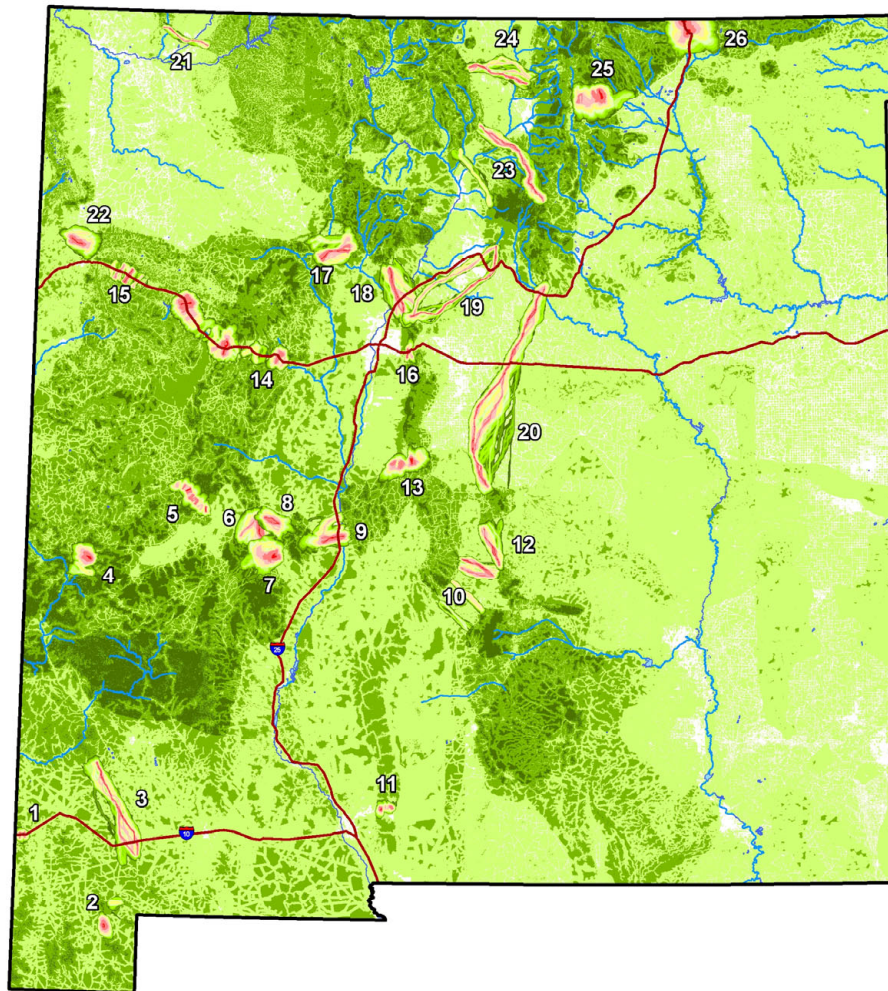


Share With Wildlife Final Project Report  
Professional Services Contract# 08-516-0000-00005

*Locating Potential Cougar (Puma concolor) Corridors in New Mexico Using a  
Least-Cost Path Corridor GIS Analysis*



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May 31, 2008

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## **Introduction & Background**

While a wildlife movement barrier assessment and several regional wildlands network designs have been completed in New Mexico, scientifically rigorous, spatially explicit least-cost corridor analyses had not yet been performed to identify potential dispersal corridors for any species.

### House Joint Memorial 3

In January of 2003, the New Mexico 44<sup>th</sup> State Legislature passed House Joint Memorial 3 (HJM 3), which was developed by Wild Friends, sponsored by Representative Mimi Stewart and signed by Governor Bill Richardson. HJM 3 directs the New Mexico Department of Game and Fish (NMDGF) and the New Mexico Department of Transportation (NMDOT) to work together to reduce the potential for wildlife/vehicle collisions on highways in New Mexico.

In part, HJM 3 states:

*“NOW, THEREFORE, BE IT RESOLVED BY THE LEGISLATURE OF THE STATE OF NEW MEXICO that the New Mexico congressional delegation be requested to help secure federal funding for enlarging or building underpasses and overpasses and for implementing other technologies to make our roads safer for wildlife and people”*

*“BE IT FURTHER RESOLVED that the department of game and fish and the state highway and transportation department be encouraged to...cooperate on long-term planning of road projects and to share information to help reduce road kill resulting from vehicle-wildlife collisions on the roads of New Mexico”*

As a result of HJM 3, the June 2003 Critical Mass Workshop was sponsored by the New Mexico Carnivore Working Group, with assistance from the U.S. Fish and Wildlife Service, U.S. Forest Service and NMGF. The Workshop was attended by approximately one hundred people representing NMDOT, NMDGF, USFS, BLM, USFWS, UNM and many NGO's. Over the course of two days, the group generated a consensus prioritized list and map of New Mexico highway segments for further analysis to determine the need for mitigation strategies to reduce the potential for wildlife vehicle collisions. The prioritization of highway segments was based on three criteria: 1) large game animal/vehicle accident report data (one year's data only); 2) proximity to major tracts of public land that are important wildlife habitats; and 3) the perceived potential for adverse effects of highways and traffic to threatened, endangered and sensitive species. Because of the limited time and availability of accident report data, the Critical Mass Workshop was intended as a first preliminary attempt to identify important wildlife/vehicle conflict areas, and not intended to be definitive.

### New Mexico Highlands Wildlands Network Design

In 2003 The Wildlands Project published the New Mexico Highlands Wildlands Network Vision<sup>1</sup>. This was the first attempt to look at the landscape in terms of core wildlife habitat, compatible use areas and dispersal corridors. To map the landscape in

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<sup>1</sup> New Mexico Highlands Wildlands Network Vision by Dave Foreman et al. (The Wildlands Project 2003). CD available from Kim Vacariu, The Wildlands Project, 520-884-0875 or [kim@wildlandsproject.org](mailto:kim@wildlandsproject.org).

this manner a series of spatial analyses were conducted to identify the portions of the landscape that need to be protected to support healthy ecosystems in New Mexico. However, the corridors were only vaguely identified.

### NMDOT and NMDGF Plans

Subsequently, the New Mexico 2025 Statewide Multimodal Transportation Plan and the 2006 New Mexico Comprehensive Wildlife Conservation Strategy (NM-CWCS) have both explicitly stated the need for cooperation between the two agencies to address the intent of HJM 3 by reducing the potential for wildlife-vehicle collisions and increasing wildlife habitat connectivity with regard to New Mexico's highway system. Additionally, the NM-CWCS identifies habitat fragmentation due to transportation infrastructure as one of the major threats to native wildlife populations. One of the research priorities highlighted in the NM-CWCS is to "Identify wildlife travel corridors and determine habitat connectivity"<sup>2</sup>.

These initiatives, plans and strategies implicitly identify the need for more spatially explicit corridor data for New Mexico. This project was designed to begin to address this data void in New Mexico. Established tools and GIS techniques were employed to identify potential travel corridors for cougars.

### Species Selection

The analysis focused on cougars for several reasons: 1) Cougars have been identified as a species of conservation concern in both regional conservation plans and the NM-CWCS, 2) This is the only wide ranging species for which adequate habitat data existed to conduct such an analysis, 3) It was assumed that cougar could serve as a surrogate for other wide ranging carnivorous species such as marten (*Martes americana*), gray wolf (*Canis lupus*), jaguar (*Panthera onca*), swift fox (*Vulpes velox*) and kit fox (*Vulpes macrotis*) where habitat overlaps. With these data NMDGF will be able to begin to plan for the needs of other species with large home ranges, seasonal migration requirements, and sensitivities to human disturbance.

### Habitat Fragmentation

Habitat fragmentation is now widely recognized as one of the leading causes of species extinction. The four million-mile network of roads we have constructed in America has enabled unprecedented mobility for human travel and commerce. However, these same roads, and the developments associated with them, have negatively affected the mobility and survival of wildlife by creating "fracture zones" between suitable habitats. Animals following their instinctual movement patterns often encounter human infrastructure as they seek food, water, mates and territory. The environmental impact of roadways extends far beyond the edge of the pavement. This "road-effect zone" is estimated to be 15 to 20 times as large as the actual paved right of way itself<sup>3</sup>. One of the unintended adverse consequences of habitat fragmentation is that this process effectively creates smaller, more isolated habitat patches and wildlife populations. Isolated

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<sup>2</sup> Mark Watson, NMDGF, Personal communication, November 2007.

<sup>3</sup> Forman, R.T.T. 2000. Estimate of the Area Affected Ecologically by the Road System in the United States. *Conservation Biology* 14(1): 31-35

populations are demographically vulnerable, less resilient to natural disturbances, and thus have a higher probability of local extinction. As growing human infrastructure fragments the landscape, it becomes less permeable to wildlife movement. Permeability is a measure of how easily traversed a landscape is for a particular species. This measurement is related to a particular species' agility, habitat preferences, and response to biophysical factors, including human-created barriers. Permeability has been estimated and mapped for various focal species using "least cost path/corridor" GIS analysis<sup>4</sup>, snow track counts<sup>5</sup>, radio/GPS collars, and genetic analysis<sup>6</sup>. Species with large home ranges, seasonal migration requirements, sensitivities to human disturbance, or those with small population sizes and limited distribution are particularly vulnerable to habitat conversion and fragmentation. Therefore, quantifying and accommodating habitat connectivity requirements for these species should be a high priority.

## **Methodology**

This study utilized ArcGIS 9.2 and the Corridor Designer tools developed by the School of Forestry at Northern Arizona University. It was developed for the sole purpose of identifying wildlife corridors and was used for the 2006 Arizona Missing Linkages Assessment. This suite of tools is freely available at [corridordesign.org](http://corridordesign.org). I followed their concepts and methodologies outlined in their guiding documents. By using this suite of tools and procedures, the analysis is repeatable and the results comparable to other efforts that have been undertaken in neighboring states.

### Habitat Suitability Model

The toolbox is organized into three tool sets: 1) Layer Preparation, 2) Habitat Modeling, and 3) Corridor Modeling. The latter requires a Habitat Suitability Model (HSM). In such a model each pixel has a numeric value representing the suitability of that piece of ground as habitat for a particular species. When modeling a corridor the tools create an inversely proportional relationship between habitat suitability and resistance to movement. This assumes that animals use the same criteria to disperse between two areas as they do when selecting habitat.

A cougar habitat suitability model (HSM) had already been completed by Bird's Eye View and Animal Protection of New Mexico in 2006. This HSM was rescaled to meet CorridorDesigner's requirement that HSM values range from 0 – 100. The model was rescaled with the following assumptions:

- 100 representing the best habitat
- 80 representing the lowest score typically associated with successful breeding
- 60 representing the lowest score associated with consistent use and breeding

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<sup>4</sup> Singleton, P.H., W.L. Gaines and J.F. Lehmkuhl. 2002. Landscape Permeability for Large Carnivores in Washington: A Geographic Information System Weighted-Distance and Least-Cost Corridor Assessment.

<sup>5</sup> Alexander, S.M, N.M. Waters, and P.C. Paquet. 2004. A probability-based GIS model for identifying focal species linkage zones across highways in the Canadian Rocky Mountains' in Applied GIS and Spatial Analysis, eds J. Stillwell and G. Clarke (West Sussex, UK: Wiley) 233–256

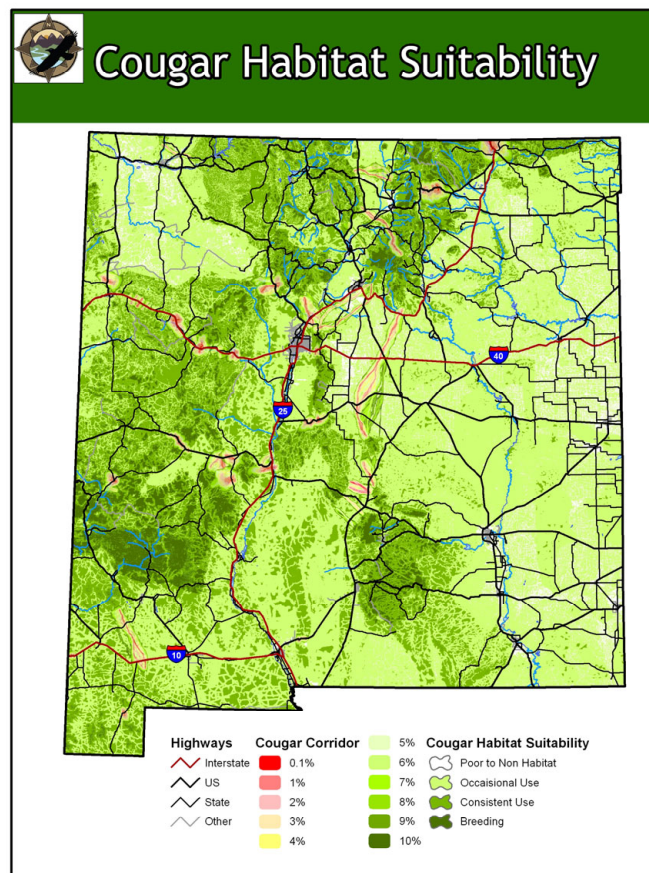
<sup>6</sup> Proctor M., B.N. McLellan, and C. Strobeck. 2002. Population fragmentation of grizzly bears in southeastern British Columbia, Canada. *Ursus* 13:153–160

- 30 representing the lowest value associated with occasional use for non-breeding activities
- 0 representing non-habitat.

The cougar HSM was derived with the following inputs:

- Prey availability (40%) (incorporated 25 prey animal ranges)
- Distance to Roads (25%)
- Human Population Density by Census Block (15%)
- Terrain Ruggedness (15%)
- Distance to Interstates (3%) (areas within a mile of an interstate were given a value of 0 and the remainder of the state 100 for this input)
- Urban Areas (2%) (urban areas were given a value of 0 and the remainder of the state 100 for this input)

The final HSM has a 30 meter resolution.



### Identifying Potential Corridor Locations

To model a corridor one must first identify the areas to connect. For this study I used a combination of the results of the 2003 Critical Mass Workshop, carnivore roadkill data, and the habitat suitability model to identify patches of habitat to connect. The 2003 Critical Mass Workshop resulted in the identification of 4 Critical Risk Highway Segments, 13 High Risk Segments and 14 Moderate Risk Segments. These were based on knowledge of the attendees and represented locations that needed to be mitigated for animal-vehicle collisions. It was decided that corridors should be modeled across each of the four Critical Highway Segments and many of the High and Moderate Highway Segments where they served to generate a connected landscape for cougars in the state. Cougar and other carnivore roadkill records were also used to inform the decision on where to model corridors. In total 26 corridors were modeled.

### Corridor Termini

The termini that define the beginning and ending points of the least cost path corridor, ideally meet as many cougar habitat criteria as possible. The identification of the starting and ending points has a great deal to do with the position and extent of the modeled corridor. In every case core habitat blocks were used as the “to” and “from” locales for the corridor to span. The “Create Habitat Patch” tool in the CorridorDesigner Toolbox delineates the habitat blocks. The output was a cougar habitat patch map for New Mexico based on the HSM. Since most of the corridors were delineated to cross roadways, if a core habitat block was coincident with a protected roadless area, then I chose the roadless area as the terminus. Where core habitat block termini nearly touched on either side of a road over which the corridor was to be modeled, a one mile buffer of the road was used to erase the termini<sup>7</sup>. This forced the model to identify a corridor that spans a minimum of two miles between core habitat patches and finds the best route - not just the shortest route. For all the corridors, a piece of the statewide HSM was extracted around the two termini, large enough to give the model room to roam and find the best path but small enough to limit processing time.

### Least Cost Path Analysis

A simple least cost path analysis produces a one pixel wide result from destination to source. That result is guaranteed to be the lowest cost or “path of least resistance” between the two locales. In this case, a typical least cost path analysis would produce a corridor 30 meters wide. No documentation was found with precise functional width requirements specific to cougar corridors. However, it is suspected that 30 meters is far too narrow to be practical. To produce a more practical corridor, The CorridorDesigner tools use an additional GIS function called “Least Cost Corridor” which identifies for each cell location, the accumulative costs for movement in each direction: one from point A to point B and one from point B to point A. These two surfaces are mathematically added together to produce the final “Cost Distance” surface. Each pixel with the Cost Distance surface represents the lowest possible cumulative resistance from that pixel to terminuses in each core habitat area. Therefore, the output raster identifies not a single least-cost path between the two sources, but a range of accumulative costs between the sources. From there the CorridorDesign tool extracts

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<sup>7</sup> P. Beier, Majka D., and Jenness J. 2007 Conceptual steps for designing wildlife corridors. <http://www.corridordesign.org/downloads/>

slices of continuous permeable pixels between the two termini. The tool produces vector representations of each swath. The final result is eleven corridor swaths for each modeled corridor. These range from the “best” or lowest cost 0.1% of the matrix of HSM to 10%.

## Results

In total twenty six corridors were modeled. Four crossed Critical Risk Highway Segments, five crossed High Risk Segments and six crossed Moderate Risk Segments. Several corridors showed strong correlations to carnivore roadkill records.

Depending on the length, width and character of the connecting matrix, anywhere from one to six distinct corridor strands were identified in a given area. In most cases the combinations of the 0.1%, 1% and 2% slices represent the best corridor. Some corridors modeled along long stretches of highway connecting habitat on either side generated numerous corridor strands such as Corridor #14 connecting the El Malpais region to Mount Taylor. In that case three distinct viable corridors were generated along with 4-6 additional lesser corridors represented by slices greater than 3%. It may well be in that case, that some of the lesser corridors may be more practical for on the ground implementation.

