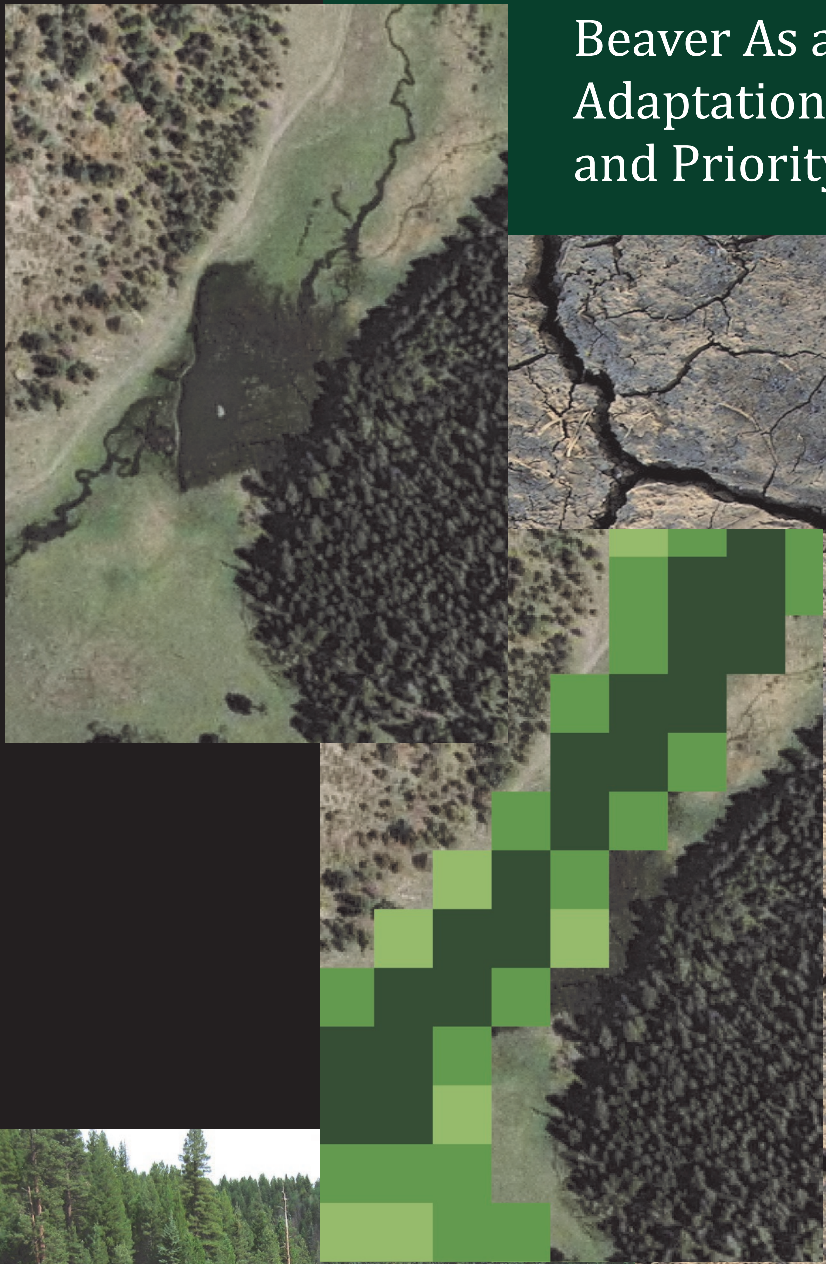
Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico



Cathryn Wild

Seventh Generation Institute

Bringing Together People And Science for Conservation

May 2011

Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico

Seventh Generation Institute
Bringing Together People
and Science for Conservation

Cathryn Wild
May 2011

Cover Images: Three views of a beaver dam and pond on the Rio Cebolla, Jemez Mountains, New Mexico. Top: 2009 NAIP imagery. Center: 2009 NAIP imagery with overlaid modeled habitat. Bottom: Ground level view of beaver pond. Photo: William J. Morris

Report Author: Cathryn Wild. Correspondence may be sent to cwild@seventh-generation.org

Acknowledgments

This study would not have been possible without the vision and financial support of the Board of Directors of Seventh Generation Institute.

The author and Seventh Generation Institute would like to thank the ESRI Conservation Program which provided software and technical assistance to this study, as well as the following for general support of the *Building Riparian Resilience through Beaver Restoration* project:

- The Norcross Wildlife Foundation
- The Biophilia Foundation
- Patagonia Inc.
- The US Fish and Wildlife Service, Partners for Fish and Wildlife Program, New Mexico
- Individual donors, supporters and volunteers

We would also like to thank Shane Moore for technical assistance, several anonymous reviewers who provided insights that improved the final report, and The Nature Conservancy of New Mexico and Arizona, the USGS Southwest Regional Gap Program, Robert Sivinski, New Mexico Forestry Department, and Rick Winslow, New Mexico Department of Game and Fish for generously sharing data and information.

Suggested Citation

Wild C. 2011. Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico. Seventh Generation Institute. Santa Fe, New Mexico. 19 pp + appendix.

About Seventh Generation Institute

Seventh Generation Institute is a nonprofit conservation organization based in Santa Fe, New Mexico. The Institute's mission is to conserve biological diversity and foster sustainable resource use through excellence in applied science and collaboration. The Institute is nonpartisan, non-confrontational, and works through applied science and collaboration to achieve its mission.

Seventh Generation Institute
PO Box 31698
Santa Fe, NM 87594
www.seventh-generation.org

Executive Summary

As climate change makes its presence known in New Mexico, conservationists and natural resource managers are seeking practical tools that help ecosystems adapt. In this report we explore the use of beaver as a climate change adaptation tool.

The report is divided into two sections. In the first, we discuss how specific ecosystem modifications that result from the presence of beaver address climate change threats and some challenges associated with using beaver for this purpose. We note that beaver populations are currently low in New Mexico and describe some causal factors.

In the second section, we describe a spatial analysis completed by Seventh Generation Institute to determine how much potential suitable beaver habitat is found in New Mexico, where it is located, and where priority areas are found for the presence of beaver.

In this spatial analysis we found a total of 281,385 hectares (695,302 acres) of potential suitable beaver habitat. Most of the habitat is concentrated in the northeast third of the state with additional significant areas of habitat in the Sacramento Mountains and the Gila River and its tributaries. The majority of potential suitable beaver habitat, 66%, is located on privately-owned land. Additional habitat may exist on intermittent streams that were excluded from the analysis. Based on the analysis, we conclude that there is a large amount of unoccupied, but potential suitable habitat in New Mexico and that the abundance of beaver in the state could increase.

We compared this habitat to priority conservation areas identified in previous work by The Nature Conservancy and ranked by its biodiversity conservation value and vulnerability to climate change. We identified ten areas that are very high priorities for the presence of beaver. In eight of these areas, we identified HUC 12 watersheds which are both priorities and contain sufficient potential suitable beaver habitat.

The two principal conclusions of the report are:

- If properly managed, beaver can be a potent climate change adaptation tool. An increase in the population is a "no-harm" strategy, since beaver are native to New Mexico. Methods for managing beaver are established and can be put into place immediately. Given the great value of riparian corridors in the state, increasing the beaver population in appropriate areas seems prudent.

- The current population of beaver in the state is quite low. Using the most conservative estimate of the population that could be supported by the modeled habitat, we find that the current population of 8000-10,000 beaver, is approximately one sixth the potential population. Less conservative estimates or inclusion of some intermittent habitat could place the population much higher. *An increase in the abundance of beaver is both necessary and desirable in order to achieve climate change adaptation goals.*

Introduction

Climate change is writing its story upon the lands and waters of New Mexico (Williams and others 2010; Enquist and Gori 2008). The first chapters in this story are sobering, causing natural resource managers and conservationists to re-evaluate their thinking about how to manage land, water, and wildlife. Reading between the lines to glimpse what lies ahead, resource managers are seeking practical and effective tools that are locally appropriate and can adapt ecosystems to climate change. This report describes one such possible tool, the beaver, and provides information on where to use this tool in New Mexico.

Report Goals and Objectives

The report has two sections. The purpose of the first section, **Beaver As a Climate Change Adaptation Tool***,* is to explore the questions:

- *How do beaver function as a climate change adaptation tool?*
- *What are some strategic challenges to the use of beaver as a climate change adaptation tool?*

This section is not intended as a comprehensive review of climate change, riparian corridor restoration, beaver ecology, or the history of land and water use decisions in New Mexico. A rich literature exists on all of these topics. We describe some climate-related changes in watersheds and riparian corridors and describe the modifications to riparian corridors made by beaver. We then "connect the dots" between beaver and climate change to show how beaver can be an adaptation tool. Following, we describe two strategic challenges to the use of beaver. The information presented in the first section of the report serves as background for understanding the concepts and results of the second section.

