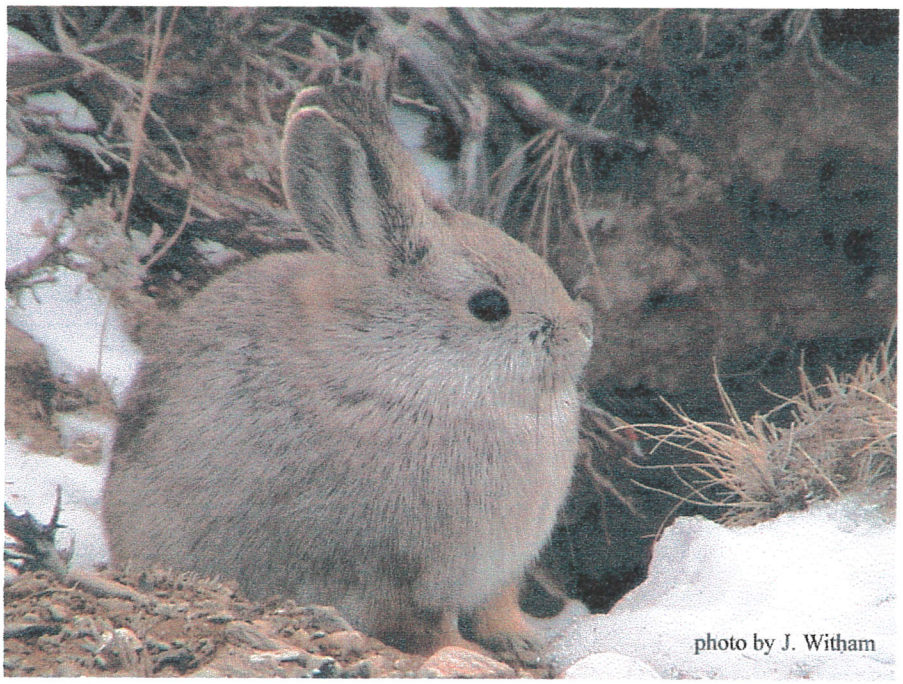
Pygmy Rabbit Habitat in Idaho

(Project Completion Report)

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Abstract

Pygmy rabbits (*Brachylagus idahoensis*) historically inhabited sage steppe regions across the Great Basin, and in Idaho, their historic distribution spanned much of the Snake River Plains. Information on current distribution and abundance is needed to assess their conservation status. The goal of this research was to evaluate potential habitat for pygmy rabbits on a statewide extent, and to provide guidance for ground surveys to improve understanding of the status and distribution of the species in Idaho. We first used information on habitat attributes from across the range of the species to identify a broad area of potential habitat in Idaho. Second, 147 known locations of rabbit populations in Idaho were used to evaluate habitat associations and to prioritize the potential habitat for allocation of survey efforts. The resulting map ranks habitat from higher to lower priorities in 6 categories. Most of the known locations fell into the top 2 priority ranks, which encompassed an area of 3.4 million hectares. Recommendations are provided for areas to survey within each of the Bureau of Land Management Field Office Areas.

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Introduction

Pygmy rabbits (*Brachylagus idahoensis*) have been characterized as sagebrush (*Artimisia* spp.) specialists or obligates (Orr 1940, Green and Flinders 1980a). Several studies have documented associations between pygmy rabbit populations and big sagebrush (*A. tridentata*), as well as selection by rabbits for sites with taller and denser sagebrush vegetation (Weiss and Verts 1984, Gahr 1993, Katzner and Parker 1997). Because pygmy rabbits excavate burrow systems, soil characteristics including depth and texture also influence their selection of habitat (Wilde 1978, Weiss and Verts 1984, Kehne 1991). Presence of these general habitat attributes appears to have shaped both historic and current distributions of pygmy rabbits. Although the historic distribution of pygmy rabbits is believed to have spanned much of the Great Basin, including shrub steppe habitats in eight western states (Green and Flinders 1980a, Lyman 1991), occurrence of populations was likely patchy, being restricted to areas of suitable sagebrush habitats (Green and Flinders 1980a, Weiss and Verts 1984, WDFW 1995).

Prehistoric records suggest a dynamic biogeography for pygmy rabbits. Archaeological and paleontological evidence indicates that the distribution and abundance of pygmy rabbits in the Great Basin reached a maximum in the late Pleistocene to early Holocene, and that populations began to decline approximately 7,000 years ago (Butler 1972, Grayson 1987). This reduction coincided with climate change in the Great Basin during the mid-Holocene that resulted in warmer, dryer conditions and a shift from winter to summer rains. Pygmy rabbits and other sagebrush obligates were likely affected by this climate change through its impact on distribution of sagebrush vegetation (Grayson 1987, Lyman 1996).

The recent listing of the Columbia Basin population of pygmy rabbits (Federal Register 2003) underscores the link between sagebrush and pygmy rabbit distributions. The range of the Columbia Basin population of pygmy rabbits in eastcentral Washington is disjunct from the rest of the species' distribution. That population historically occurred in 5 counties in Washington, and currently persists in only one location in Douglas County (WDFW 1995, 2001). The

Columbia Basin population appears to have expanded in eastern Washington during the early Holocene (10,000 – 3,000 years ago) along with the range of sagebrush following retreat of the Wisconsin glaciers (Lyman 1991). During the late Holocene, distribution of pygmy rabbits in the Columbia Basin was reduced, and paleobotanical evidence indicates a concomitant collapse in the range of big sagebrush (Lyman 1991, 1996). This natural reduction in distribution was exacerbated during the 1900s as a result of anthropogenic influences, including clearing of sagebrush and conversion of shrub steppe to agriculture in eastern Washington (WDFW 1995, Lyman 1996). Recent information suggests that <30 individuals are known to remain free-ranging in eastern Washington (Federal Register 2003).

Current known occurrences for pygmy rabbits suggest a highly fragmented distribution across the range of the species. Recent efforts to develop more comprehensive knowledge of their distribution and abundance have centered on investigation of historic locations. In Nevada Oregon, and Idaho recent surveys have documented apparent extirpation of historic populations (Nevada National Heritage Program 2002, Bartels and Hays 2002). Although it is not known if pygmy rabbit populations cycle, it has been suggested that their numbers may fluctuate, resulting in shifting distributions across the landscape (Rauscher 1997, Federal Register 2003).

Within Idaho, the historic distribution of pygmy rabbits likely extended across much of the Snake River Plains and adjoining areas of sage steppe. Museum records documenting the prehistoric distribution of the species in Idaho reflect a similar range. Jefferson et al. (2002) compiled information on vertebrate remains at archaeological sites, and reported that pygmy rabbits were present at sites in 7 Idaho counties (Elmore, Lemhi, Blaine, Butte, Bingham, Power and Bannock). These records date from the late Pleistocene through the late Holocene representing a span of 130,000 to 100 years before present. Evidence from prehistoric sites also suggests a decline in rabbit populations in southern Idaho during the Holocene (Butler 1972, Grayson 1987).

Historic and recent land use practices have likely influenced current distribution of pygmy rabbits in Idaho. Conversion of shrub steppe habitats to agriculture in the 1900s reduced the range of sagebrush in the Snake River Plains, and continued disturbance and altered fire regimes

have further fragmented sagebrush habitats (Knick and Rotenberry 1997). Information on recent occurrences of pygmy rabbits in Idaho suggests a patchy distribution, however, comprehensive data are lacking for either historic or current ranges. Roberts (2002) identified 3 regions in Idaho that currently support pygmy rabbits. One area with relatively large expanses of remaining habitat is north of the Snake River in the eastcentral valleys. Populations in that area appear to be connected to those in southwestern Montana (Rauscher 1997, Roberts 2001, 2002). A second focal area for pygmy rabbits occurs in southwestern Idaho in Owyhee County, and survey efforts during 2002 documented several populations in that region (H. Ulmschneider, pers. com.). The third region identified by Roberts (2002) is in southcentral-southeastern Idaho, south of the Snake River. Survey work was conducted in the BLM Burley Field Office Area during 2002 to search for populations in that region (Bartels, pers. com.).

Many vertebrate species occupying shrub steppe regions appear to be declining or are of conservation concern (DeSante and George 1994, Knick 1999). In March 2003, the Columbia Basin population of pygmy rabbits, in the state of Washington, was listed as "Endangered" under the Endangered Species Act (Federal Register 2003). In Idaho, pygmy rabbits are listed as a "Sensitive Species" by the Bureau of Land Management (BLM) and a "Species of Special Concern" by the Idaho Department of Fish and Game (IDFG). Additionally, pygmy rabbits are placed in the category of "Undetermined Status" on the Idaho state list because sufficient data are not available to evaluate their conservation status within the state. Agencies have recently increased their efforts to document the current distribution and status of pygmy rabbits regionally, and are beginning to coordinate these efforts range-wide.