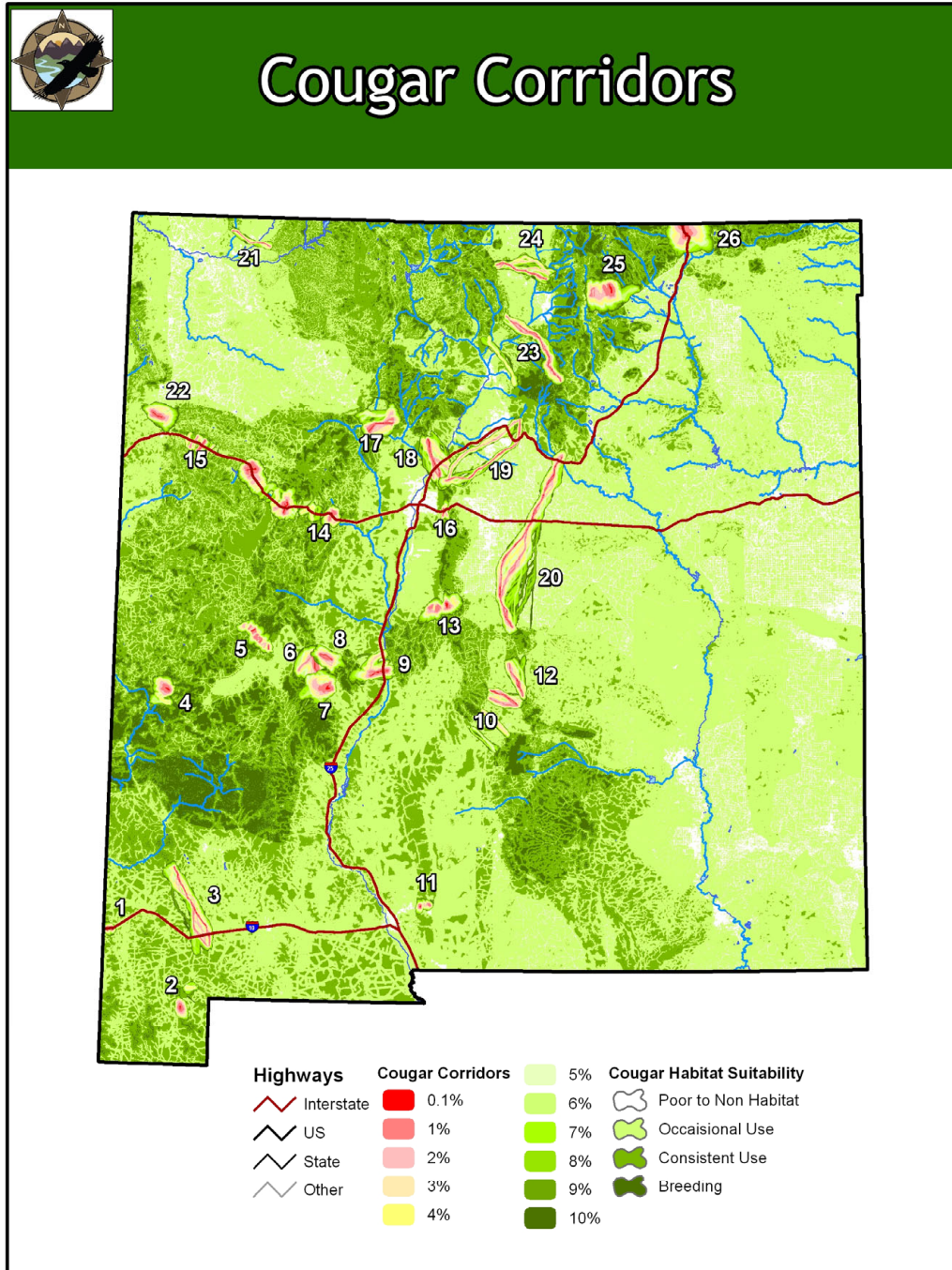
Since these are potential corridors and no field truthing has been done, it is difficult to know how significant they are. The only dataset that could be used to measure the validity of the corridors was NMDOT roadkill data records which spanned the years from 1993 – 2005. The NMDOT roadkill data showed carnivore roadkills had occurred within 13 of the corridors. Of those 13 corridors, 9 showed the carnivore roadkills occurring within the most optimum corridor swaths. For example, Corridor #15 (I-40 over the Continental Divide) shows the best 0.1% corridor running between two closely spaced coyote roadkills. Corridor #23 (San Juan Mountains – Sangre de Cristo Mountains) has a black bear, a coyote, and a cougar roadkill all occurring within the 1% slice. Corridor #26 (Raton Pass) shows two cougar roadkills framing the 0.1% swath on I-25. The corridor connecting the Sandia Mountains and the Manzanita Mountains through Tijeras Canyon, Corridor #16, is the most studied corridor in the state due to work spearheaded by the Tijeras Canyon Sage Passage Coalition. In that location the 0.1% corridor swath runs just west of Dead Man’s Curve which is a known hot spot for animal-vehicle collisions. This swath actually runs through the overland crossing NMDOT constructed in 2007 with an animal detection system. Cougar roadkill data were present on four of the modeled corridors. At all four, the roadkill records show strong correlations with the modeled corridors.

It must be noted that roadkill data is only collected when a law enforcement officer is called out to a motor vehicle accident involving wildlife. Therefore the dataset constitutes only a small fraction of the total roadkilled animals. Of the individual incidents recorded, the animal species is only occasionally reported. It is also likely that roadkill records indicate high traffic volume as much as they may indicate dispersal routes for wildlife.

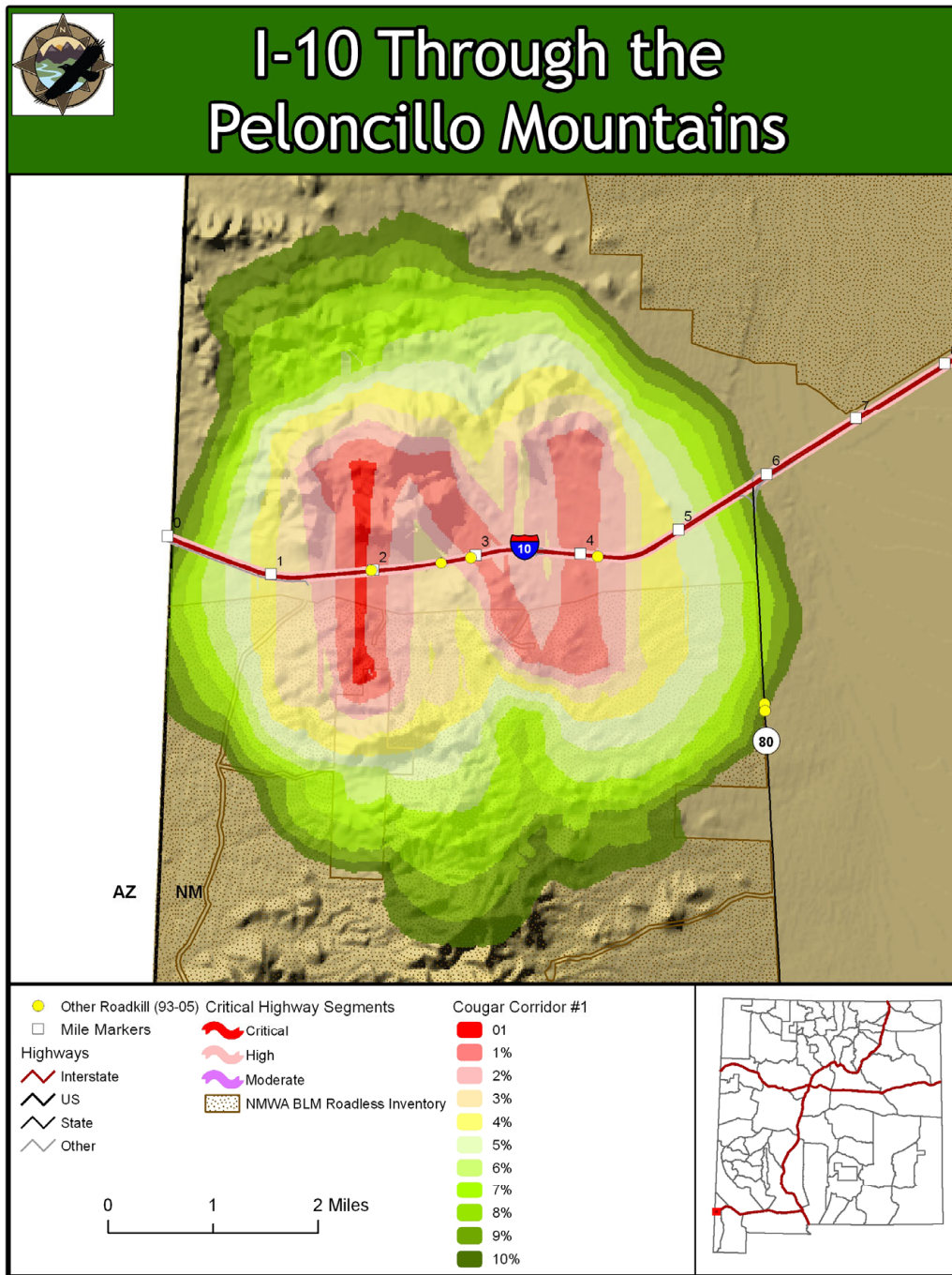
Maps of each modeled corridor were produced depicting the result. Each map includes the Critical Highway Segments, carnivore roadkill where data existed, other big game roadkill records, mile markers with key markers labeled, highways, and protected areas. For cartographic reasons the corridor swaths were unioned together for each



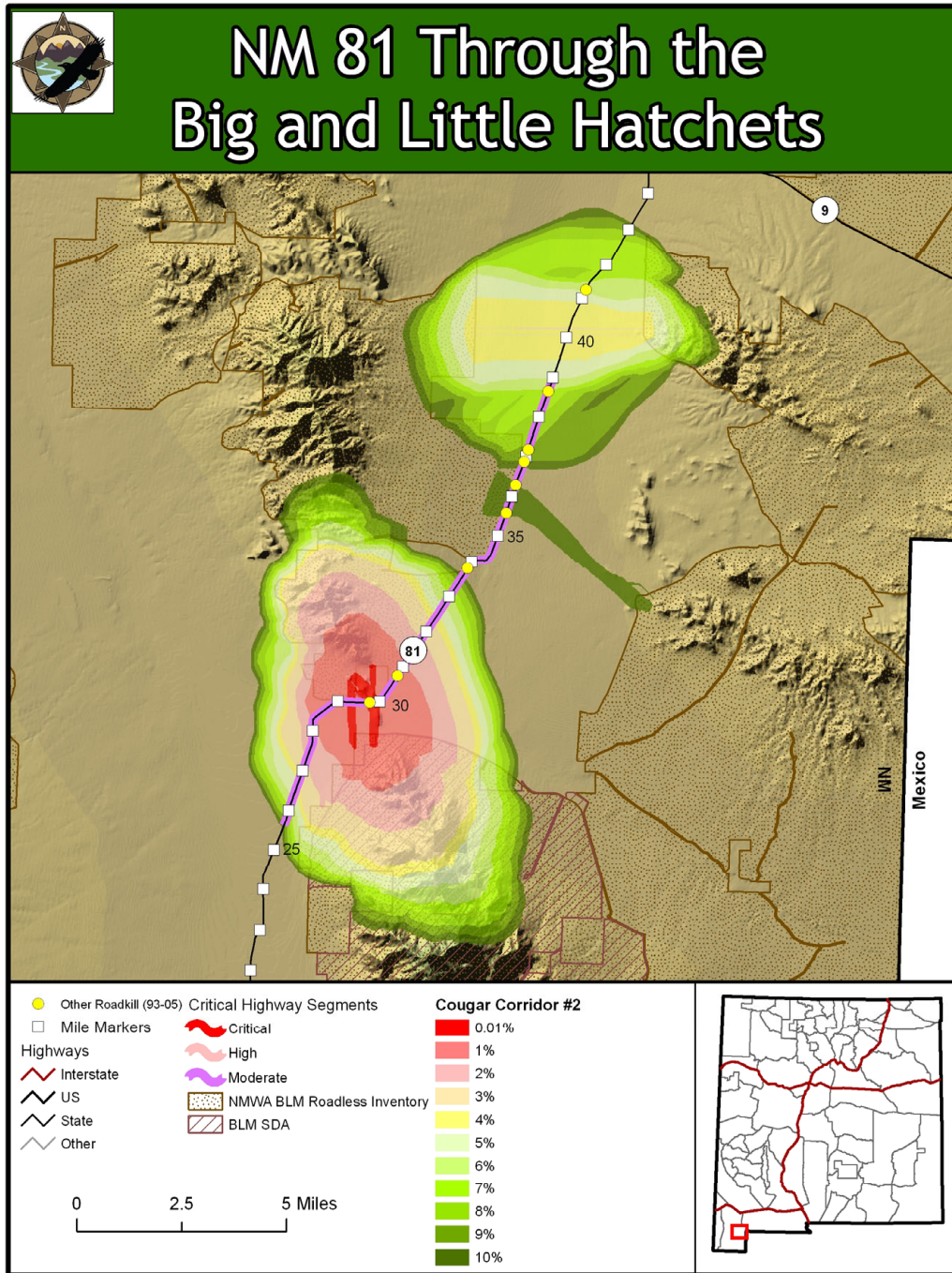
corridor. In actuality each consecutive higher cost corridor swath includes all the lower costs swaths as well. For example, the 10% swath includes all swaths from 0.1% - 9% even though only the outer ring is visible on a particular map.



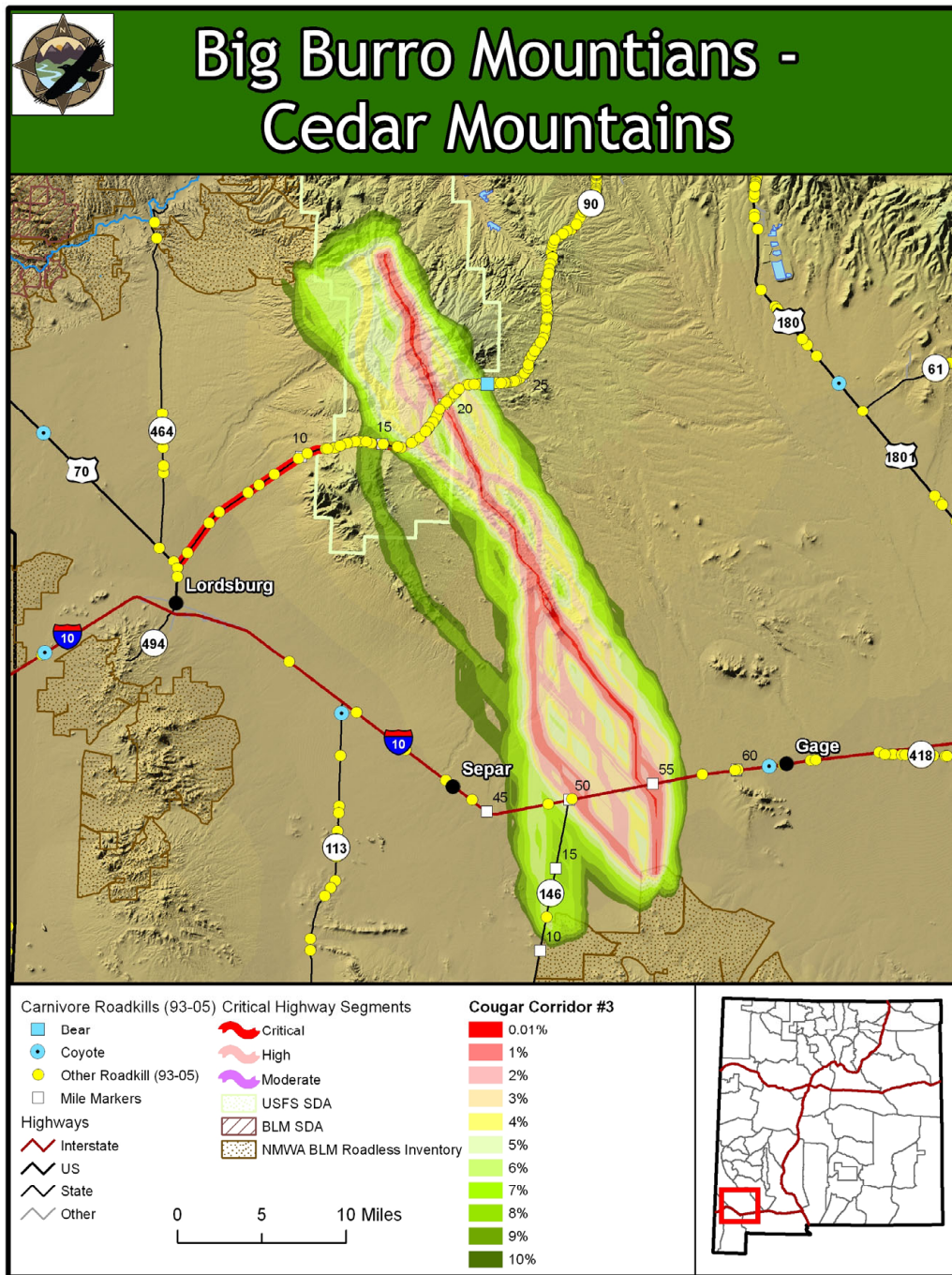
Corridor #1 – I-10 Through the Peloncillo Mountains

