas-fir/Ponderosa Pine		4230	
Douglas-fir/Limber Pine		4231	
Douglas-fir/Engelmann Spruce		4232	
Limber Pine/Juniper		4234	
Mixed Whitebark Pine Forest		4260	
WBP ≥ 10%			
Mixed Subalpine Forest		4270	
WBP 1-9% or SF ≥ 10% or ES ≥ 10%			
Mixed Mesic Forest		4280	
RC or GF or WL ≥ 10% & DF or PP			
Mixed Xeric		4290	
RMJ, UJ, PF, DF, PP			
Mixed Broadleaf and Conifer Forest		4300	
Standing Burnt or Dead Forest		4400	
Moderate Intensity Burns			4402
High Intensity Burns			4403
Timber Harvest Units		4500	
WATER 5000-5999			
Water	5000		
Rivers & Streams		5100	
Lakes		5200	
Reservoirs and Potholes		5300	

	General	Parent	Sub-code
RIPARIAN 6000-6999			
A. Is it Tree Dominated Riparian? FC > 10%			
B. Is it Shrub Dominated Riparian? FC < 10%, SC ≥ 15%			
C. Is it Graminoid Dominated Riparian? FC < 10%, SC < 15%, HC > 15%			
Tree Dominated Riparian	6100		
Conifer Dominated Riparian		6110	
Broadleaf Dominated Riparian		6120	
Mixed Tree Riparian		6130	
Mixed Forest & Non-forest Riparian		6140	
Herbaceous Dominated Riparian	6200		
Graminoid & Forb Dominated		6210	
Sedge/Grass Communities			6211
Cattail Marshes			6212
Alpine Wetlands		6250	
Shrub Dominated Riparian	6300		
Shrub Dominated Riparian		6310	
Willow Dominated Riparian			6313
Other Shrub Dominated Riparian			6315
Mixed Shrub & Herbaceous Riparian		6400	
BARREN LAND 7000-7999			
Tree Cover, Shrub Cover, and Herbaceous Cover <10%			
Barren Land	7000		
Dry Salt-Flats		7100	
Sandy Areas, Blowouts		7200	
Rock-Dominated Sites		7300	
Exposed Rock			7301
Tree-Scree			7302
Shrub-Scree			7303
Basalt Flows			7304
Barren Alpine Tundra		7400	
Mines, Quarries, Gravel Pits		7500	
Badlands		7600	
Shrub Badlands			7601
Grass Badlands			7602
Mixed Shrub/Grass Badlands			7603
Missouri Breaks			7604
Mixed Barren Sites		7800	
Shoreline and Stream Gravel Bars		7900	

	General	Parent	Sub-code
ALPINE AREAS 8000-8700			
Areas above Tree Line			
Alpine Areas	8000		
Alpine Meadows		8100	
Alpine Grasslands			8101
Alpine Sedge			8102
Alpine Cushion Plant			8103
Alpine Snowbeds			8104
Alpine Shrub Communities		8500	
SNOW AND CLOUDS 9000-9999			
Snowfields or Ice	9100		
Clouds	9800		
Cloud Shadow	9900		

Tree Size Class		Code
Seedling/Sapling	(1.0 - 4.9" DBH)	1
Pole	(5.0 - 8.9" DBH)	2
Medium	(9.0 - 20.9" DBH)	3
Large	(>21.0" DBH)	4