The goal of this research was to synthesize existing information on the distribution of pygmy rabbits and to evaluate potential habitat for the species in Idaho. We used information on general habitat attributes from across the range of the species to first identify potential habitat within Idaho. Secondly, we used observed habitat associations for known populations within Idaho to prioritize areas for survey efforts. The resulting habitat model can be used to identify areas of potential habitat for pygmy rabbits and to guide future survey efforts to improve knowledge about the distribution of this species in Idaho.

Methods

We reviewed literature to identify and select habitat attributes associated with presence of pygmy rabbits (or their burrows). We used a Geographic Information System (GIS) to create a base map of potential habitat in Idaho, and to rank the potential habitat to prioritize survey efforts. Locations of historic and current populations were used to evaluate habitat variables to assign priority ratings. Occurrences were plotted and assessed for the following variables: vegetation type, elevation, slope, soil depth, and average percent clay in the soil. Values for each variable that encompassed 80-85% of all occurrences were considered "higher priority", and were assigned a priority rating of "1." Values outside of those ranges were assessed as "lower priority", and were assigned a priority rating of "2." Because fire can have long-term effects on sagebrush habitats (Nelle et al. 2000), we considered areas that had burned since 1990 to be lower priority rating. Information on response of pygmy rabbits to fire is lacking; therefore, the choice of this cut-off date is intuitive, but arbitrary. Research exploring the effect of fire on pygmy rabbit demography, dispersal, and recolonization would provide valuable insight for understanding and managing potential habitat following fire disturbances.

All habitat variables were overlaid using a GIS and average priority ratings were assigned to each pixel of 30 m (Figure 1). The resulting map provides priority ranking in 6 categories with average values ranging from 1 to 2 for the entire area identified as potential pygmy rabbit habitat in Idaho. We evaluated the fit of this model qualitatively by examining the priority ranks for known occurrences of pygmy rabbit populations.

Spatial data were compiled by the Landscape Dynamics Lab at the University of Idaho. We used vegetation data from the Idaho Gap Analyses Project (Scott et al. 2002) at a resolution of 30 m and a minimum mapping unit of 2 ha for upland vegetation types. In southern Idaho, the accuracy of this dataset ranges from 65.5% to 79.3% for all covertypes with areas of the Lemhi region and along the Snake River plain having the highest accuracy. We downloaded the National Elevation Database (US Geological Survey 1999) from INSIDE Idaho [http://inside.uidaho.edu] at 30 m resolution and derived both elevation (meters) and slope (degrees) information. Broad scale (1 km^2 resolution) information on average soil depth-to-bedrock and percent clay content in upper soil layers (<60 cm) was obtained from CONUS, the

conterminous U.S. multi-layer soil characteristics data set originally based on the USDA State Soil Geographic Database (Miller and White 1998). Large fire perimeters were received from the U.S. Forest Service (USFS) Region 4 and the Idaho state office of the Bureau of Land Management (BLM). The USFS dataset included all large (minimum mapping unit varied) fires that occurred across southern Idaho between 1981 and 2001. The dataset received from the BLM included fires larger than 40 acres (16.2 ha) that occurred in BLM's Upper Snake River District between 1939 and 2001. All data were reprojected to Idaho Transverse Mercator, NAD27, projection and overlaid with known pygmy rabbit locations using ArcGIS 8.1.2 (Environmental Systems Research Institute, Inc. 1982-2001). The spatial coordinates of known locations of pygmy rabbits were gathered from the IDFG Idaho Conservation Data Center (2002), H. Ulmschneider (BLM wildlife biologist, Owyhee field office) and H. Roberts (retired USFS wildlife biologist, Salmon region). Only locations precise to 30 m were used in the analyses. To limit spatial dependence, locations less than 300 m apart were excluded.

Results

Habitat associations reported for pygmy rabbits are summarized in Appendix 1. Although observed habitat associations differed across studies, two features, sagebrush and soil suitable for burrowing, were consistently associated with presence of pygmy rabbits. Other habitat characteristics describing cover of grasses and forbs, topography, and geology also are summarized in Appendix 1. Those habitat attributes were not recorded in all studies, and observed values varied across study sites.

We used documented locations of pygmy rabbits in Idaho in developing and evaluating the habitat model. We obtained 147 records from the Idaho Conservation Data Center, of which 110 were precise to 30 m and were included in our analyses. We received 11 additional locations from southern Idaho collected by H. Roberts during 2002, and H. Ulmschneider provided data from 237 sites in Owyhee County. After eliminating points $\leq$300 m apart to reduce spatial dependence, the model was constructed using a total of 164 locations of pygmy rabbits (Figure 2).

We first defined a broad area of potential habitat for pygmy rabbits. Potential habitat was defined using the two attributes that were consistently correlated with presence of pygmy rabbits

in the literature (Appendix 1), sagebrush vegetation and soil depth (depth to bedrock). Of the 164 locations, all but 8 occurred in one of the xeric shrub vegetation categories defined in the Idaho GAP analysis, and all existed in areas of average soil depth ≥60 cm (Figure 3). Therefore, we defined potential habitat for pygmy rabbits in Idaho as those areas that were mapped as xeric shrub with soil depths ≥60 cm. Together, these variables defined an area of 5,696,000 ha of potential pygmy rabbit habitat in Idaho (Figure 4).

Habitat variables used to prioritize potential habitat (Table 1) included average percent clay in the soil, elevation, and slope (Figures 5-7). Sagebrush shrub vegetation was separated from other shrub types, and was assigned higher priority (Figure 8a). Lastly, areas that burned since 1990 were assigned a lower priority (Figure 8b). The average priority values were placed into 6 categories ranking potential habitat from higher to lower priority (Figure 9).

Table 1. Values for priority ratings for habitat variables associated with occurrence of pygmy rabbits in Idaho. These values were applied to the entire area identified as potential habitat to obtain average priority ratings on a statewide extent.

Habitat Variable	Higher Priority	Lower Priority
Percent clay in soil	13-31% in top 60 cm	<13% or >31% in top 60 cm
Elevation	1601 to 2200 m	<1601 or >2200
Slope	0 to 8° slope	>8° slope
Fire history	not burned after 1990	burned during or after 1990
Vegetation	Preferred sagebrush types (mountain big sage, basin and Wyoming big sage, mountain low sage)	Other shrub types (curl-leaf mountain mahogany, bitterbrush)

We evaluated the model's priority ranking for known rabbit locations. Of the 164 locations used to build the model, 8 points were outside of the potential habitat because they did not occur in xeric shrub vegetation. Of the remaining 156 locations, 140 (85%) fell within the two highest

priority areas (Table 2). Although this does not constitute a test of the model, these results suggest that the model is accurately describing areas occupied by pygmy rabbits in Idaho.

Table 2. Land area within Idaho and number of known pygmy rabbit locations that occurred in all habitat categories (potential habitat, priority rank category1-6, and non-habitat). Over 85% (140) of known locations of pygmy rabbits in Idaho fell within the top two priority ranks.

Habitat Priority Category	Area (ha)	# of locations
All Potential Habitat	5,689,507	156
Priority Rank 1	966,832	79
Priority Rank 2	2,465,746	61
Priority Rank 3	1,643,290	12
Priority Rank 4	545,250	4
Priority Rank 5	65,740	0
Priority Rank 6	2,649	0
Non-habitat	N/A	8

Discussion

Habitat models can serve as useful tools for evaluating habitat suitability over large areas and for guiding survey efforts for rarer species (Peterson et al., *in press*). Using information on distribution of potential habitats, biologists can increase efficiency and efficacy of surveys by focusing efforts on locations that have a higher probability of containing suitable habitat for the target species of interest.

The goal of this project was to identify and evaluate potential pygmy rabbit habitat in Idaho, and to use this information to identify locations for future survey work. Because detailed information about habitat associations for pygmy rabbits is limited, we chose a conservative approach to identifying potential habitat. Only habitat characteristics consistently associated

with pygmy rabbits across their range, vegetation and soil depth, were used to determine potential habitat. However, this approach results in designation of >5 million ha within Idaho as potential habitat. Undoubtedly, as more information about habitat relationships for pygmy rabbits becomes available, much of this area will prove to be unsuitable for the species. Lacking detailed data at this time, we opted to err on the side of over-estimating potential habitat (commission error).