Sidebar 1.

Resilience. Resilience is defined as the amount of change or disturbance that a system can absorb without undergoing a fundamental shift to a different set of processes and structures (Holling 1973).

Riparian corridors. In this report, we define riparian corridors as follows: the riparian corridor includes the aquatic ecosystem and that portion of the terrestrial ecosystem substantially affected by the presence of surface and groundwater. Riparian corridors consist of perennial and intermittent streams, along with embedded ponds and wetlands, and adjacent lands with soils, vegetation, and landforms indicative of high soil moisture or frequent flooding. They have variable widths that are determined by ecologically significant boundaries rather than arbitrary distances. No single feature is used to delineate these ecosystems.

Functional beaver management. A spectrum of land and water management approaches that range from minimal acceptance of beaver (tolerance of beaver in the area, refraining from removal, use of impact management techniques such as flow devices, etc.) to proactively seeking to support or restore beaver populations in an area (habitat restoration, reintroduction, etc.). These approaches are linked by the goal of accruing benefits from the presence of beaver. Functional beaver management acknowledges that not all areas are appropriate for beaver and that removal of beaver from these areas may sometimes be required.

In section two, **Priority Areas For Beaver As a Climate Change Adaptation Tool**, we sought to address one of the strategic challenges noted in section one. Specifically, we explore the question:

- *Where are some priority areas in New Mexico for the use of beaver as a climate change adaptation tool?*

To answer this question, Seventh Generation Institute carried out a spatial analysis. Specific objectives of the analysis were:

1. Develop a GIS-based habitat suitability index model of potential suitable beaver habitat.
2. Identify climate change-related "hot spots" - areas of high biodiversity conservation value and high climate change exposure.
3. Compare the habitat model results with the hot spots to develop a final suite of high priority sites for "functional beaver management" (Sidebar 1) mapped at the HUC 12 watershed level. The watersheds will meet the following criteria:
   - Contain sufficient potential suitable beaver habitat to maintain viable populations.
   - Be located within areas of forecast high climate change vulnerability.
   - Be located within areas of high biodiversity value.

Seventh Generation Institute will use the information developed through the study to guide actions in its project, *Building Riparian Resilience through Beaver Restoration*. We hope that the information in this report will be used by other managers and restoration practitioners, when considering management actions in New Mexico.

Beaver As a Climate Change Adaptation Tool

Climate Change Effects

Recently released studies describe the current and anticipated effects of climate change in the western US and New Mexico (Williams and others 2010; CCSP 2008A; Enquist and Gori 2008; Saunders and others 2008). From 2003-2007, average temperatures in the western US increased 70% more than global average temperatures (Saunders and others 2008). In New Mexico, Enquist and Gori (2008) found that over 95% of the state had experienced heating and drying.

Below, we list some climate change effects which are relevant to this study:

- Warming temperatures.
- Changes in the form, timing, quantity and/or distribution of precipitation, including both increases in the number of, length of, or severity of droughts and an increase in the number and/or severity of intense precipitation events.
- Changes in the timing or intensity of snowpack melt and peak runoff events, and resulting changes in stream flows – typically greater winter flows and lesser summer flows.
- Consequent loss or degradation of habitats from the above, e.g. increasing temperatures in mountain streams, accelerated erosion, drying and loss of riparian vegetation, increased number and severity of wildfires, and others.
- Shifts in species distribution, often along altitudinal gradients.

Over the coming decades, heating and drying trends are expected to persist and increase. The changes will not be uniform across the lands and waters of New Mexico, but rather will vary from place to place (Enquist and Gori 2008). Since water and watersheds in New Mexico are vital for human consumption, economic activities, recreation, wildlife and more, the outlook is worrisome.

Many Conceptual Approaches; Fewer Practical Tools

Presently, the natural resource manager's toolbox for adapting ecosystems to climate change contains mostly conceptual tools, including "resistance," "resilience," "response," "refugia," "triage," and others, which have been discussed by various authors (Cole and others 2010; Seavy and others 2010; CCSP 2008B; Enquist and Gori 2008; Heller and Zavaleta 2008; Millar 2007). But as these authors have noted, translating these conceptual tools into practical, on-the-ground techniques and selecting those that are appropriate for specific locations, has been challenging.

Although something of a buzzword, increasing the resilience (Sidebar 1) of ecosystems is a commonly suggested adaptation strategy that can, at a minimum, buy time for species and communities (Millar 2007). Resilience succinctly captures the concept of healthy function, describing an ecosystem in which past damage has been repaired, processes are intact or nearly so, and which is in the best condition to spring back from climate change-related disturbances and continue to provide ecosystem services. Resilience is also a low-risk approach relative to other possibilities such as assisted migration. Under the umbrella concept of fostering resilience, two strategies are frequently suggested: 1) to restore keystone species; 2) to restore intact disturbance regimes (CCSP 2008B).

Connecting the Dots - The Beaver As Resilience Engineer

In 2008, Seventh Generation Institute recognized that beaver could be a tool to build resilience in riparian corridors (Sidebar 1) for the purpose of adapting to climate change. Further, that beaver could be the practical, on-the-ground tool that was entirely appropriate for New Mexico's watersheds.

Using beaver as a riparian corridor restoration tool is an established technique. Early projects using beaver as a restoration tool were completed by Apple and others (1985), McKinstry and Anderson (1997), Vore (1993), and others. Much of this work received surprisingly little attention, likely due to the perception of beaver as a nuisance species. But a small number of projects using beaver for habitat restoration and stream restoration are currently underway in Utah, Oregon, Washington, and elsewhere in the US. To make the conceptual leap from beaver-as-restoration-tool to beaver-as-climate-change-adaptation-tool requires only "connecting the dots" (Table 1).

Seventh Generation Institute launched the *Building Riparian Resilience through Beaver Restoration* project in the summer of 2008. The project seeks to use beaver to adapt riparian corridors to climate change in New Mexico, where possible and practical, using a variety of techniques, which we label "functional beaver management" (Sidebar 1).

How Can Beaver Be a Tool to Build Resilience?

Beaver are "ecosystem engineers" (sensu Jones and others 1994), a cross-cutting label that incorporates at once the concept of keystone species and agent-of-disturbance, two of the recommended strategies for resilience building. Beaver are capable of modifying their physical environment more than any other animal except humans (Johnston and Naiman 1987), and arguably are the foremost biological influence in shaping riparian corridors (Naiman and others 2000). Excellent reviews of the effects of beaver on all aspects of riparian corridors are provided by Rosell (2005), Pollock (2003), Gurnell (1998) and Naiman and others (1988). The loss of huge numbers of beaver by intense trapping was a first step in converting dynamic and complex stream and river ecosystems into the relatively static and simplified water delivery systems that we see today. Below is a summary of ecosystem modifications, derived from Hammerson (1994) that may occur when a section of stream is converted to a beaver dam-pond complex (actual effects are site specific):

- Storage of precipitation, which is gradually released through dry periods, and reduced variability in discharge regime.
- Decreased current velocity.
- A several hundred-fold increase in the wetted surface area of the channel (in areas of gentle topography).
- Increased water depth.
- Elevation of the water table.
- In forested areas, an increase in the amount of open canopy.
- Loss of wildlife species that depend on living riparian deciduous trees.
- Enhancement or degradation of conditions for fishes.
- Creation of conditions favorable to wildlife that depend upon ponds, pond edges, dead trees or other habitats not present or in limited supply in stream systems not modified by beaver.
- Replacement of running-water invertebrate taxa by pond taxa, and an increase in the absolute importance of collectors and predators and a decrease in the relative importance of shredders and scrapers in impounded sites.
- A several-fold increase in the mass of insects emerging from the water surface per meter of stream length.
- Increased plankton productivity.
- Increased trapping of sediment and a decrease in turbidity downstream.
- More favorable conditions for the growth of plants such as willow and alder.
- A great increase in the amount of organic carbon, nitrogen (and its availability) and other nutrients in the channel; an increase in carbon turnover time; and an increase in nitrogen fixation by sediment microbes.
- Amelioration of stream acidity.
- An increase in aerobic respiration, the amount in a pond being 16 times that in a riffle.
- In low-order streams a substantial shift to anaerobic biogeochemical cycles in sediments

beneath the aerobic pond sediments.