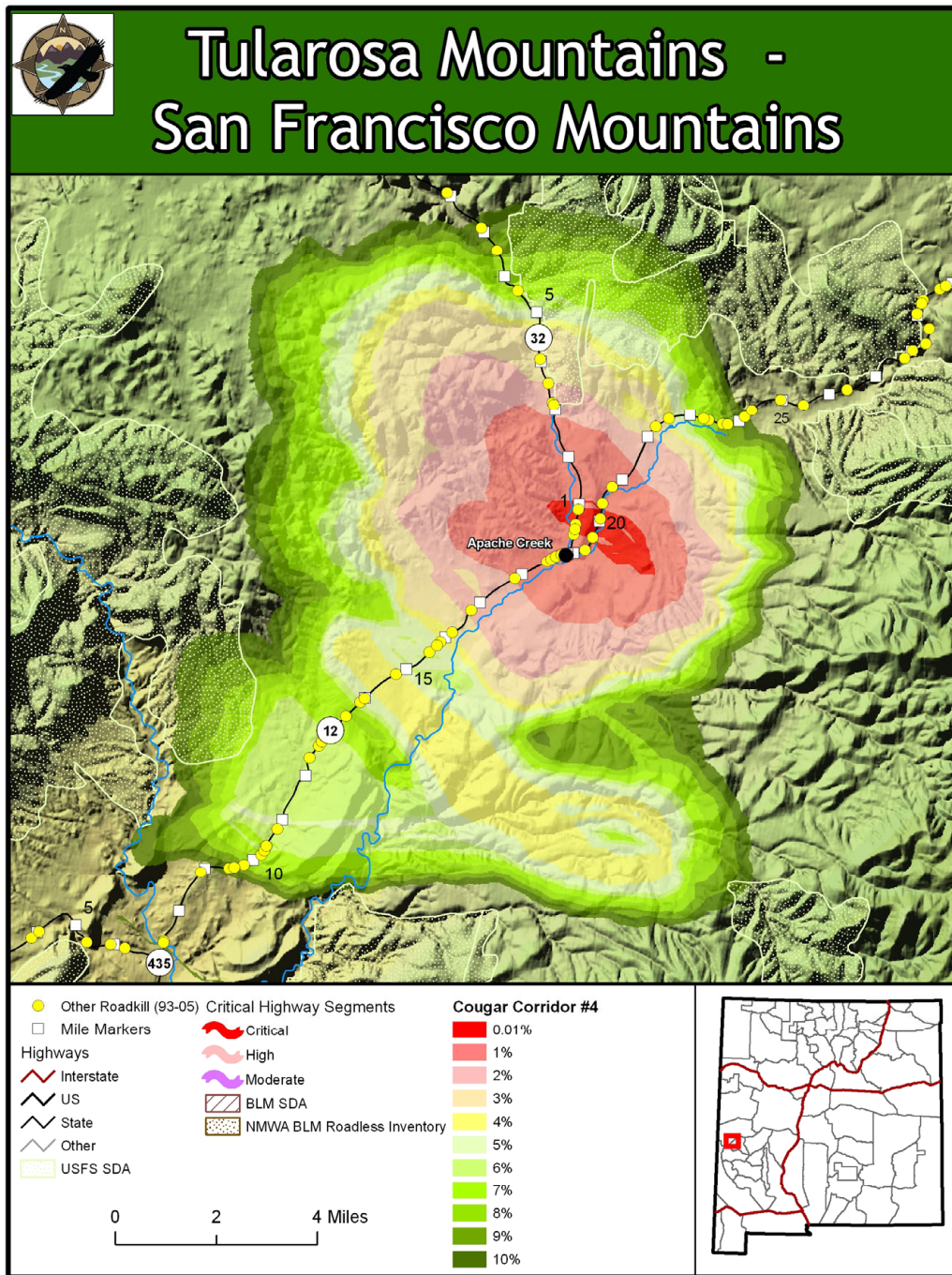


Corridor #2 – NM 81 Through the Big and Little Hatchets

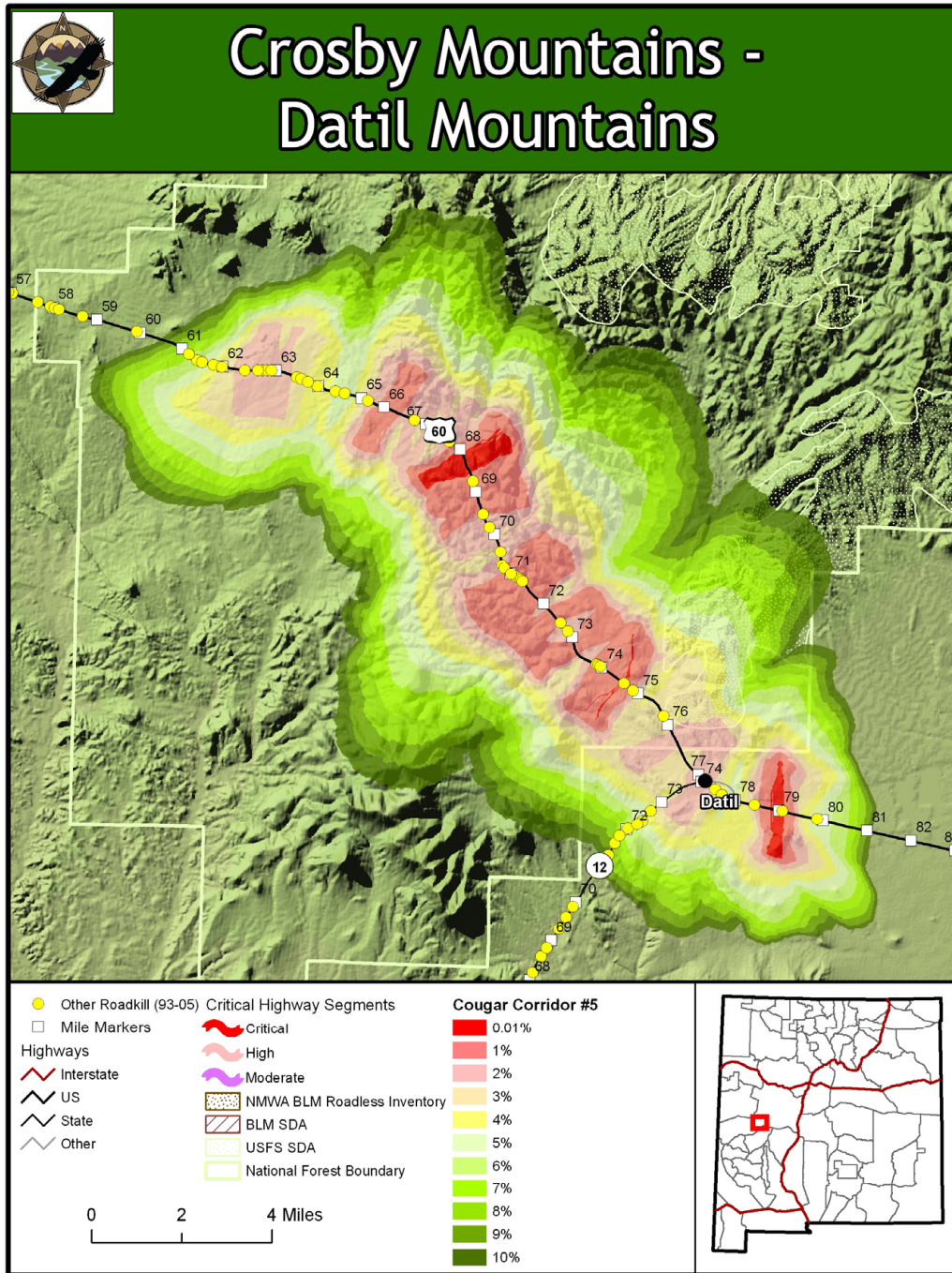


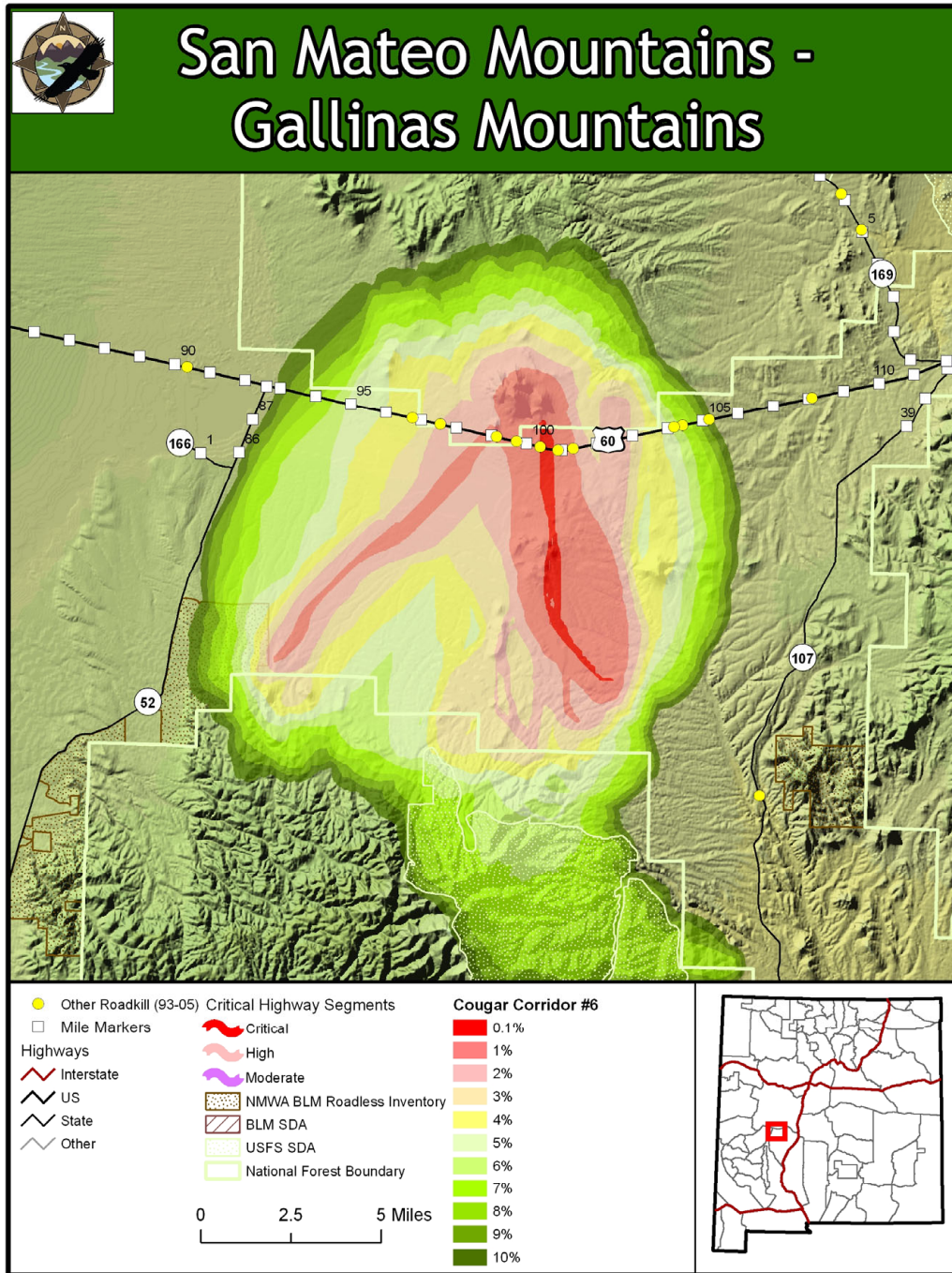
Corridor #3 – Big Burro Mountains – Cedar Mountains

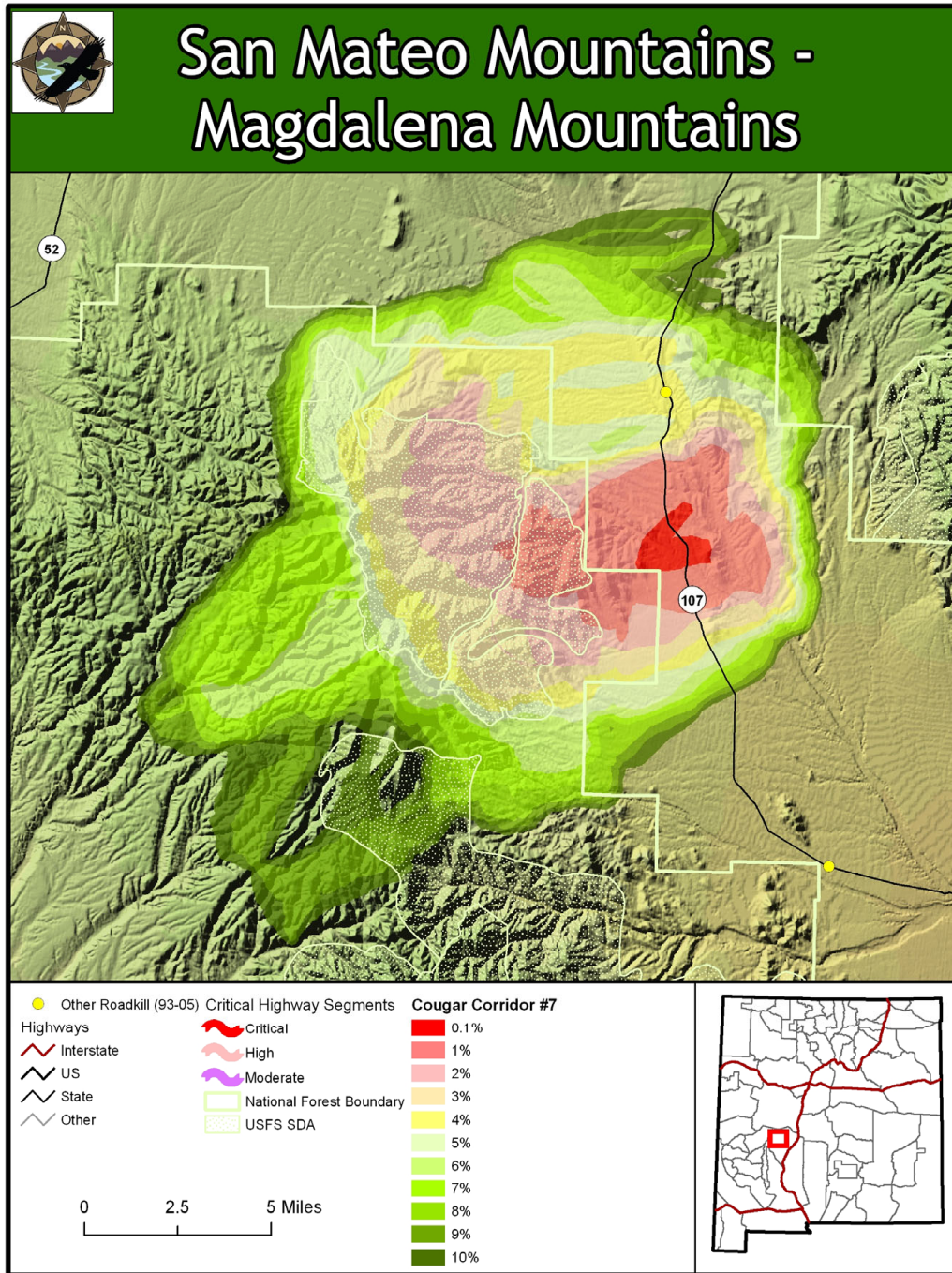




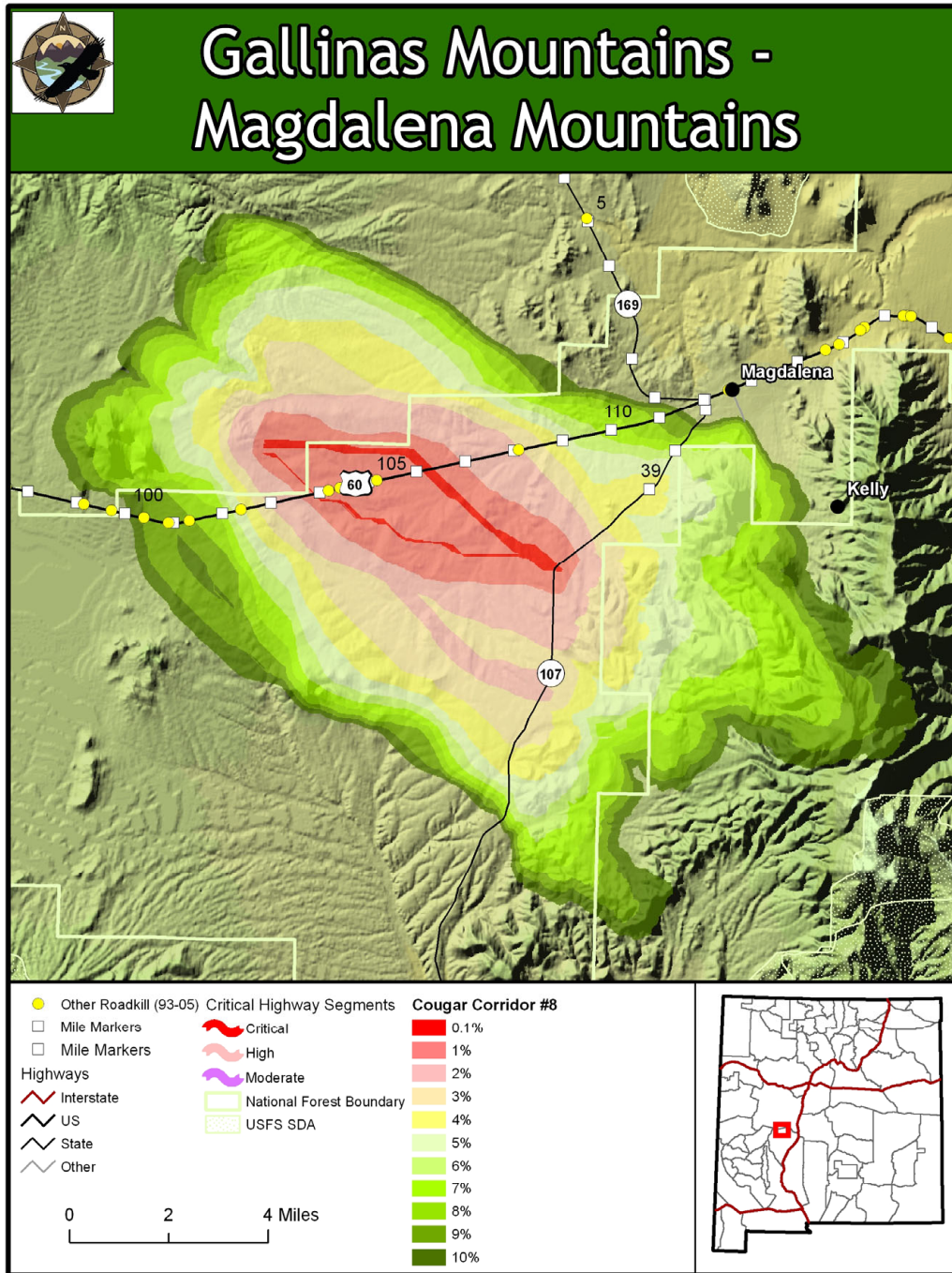
Corridor #5 – Crosby Mountains – Datil Mountains



