# THE ASSOCIATION BETWEEN LANDSCAPE FEATURES AND TRANSPORTATION CORRIDORS ON MOVEMENTS AND HABITAT-USE PATTERNS OF WOLVERINES

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FEDERAL HIGHWAY ADMINISTRATION

*June 2006*

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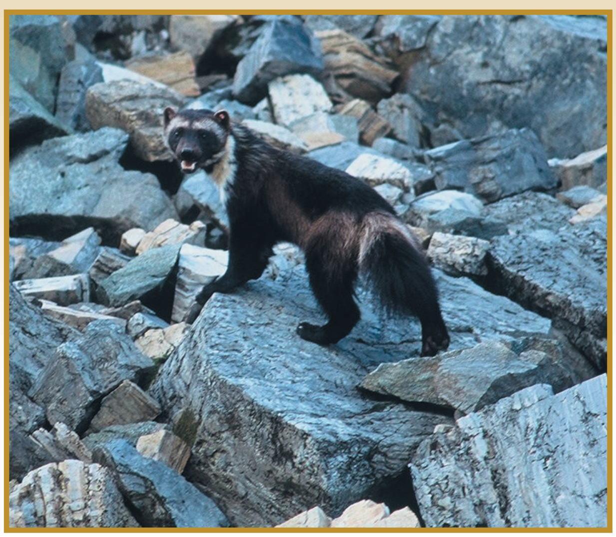

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# The Association between Landscape Features and Transportation Corridors on Movements and Habitat-Use Patterns of Wolverines

## Final Report

## June 2006

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16. Abstract: Wolverines are a rare carnivore that live at low densities and have large spatial requirements; characteristics that leave them vulnerable to both direct and indirect effects of highways. Maintaining connectivity between sub-populations is necessary to allow dispersal for gene flow and recolonization of vacant habitats. We captured and monitored 14 wolverines between 2002 and 2005 to determine spatial requirements in relation to major roads in our study area in southwestern Montana, as well as to collect general ecological data. We performed 30 backtracks of wolverines to investigate their movements in relation to habitat and topography, and identified locations where wolverines interacted with roads. Wolverine habitat ranged from lower tree line to mountaintops, and did include non-forested valley bottoms. Within this distribution, wolverines did not select for any forest cover type or other habitat variables. Wolverines selected for low elevation, low slope, and low curvature areas where available, yet they were observed traversing the most rugged landscapes, suggesting that wolverines are not constrained by natural topographical features. Wolverines do not appear to be predictive in their movements; therefore, planning highway mitigation for this species is difficult. Crossings of major roads occurred in areas in areas with the narrowest distance between forest cover on each side of the road, suggesting that the width between habitat for road rights-of-way should be an important consideration for highway planning. However, the unpredictable movements of wolverine, combined with their agility, are not well suited for planning structural mitigation projects. While wolverines may prove to use crossing structures implemented for other species, we suggest a more effective approach would be to minimize disturbance in general wolverine linkage areas by limiting development through conservation easements and land purchases.

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## INTRODUCTION

Over the last decade, natural resource agencies and transportation agencies have become increasingly aware of the effects that highway and railroad systems have on wildlife (Evink [1]). Major improvements in our understanding of the relationship between roads and wildlife have occurred since the first International Conference on Wildlife Ecology and Transportation occurred in 1996, yet transportation planning to accommodate wildlife, and the larger natural systems they inhabit, still poses many challenges. Issues of scale and variation in the affects that roads have on a large array of species complicate our ability to understand and mitigate road effects. Recognition of these issues has resulted in research at all levels of landscapes from microhabitats to international landscapes, as well as on a variety of individual species ranging from amphibians and reptiles to grizzly bears (TRB [2]). The lack of understanding about basic biological factors for many species in the scientific community has led state transportation agencies into basic biological studies of organisms and systems to develop the science to address impacts (TRB [2]). This is especially true for rare species and their habitats.

Road and highway construction affect wildlife through the direct loss and fragmentation of habitat, by introducing a source of additive mortality for wildlife populations, and by disrupting animal movement and dispersal (Andrews [3]; Bennett [4]; De Santo and Smith [5]; Jackson [6]; Trombulak and Frissell [7]). Forest carnivores are particularly vulnerable to highway-related mortality and habitat fragmentation because of the large spatial requirements of individuals and populations, small population sizes, and low fecundity. Of all the carnivores in North America, the wolverine (*Gulo gulo*) remains the least understood. Wolverines not only have the traits listed above, but they also occur at extremely low densities and typically inhabit rugged, remote habitats (Banci [8]); therefore, it is no coincidence that scientific data on wolverine are lacking. The wolverines' status as a rare and poorly understood carnivore has resulted in conservation concerns leading to 2 petitions to list the wolverine for protection under the Endangered Species Act (Federal Register [9], [10]). The combination of small population size, large spatial requirements, and conservation concern for this rare species makes the wolverine a high priority for mitigation efforts by transportation agencies.