- An increase in the amount of organic matter suitable for methane-producing microorganisms and increased carbon output by methanogenesis.
- Reduced oxygen levels in the water in spring and early summer due to decomposition of the augmented organic matter.
- Increased resistance of the ecosystem to perturbation.

Linking Beaver, Resilience and Climate Change

These structural and biogeochemical modifications created by beaver are the elements that riparian corridors and surrounding watersheds need to buffer them against the altered conditions and intensified disturbances that climate change will deliver. In Table 1 below, we have paired beaver-driven ecosystem modifications with the climate change threat that is addressed. We expect that there are additional adaptation mechanisms in a beaver-influenced system that will be revealed through research or restoration case studies.

Challenges In the Use of Beaver

Functional Absence of Beaver in New Mexico

Beaver are present in New Mexico. Why are they not already operating as a climate change adaptation tool? In some places in New Mexico, they may be. But in many other places, their numbers are low, or they are lacking entirely.

Early fur trappers described the state's beaver population in rivers and tributaries as "exceedingly numerous" (Bailey 1931). Nationally, the beaver population has been reduced from a pre-European estimate of 60-400 million to a current estimated level of 6-12 million (Nillsen and others 2007; Pollock and others 2003; Naiman and others 1988). The New Mexico Department of Game and Fish (NMDGF) estimates that 8000-10,000 beaver are present (personal communication, Rick Winslow, NMDGF). NatureServe (2010) ranks beaver populations as "secure" in most of the West. The exception is New Mexico, in which beaver populations are ranked "vulnerable."

The abundance of beaver is key to their function. At this population level, beaver are not fulfilling their role as ecosystem engineers, a concept variously termed "ecological absence" (McKinstry and others 2001; Naiman and others 2000) or "below the threshold of ecologically effective density" (Soule and others 2003). In order to function as a climate change adaptation tool, beaver need to be present in New Mexico in greater numbers.

The population remains low for several reasons. Poor habitat quality impedes recolonization in some areas. NMDGF euthanizes approximately two hundred nuisance beaver per year at the request of landowners. Legal recreational trapping and landowners who act to destroy nuisance beavers remove an unknown additional number (personal communication, Rick Winslow, NMDGF). Many landowners and managers consider beaver to be valueless (Seventh Generation Institute, unpublished data).

Where Are the Priority Areas For the Use of Beaver?

Additional challenges in the practical use of beaver, include determining where the approach will work and where it can be most effective. There has been little information available on the location of beaver habitat in New Mexico. Nor has there been information available on where the presence of beaver will yield the greatest benefits. Resource management and conservation are today conducted in a context of scarce resources and the need to demonstrate results, so information on priority areas for functional management of beaver is needed to guide efforts.

Table 1 . Connecting the Dots: Beaver as a Climate Change Adaptation Tool

Climate-related Threat	Link to Beaver Ecosystem Modifications
Warming temperatures	Elevated water tables surrounding beaver-modified areas increase the density and height of shrubby vegetation, shading water and lowering temperatures (Baker and Hill 2003; Collen and Gibson 2001; McKinstry and others 2001; Naiman and others 1988). Dam-pond complexes and an increase in large woody debris from beaver foraging and dam building activity create greater aquatic habitat complexity, including deep pools and other thermal refugia for temperature sensitive species in both summer and winter (Baker and Hill 2003; Pollock and others 2003; Collen and Gibson 2001; McKinstry and others 2001; Naiman and others 1988).
Increased severity or frequency of drought; diminished summer stream flows	Reduced discharge variability (Pollock and others 2003; Hammerson 1994:;Naiman and others 1988). Beaver dam-pond complexes increase water storage in the surrounding soil, which is slowly released during times of low flow. Seasonal stream flows will be extended, maintaining habitat for aquatic species and maintaining a floodplain connection, in turn maintaining complex communities of native vegetation (Baker and Hill 2003; Hammerson 1994). Extended stream flows will be even more important in coming years as precipitation decreases (CCSP 2008B).
Intensified run-off events, increased erosion, sediment loads	Beaver dam-pond complexes create a stair-step profile in the stream, decreasing current velocity, stream energy and channel down-cutting (Rosell and others 2005; Baker and Hill 2003; Gurnell 1998; Hammeson 1994). Sediment loads are dropped in the slowed water behind ponds. Downstream water quality and habitat for some fish, as well as amphibians and other species, are improved (Baker and Hill 2003; Collen and Gibson 2001; Naiman and others 1988). Beaver activity adds large woody debris to streams and ponds, increasing channel complexity, improving habitat and further decreasing stream velocity (Naiman and others 2000).
Down-cutting of channels, Disconnection of water table from flood plain, loss or alteration of riparian vegetation communities	Beaver dam-pond complexes decrease or halt stream channel incision, aggrade sediment, and elevate the water table, increasing the extent and complexity of riparian vegetation, and locally decreasing the risk or severity of fires (Cooke and Zack 2008; Baker and Hill 2003; Pollock and others 2003; Collen and Gibson 2001; Hammeson 1994; Naiman and others 1988).
Shifts in species distributions	Cooler, moister microhabitats in riparian corridors can provide refugia for some aquatic, riparian or terrestrial species (Brosofske and others 1997). Riparian corridors are movement corridors for wildlife at scales ranging from local to continental. Improving the structure, composition and function of these corridors gains value under changed climate scenarios (CCSP 2008B). Ponds and vegetation in riparian corridors are excellent stopover and resting areas for migratory birds, e.g. Southwestern willow flycatcher.

Priority Areas for Beaver As a Climate Change Adaptation Tool

Seventh Generation Institute carried out a spatial analysis to answer the question: Where are some priority areas in New Mexico for the use of beaver as a climate change adaptation tool?

Specific objectives of the analysis were:

1. Develop a GIS-based habitat suitability index model of potential suitable beaver habitat.
2. Identify climate change-related "hot spots" - areas of high biodiversity conservation value and a high climate change exposure in New Mexico.
3. Compare the habitat model results with the hot spots to develop a final suite of high priority sites for "functional beaver management" (Sidebar 1) mapped at the HUC 12 watershed level. The watersheds will meet the following criteria:
    - Contain sufficient potential suitable beaver habitat to maintain viable populations.
    - Be located within areas of forecast high climate change vulnerability.
    - Be located within areas of high biodiversity value.

The study area was the state of New Mexico. All analysis was done in ArcGIS 9.3, including the Spatial Analyst extension.

Methods

Habitat Modeling

Our first objective was to develop a GIS-based habitat suitability index model of potential suitable beaver habitat. We defined "potential suitable beaver habitat" fairly narrowly and within the context of beaver's resilience building abilities, which are linked to complexes of dams, ponds, and canals in lotic systems and the activities associated with constructing these. Beaver that occupy lakes, ponds, or springs typically do not construct dams and ponds and therefore there is little or no resilience gain derived from the presence of beaver in these sites. Similarly, beaver found in irrigation canals, stock tanks, golf course ponds, or other manmade impoundments offer no real contribution to resilience. We did not include these areas in our modeling of potential suitable beaver habitat or additional analyses.

We began by selecting habitat factors to model. These had to be appropriate for the habitats found in New Mexico, as well as appropriate for modeling at the statewide scale and readily available as digital data. We reviewed publications on predictive models of beaver habitat or for beaver dam site selection criteria and qualitative descriptions of beaver habitat. Interestingly, relatively little descriptive work has been done in the Southwest. We found most useful the detailed description of beaver habitat in Colorado by Retzer and others (1956), the habitat model developed by Allen (1983), and the review by Baker and Hill (2003). Retzer's work was specific to Colorado which, while not identical, is more similar to New Mexico in latitude, topography, climate patterns and other factors than would be data from similar studies in Minnesota or British Columbia. Allen's habitat model was designed to be predictive across a variety of ecoregions and ecosystems. We also consulted with expert sources (personal communication Robert Sivinski) on the distribution of appropriate forage vegetation for beaver in New Mexico.

From these sources, we determined that the model of potential suitable beaver habitat would include the following inputs, all equally weighted:

- Elevation. An elevation of 3400 meters or less was designated habitat; elevation > 3400 meters was designated as nonhabitat (Hill 1982; Novak 1987 as cited by Baker, 2003*)*. Elevation data used was 30-meter resolution Digital Elevation

Model from the USGS National Elevation Dataset (NED) (Gesch 2007).