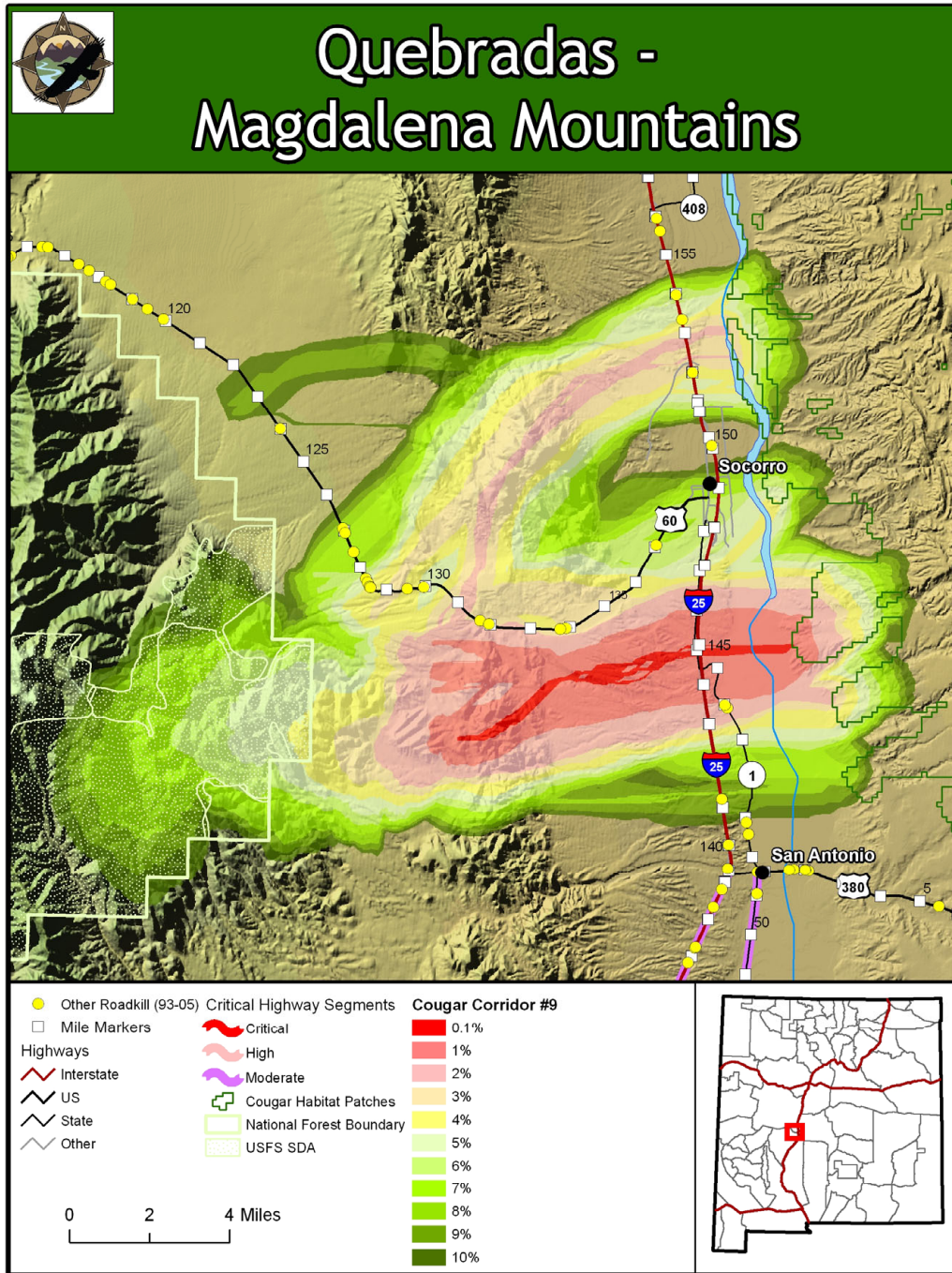




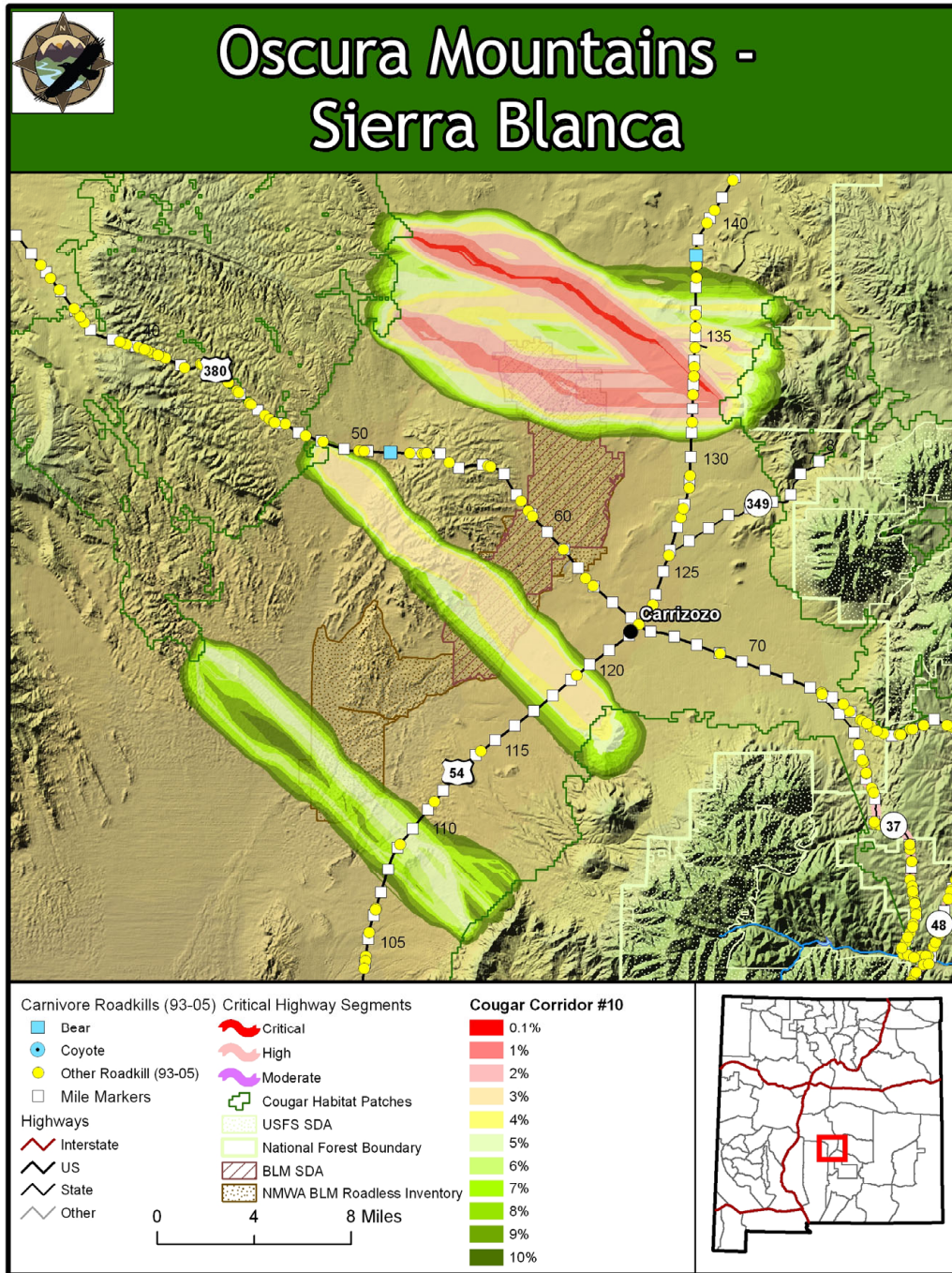




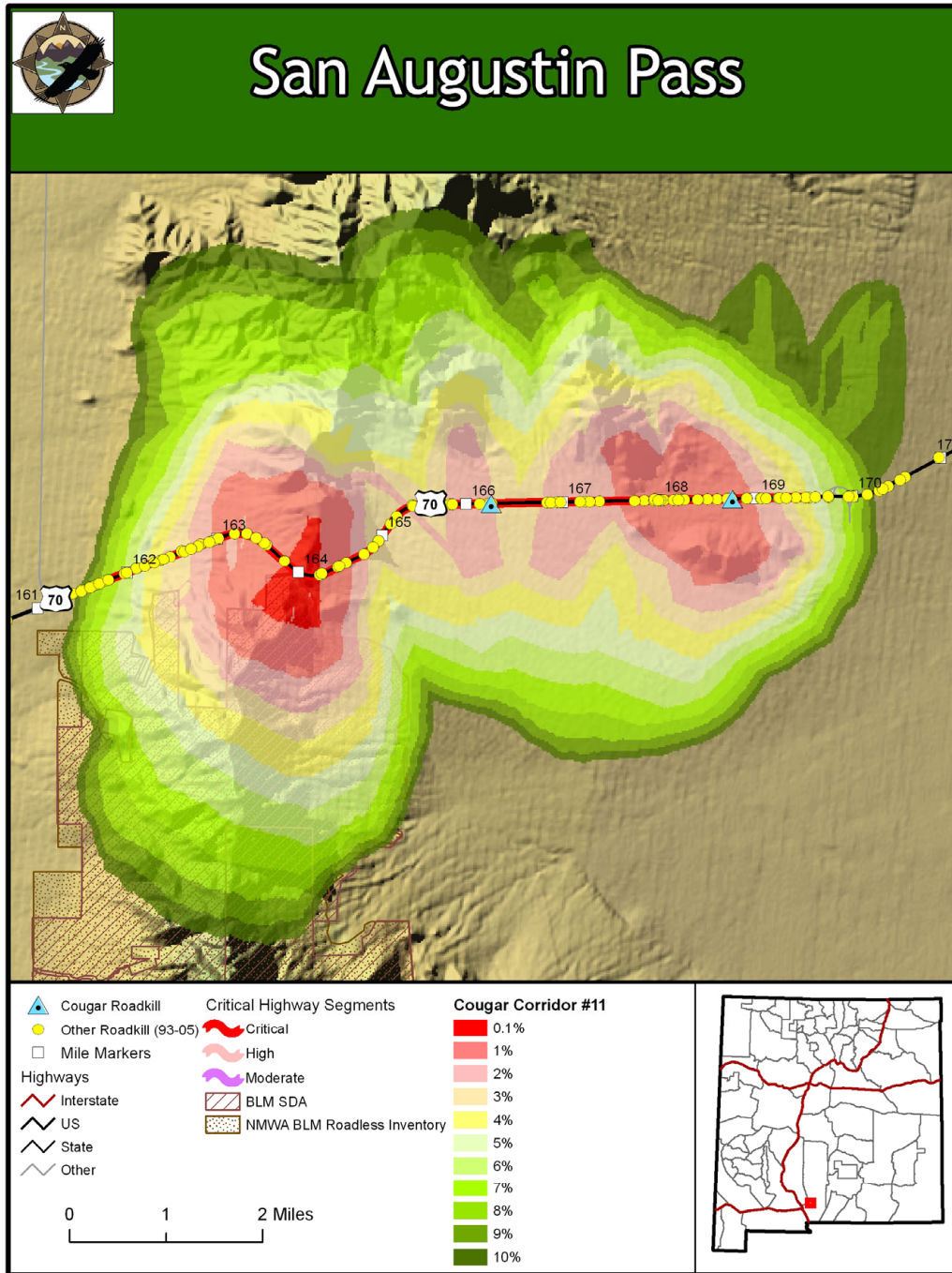
Corridor #9 - Quebradas – Magdalena Mountains