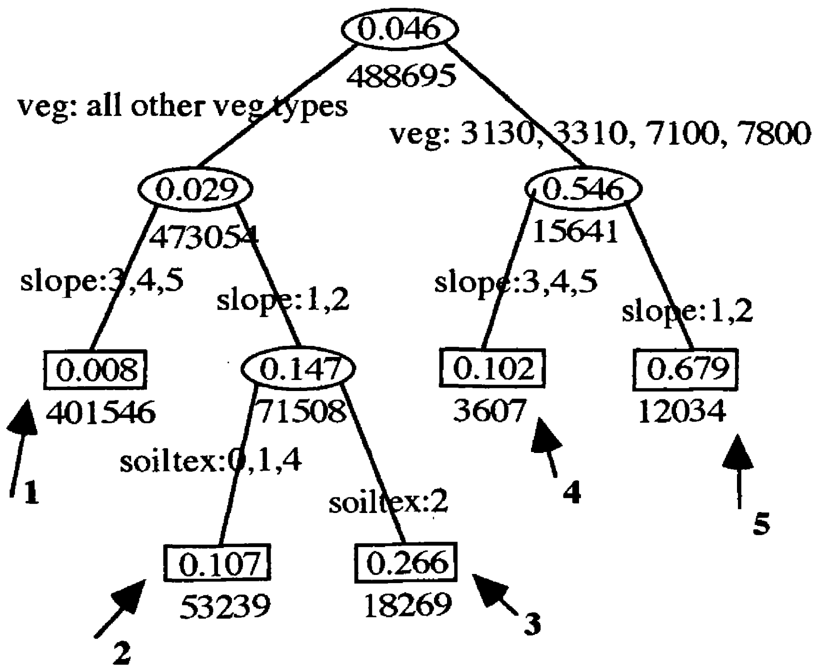
Tree Canopy Closure	Code
Low (10-39%)	1
Moderate (40-69%)	2
High (>= 70%)	3

* Note: if possible, training data should have 10% canopy cover breaks

Appendix C: Classification Tree Models

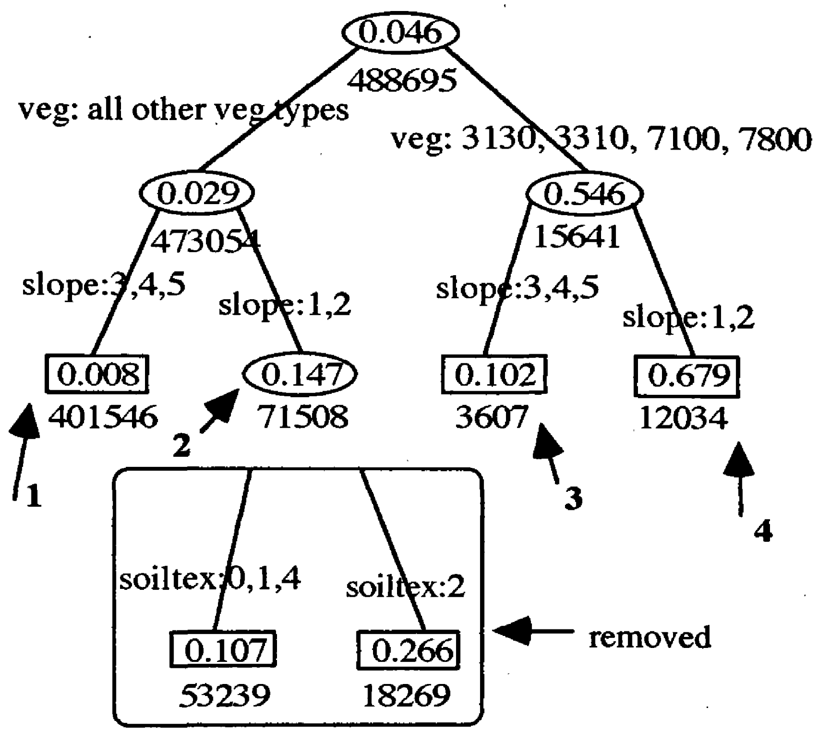
with codes for use in GIS modelling

North Dataset



(Bold numbers refer to habitat categories)

Revised Classification Tree



(Bold numbers refer to habitat categories)

Literature Cited

Agnew, W., D.W. Uresk, and R.M. Hansen. 1986. Flora and fauna associated with prairie dog colonies and adjacent ungrazed mixed-grass prairie in western South Dakota. J. Range Manage. 39(2):135-139.

Anderson, E., S.C. Forrest, T.W. Clark, and L. Richardson. 1986. Paleobiology, biogeography, and systematics of the black-footed ferret, Mustela nigripes(Audubon and Bachman), 1851. In The black-footed ferret. Great Basin Naturalist Memoirs. 8:11-62.