- Stream gradient. A stream gradient of 15% or less was designated as habitat; a stream gradient > 15% was designated as nonhabitat. Based on Retzer and others (1956), we further subdivided stream gradient into three classes: 0-6% gradient = excellent habitat; 6-12% = good habitat; 12 - 15% gradient = marginal habitat. Stream gradient was represented by slope, derived from the 30-meter NED.
- Distance to perennial flowing water. A 200 meter or less distance to a perennial stream or river was designated as habitat; a distance > 200 meters was designated nonhabitat. The National Hydrography Dataset (high resolution 1:24,000) (Simley and Carswell 2009) provided the perennial flow data.
- Landcover. 30-meter landcover data from the Southwest Regional Gap Analysis project (SWreGAP) (USGS National Gap Analysis Program 2004) was used as the input. We considered that potential suitable beaver habitat could occur as a narrow band adjoining perennial flows within a very broad set of surrounding landcovers. Since riparian corridors are known to be difficult to map from coarse scale imagery, including the Landsat Enhanced Thematic Mapper imagery used in the SWreGAP (Prior-Magee and others 2007), nearly all landcover classes were designated as potential suitable habitat, excluding barren (rocky, cinder, etc.) lands and disturbed and developed lands.

The final model output was divided into nonhabitat and three classes of potential suitable habitat: excellent, good and marginal.

Hot Spot Identification

In the next step, we identified "hot spots" in New Mexico – areas of both high biodiversity and high climate change exposure. The term "biodiversity hotspot" was coined by Myers (1988) and originally described areas with the two characteristics: 1) high biological diversity and 2) intense stressors or threats (not limited to climate change). With a nod to the original, we use the term "hot spot" here to indicate areas with a high biological diversity and under stress from climate change – literally hotter, drier spots. Other types of threats or stressors were not included in this analysis.

To identify hot spots in New Mexico, we worked with a GIS dataset and ancillary information developed by The Nature Conservancy. The dataset, which identifies areas with high biological diversity, was the Priority Conservation Areas of Western North America (The Nature Conservancy 2008). Priority conservation areas are defined and described as "… geographic areas that have been selected because of the sensitive biological species, habitats, and features (targets) that are known to occur in these areas. Conservation, protection, and management actions within these areas should be prioritized in order to ensure persistence and survival of these sensitive biological features." These areas are selected via a well-established ecoregional conservation planning framework and are widely referenced by other conservation planning efforts, including New Mexico's Comprehensive Wildlife Conservation Strategy (New Mexico Department of Game and Fish 2006). The dataset was clipped to the New Mexico state boundaries, resulting in 249 areas.

We ranked these 249 areas, using the tabular data provided, by the combined number of species and community targets. Percentile rank for each area was calculated from this number. Additional information about these same areas was derived from the report *Implications of Recent Climate Change and Conservation Priorities in New Mexico* (Enquist and Gori 2008), a spatially explicit forecast of climate change impacts in New Mexico. The report assigns a climate exposure score "based on mean temperature departures, mean precipitation departures, and standard deviations from each departure period" to the priority conservation areas in New Mexico (for details on the calculation of this score, see Enquist and Gori (2008)). We coded each area with the climate exposure score and percentile rank from the report. The final step was to sum the biodiversity value and climate change exposure percentile rankings into a combined hot spot ranking for all the conservation areas.

Prioritization

In this step, the modeled habitat was overlaid on the ranked hot spot areas. We visually reviewed the hot spots for the presence of modeled beaver habitat.

Some contained no modeled habitat, others contained amounts too small or too isolated to support beaver populations. These were eliminated from further consideration. In other cases, hotspots that had been identified for different sets of targets had similar boundaries; in these cases we considered only the highest ranked area. While all of the areas are valuable, we selected the final ten top-ranked areas that contained beaver habitat as the greatest priority areas to manage for the presence of beaver. Within these areas, we further selected and mapped the HUC 12 level watersheds that contain beaver habitat. These final watersheds represent the areas in New Mexico where functional beaver management can produce the greatest buffering effect against climate change to the most conservation targets.

Results

Habitat Modeling

The National Hydrography Dataset identified 14,167 kilometers (8,803 miles) of perennial streams and rivers in New Mexico. Along these waterways, are found a total of 281,385 hectares (695,302 acres) of potential suitable beaver habitat, comprised of 186,333 hectares (460,428 acres) of excellent habitat, 69,850 hectares (172,600 acres) of good habitat, and 25,202 hectares (62,274 acres) of marginal habitat (Figure 1).

The majority of habitat is found in the northeastern part of the state, roughly defined by a rectangle drawn with the lower left corner in Albuquerque and extending north and east to the state borders. Significant patches or corridors of habitat are also found in the Upper Pecos, Upper Gila and Upper San Juan Basins, with scattered amounts in other watersheds.

By far the majority, a full 66%, of the habitat is found on private lands. Table 2, below, provides a breakdown of habitat by ownership across New Mexico.

Table 2. Ownership of Lands With Potential Suitable Beaver Habitat in New Mexico.

	Excellent Habitat		**Good Habitat**		**Marginal Habitat**		**Total Habitat**		**% Total**
	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres	
Statewide Total	186,333	460,428	69,850	172,600	25,202	62,274	281,385	695,302	**100%**
Private Land	132,179	326,616	42,139	104,127	12,752	31,510	187,071	462,252	**66%**
Forest Service	12,337	30,485	17,121	42,306	8,951	22,118	38,409	94,909	**14%**
Tribal Land	19,687	48,646	4,834	11,945	1,637	4,045	26,158	64,635	**9%**
Bureau of Land Mgmt	7,299	18,036	2,400	5,930	719	1,777	10,418	25,743	**4%**
State	8,029	19,840	2,092	5,169	680	1,681	10,801	26,690	**4%**
Other	6,801	16,806	1,264	3,122	463	1,144	8,528	21,073	**3%**

Figure 1. Potential beaver habitat in New Mexico

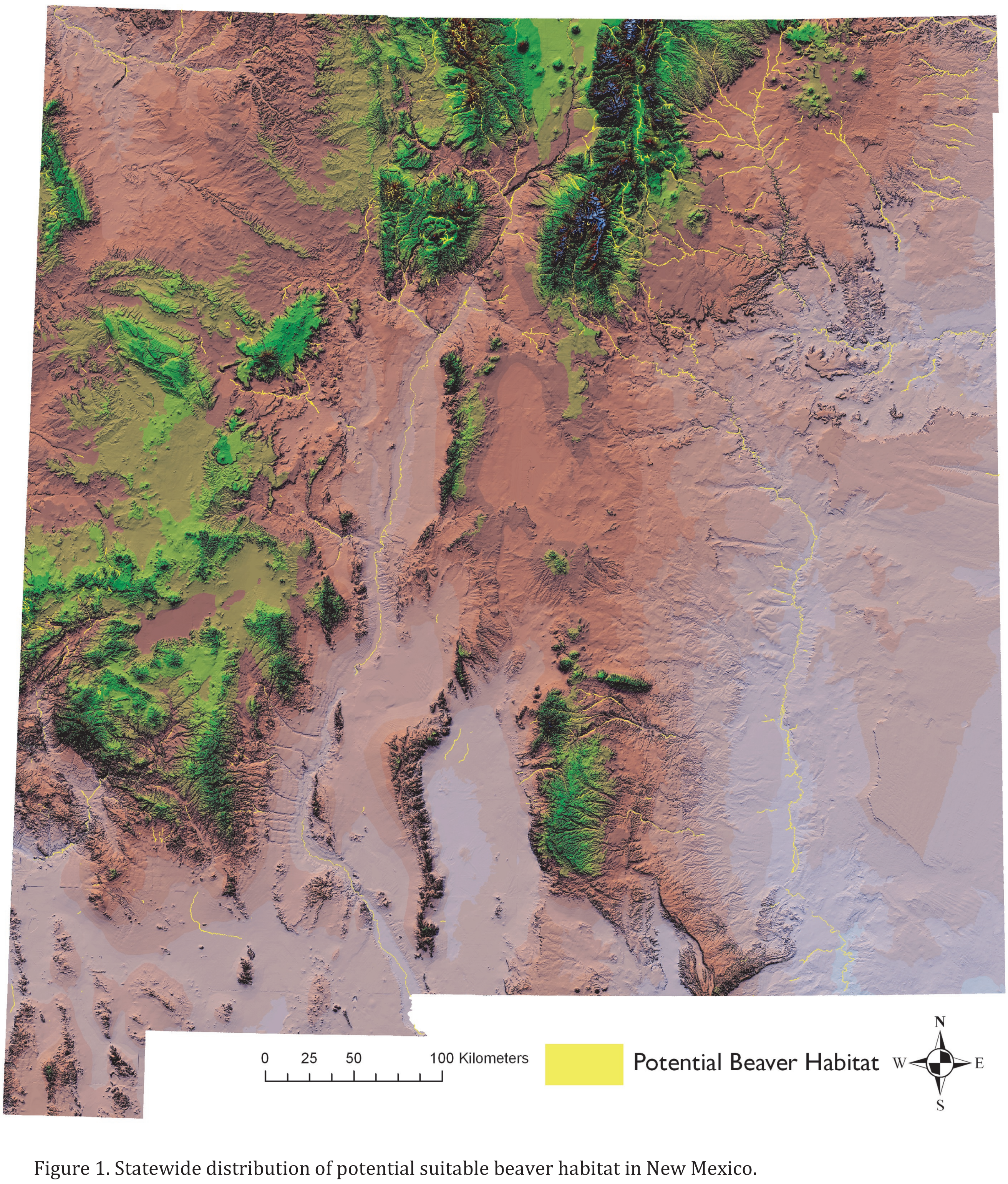


Figure 1. Statewide distribution of potential suitable beaver habitat in New Mexico.