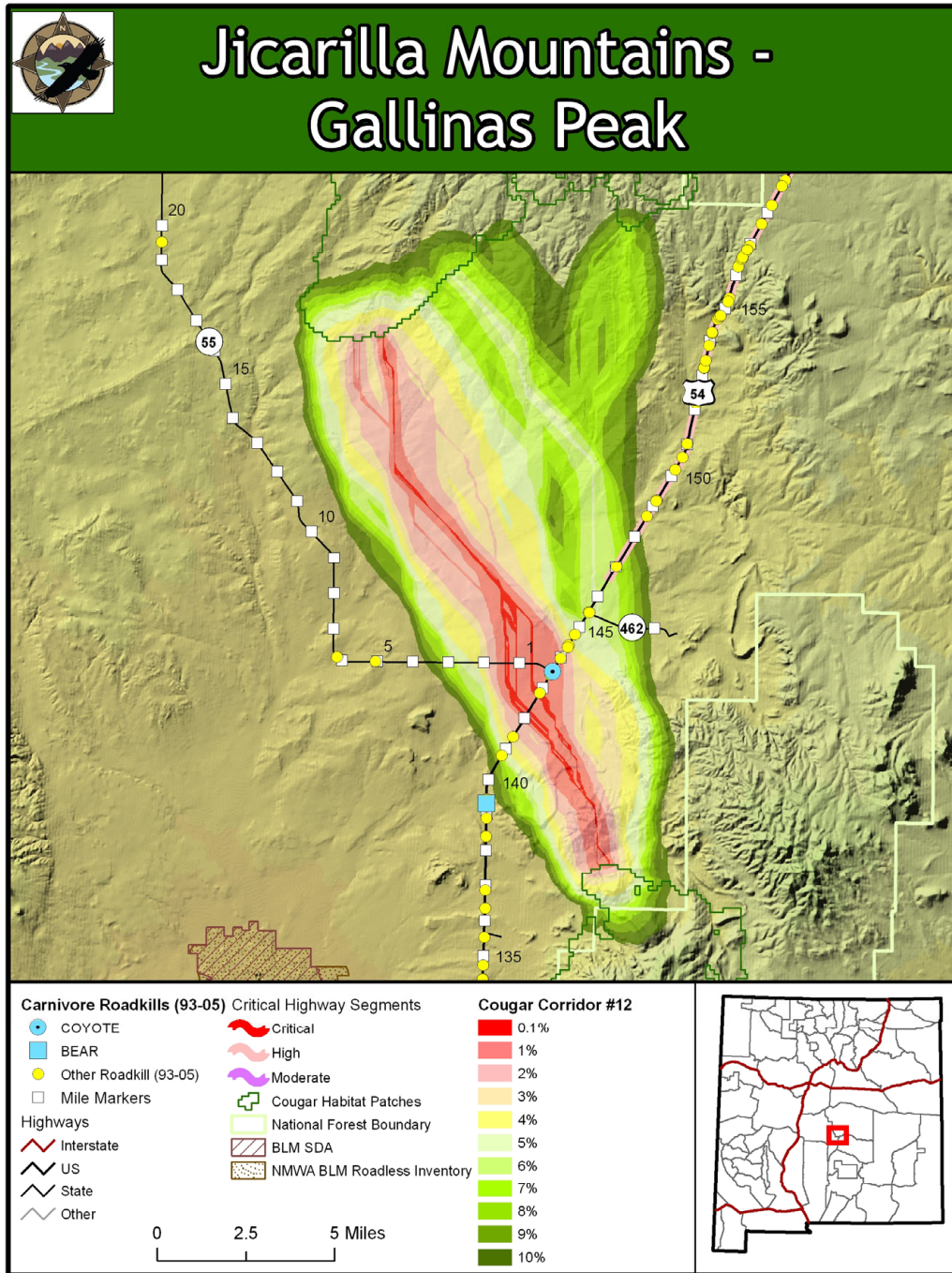


Corridor #10 – Oscura Mountains – Sierra Blanca

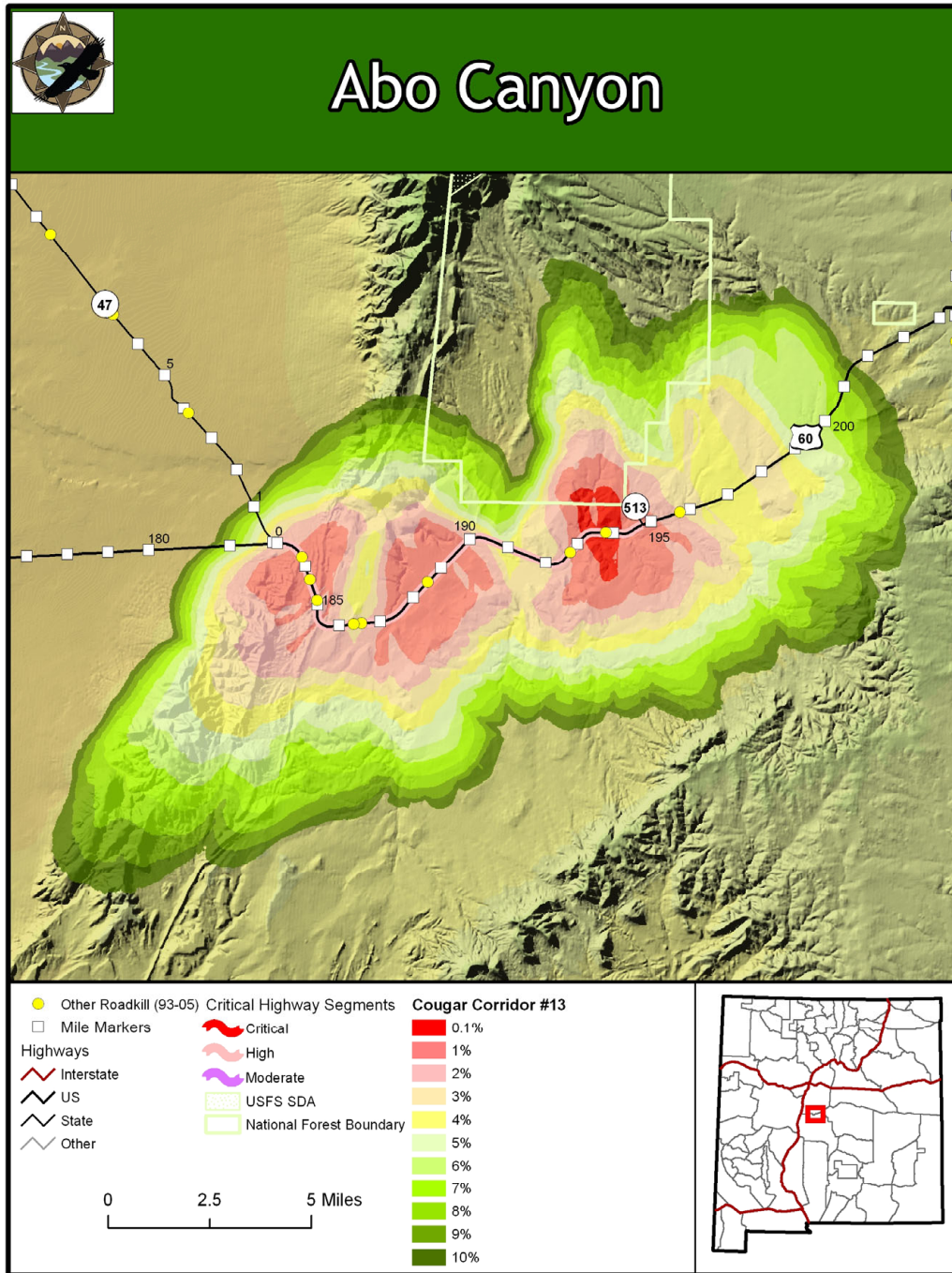


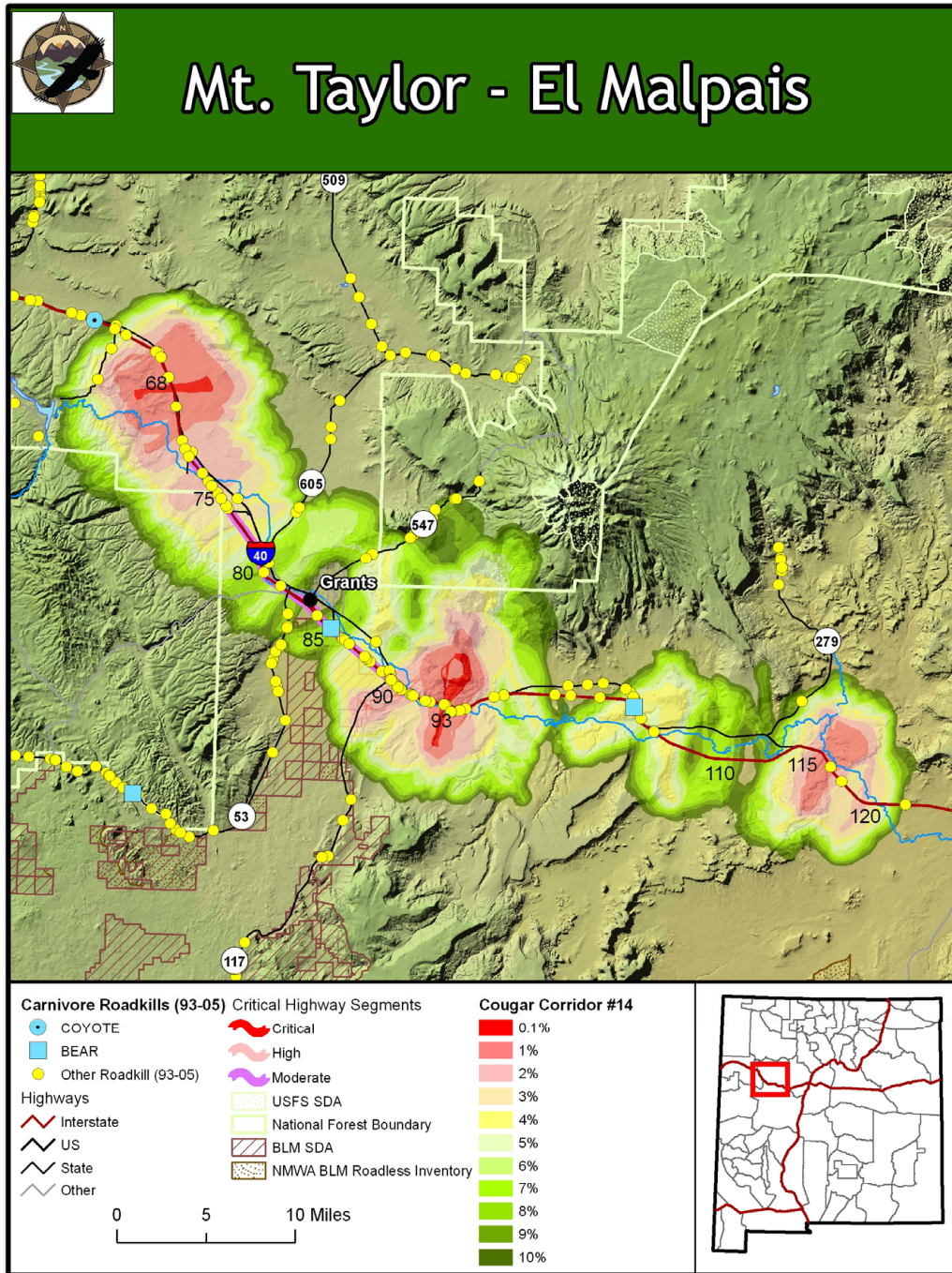
Corridor #11 – San. Augustin Pass



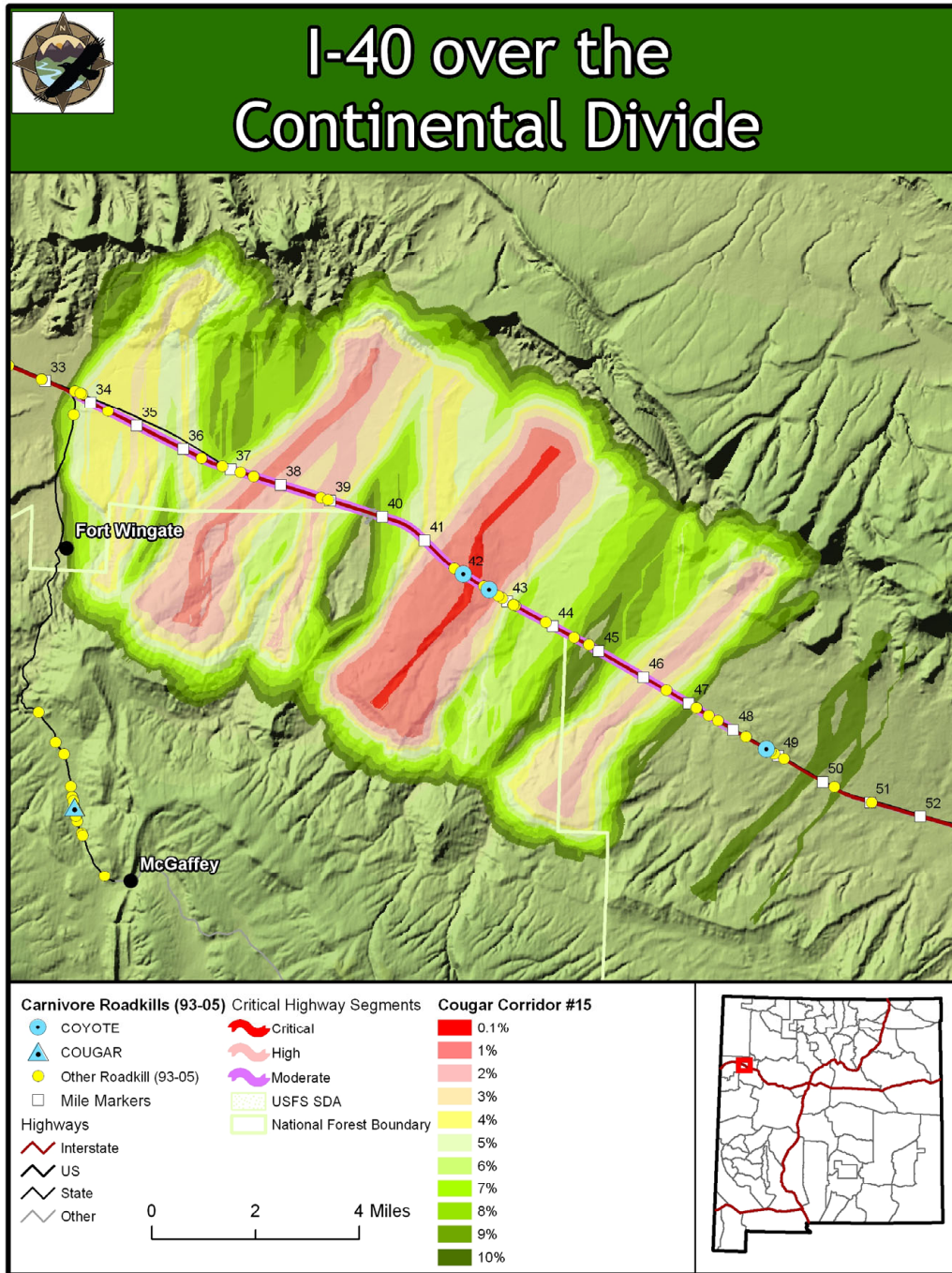


Corridor #13 – Abo Canyon



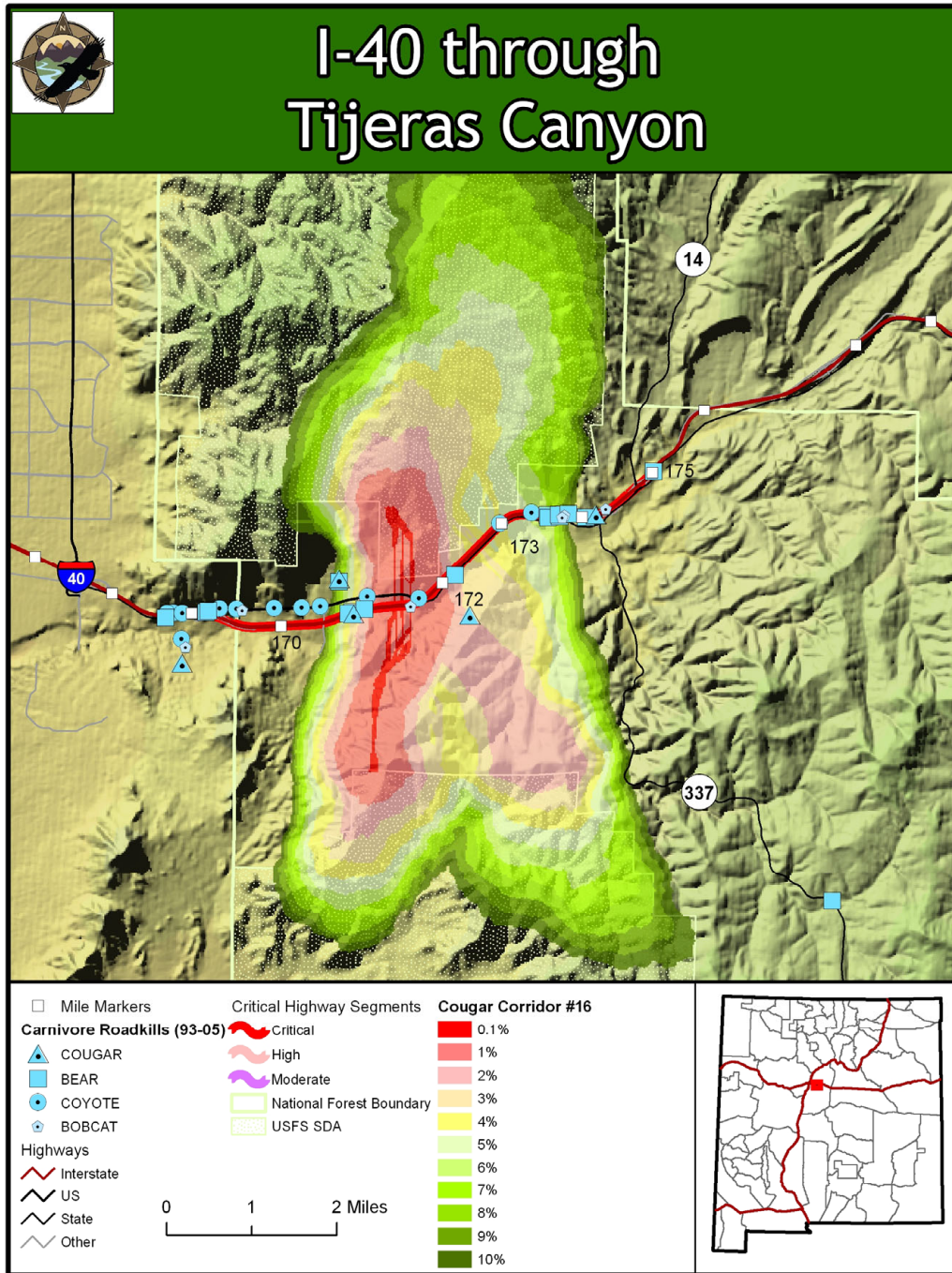


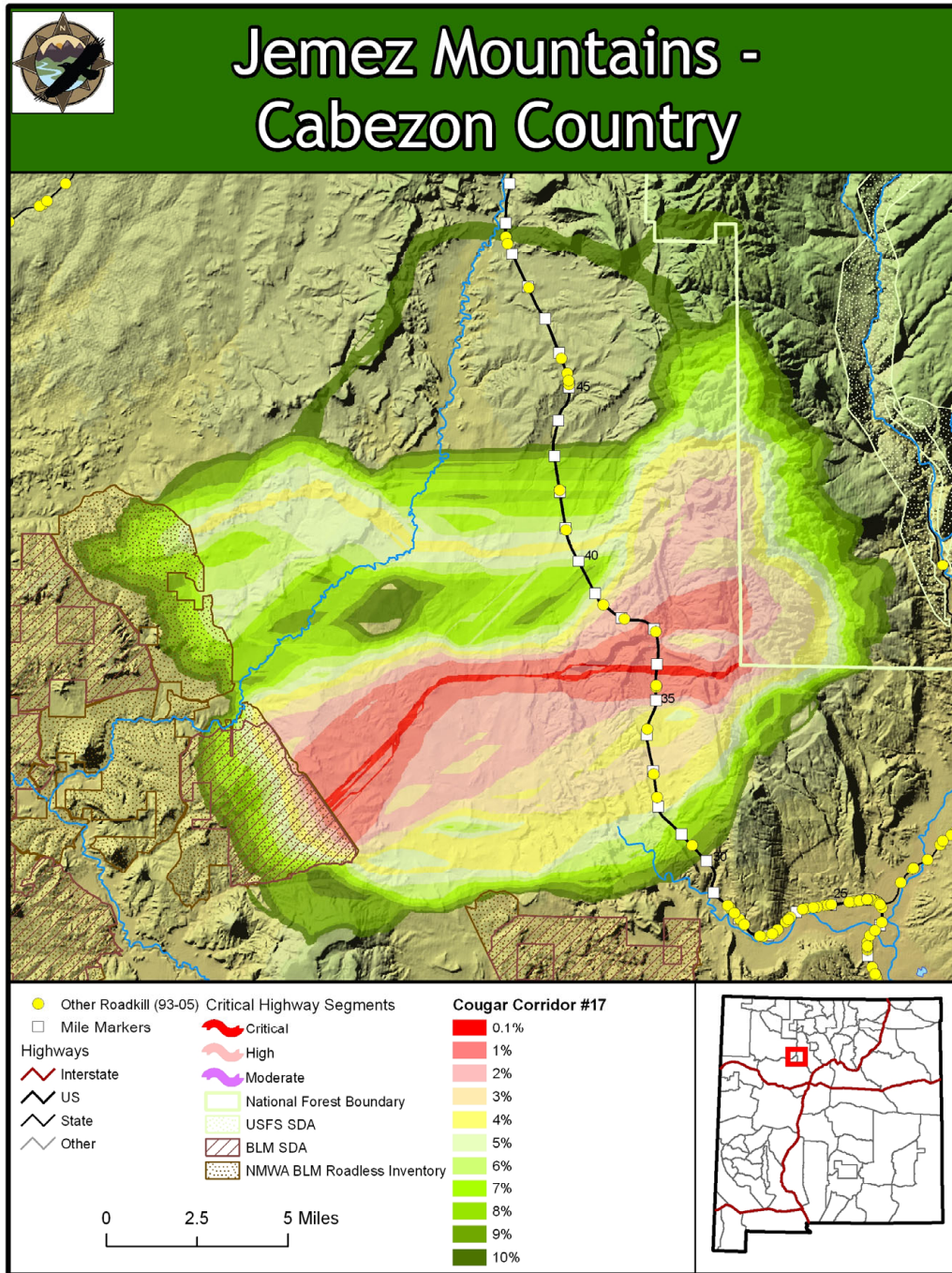
Corridor #15 – I-40 over the Continental Divide