In order to help focus survey efforts on areas likely to contain suitable habitat for pygmy rabbits, we prioritized the potential habitat. Those areas that included habitat characteristics more frequently associated with pygmy rabbits in Idaho received higher priority ratings. We refrained from assigning greater importance or statistical weight to individual habitat variables because data are not available to evaluate the relative importance of various habitat components. Prioritizing the potential habitat provided a basis for ranking areas for survey efforts.

The habitat model we developed describes areas used by pygmy rabbits in Idaho as higher priority areas. Most (85%) of the known locations of pygmy rabbits in Idaho fell within the top two priority ranks. Because these points were used to construct the model, this does not constitute a test of the results, but rather, a qualitative assessment of whether locations known to be occupied by rabbits were ranked as higher priority areas. To test or validate the model, new sites must be surveyed for rabbits, both within and outside of predicted potential habitat.

Our approach differed from previous efforts to model habitat for pygmy rabbits in Idaho. Gabler et al. (2000) used 4 GIS layers (vegetation, slope, geology, and aspect) to identify potentially suitable habitat within 2000 km^2 of the Idaho National Engineering and Environmental Laboratory (INEEL). That model was subsequently modified and applied across a portion of Owyhee County in southwestern Idaho (Simons 2001). Both efforts were based on data gathered over relatively small areas. Habitat relationships modeled at one scale (or extent) may not accurately reflect relationships at other (either smaller or larger) scales or extents. For example, Gabler (1997) identified aspect as an important variable characterizing locations of pygmy rabbit burrows at their study site. However, studies in Washington documented a different range of aspects for burrow entrances (Kehne 1991, Gahr 1993). While aspect may be useful for

predicting presence of pygmy rabbit burrows at specific locations, the association may not apply when broader areas are considered. This point is important when examining potential habitat across relatively large areas over which habitat conditions may vary. Preliminary observations indicate differences in vegetation structure and soil characteristics between areas occupied by pygmy rabbits in southwestern and southcentral Idaho (H. Roberts and H. Ulmschneider, pers. com.). We used data from across the State, and applied those results to the same area. Although this approach is course-grained, it is a conservative approach that can and should be refined as additional information is gathered from across the range of the species in Idaho.

Our aim in this modeling effort was to aid biologists in identifying those areas most likely to contain suitable habitat and to support rabbit populations. We addressed this goal by prioritizing areas based on habitat relationships of existing populations. Previous models did not attempt to prioritize habitat, but rather categorized habitat as suitable or unsuitable. We anticipate that use of this model will expedite location of new populations in Idaho.

A couple of caveats should be considered regarding application of the habitat model presented here. First, the model is developed on a relatively coarse scale (30 x 30 m pixel grain size and a statewide extent). Such models are useful in directing search efforts to areas of suitable habitat, but will not pin-point exact locations of pygmy rabbit habitat or populations. Second, although we used known locations of pygmy rabbits from across the State, the model is strongly influenced by points from two regions, southcentral and southwestern Idaho (Figure 1). In part, this distribution reflects recent survey efforts focused in those two areas. Additional surveys are needed to examine other areas of predicted habitat for pygmy rabbits. Such information will provide a test of the existing habitat model, and can be used to refine the model, reduce commission error, and improve our understanding of pygmy rabbit distribution in Idaho.

Recommendations for Surveys

Efforts to locate populations of pygmy rabbits in Idaho should include surveys in areas designated as higher priority ranks. A comparison of the distribution of documented pygmy rabbit locations (Figure 2) with predicted areas of higher priority potential habitat (Figure 9),

reveals several regions that appear to have suitable habitat, but lack records documenting rabbit populations. Following is a breakdown by BLM Field Office Areas (FOAs):

- Idaho Falls FOA: Much of the northern region of this FOA includes areas in the highest two priority ranks. Although not included in records received from the CDC, Green and Flinders (1980b) conducted a habitat assessment for pygmy rabbits on the U.S. Sheep Experiment Station near Dubois, and 15 rabbits were captured at the Station for feeding trials (White et al. 1982). Surveys should be conducted at the Experiment Station to determine the current status and distribution of those populations. Additionally, relatively large tracts of higher priority habitat were mapped at sites west and east of Spencer. Areas surrounding Arco including portions of the INEEL and Craters of the Moon National Monument also were mapped as higher priority. Recent surveys within the INEEL conducted by researchers from Washington State University failed to find signs of active populations at several previously documented sites (R. Westra, pers. com.). A search of suitable habitat within the Idaho Falls FOA should include coordination of efforts with the WSU research team to gain a better understanding of the current distribution of rabbits at the INEEL. Areas of higher priority habitats in the southeastern portions of the Big Lost and Little Lost Rivers and Birch Creek will be surveyed during 2003 by H. Roberts.

- Pocatello FOA: Relatively large tracts of higher priority habitat were mapped in the Pocatello Field Office Area (FOA) to the east and southeast of Pocatello. Pygmy rabbits were recently detected at two sites near Bear Lake (Roberts 2002). Additional surveys along the southeastern State border may provide information regarding potential connections with pygmy rabbit populations in northwestern Wyoming.

- Burley FOA: Most potential habitat within this FOA was mapped south of the Snake River. On-going survey efforts are continuing in this area and will provide needed information about distribution of pygmy rabbits across the southern portion of the State.

- Jarbridge FOA: Much of the southern two-thirds of the Jarbridge FOA contains habitat mapped as higher priority, and some of the largest tracts of highest priority habitat were identified in the southern region, along the Nevada border. This area should be a focus of extensive surveys for pygmy rabbits.

- Owyhee FOA: Several areas of the highest priority rating were mapped across the southwest portion of the Owyhee FOA. Recent surveys by H. Ulmschneider have documented populations in the central region. Additional survey efforts should include areas: a) along the Nevada and Oregon borders; b) west of the Bruneau River and southeast of Grasmere Reservoir; c) southwest and northeast of the Owyhee River; and d) within and adjacent to the Duck Valley Indian Reservation.

- Four Rivers FOA: Although large blocks of higher priority habitat were not mapped in this FOA, areas southwest of Boise along both sides of Highway 84 appear to support suitable habitat and should be surveyed. Additionally, pockets of higher priority habitats were mapped to the north of Boise between Indian Valley and the Crane Creek Reservoir.

Location of rabbits in that area would represent a substantial range extension for the species in Idaho, and may identify isolated and genetically distinct populations.

- Shoshone FOA: A relatively large area north of Cary and east of the Big Wood River was mapped as higher priority habitat and should be a focus for survey efforts. Areas of suitable habitat also were mapped to the north of the Camas Prairie, and smaller patches were apparent along the southern edge of the Prairie. A smaller site of higher priority habitat is apparent north of Bliss, and areas of moderate priority extend eastward and westward from that location.

- Challis FOA: Much of the higher priority habitat in the Challis FOA was surveyed by Roberts (2001) who reported a patchy distribution of pygmy rabbits across most of the remaining intact sagebrush habitat. Active burrows were located at one site to the west of the Salmon River, which was also mapped as higher priority habitat. Additional surveys should investigate the extent of populations in that area.

- Salmon FOA: Much of the higher priority habitat in the Salmon FOA was surveyed in 2001 (Roberts 2001). Known locations for pygmy rabbits are south of Hayden Creek. Areas of higher priority habitat also were mapped north of this location, extending north towards Baker and to the east of Salmon. Surveys in those areas would provide information about the northern extent of the species range in Idaho.

The priority rankings can be used to provide guidelines for allocating survey effort. First, many areas currently managed for wildlife in some capacity (national refuges, national monuments, wildlife management areas, etc.) contain potential habitat mapped in the higher priority ranks (Appendix 2). Because these areas offer at least some protection for native habitats and have personnel who could conduct biological inventories, searching for pygmy rabbits should be raised as a priority within their management objectives. Second, sites that currently lack habitat protection, but are mapped as highest priority, should be searched to identify areas that may contain significant, but vulnerable populations. Decisions regarding habitat management for those areas could accommodate habitat requirements for pygmy rabbits. Lastly, surveys should be conducted in areas of predicted non-habitat that are suspected to support pygmy rabbits. Knowledge about such areas will improve our understanding of the range of habitats used by the species. For example, portions of Craters of the Moon are mapped as non-habitat because soil depths do not exceed 60 cm. However, pygmy rabbits are included on the species list for that area and biologists believe that they may currently inhabit areas on and around cinder cones (M. Muntz, pers. com.). Attributes of those sites should be documented and used to modify and improve the habitat model.