Hot Spot Identification and Prioritization

The 249 priority conservation areas in New Mexico are shown in Figure 2. Darker green indicates an area with a higher ranking in the combined biodiversity value and climate exposure score. These are the hot spots.

Figure 3 shows the final prioritized areas. Two types of areas are shown. In the Gila River hot spot and the Chama River hot spot, we did not extract individual HUC 12 watersheds, but rather left these riverine priority areas intact. Each contains large amounts of potential suitable beaver habitat. Attempting to extract individual HUC 12 watersheds in these areas was not productive. For the remaining prioritized areas, we mapped individual HUC 12 watersheds. We identified a total of 85 HUC 12 level watersheds (Appendix A). By nature, these watersheds sometime extend beyond the bounds of the corresponding hot spot area.

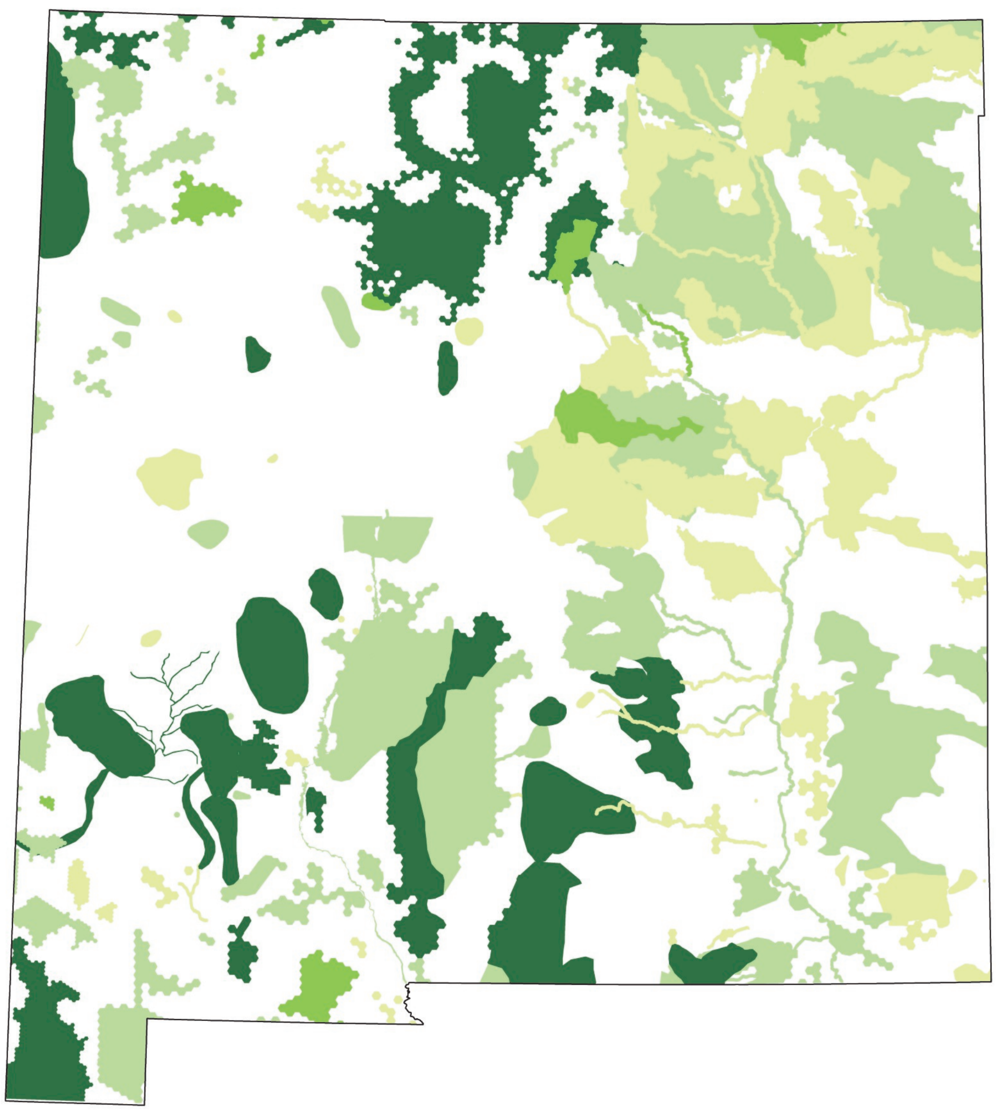


Figure 2. Priority conservation areas in New Mexico, ranked by combined percentile score, biodiversity value and climate change exposure. Darker green indicates higher rank. Original data courtesy of The Nature Conservancy of New Mexico. Climate exposure scores from Enquist and Gori (2008).

Figure 3. HUC-12 watersheds for beaver-driven climate change adaptation in New Mexico