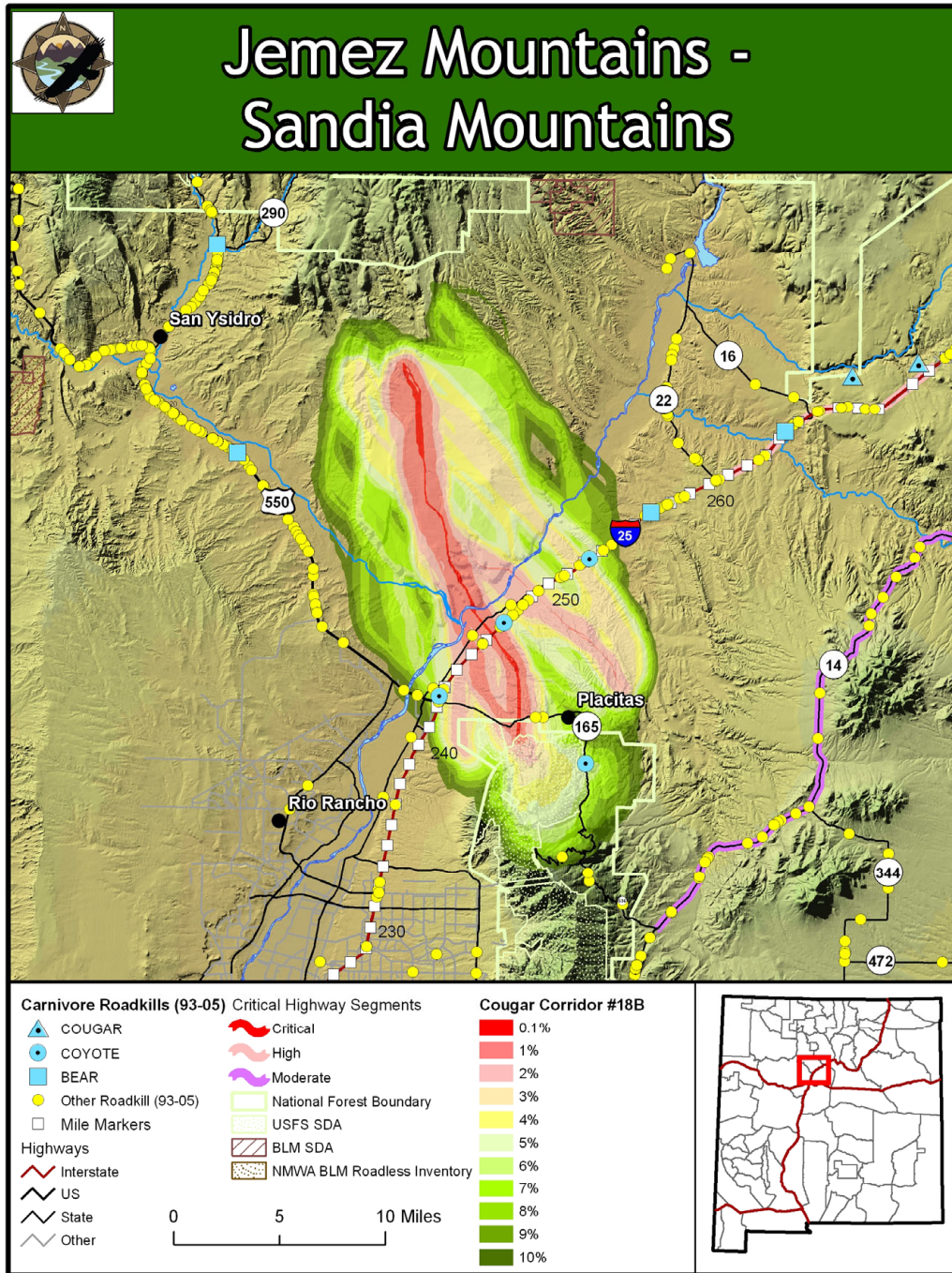


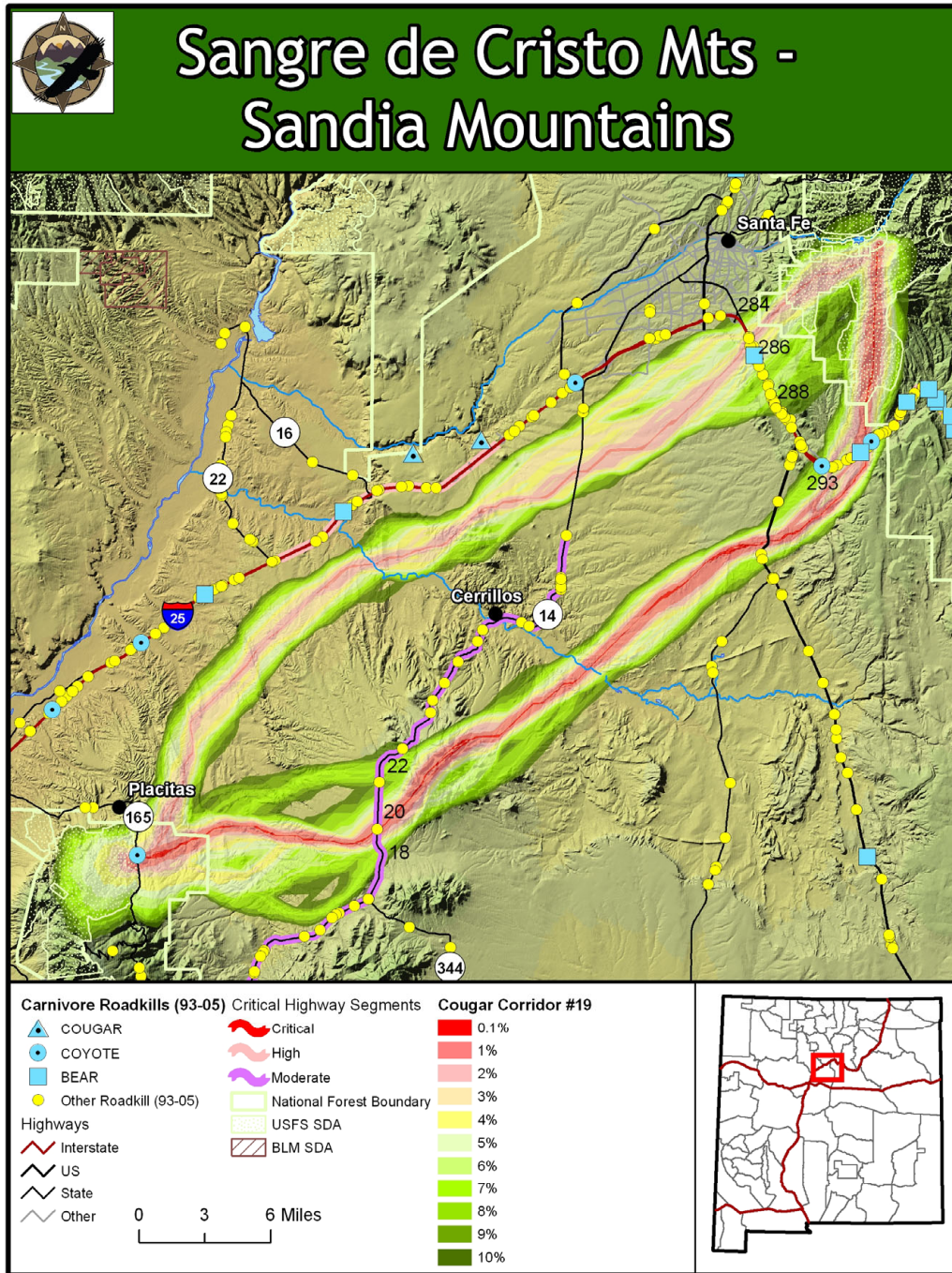


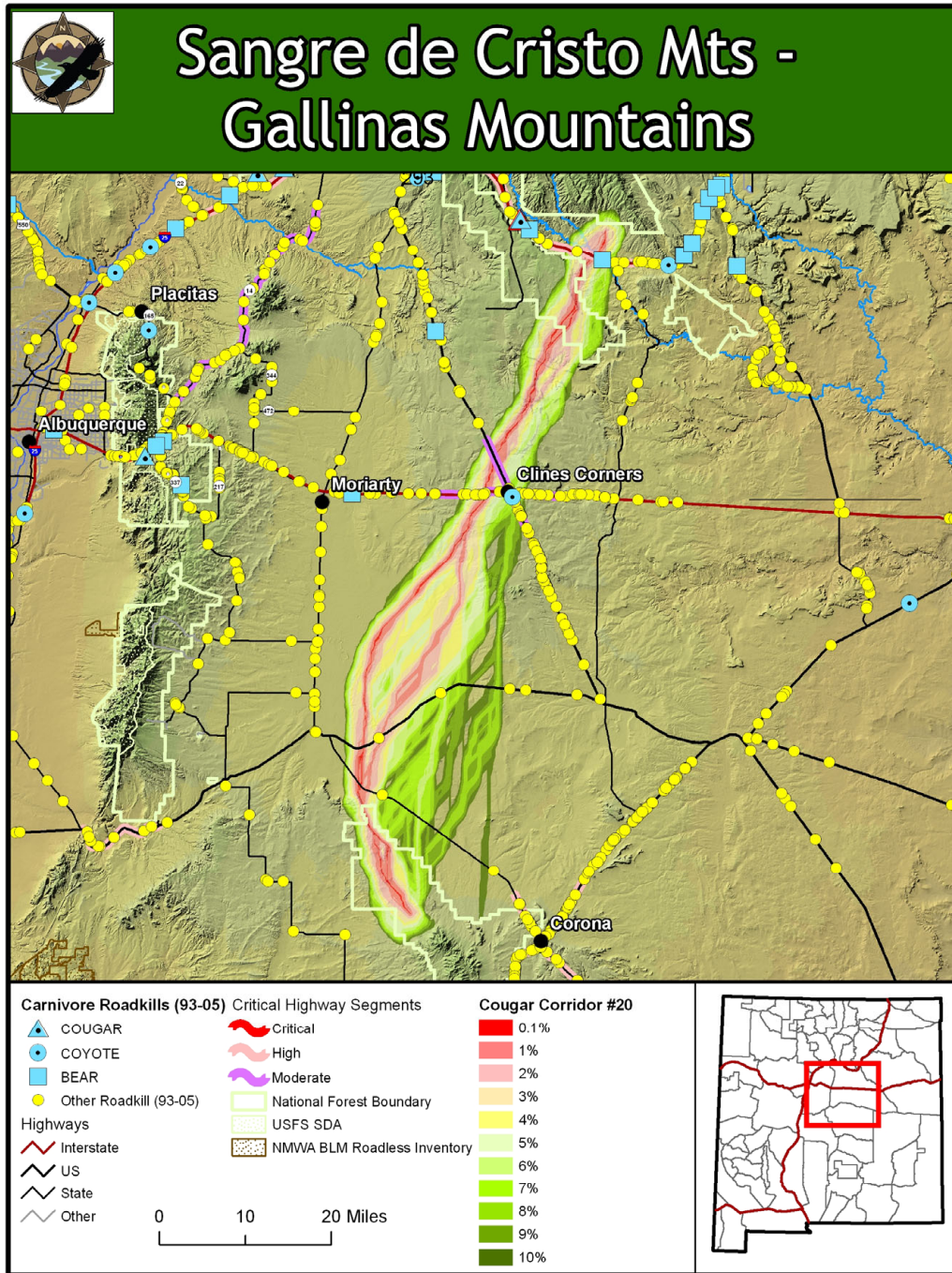
Corridor #16 – I-40 through Tijeras Canyon