This report and an ArcView GIS map of the priority rankings for pygmy rabbit habitat in Idaho are available upon request from the Idaho State BLM Office and the authors. The GIS map can be used to help identify local areas for ground surveys.

Future Directions

The Idaho State Office of the BLM coordinated the formation of a Pygmy Rabbit Working Group in December 2002 to assist in establishing a survey protocol for pygmy rabbits in the State. Additional efforts have been initiated at the national level through the USFWS. We anticipate coordinating with the Idaho Pygmy Rabbit Working Group and with other biologists (NPS, IDFG, BLM, USFWS, USFS, UI) working in the Idaho sagebrush steppe to compile information on locations of pygmy rabbits, and to survey for rabbits in areas that have higher priority ranks. Survey work during the summer of 2003 is jointly supported by the IDFG, BLM, and University of Idaho. These data will be used to test the model for pygmy rabbits and to refine the model attributes to more accurately reflect habitat associations for this species.

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Appendix 1. Habitat associations for pygmy rabbits and their burrows reported in the literature. See References for complete citations.

Habitat Variable	Reported Association	Selected References
Vegetation Type	Big sagebrush (*Artemisia tridentata*)	Green and Flinders 1980 a & b, Rauscher 1997, Roberts 2001, WDFW 1995, Wilde 1978
	Bitterbrush (*Purshia tridentata*)	Green and Flinders 1980b
	Greasewoood (*Sarcobatus*)	Davis 1939
	"Sagebrush-steppe on lava, sagebrush-steppe off lava, sagebrush-winterfat (*Eurotia lanata*)	Gabler 1997, Gabler et al. 2000
	Lower cover of grasses and/or forbs	Gahr 1993, Katzner and Parker 1997
	No apparent selection for grasses and/or forbs	Green and Flinders 1980b
	Greasewoood (*Sarcobatus*)	Davis 1939
Vegetation Cover & Height	"tall" and "dense sagebrush"	Orr 1940, WDFW 1995
	Greater shrub or sagebrush cover/density	Heady 1998, Gabler 1997, Katzner and Parker 1997, Weiss and Verts 1984, Green and Flinders 1980b, Heady 1998
	Higher shrub height	Weiss and Verts 1984, Green and Flinders 1980b, Gahr 1993
	Greater vegetation structural complexity	Katzner 1994, Katzner and Parker 1997, Heady 1998
	Height: 18-48 in on mounds, <24 in between mounds Cover: 20-60% on mounds, <30% between mounds	Roberts 2001
Soil	"deep," and "loose" soils	WDFW 1995, Weiss and Verts 1984, Wilde 1978
	51 cm depth, greater surface and subsurface strength	Weiss and Verts 1984
	Coarse-silty, fine-loamy, ashy, and coarse-loamy soil types	Kehne 1991
	Greater sand and less clay (< 12.5%)	Gabler 1997
	72% of burrows in <18% clay	Kehne 1991

	96% of burrows in >51cm deep	Kehne 1991
Slope	"a slope"	Wilde 1978
	0-15%	Gabler 1997. Gabler et al. 2000
	Slopes of 2-16% (87% of burrows on slopes of <8%)	Kehne 1991
	5 - 25%	Roberts 2001
Aspect	NE-SW drainages	Gahr 1993
	Southwest to southeast aspect for 53% of burrows	Kehne 1991
	0-120°, 300-360°	Gabler 1997, Gabler et al. 2000
Elevation	5600-7700 ft	Roberts 2001
Topography	"Mound/intermound topography" for 49% of burrows; areas of "microrelief"	Kehne 1991
	"Mima-type mounds"	Roberts 2001
	"contours" and "slope"	WDFW 1995
Geology		
	Alluvial fans	Orr 1940, Green and Flinders 1980, Roberts 2001
	Loess or glacial parent materials	Kehne 1991
	Surfacial and alluvial deposits (QMP,QFY,QP,QES) and basaltic lava flows and pyroclastic deposits (QBB,QBC,QBD)	Gabler et al. 2000, Heady et al. 2001

Appendix 2. Area (ha) of predicted potential habitat for pygmy rabbits listed by priority rank for managed areas in Idaho. Only managed areas without pygmy rabbits listed on the known species list are shown. Some of the managed areas listed below are outside of currently known range for pygmy rabbits in Idaho (i.e. Craig Mountain WMA and Garden Creek Preserve).

Managed Area	1.00	1.20	1.40	1.60	1.80	2.00	Total
Barber Dam Pool Area	0	0	1	3	0	0	4
Big Creek Drainage	26	655	1559	2662	1704	77	6683
Blackfoot River WMA	232	97	0	0	0	0	329
Bruneau Dunes State Park	0	0	4	324	79	0	407
Camas NWR	0	1611	462	110	24	0	2206
Camas Prairie Centennial Marsh WMA	0	94	0	0	0	0	94
Carey Lake WMA	0	68	0	0	0	0	68
Cartier Slough WMA	0	4	25	3	0	0	32
Cecil Andrus WMA	1	262	1052	1612	51	0	2977
Chilly Slough WHA	5	0	0	0	0	0	5
Cottonwood WMA	0	139	63	25	0	0	227
Craig Mountain WMA	0	0	23	560	909	0	1492
Flat Ranch	44	0	0	0	0	0	44
Fort Boise WMA	0	0	0	36	0	0	36
Garden Creek Preserve	0	0	13	313	258	0	584
Georgetown Summit WMA	138	315	7	0	0	0	460
Grays Lake NWR	507	62	0	0	0	0	569
Hagerman Fossil Beds NM	0	111	127	100	9	0	347
Hagerman WMA	0	0	10	14	0	0	24
Harriman State Park	126	0	0	0	0	0	126
Mahogany Creek RNA	0	2	4	0	0	0	6
Market Lake WMA	0	408	180	3	0	0	591
Meadow Canyon RNA	0	4	9	2	0	0	14
Middle Canyon RNA	10	228	84	105	0	0	427
Minidoka NWR	0	21	2037	842	2	0	2903
MontpelierWMA	114	636	91	0	0	0	841
Mud Lake WMA	0	529	551	426	25	0	1531
North Fork Boise River RNA	0	0	3	0	0	0	3
Portneuf WMA	89	324	377	57	1	0	849
Sawtooth NRA	2705	7436	9622	746	0	0	20509
Silver Creek Preserve	0	7	11	2	0	0	20
Sterling WMA	0	0	338	37	0	0	375
Tex Creek WMA	833	2066	2482	771	74	0	6226