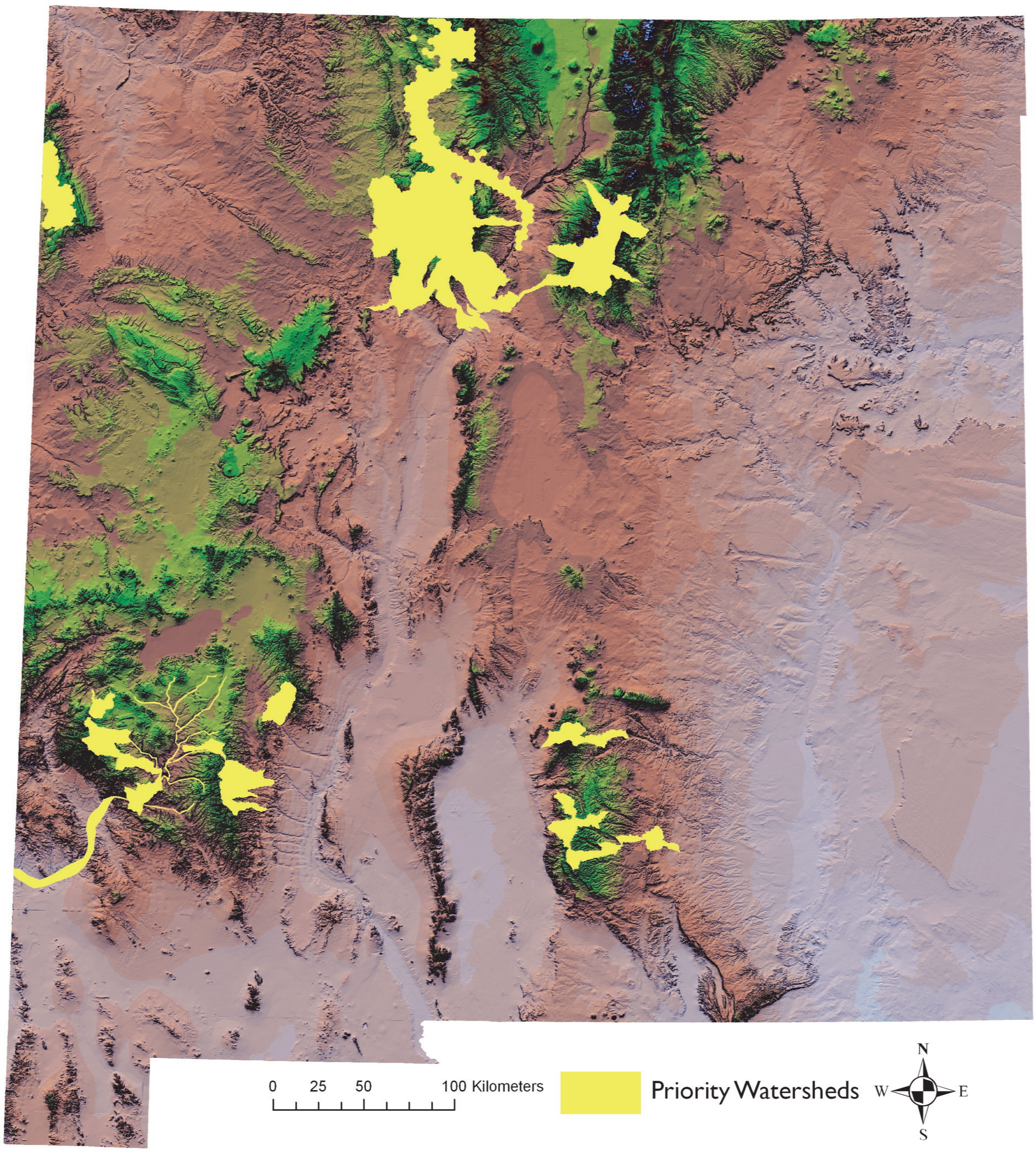


Figure 3. Final suite of priority HUC 12 watersheds for functional beaver management. Areas shown in yellow are the prioritized HUC 12 watersheds. The map has been kept simple to better display statewide data. A full list of these watersheds is found in Appendix A.

Discussion

Habitat Modeling Considerations

Comparison to Other Models

To our knowledge, the only other statewide model of potential suitable beaver habitat was developed by the Southwest Regional Gap Analysis Project (SWreGAP) (USGS National Gap Analysis Program 2004). That model was also a habitat suitability index model and used similar input data. However, our model differs in three of the four input parameters. Our model incorporated additional landcover classes and did not consider lakes, springs, or anthropogenic impoundments. It also considered suitable habitat as limited to a maximum stream gradient of 15% slope and to a maximum distance from perennial stream flows of 200 meters. In contrast, the SWreGAP model determined suitable habitat to include stream gradients of up to 15 degree slope (26.8%) – a difference of almost double - and a distance from perennial flow to 400 meters, again double. Our review of the literature did not find support for these choices and the two models resulted in very different outputs both in the total amount of habitat identified and its distribution.

Data and Use Limitations

The habitat model was developed as a landscape scale model and as such the results should be used for landscape scale planning or decision making. Site -level evaluation should be done when beaver establishment is being considered.

We have termed the modeled habitat as "potential suitable" because it does not include site-specific information such as recent burns, current vegetation condition, or the presence of rocky substrate that could prevent dam construction. Developed areas were removed from consideration as habitat, but areas occupied at low levels by people are included. Some of these areas may be useful beaver habitat, depending on the attitudes of nearby residents.

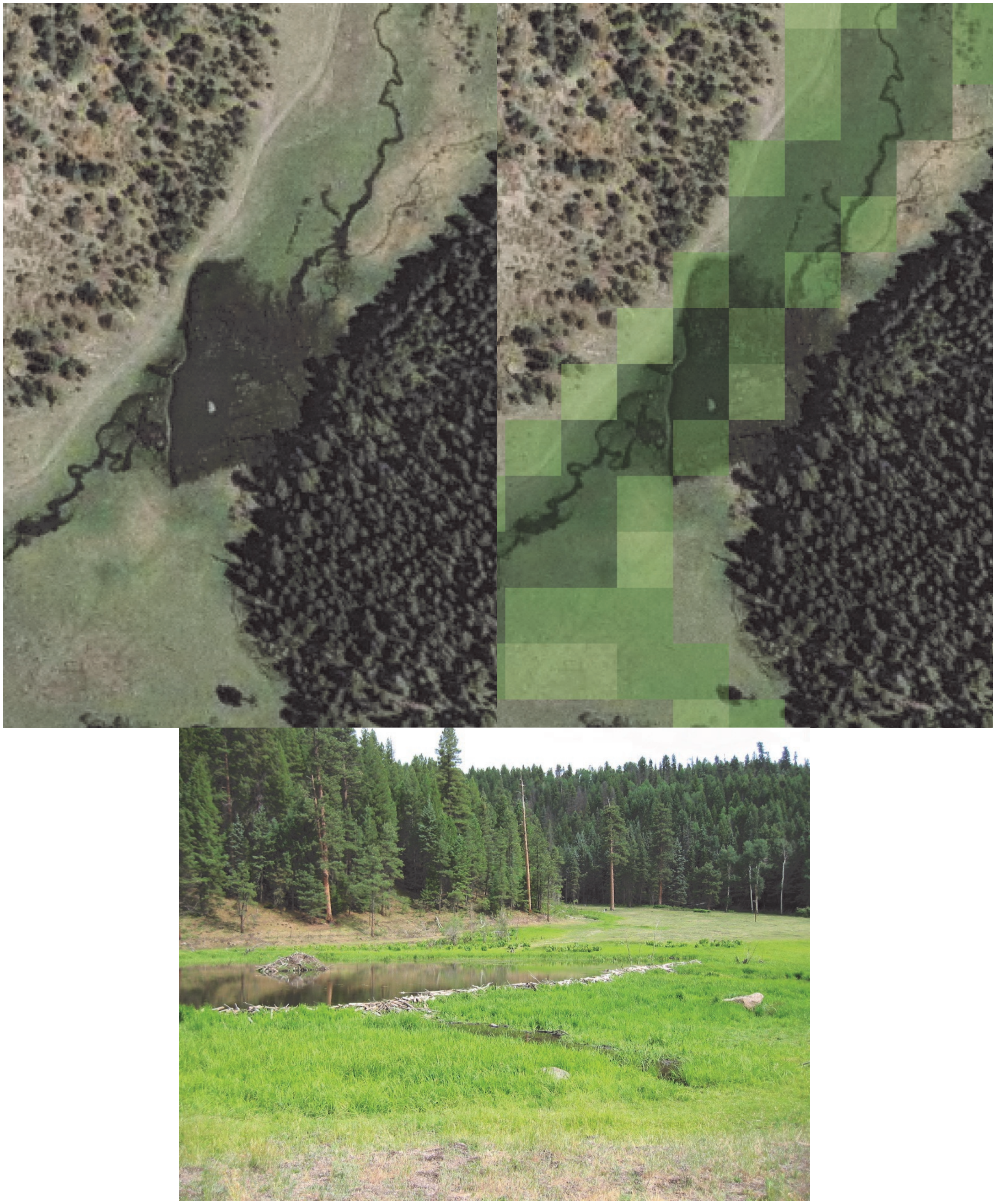
Landcover data was developed by the SWreGAP through interpretation of imagery and this process is never 100% accurate. In addition, the data was developed in 2004 and changes may have occurred due to fires, conversion to human use, or other factors since that time.

Issues surrounding the National Hydrography Dataset classification and use of intermittent streams by beaver suggest that the amount of potential suitable beaver habitat in New Mexico may be considerably higher than the model results. First, although some authors state that beaver require perennials flows, other authors disagree (Baker and Hall 2003; Albert and Trimble 2000). Under the right circumstances, beaver will colonize intermittent streams during periods of flow, create dams, and impound enough water to serve as the predator protection they require during low flow or dry periods. Data in the NHD does not provide sufficient information to determine which streams might have sufficient flow to support this, but 88% of the streams in New Mexico are classified as either intermittent or ephemeral in the NHD (Levick and others 2008). Second, the classification in the NHD contains an unknown number of errors. In site visits around northern New Mexico, we have encountered several streams which are classified in the NHD as intermittent, but which local residents told us were indeed perennial. And finally, there are anecdotal reports of many streams in New Mexico that are presently intermittent (and correctly classified) but historically were perennial. Typically the conversion from perennial to intermittent is attributed to surface water diversion, ground water extraction, or even the historic removal of beaver. There is no information available on the number or locations of converted streams. However, it is clear that if a significant number of intermittent streams were added to the analysis, the modeled habitat would be quite different.

Validation

The model identified 281,385 hectares in the state of New Mexico as potential suitable beaver habitat, slightly less than 1% (0.9%) of the state's total land area. This seems reasonable, given that riparian corridors typically comprise 0.5 - 2% of land area in the West (Dwire and Kauffman 2003), and the fact that not all riparian corridors are suitable for beaver.