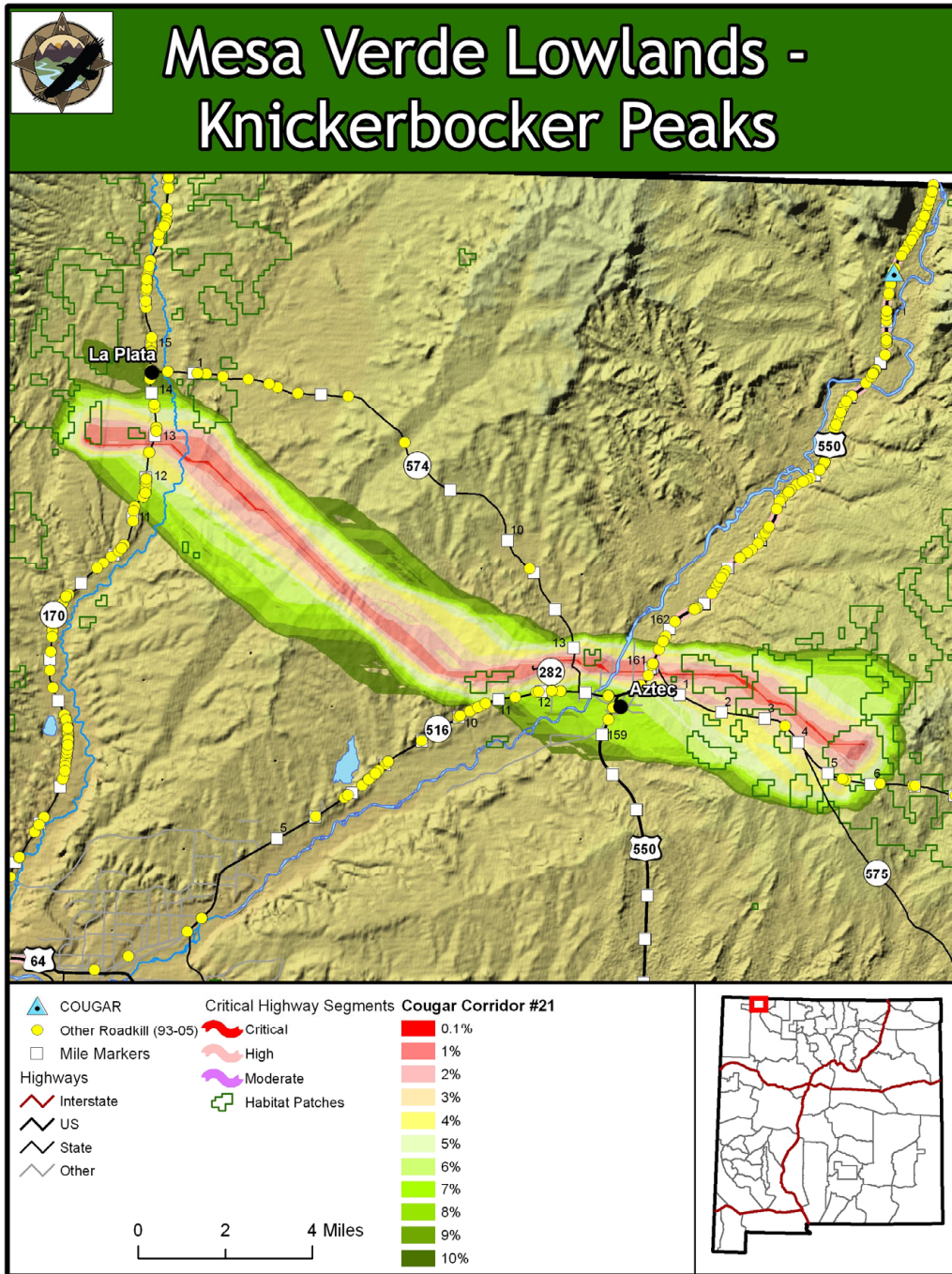




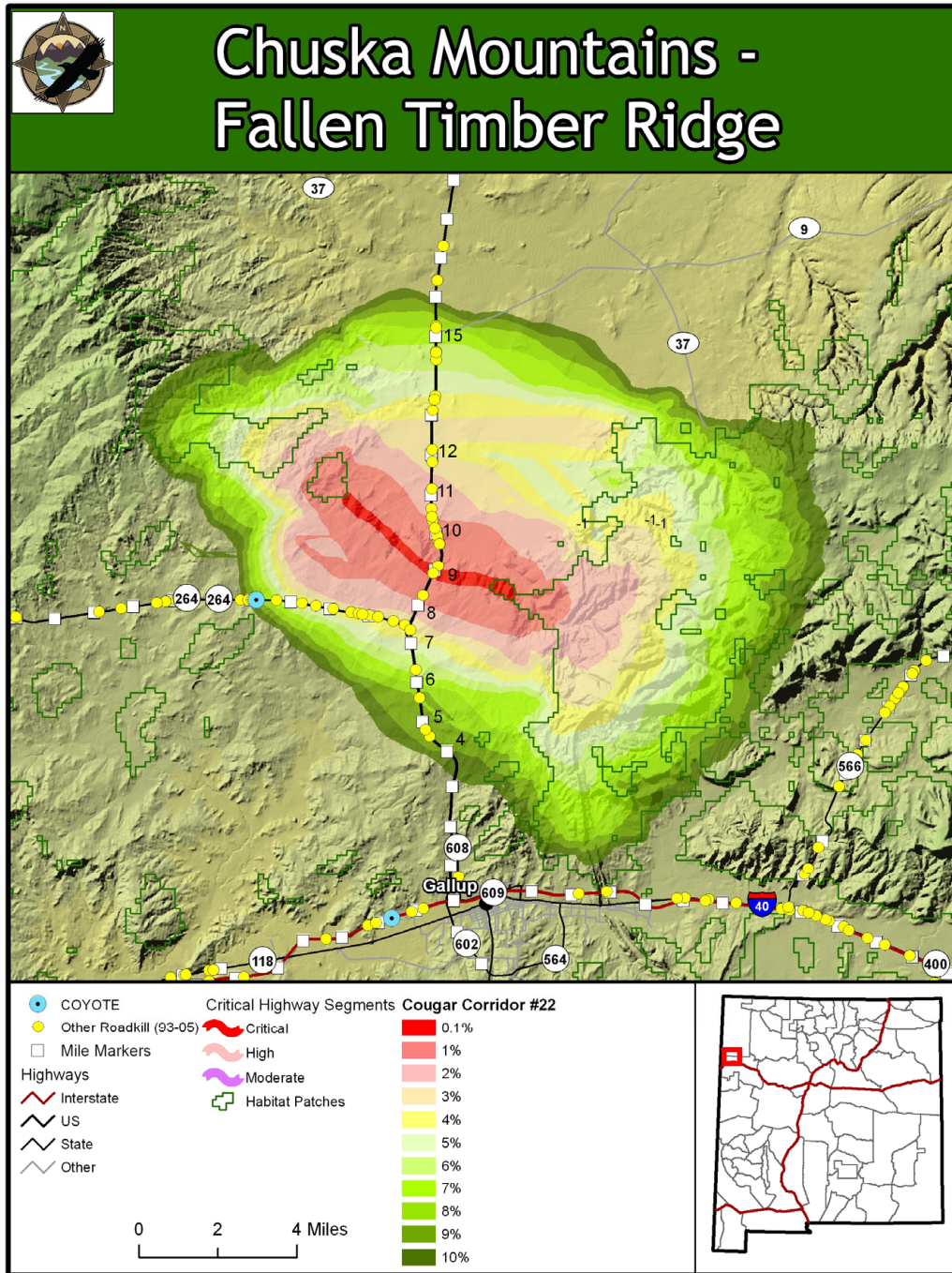




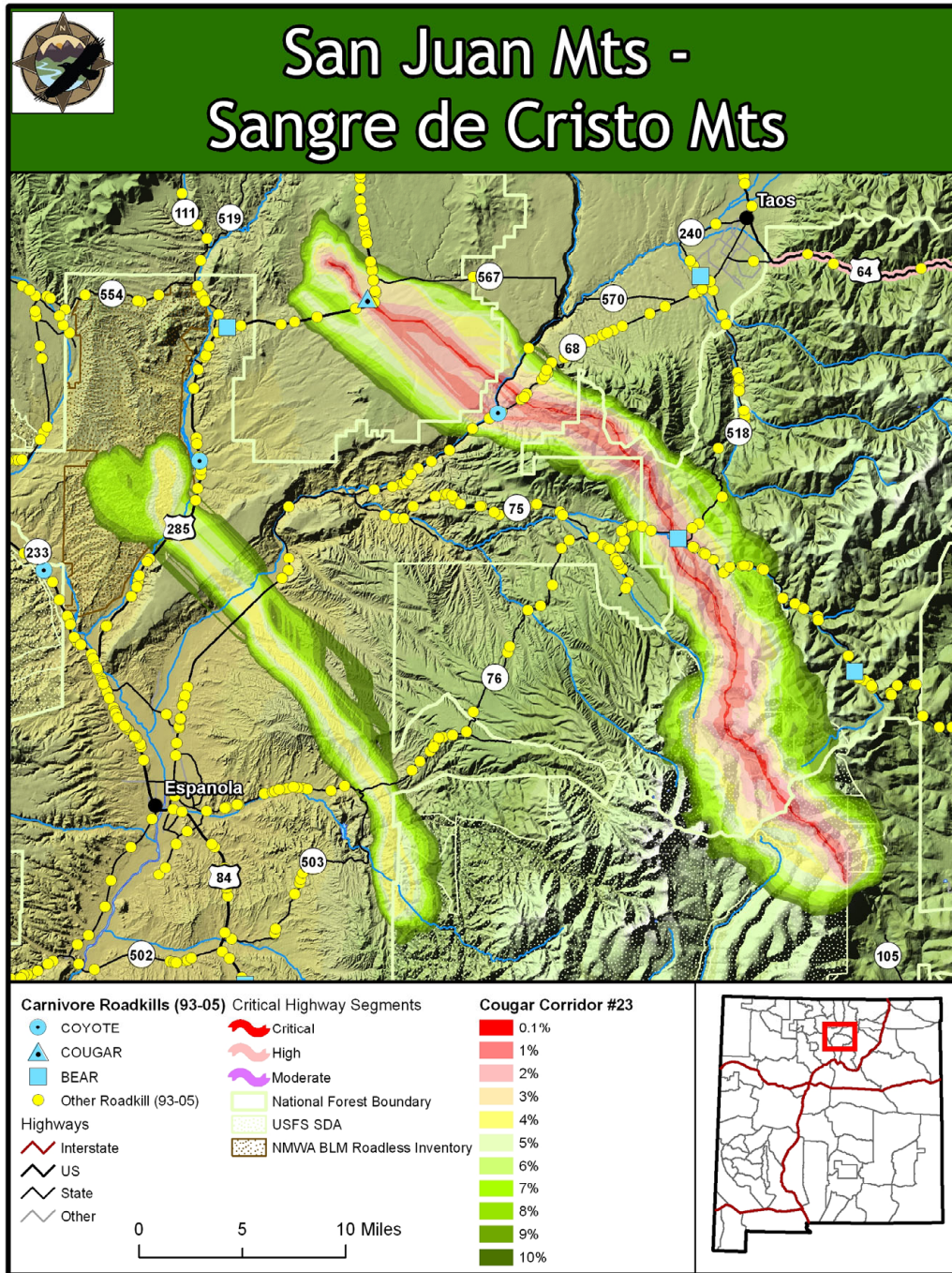




Corridor #22 – Chuska Mountains – Fallen Timber Ridge

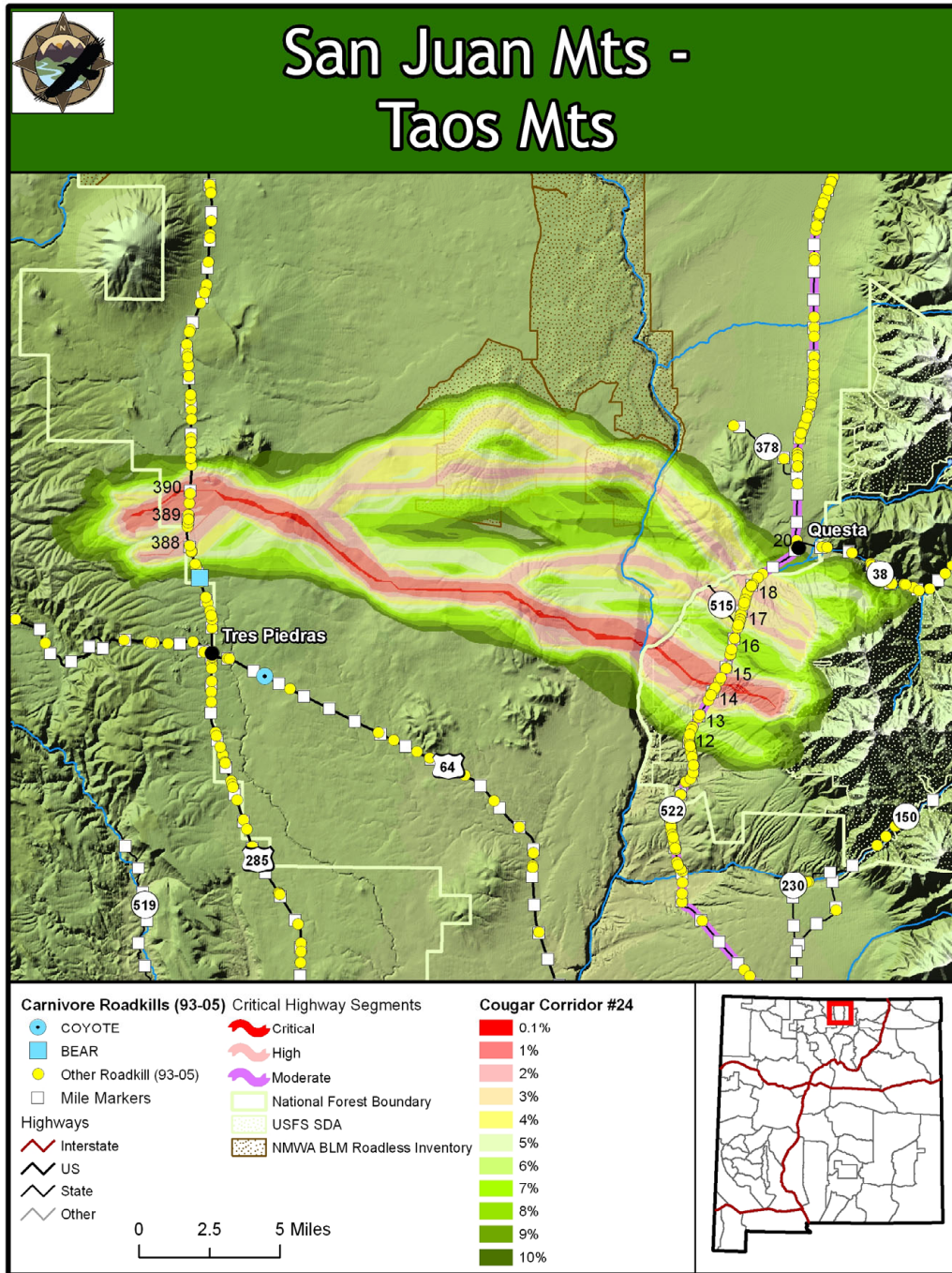


Corridor #23 – San Juan Mts – Sangre de Cristo Mts

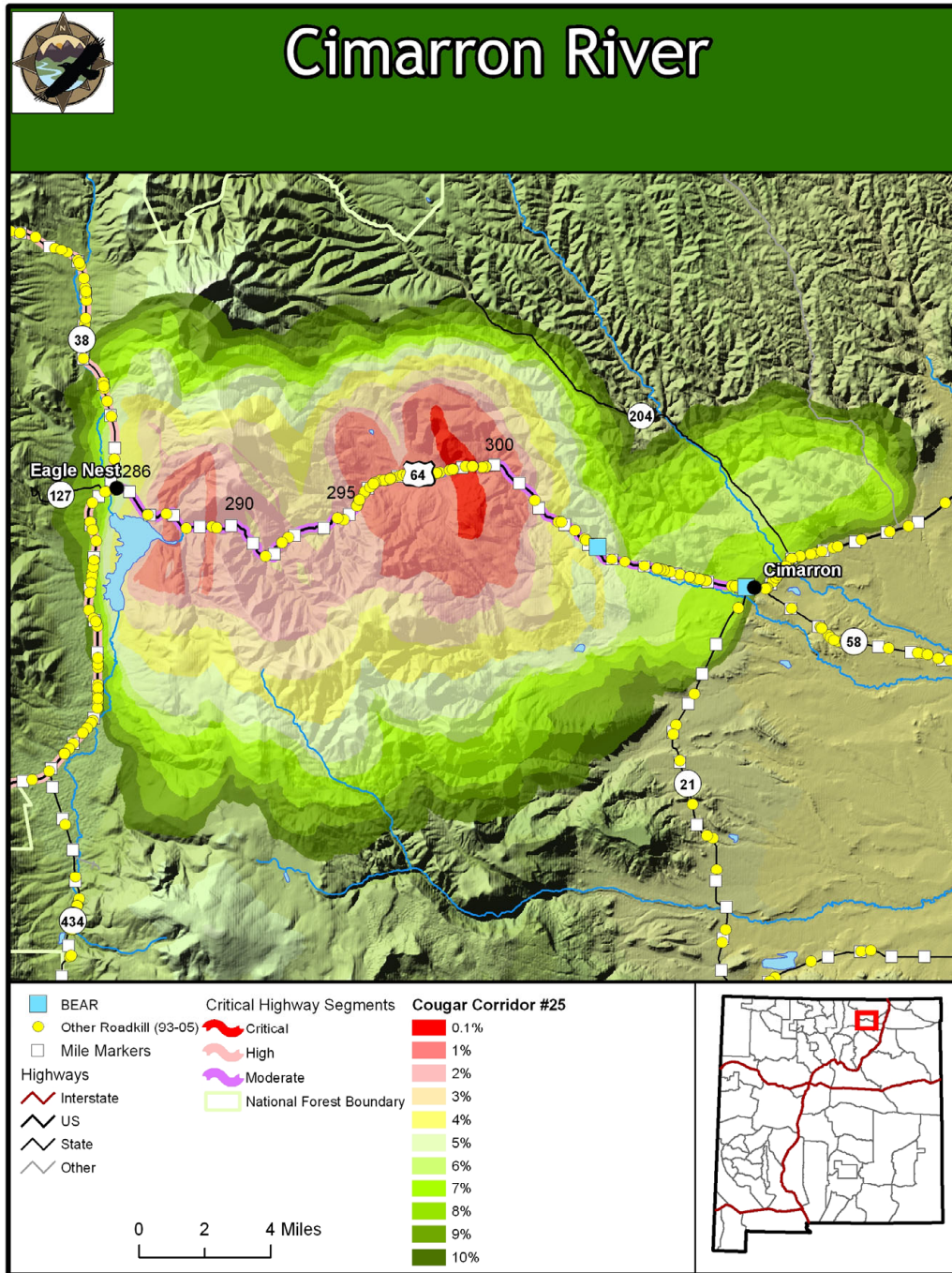




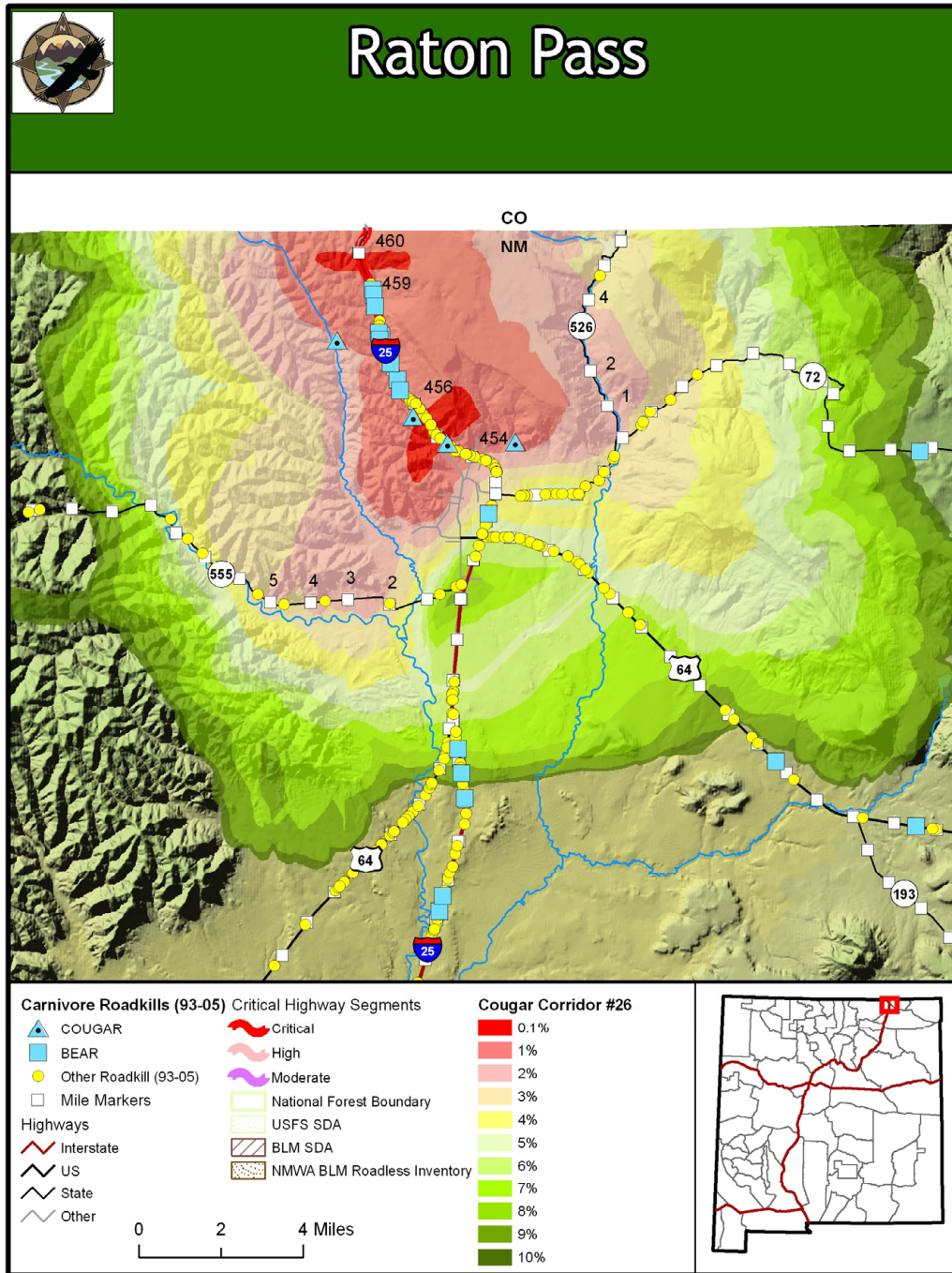
Corridor #24 – San Juan Mts – Taos Mts



Corridor #25 – Cimarron River



Corridor #26 – Raton Pass

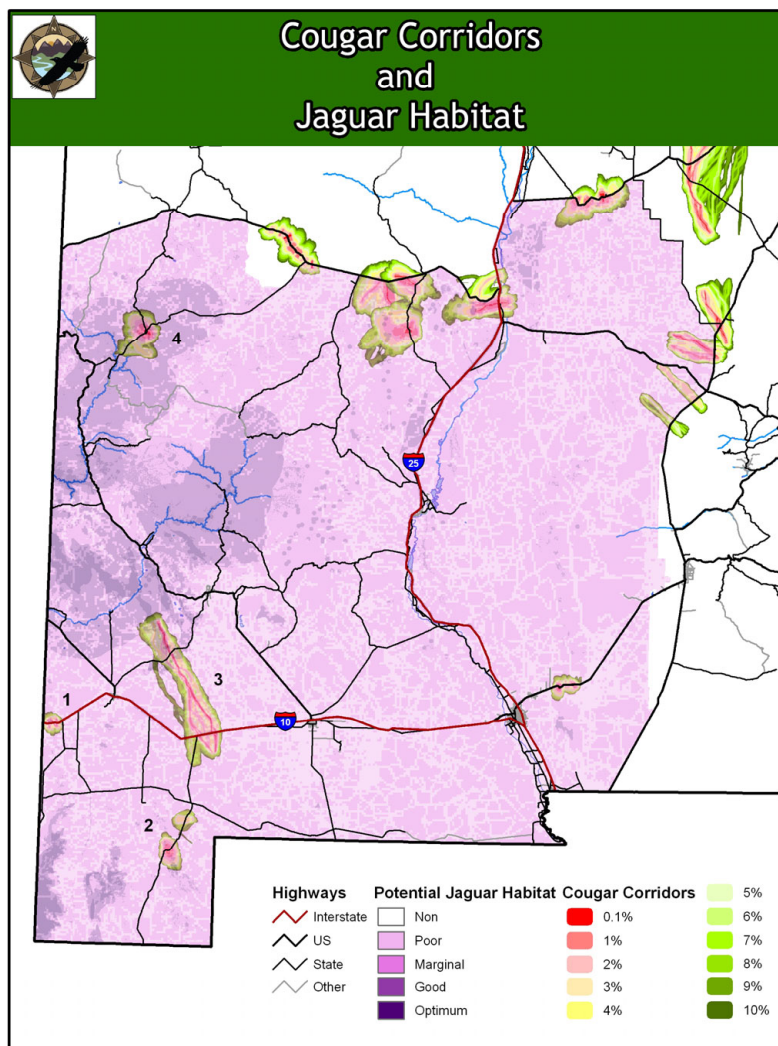


## Relationship to Meso Carnivores

The cougar corridors were compared visually to marten (*Martes americana*), gray wolf (*Canis lupus*), jaguar (*Panthera onca*), swift fox (*Vulpes velox*) and kit fox (*Vulpes macrotis*). The habitat data for these species was obtained from the Southwest Regional GAP Program with one exception. The jaguar potential habitat suitability data was developed in 2002 by Hayes and Menke<sup>8</sup>. These are all listed as species of greatest conservation need in the NM-CWCS. The results show that many of the corridors for cougar dispersal may also serve these other species.

### Jaguar

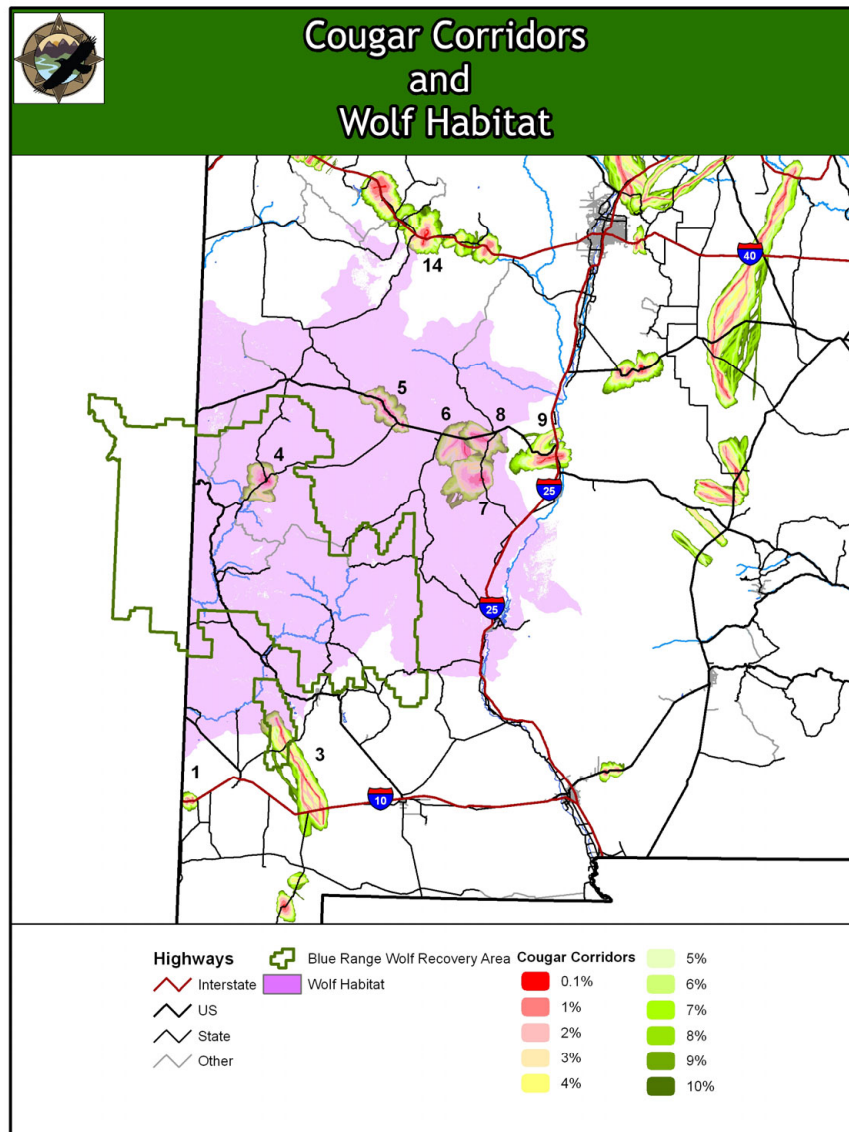
Corridors #1 – 4 all connect patches of potential jaguar habitat. Corridors 1# and #3 may indicate useful locations to study for Jaguar dispersal across Interstate 10.



<sup>8</sup> Hayes C. and K. Menke. 2002 Evaluation of the Relative Suitability of Potential Jaguar Habitat in New Mexico. Unpublished Manuscript

## Wolf

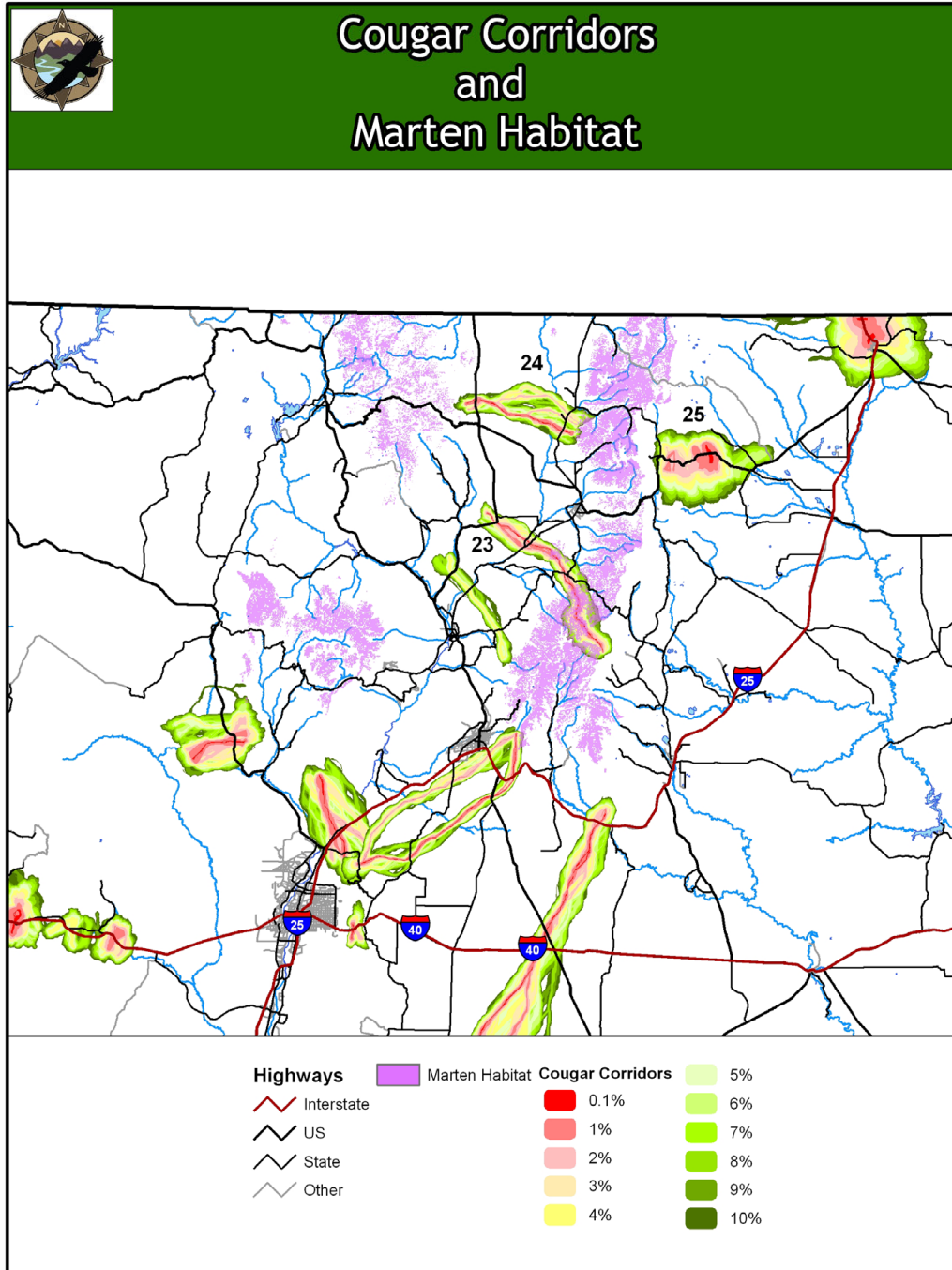
Corridors #4 – 8 all heavily overlap potential wolf habitat. Corridors #1 and #3 may indicate useful locations to study for wolf dispersal across Interstate 10 and Corridor #14 shows potential wolf dispersal routes north over Interstate 40. One linkage that may be crucial for wolf dispersal but was not modeled in this exercise is a linkage from the San Mateo Mountains to the Black Range to the southwest. It is known that some wolves successfully cross between those ranges based on telemetry data<sup>9</sup>. The main barrier to movement there by wolves is probably State Highway 52. This route is currently dirt and lightly traveled. However, if that route is someday paved or future development in that area occurs, a likely permeability point for Mexican wolves might become more difficult, which could be critical for their long-term persistence.



<sup>9</sup> Chuck Hayes (NMDFG), Personal communication, May 15, 2008

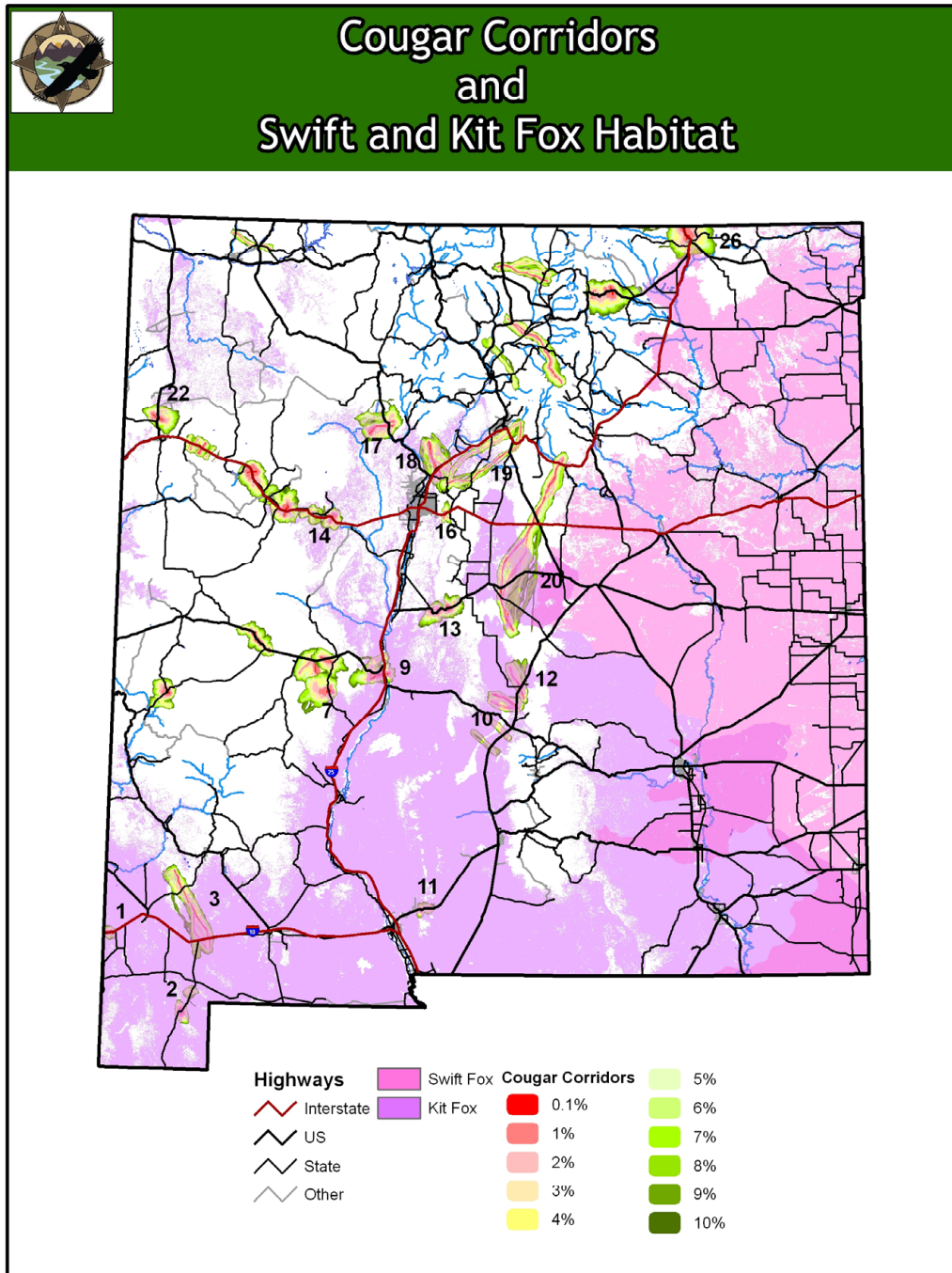
## Marten

Corridors #23 and #24 show potential dispersal routes for marten between the Sangre de Cristo and San Juan Mountain ranges. Due to the elevation requirements of marten it is unclear whether they would be likely to attempt such migrations.



## Swift and Kit Fox

Due to their extensive habitat well over half the cougar corridors look to provide dispersal routes for fox. Corridors #1, #2, #3, #9, #10, #11, #12, and #13 appear to be the most relevant.