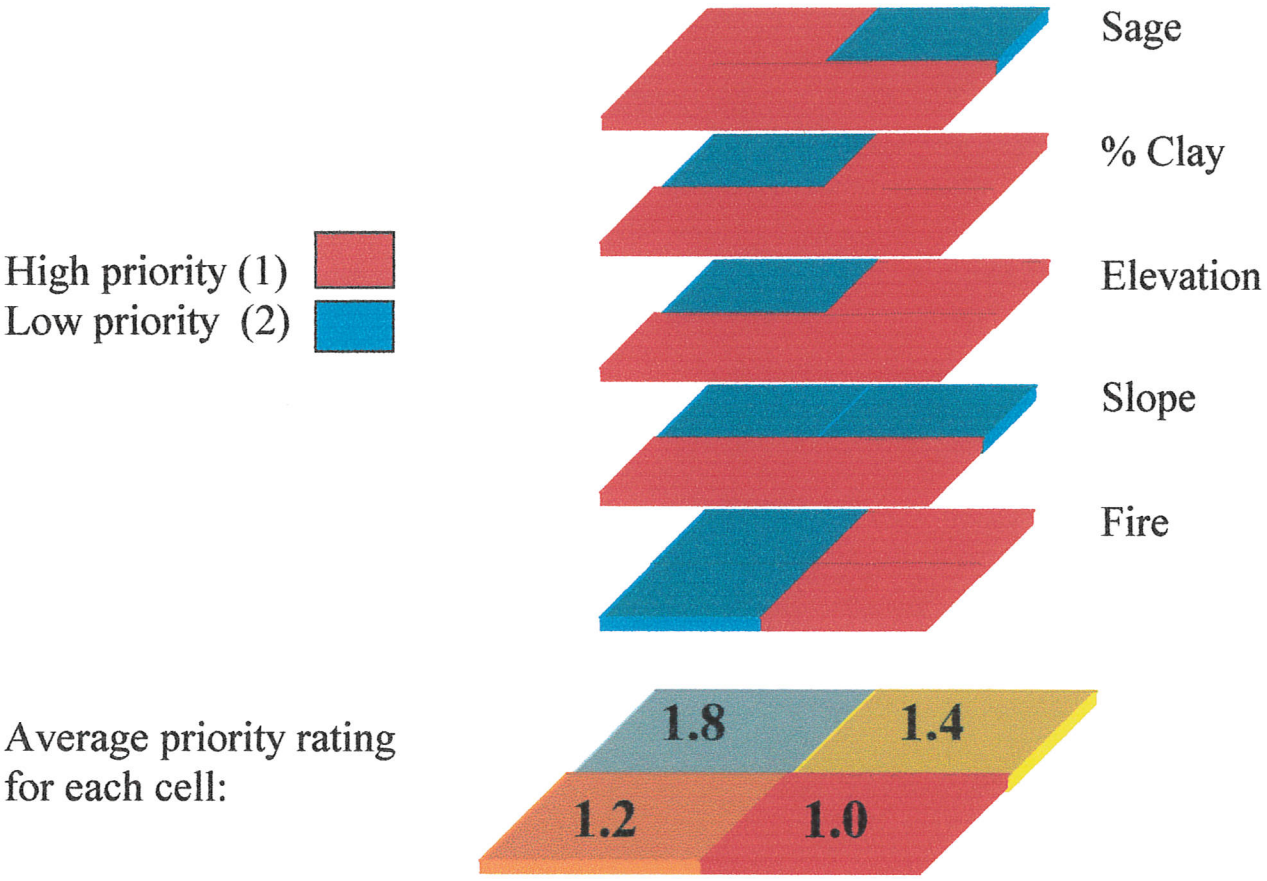


Figure 1. Schematic diagram illustrating how high and low priority ratings for each variable were combined to calculate an overall priority rating for potential pygmy rabbit habitat. Priority ratings were placed into 6 categories ranking habitat from higher to lower priority for survey efforts.

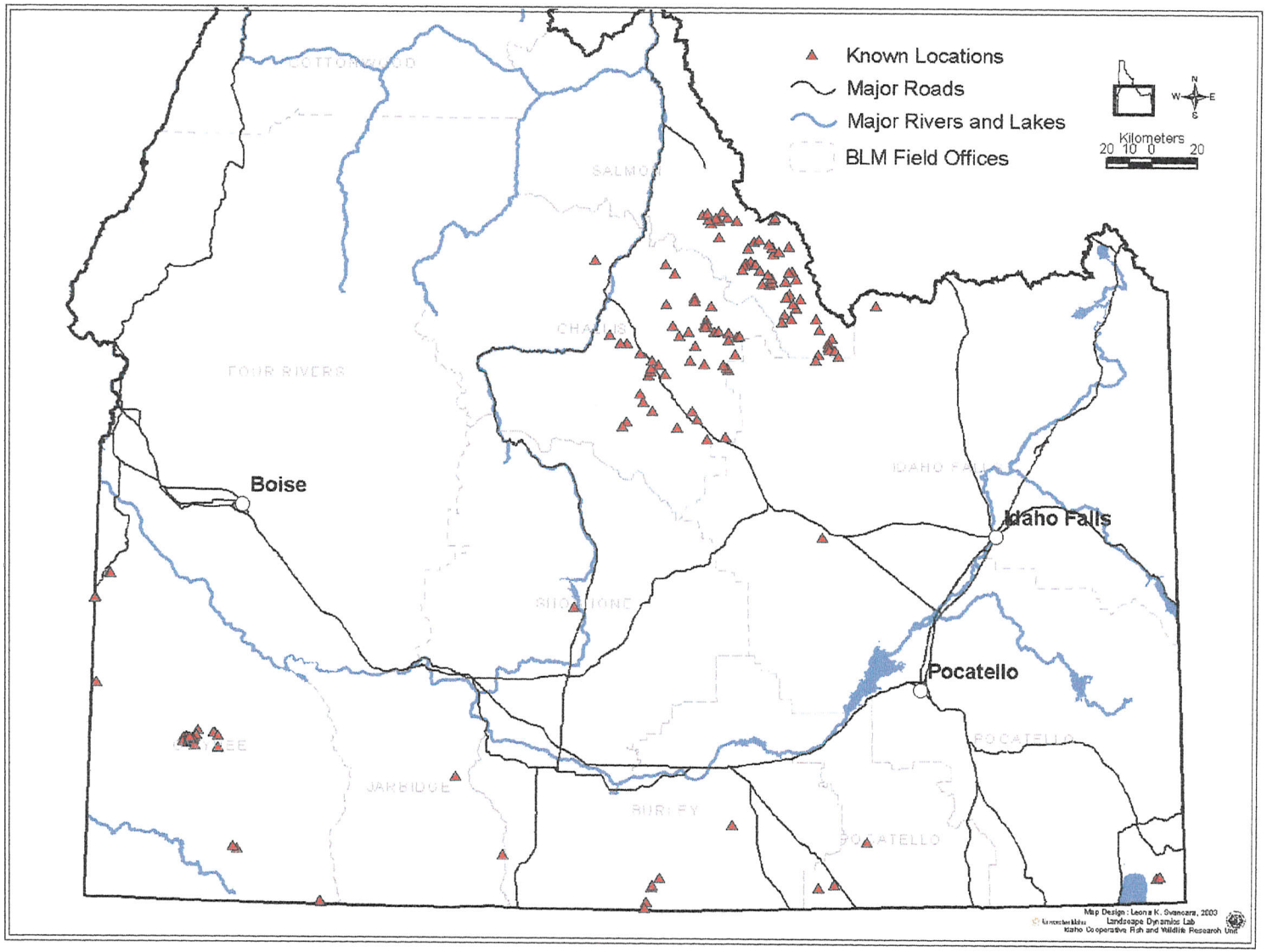
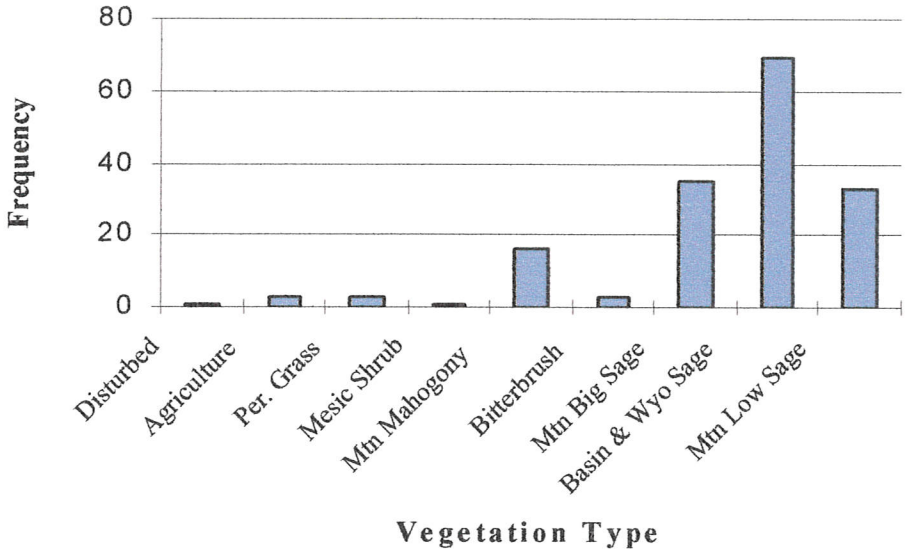


Figure 2. Locations of pygmy rabbit occurrences (n = 164) used to construct the statewide model of potential pygmy rabbit habitat. Location data were received from the Idaho state Conservation Data Center and from surveys conducted by H. Roberts and H. Ulmschneider during 2002.

a)



b)

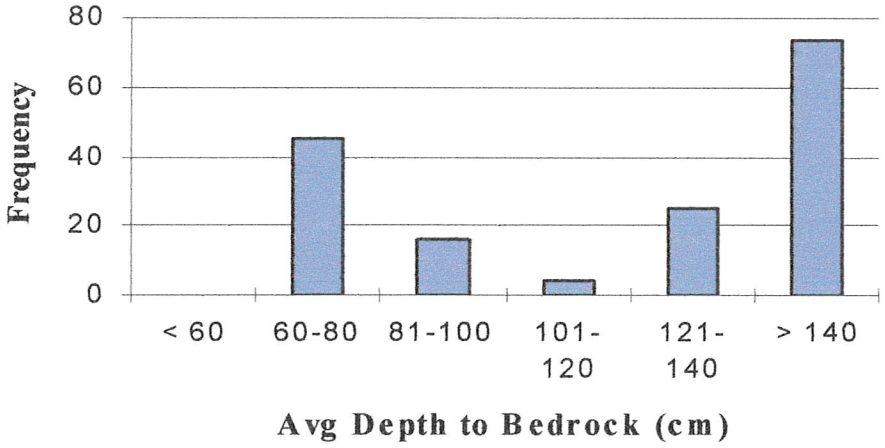


Figure 3. Distribution of values for a) vegetation cover type and b) soil depth-to-bedrock for known rabbit locations in Idaho (n=164). These two habitat variables were used to identify potential habitat for pygmy rabbits in Idaho.