No systematic or comprehensive field validation of the model was done. We visited a number of modeled habitat sites in northern New Mexico and all of these have had actual habitat present, so we believe that the model accurately captures habitat associated with perennial stream flows (but see



Figures 4-6. Beaver Pond on Rio Cebolla, Jemez Mountains, New Mexico. Upper left image: NAIP 2009 Imagery. Note the dam visible as a roughly vertical grayish line and the lodge visible as a grayish dot in the center of the pond. Upper right image: 2009 NAIP Imagery, with modeled habitat superimposed. Habitat is indicated by the green squares, with darker green representing better habitat. Here, it is displayed at 50% transparency so that the pond and stream are visible through the squares, demonstrating that the modeling has accurately predicted habitat. Lower photo: ground level view of the same dam and pond.

comments on streams with intermittent flow above). Figures 4-6 show several views of a beaver pond on the Rio Cebolla in the Jemez Mountains of New Mexico. Here, a large beaver dam and pond are found in modeled habitat. Modeled habitat is draped over a National Agriculture Imagery Program (NAIP) image for comparison.

Implications

Hypothetically, if all of the modeled habitat were suitable, correctly configured, occupied, and there were no checks on beaver population, how many beaver or how many beaver colonies would this habitat support? Beaver territory size varies widely, from about 8 hectares to 18 hectares, depending on the type of habitat and the population density (Baker and Hill 2003). This would place the number of possible beaver colonies between 15,632 and 35,173. Since colonies average 4-8 members, again depending on the habitat and surrounding population density, the total beaver population of New Mexico could range from approximately 62,500 to 281,400.

Compared to these estimates, the current population of beaver in the state is quite low, approximately one sixth of the most conservative estimate of the potential population. Large areas of potential habitat are unoccupied. This may be because the habitat is in poor condition and beaver are unable to colonize it or because landowners and managers have taken steps to remove beaver. Regardless of the reason, an increase in the abundance of beaver is both necessary and desirable in order to achieve the goal of climate change adaptation.

The large quantity of potential suitable beaver habitat found on private land indicates a particular need to expand beaver conservation and management efforts with these landowners. The presence of beaver can be very compatible with some existing land uses, such as ranching or forestry, while not compatible with others.

Hot Spot and Prioritization Considerations

Comparison to Other Analyses

Our hot spot and prioritization analysis is quite similar to the prioritization of Enquist and Gori (2008). The two analyses used similar data, but theirs focused on drought sensitive species, while ours used targeted biological communities and species. We considered and discarded the possibility of limiting the analysis to drought sensitive species or to species associated with riparian corridors, however we believe that this underestimates the landscape-level roles played by both beaver and riparian corridors, roles that are expected to increase in importance as the climate warms (Seavy and others 2009; Wright and others 2002).

Data and Use Limitations

Inherent in the forecast of climate change effects is the expectation that plant and animal communities will shift geographically or shuffle their component species (CCSP 2008B). Hence this analysis should be considered a snapshot-in-time and subject to change.

The hot spots analysis is a triage approach for climate change (sensu Millar 2007). It does not claim to capture every threatened community or species (Kareiva and Marvier 2003). Nor does it consider the value of beaver for water storage, water quality, improvement of grazing lands, or other restoration goals. Consideration of these goals would likely result in an entirely different set of prioritized areas.

Implications

No one knows exactly where beaver habitat in New Mexico is currently occupied. NMDGF conducts beaver surveys, but beaver are considered impossible to accurately survey (Baker and Hill 2003). Site occupancy changes as beaver are removed by landowners or NMDGF or move of their own volition. Beaver territories may be occupied for several months or decades. Hence it is impossible to know which of these priority areas may already be occupied by beaver.

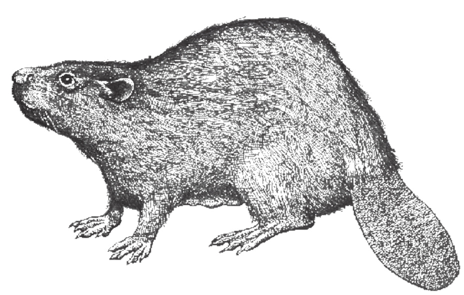
The final priority areas shown in Figure 3 provide a first cut at the top priorities in the state. Our selection of ten areas to map was arbitrary and the presence of beaver would be beneficial to many of the other priority conservation areas in the TNC database as well as other areas.

Conclusions

Seventh Generation Institute hopes that the information in this report will be useful to land, water and wildlife managers, as well as restoration practitioners, when considering management actions in New Mexico.

We offer the following conclusions and recommendations:

- If properly managed, beaver can be a potent climate change adaptation tool. An increase in the population is a "no-harm" strategy, since beaver are native to New Mexico. Methods for managing beaver are established and can be put into place immediately. Given the great value of riparian corridors in the state, increasing the beaver population in appropriate areas seems prudent.
- The current population of beaver in the state is quite low. Using the most conservative estimate of the population that could be supported by the modeled habitat, we find that the current population of 8000-10,000 beaver, is approximately one sixth the potential population. Less conservative estimates or inclusion of some intermittent habitat could place the population much higher. *An increase in the abundance of beaver is necessary to achieve the goal of adaptation.*
- Habitat quality and public attitudes will need to be addressed concurrently with actions to manage beaver if the abundance of beaver in New Mexico is to increase.
- Planning for beaver should be incorporated early into riparian restoration projects. When beaver are added to projects as an afterthought, whether intentionally or through colonization, they will alter the project to suit their own needs. This may be perceived as undesirable, but it is part of the dynamic nature of riparian corridors and should be embraced. Early planning should incorporate working closely with stakeholders, and especially private landowners, to provide realistic information about the advantages and disadvantages of beaver, the relationship to climate change and ecosystem health, and the available beaver impact management tools.
- If an increase in the beaver population occurs, there will be tradeoffs. Beaver impacts are not desirable in some places. It is useful to consider all options for management of beaver. There are well-developed tools, such as flow devices, for the management of beaver impacts. These tools are not appropriate for all sites, but where appropriate, can minimize the impacts of beaver while permitting their continued presence in the system.



Literature Cited

Albert S. and T. Trimble. 2000. Beavers are partners in riparian restoration on the Zuni Indian Reservation. *Ecological Restoration* 18:87-96.

Allen A. 1983. Habitat suitability index models: Beaver. (FWS/OBS-82/10.30, rev.). U.S. Department of the Interior, Fish and Wildlife Service.

Apple L., B. Smith, J. Dunder, and B. Baker. 1985. The use of beavers for riparian/ aquatic habitat restoration of cold desert, gully cut stream systems in Southwestern Wyoming. Pages 123–130 *in* G. Pilleri (ed.), Investigations on beavers, Vol 6. Brain Anatomy Institute, Berne.

Bailey, V. 1931. Mammals of New Mexico. Report #53 USGS Series North American Fauna. 412 pp.

Baker B. and E. Hill. 2003. Beaver (*Castor canadensis*). Pages 288-310 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. Second Edition. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Brosofske K., J. Chen, R. Naiman and J. Franklin, 1997. Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. *Ecological Applications.* 7:1188-1200.

CCSP. 2008A The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. U.S. Department of Agriculture, Washington, DC., USA, 362 pp.

CCSP. 2008B. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius, S.H., J.M. West (eds.), J.S. Baron, B. Griffith, L.A. Joyce, P. Kareiva, B.D. Keller, M.A. Palmer, C.H. Peterson, and J.M. Scott (Authors)]. U.S. Environmental Protection Agency, Washington, DC, USA, 873 pp.

Cole D., N. Stephenson and C. Millar. 2010. Responding to climate change: A toolbox of management strategies. Chapter 11 in D.N. Cole and L. Yung (Eds), Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change. Island Press.

Collen P. and R. Gibson. 2001.The general ecology of beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. *Reviews in Fish Biology and Fisheries* 10:439-461.

Cooke H. and S. Zack. 2008. Influence of beaver dam density on riparian areas and riparian birds in shrubsteppe of Wyoming. *Western North American Naturalist.* 68:350-364.

Dwire K. and J. Kauffman. 2003. Fire and riparian ecosystems in landscapes of the western USA. *Forest Ecology and Management.* 178:61-74

Enquist C. and D. Gori. 2008. Implications of Recent Climate Change and Conservation Priorities in New Mexico. The Nature Conservancy New Mexico Conservation Science Program, 79pp. Available online at: http://nmconservation.org/dl/NMClimateChange_report1_527.pdf

Gesch D. 2007. The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for

Photogrammetry and Remote Sensing, p. 99-118. Accessed online at http://ned.usgs.gov/Ned/index.asp

Gregory S., F. Swanson, A. McKee and K. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* 41:540-550.

Gurnell A. 1998. The hydrogeomorphological effects of beaver dam-building activity. *Progress in Physical Geography*. 22:167-189.