Biodiversity Legal Foundation and J.C. Sharps. 1994. Petition to classify the black-tailed prairie dog (Cynomys ludovicianus) as a category 2 candidate species pursuant to the administrative procedures act and the intent of the endangered species act. Letter to the U.S. Fish and Wildlife Service dated Oct. 21. 82 pp.

Clark, J.W., T.M. Campbell III, D.G. Socha, and D.E. Casey. 1982. Prairie dog colony attributes and associated vertebrate species. Great Basin Nat. 42(4):572-582.

Clippinger, N.W. 1984. Habitat suitability for the black-tailed prairie dog at Rocky Mountain Arsenal. U. of Colorado, B.A. thesis. 94 pp.

Clippinger, N.W. 1989. Habitat suitability index models: black-tailed prairie dog. U.S. Fish and Wildlife Service. Biological Report 82(10.156) 21pp.

Coppock, D.L., J.E. Ellis, J.K. Detling, and M.I. Dyer. 1983. Plant herbivore interactions in a North American mixed-grass prairie. Oecologia 56:10-15.

Cully, J.F., Jr. 1989. Plague and the prairie dog ecosystem: importance for black-footed ferret management. In The prairie dog ecosystem: managing for biological diversity. Clark, T.W., D.K. Hinckley, and T. Rich (eds.). Montana BLM Wildl. Tech. Bull. No. 2.

Dalsted, K.J., S. Sather-Blair, B.K. Worcester, and R. Klukas. 1981. Application of remote sensing to prairie dog management. J. Range Manage. 34(3):218-223.

Environmental Systems Research Institute, Inc. 1994a. ArcView. Version 3.0a for Microsoft Windows. Redlands, CA.

Environmental Systems Research Institute, Inc. 1994b. PC ARC/INFO. Version 3.4.2. Redlands, CA.

Environmental Systems Research Institute, Inc. 1997. Understanding GIS: the ARC/INFO method. Version 7.1.1 for Microsoft Windows. Redlands, CA.

Fagerstone, K.A. and C.A. Ramey. 1996. Rodents and lagomorphs. In: P.R. Krausman, ed. Rangeland Wildlife. Denver: The Society of Range Management: 83-132.

Flath, D.L. and T.W. Clark. 1986. Historic status of black-footed ferret habitat in Montana. Great Basin Nat. Mem. 8: 63-71.

Hall, E.R. 1981. The mammals of North America, 2nd ed. New York: J. Wiley and Sons. 1181pp.

Hoogland, J.L. 1981. The evolution of coloniality in white-tailed and black-tailed prairie dogs. Ecology 62: 252-272.

Kelso, L.H. 1939. Food habits of prairie dogs. U.S. Dept. Agric., Cir. 529, 15 pp.

Knowles, C.J. 1982. Habitat affinity, populations, and control of black-tailed prairie dogs on the Charles M. Russell National Wildlife Refuge. U. of Montana, Dept. of zoology. Ph.D. thesis. 171 pp.

Knowles, C.J. 1995. A summary of black-tailed prairie dog abundance and distribution on the central and northern great plains. Faunawest Wildlife Consultants, Boulder, MT.

Knowles, C.J. 1998. Personal communication.

Knowles, C.J. and P.R. Knowles. 1994. A review of black-tailed prairie dog literature in relation to rangelands administered by the Custer National Forest. USDA Custer National Forest, Billings, MT. 61 pp.

Koford, C.B. 1958. Prairie dogs, whitefaces, and blue grama. Wildl. Monogr. 3: 1-78.

Manly, B.F., L.L. McDonald, and D.L. Thomas. 1993. Resource selection by animals: statistical design and analysis for field studies. Chapman and Hall, London. 177pp.

Miller, B., G. Ceballos, and R. Reading. 1994. The prairie dog and biotic diversity. Cons. Biol. 8: 677-681.

Montana Black-footed Ferret Working Group. 1988. Montana prairie dog management guidelines. Bureau of Land Management, Billings. 14pp.