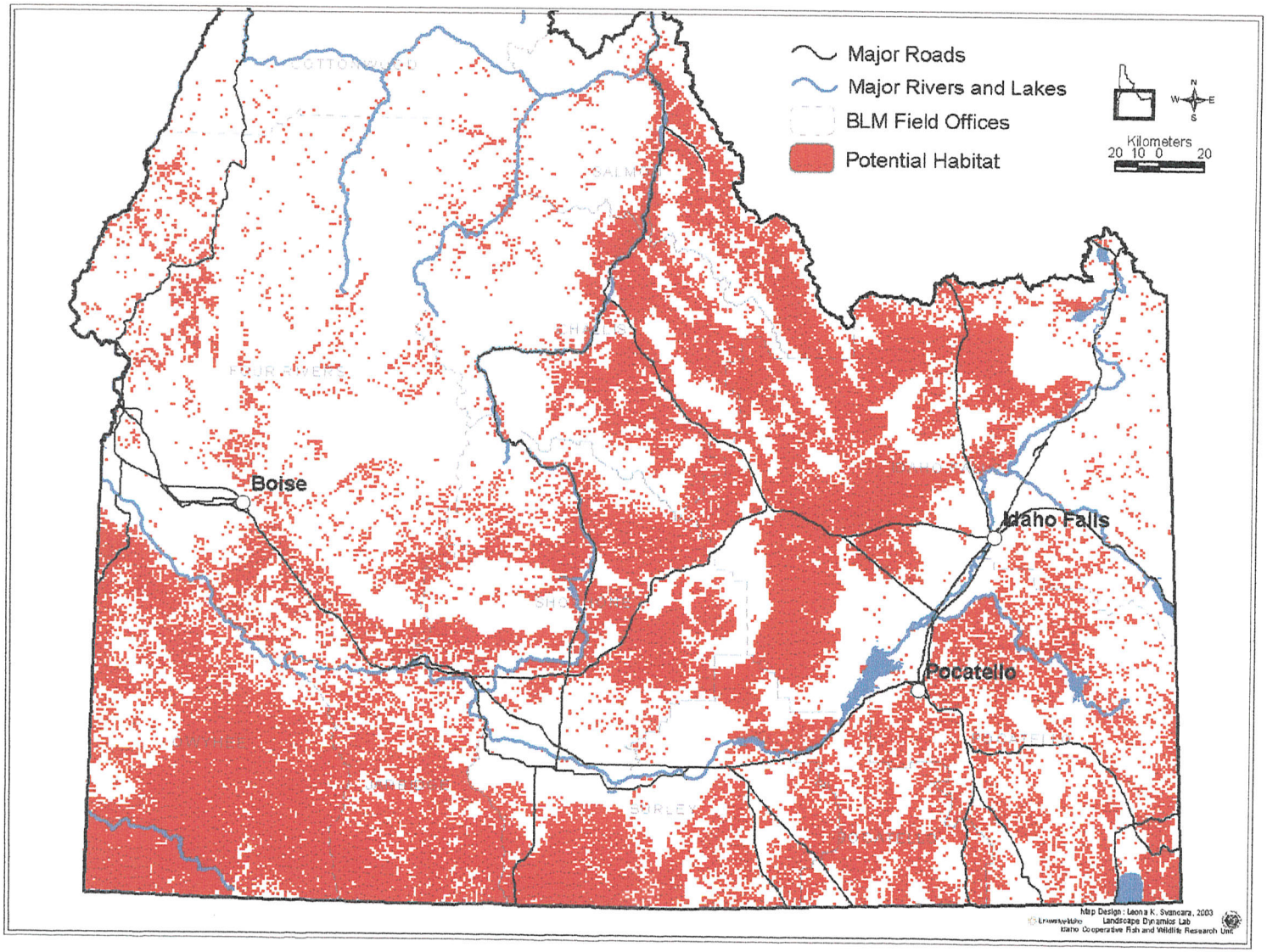


Figure 4. Potential habitat for pygmy rabbits in Idaho defined as areas with xeric shrub vegetation type and average depth-to-bedrock > 60 cm.

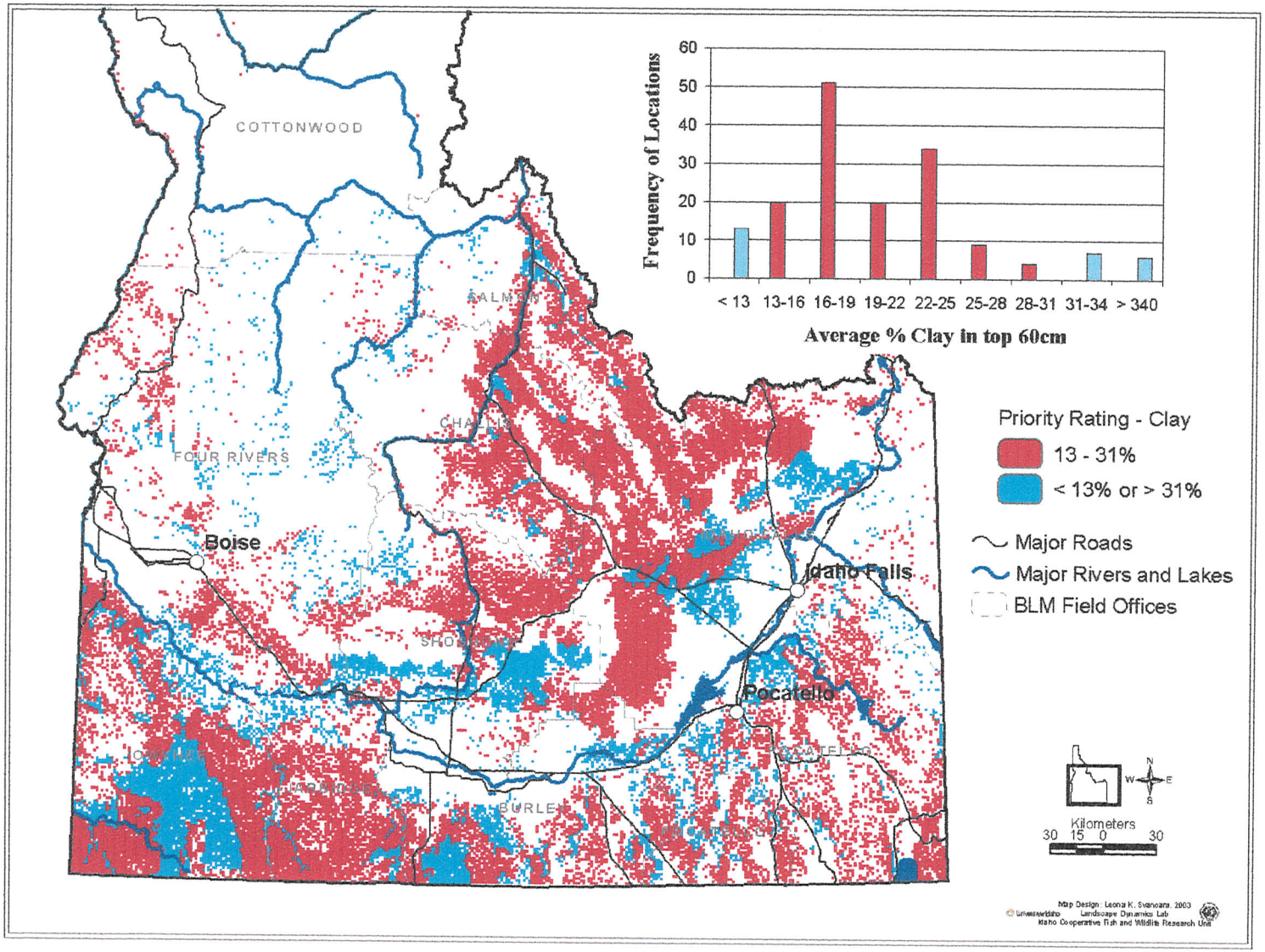


Figure 5. Spatial and quantitative distribution of higher priority areas based on the average percent clay in the top 60 cm of soil. High priority areas are shown in red.