Hammerson G. 1994. Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring. Natural Areas Journal 14:44-57.

Hansen L., J. Biringer and J. Hoffman. 2003. Buying time: a user's manual for building resistance and resilience to climate change in natural systems. Available online at www.worldwildlife.org.

Heller N. and E. Zavaleta. 2008. Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation* 142:14–32.

Hill E. 1982. Beaver (*Castor canadensis*). Pages 256–81 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild mammals of North America. Johns Hopkins University Press, Baltimore.

Holling C. 1973. Resilience and stability of ecological systems. *Annu. Rev. Ecol. Syst.* 4:1–23

Johnston C., and R. Naiman. 1987. Boundary dynamics at the aquatic-terrestrial interface: the influence of beaver and geomorphology. *Landscape Ecology* 1:47-57.

Jones C., J. Lawton, and M. Shachak. 1994. Organisms as ecosystem engineers. *Oikos* 69: 373-386.

Kareiva P. and M. Marvier. 2003. Conserving Biodiversity Coldspots. *American Scientist* 91:344-351.

Levick L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The Ecological and Hydrological Significance of Ephemeral and Intermittent Streams in the Arid and Semi-arid American Southwest. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center, EPA/600/R-08/134, ARS/233046, 116 pp.

McKinstry M., and S. Anderson. 1997. Use of beaver to improve riparian areas in Wyoming. Pages 128-134 in Goertler, C., C. Rumsey, T. Bray, and D. Boysen (Eds). Wyoming Water 1997: Applied Research for Management of Wyoming's Water Resources. Casper, WY.

McKinstry M., P. Caffrey, and S. Anderson. 2001. The importance of beaver to wetland habitats and waterfowl in Wyoming. *Journal of the American Water Resources Association.* 37:1571-1577.

Myers N. 1988. Threatened biotas: `hotspots' in tropical forests. *Environmentalist* 8:187-208.

Naiman R., C. Johnston, and J. Kelly. 1988. Alteration of North American streams by beaver. *Bioscience* 38:753-762.

Naiman R., S. Elliott, J. Helfield and T. O'Keefe. 2000. Biophysical interactions and the structure and dynamics of riverine ecosystems: the importance of biotic feedbacks. *Hydrobiologia* 410:79–86.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: June 8, 2009).

New Mexico Department of Game and Fish. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico. New Mexico Department of Game and Fish. Santa Fe, New Mexico. 526 pp + appendices.

Nilsson C., R. Jansson, B. Malmqvist, and R. Naiman. 2007. Restoring riverine landscapes: the challenge of identifying priorities, reference states, and techniques. *Ecology and Society*. Available online at: http://www.ecologyandsociety.org/vol12/iss1/art16/

Novak M. 1987. Beaver. Pages 283–312 in M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Association and Ontario Ministry of Natural Resources.

Paine R. 1969. A note on trophic complexity and species diversity. *American Naturalist*. 100:91-93.

Parker M., F. Wood, Jr., B. Smith, and R. Elder. 1985. Erosional downcutting in lower order riparian ecosystems: have historical changes been caused by removal of beaver? Pages 35-38 in R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Ffolliott and R.H. Hamre (eds.), Riparian ecosystems and their management: reconciling conflicting uses. US Forest Service General Technical Report RM-120. First North American Riparian Conference, April 16, 18, Tucson, Arizona. Rocky Mountain Forest and Range Experimental Station. Fort Collins, Colorado.

Pollock M., M. Heim and D. Werner. 2003. Hydrologic and Geomorphic effects of beaver dams and their influence on fishes. American Fisheries Society Symposium 37:213-233.

Power M., D. Tilman, J. Estes, B. Menge, W. Bond, L.S. Mills, G. Daily, J. Carlos Castilla, J. Lubchenco and R. Paine. 1996. Challenges in the Quest for Keystones. *Bioscience.* 46:609-620.

Prior-Magee J., K. Boykin, D. Bradford, W. Kepner, J. Lowry, D. Schrupp, K. Thomas, and B. Thompson, Editors. 2007. Southwest Regional Gap Analysis Project Final Report. U.S. Geological Survey, Gap Analysis Program, Moscow, ID.

Retzer J., H. Swope, J. Remington, and W. Rutherford. 1956. Suitability of physical factors for beaver management in the Rocky Mountains of Colorado (Technical Bulletin 2). Colorado Department of Game and Fish.

Rosell F., O. Bozer, P. Collen and H. Parker. 2005. Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems. *Mammal Rev.* 35:248-276.

Saunders S., T. Montgomery, T. Easley, and T. Spencer. 2008. Hotter and drier: the West's changed climate. Available online from The Rocky Mountain Climate Organization at www.rockymountainclimate.org. or from The Natural Resources Defense Council at www.nrdc.org.

Seavy N., T. Gardali, G. Golet, F. T. Griggs, C. Howell, R. Kelsey, S. Small, J Viers and J. Weigand. 2009. Why Climate Change Makes Riparian Restoration More Important than Ever: Recommendations for Practice and Research. *Ecological Restoration*. 27:330-338.

Simley J., W.J. Carswell Jr. 2009. The National Map-Hydrography: U.S. Geological Survey Fact Sheet 2009-3054, 4 p.

Soule M., J. Estes, J. Berger, andC. Del Rio. 2003. Ecological Effectiveness: Conservation Goals for Interactive Species. *Conservation Biology* 17:1238-1250.

The Nature Conservancy (TNC). 2008. Ecoregional Assessment Geodatabase for Western North America. Tucson, AZ: The Nature Conservancy. Available: online at http://azconservation.org/projects/ecoregions/. Accessed June, 2009.

USGS National Gap Analysis Program. 2004. Provisional Digital Land Cover Map for the Southwestern United States. Version 1.0. RS/GIS Laboratory, College of Natural Resources, Utah State University. Accessed online at http://earth.gis.usu.edu/swgap/landcover_nm.php

Vore J. 1993. Guidelines for the Reintroduction of Beaver into Southwest Montana Streams. Montana Department of Fish, Wildlife, and Parks. 34 pp.

Williams P., C. Allen, C. Millar, T. Swetnam, J. Michaelsen, C. Still, and S. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. Proc. Nat. Acad. Sci. Vol.107, No.50, pgs. 21289-21294.

Wright, J., C. Jones, A. Flecker. 2002. An Ecosystem Engineer, the Beaver, Increases Species Richness at the Landscape Scale. Oecologia. 132: 96-101.

Appendix A

Prioritized Hot Spots and HUC 12 Watersheds

Hot Spot Rank	Hot Spot Name	Sufficient Habitat?	HUC 12 Priority Watersheds
1	Jemez Mountains	Yes	130202020101, 130202020204, 130202020105, 130202020202 130202020104, 130202020107, 130202020205, 130202020402 130202020308, 130202010608, 130201021005, 130201020801 130201020803, 130201021004, 130201020802, 130202040102 130202040106, 130202020102, 130202020103, 130201011301 130202040105, 130202020201, 130202020203, 130202010205 130202010206, 130202010207, 130202010601, 130202010605 130202020403, 130202010606, 130202010604, 130202020404 130202020307, 130202040201, 130202020106, 130201020804 130202040101, 130202010209, 130202010107
2	*Sierra San Luis/Peloncillo Mountains*	*No*	*N/A – Insufficient habitat*
3	Northern Black Range	Yes	130301010207, 150400010401, 130301010204, 130301010206, 130301010401, 130301010205, 130301010406
4	Sacramento Mountains	Yes	130600100306, 130600100302, 130500031501, 130600100304, 130500031502, 130500031203, 130600100101, 130600100503
5	Rio Chama	Yes	N/A -Treated as one area
6	S. Sangre de Cristo Mtns/ Pecos River Headwaters	Yes	130600010205, 130600010101, 130201010904, 130202010102, 130600010204, 130201010902, 130201010905, 130600010201, 110800040304, 130600010202, 130600010203, 130201011201, 110800040306, 130600010802
7	Mogollon Divide	Yes	150400010505, 150400010502, 150400010602, 150400010902, 150400010604, 150400010901, 150400040203
8	San Mateo Mtns Complex	Yes	130202110701, 130202110702
9	Chuska Mtns	Yes	140802040101, 140802040202, 140802040203, 150200060301, 150200060302
10	Sierra Blanca	Yes	130600080105, 130500031102, 130600080201
11	Gila River		N/A - Treated as one area

Beaver As a Climate Change Adaptation Tool: Concepts and Priority Sites in New Mexico

Seventh Generation Institute

Bringing Together People And Science for Conservation