## **Recommendations**

It should be noted that these are potential corridors. While many show strong relationships to existing roadkill data they should only be used as an indication of where on the ground studies should be undertaken and as an initial focus for such studies. They should not be used to locate individual animal-vehicle collision mitigation structures such as underpasses, overpasses or fencing. Before such mitigation measures are undertaken it is strongly recommended to take multiple species into account such as mule deer, elk, pronghorn, and other large wide ranging mammals. Thorough field work should be undertaken in any area being considered for wildlife mortality mitigation measures. Such field work should include surveys for locations where wildlife are being killed, as well as, where they are safely crossing, where existing infrastructure exists that could be retrofitted for use by wildlife, and the protection status of key parcels of lands on either side of the roadway.

While all the corridor slices are shown on the maps it is recommended to consider the optimum width for a given corridor. An optimum corridor should be wide enough to allow for cougar dispersal, but not so wide that management of the corridor becomes impractical. In general, it is felt that swaths up to 2-3% are the most useful. Depending on the situation however, the model found additional strands as with Corridors #10, #14, #15, #19 and #23. In these cases some of these other strands composed of higher percentage slices may be more practical on the ground.

There are two components to protecting wildlife corridors. One is the mitigation strategies used by departments of transportation in reducing animal-vehicle collisions. These data are designed to expand that focus to simultaneously increasing landscape permeability for wildlife. The second component is land use and planning. No corridor will remain viable if land on either side of the roadway is developed. Several of the corridors identified in this study run very close to or through areas of exurban development. Examples of these are Corridors #11, #16, #18 and #21. If urban sprawl continues in these areas around the cities of Las Cruces, Albuquerque, Placitas and Aztec the suitability of these corridors could be severely compromised. Therefore these data should also be used to focus land use planning efforts around wildlife corridors.

This was the first statewide attempt to model dispersal corridors for a wide ranging mammal. It is recommended that this effort be undertaken for several other important wide ranging mammals commonly killed by motor vehicles on NM highways including: mule deer, elk, black bear and pronghorn. At that point one could begin to determine where multi-species corridors are located. That information would then provide a logical priority for mitigating wildlife corridors in New Mexico with the NM Department of Transportation. It is also recommended that the NMDOT Statewide Transportation Improvement Program (STIP) be taken into account when prioritizing mitigation efforts.

## **Final Products**

In addition to this report a CD will be provided with all the GIS data for the corridors including the corridor swaths, habitat suitability model and roadkill records. All these spatial data will be provided in the Universal Transverse Mercator (UTM) projection, zone 13.