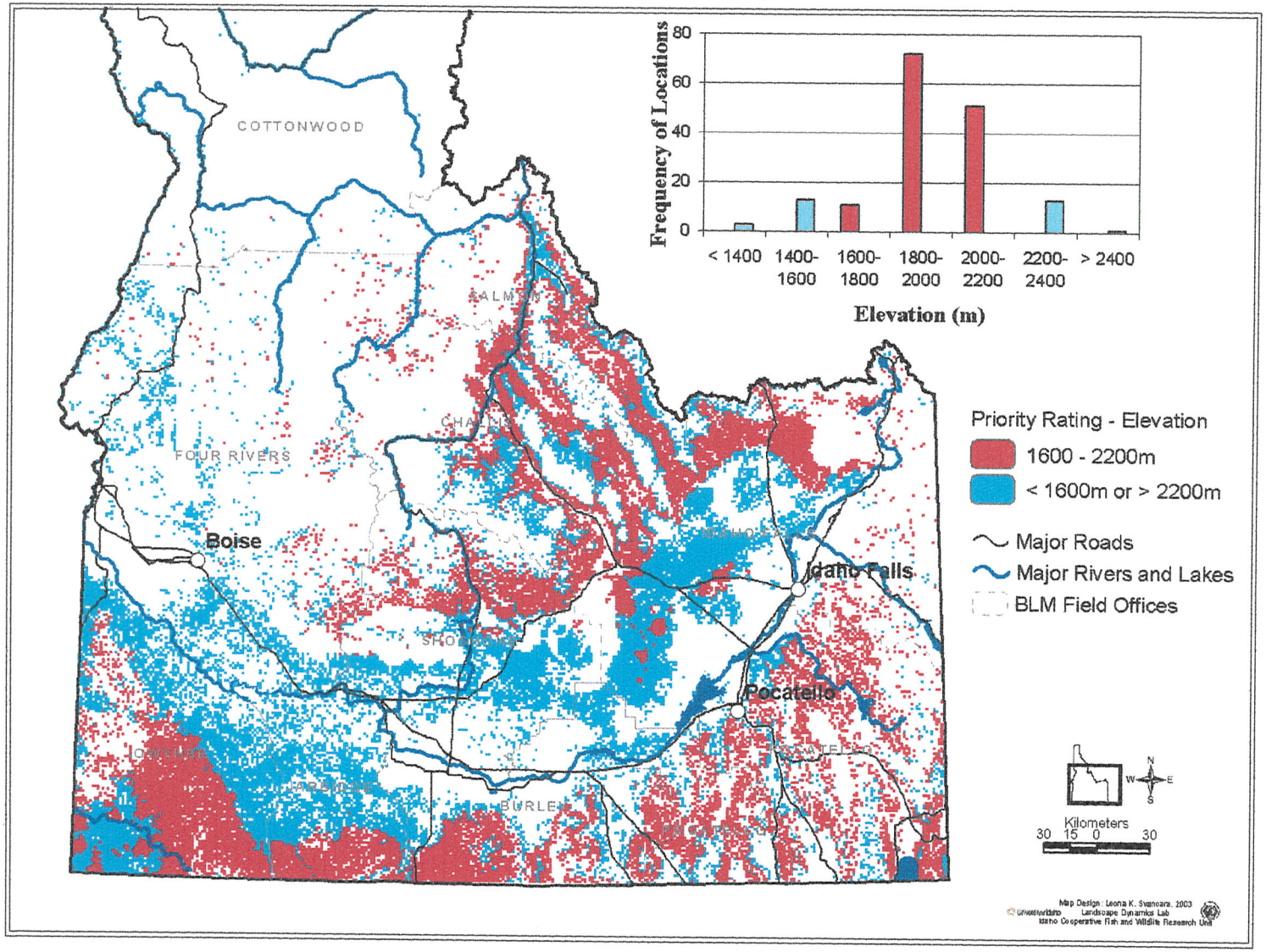


Figure 6. Spatial and quantitative distribution of higher priority areas based on elevation. High priority areas are shown in red.

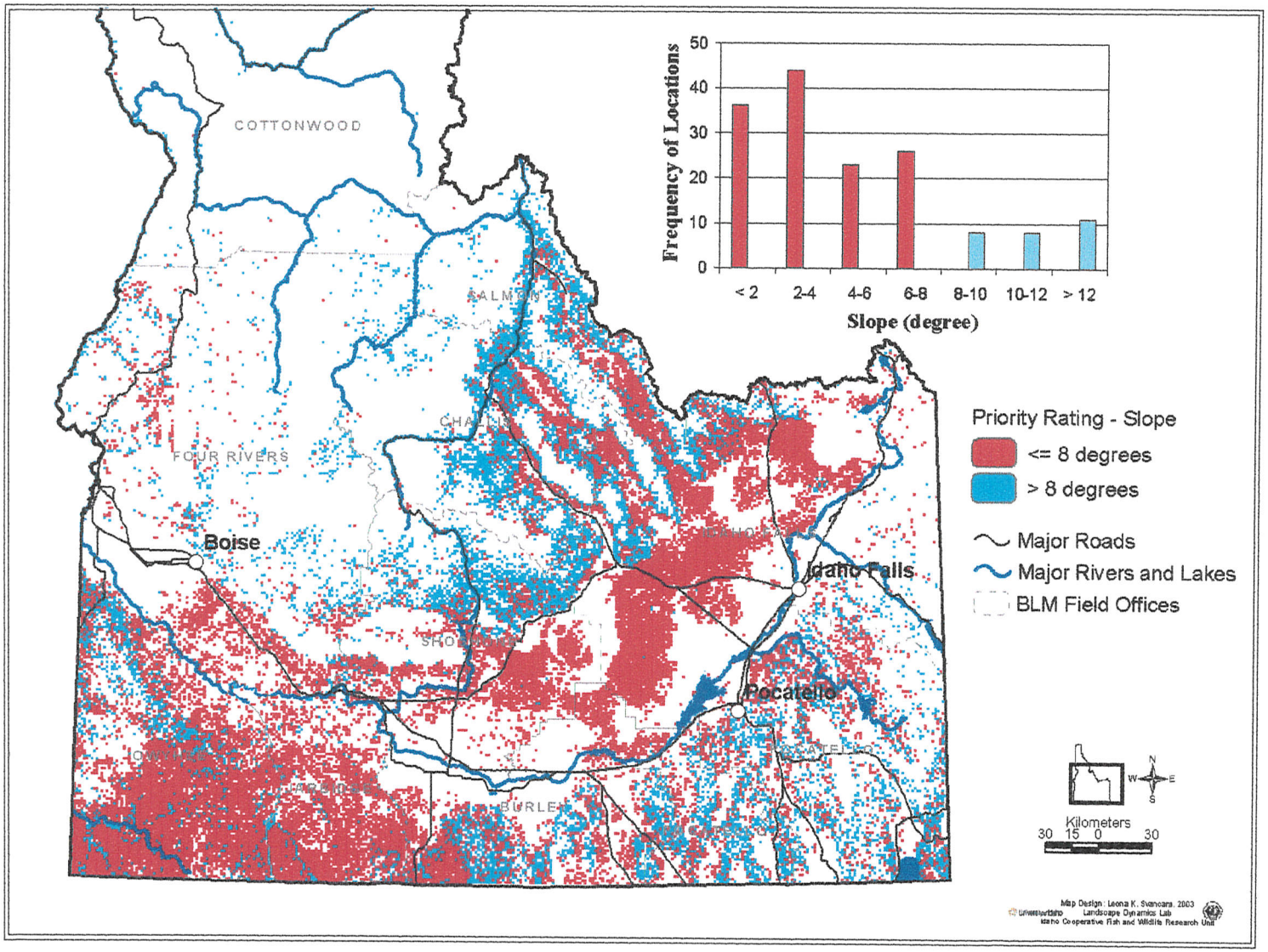
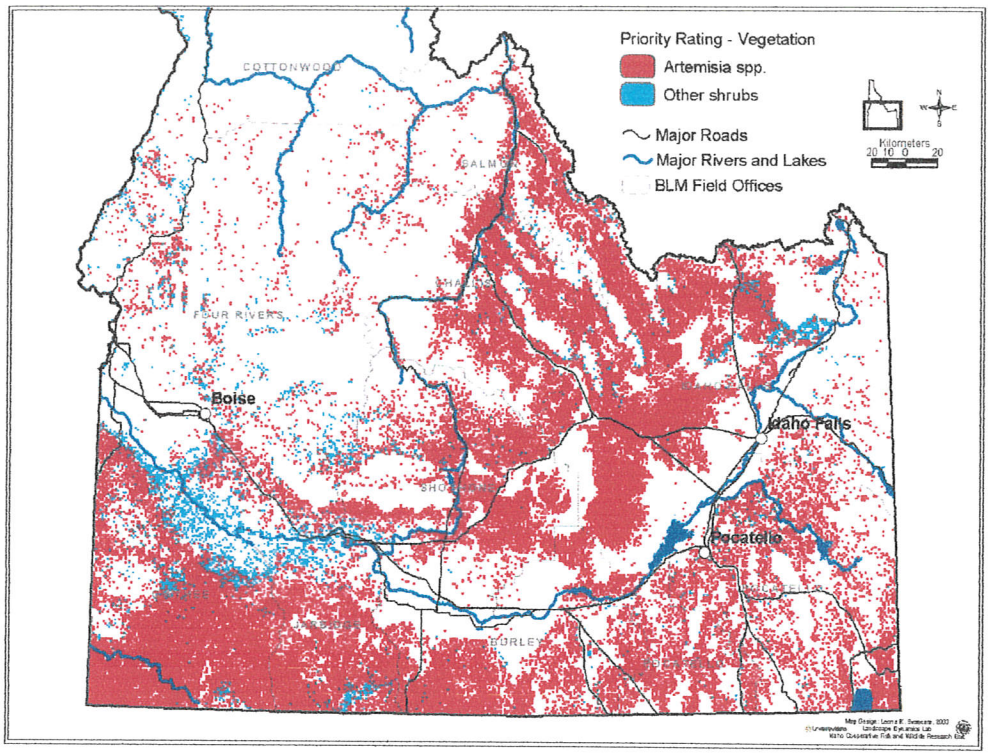