Montana GIS Lab. 1995. Custer National Forest (eastern Montana, Dakotas) vegetation and land cover classification system modified from Montana and Idaho vegetation and land cover classification system of December 1995. Unpub. U. of Montana, Missoula.

Nemani, R., L. Pierce, and S. Running. 1993. Forest ecosystem processes at the watershed scale: senistivity to remotely-sensed Leaf Area Index estimates. Int. J. Remote Sensing 14: 2519-2534.

Noss, R. 1994. The Wildlands Project: land conservation strategies. Wild Earth, Special Issue: 10-25.

Olson, S.L. and D. Edge. 1985. Nest site selection by mountain plovers in northcentral Montana. J. Range Manage. 38: 278-280.

Osborn, B. 1942. Prairie dogs in shinnery (oak scrub) savannah. Ecology 23: 110-115.

Osborn, B. and P.F. Allan. 1949. Vegetation of an abandoned prairie dog town in tall grass prairie. Ecology 30: 322-332.

Proctor, J.D. 1995. A case for change in prairie dog management on Montana's state lands. Unpub. U. of Montana, Missoula. 20pp.

Reading, R.P. 1993. Towards an endangered species reintroduction paradigm: a case study of the black-footed ferret. PhD. dissertation, Yale University, 552 pp.

Reading, R.P., T.W. Clark, A. Vargas, L.R. Hanebury, B.J. Miller, D.E. Biggins, and P.E Marinari. 1997. Black-footed ferret (Mustela nigripes): Conservation update. Small Carnivore Conservation 17: 1-6.

Reading, R.P. and R. Matchett. 1997. Attributes of black-tailed prairie dog colonies in northcentral Montana. J. Wildl. Manage. 61(3); 664-673.

Reid, N.J. 1954. The distribution of the black-tailed prairie dog in the Badlands of southwestern North Dakota. State Univ. of Iowa, Iowa City. 30pp.

Schaffner, J.H. 1926. Observations on the grasslands of the central United States. The Ohio State University Press. Columbus, OH. 56pp.

Seton, E.T. 1929. Lives of game animals. Doubleday, Dovan, and Co. Inc. Garden City, N.Y.

Sharps, J.C. and D.W. Uresk. 1990. Ecological review of black-tailed prairie dogs and associated species in western South Dakota. Great Basin Naturalist Memoirs 50: 339-345.

Sheets, R.G. 1970. Ecology of the black-footed ferret and the black-tailed prairie dog. M.S. thesis. South Dakota State University, Brookings. 33pp.

S-Plus version 3.4, StatSci, Seattle, WA, 1996

Summers, C.A. and R.L. Linder. 1978. Food habits of the black-tailed prairie dog in western South Dakota. J. Range Manage. 31: 134-136.

Tepley, B., F. D'Erchia, and T. Schulz. 1990. Sighting of black-tailed prairie dog towns as potential reintroduction sites for the black-footed ferret. Colorado State U., unpublished. 22pp.

Thorp, J. 1949. Effect of certain animals that live in soils. Sci. Monthly, 68: 180-191.

Tileston, J.V. and R.R. Lechleitner. 1966. Some comparisons of the black-tailed and white-tailed prairie dogs in north-central Colorado. Amer. Midl. Nat. 75:292-316.

U.S. Bureau of Land Management. 1992. Judith Valley Phillips resource management plan and final environmental impact statement. Lewistown, MT. 436 pp.

U.S. Fish and Wildlife Service. 1985. Final environmental impact statement for the management of Charles M. Russell National Wildlife Refuge. Denver, CO. 453 pp.

U.S. Fish and Wildlife Service. 1988. Black-footed ferret recovery plan. Denver, CO. 154 pp.

U.S. Forest Service. 1986. Custer National Forest plan. Billings, MT.

Wuerthner, G. 1997. Viewpoint: The black-tailed prairie dog—headed for extinction? J. Range Manage. 50:459-466.

Wydeven, P.R. and R.B. Dahlgren. 1982. A comparison of prairie dog stomach contents and feces using a microhistological technique. J. Wildl. Manage. 46(4):1104-1108.