Figure 7. Spatial and quantitative distribution of higher priority areas based on slope. High priority areas are shown in red.

a.



b.

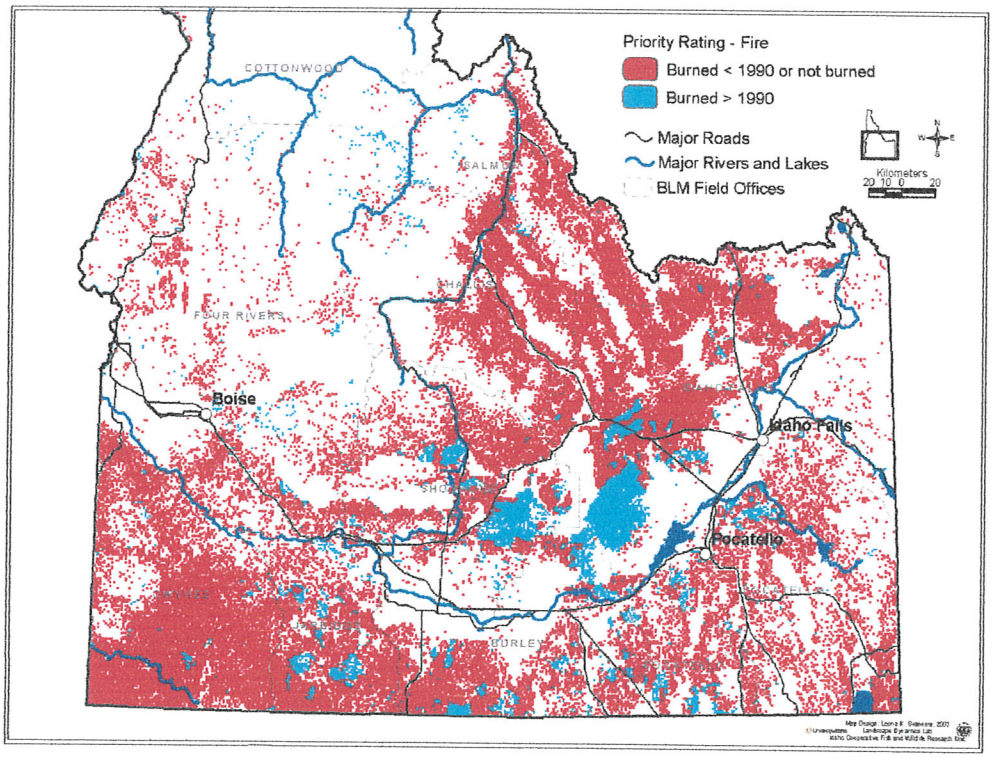


Figure 8. Spatial distribution of higher priority areas for a) vegetation and b) fire. High priority areas are shown in red.

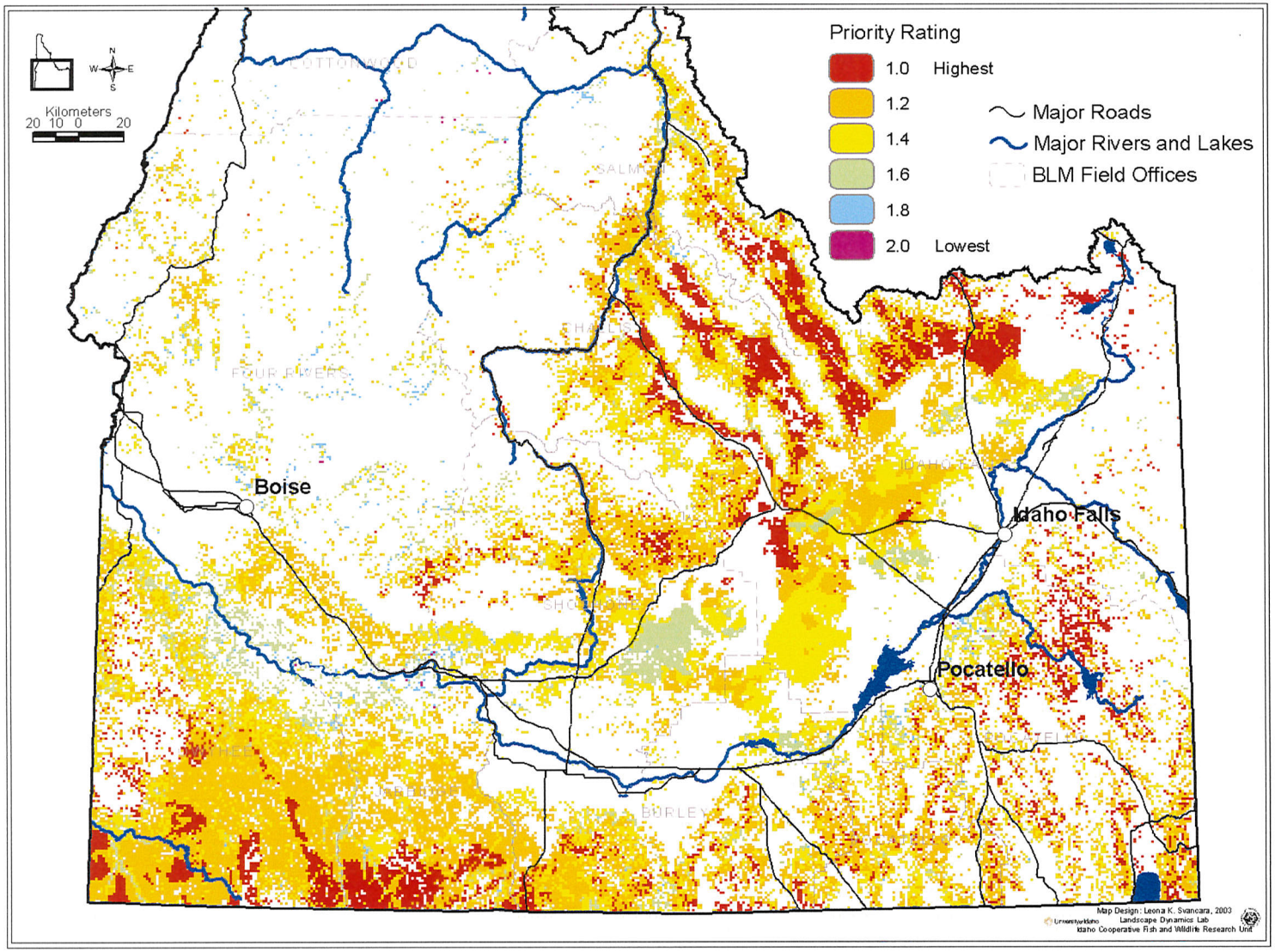


Figure 9. Priority rankings for potential habitat for pygmy rabbits in Idaho. Ranks were assigned by averaging values for variables described in Table 1. Each pixel of potential habitat was ranked from higher to lower priority to guide survey efforts for pygmy rabbits.