While we have basic understandings of wolverine ecology and spatial requirements in the conterminous United States (Hornocker and Hash [11], Copeland [12]), minimal data are available regarding how wolverines move across the landscape, their spatial arrangement relative to roads, or the frequency that wolverines cross roads. The wolverines' large spatial requirements and high mobility makes the species susceptible to direct road mortality as well as the barrier effects of roads on their movements. The deaths of large animals from vehicle collisions are easily observed and documented, yet the indirect impacts of road avoidance on carnivores are believed to well exceed either the direct impacts of road kills or direct habitat loss in road corridors (Noss [13]). Dispersal of individuals is necessary to maintain small populations through movement of individuals (and their genes) both within and between populations and to allow recolonization of areas where a species has been extirpated (Shaffer [14], Fahrig and Merriam [15]). Road avoidance and direct mortality from road kill can have major population-level effects if the dispersal of wolverines between populations is limited to relatively few individuals, or if entire populations are limited to a few individuals, as reported for rare carnivores such as Iberian lynx (Ferreras et al. [16]) and Florida panthers (Maehr et al. [17]).

The degree to which transportation corridors impact forest carnivores such as the wolverine likely depends on a variety of factors including road design, habitat and topography adjacent to the road, and vehicular traffic patterns. For instance, road improvements in such areas as mountain passes could have large impacts on carnivore movements, but this theory is based on untested assumptions concerning how carnivores navigate mountainous terrain. If wolverine follow the crest of mountain ranges and they are strongly funneled into specific areas by topographic constraints, then a specific road improvement project in the "wrong" place could negatively impact populations. However, if wolverines move randomly through the landscape, then putative impacts to wolverine would be generally distributed along the road length rendering site-specific mitigation (overpasses, underpasses, etc.) ineffective. Until we gain a clearer understanding of how wolverine traverse landscapes, highway planners will be unable to design effective mitigation for this species.

Limited data exist regarding direct or indirect effects of roads on wolverines. Austin [18] directly addressed wolverine movements relative to the high-volume TransCanada highway and found that wolverines approaching the highway exhibited a consistent pattern of repeated approaches and retreats and only crossed 50% of the time. Crossings occurred where the mean vegetated right-of-way was significantly narrower than that of sections where individuals approached but didn't cross, suggesting that roads with narrow rights-of-way (<50m) may be more suitable for wolverine movements (Austin [18]). Ruediger [19] proposed that increasing road densities are a primary factor for why this species no longer exists in formerly occupied habitats in California, Oregon, and Washington; areas where wolverine harvest is prohibited and habitat remains otherwise relatively intact. Understanding localized effects of roads on rare species, as well as the broader issue of connectivity between core habitat areas, is increasingly important as human development in the Rocky Mountain West continues to increase.

The Pioneer Wolverine Project was initiated in 2000 in collaboration with the U.S. Department of Transportation's Western Federal Lands Highway Division (WFLHD) to address potential wildlife impacts on lynx and wolverine resulting from road improvements to the Pioneer Mountains Scenic Byway in southwestern Montana. Results from the three-year project were presented to WFLHD in December 2003 in the Final Report titled "Carnivore Studies in the Pioneer Mountains and Adjacent Mountain Ranges of Southwest Montana"(Squires et al. [20]). At the end of this contract in 2003, MDT awarded 2 years of additional funding to broaden the scope of the project to investigate whether transportation corridors affect wolverines at a larger landscape scale and to determine possible mitigation measures, if necessary.

The Transportation Research Board of the National Academy of Sciences identified key areas of research needed for understanding the effects of roads on wildlife (TRB [2]), yet the reality of studying interactions between rare carnivores, such as the wolverine, and roads is extremely difficult. Because wolverines occur at low densities and appear to have home ranges that do not include major highways, we expected that wolverine movements across roads would be limited to infrequent forays or dispersal movements; therefore, focusing only on actual road crossings would extremely limit our data set. In addition, few crossing structures exist within our study area, which prevents us from monitoring interactions between wolverines and existing infrastructure to determine what mitigation options may be best. Instead, our research goal was to better understand how wolverines respond to changes in landscape pattern relative to vegetation type, topography, and other environmental factors, while still providing observations of highway crossings when they occurred. Within this context, our specific objectives were to:

1) *Characterize wolverine movement paths and test the hypothesis that observed movement paths are non- random relative to vegetation type, topography, streams, roads, and putative linkage zones.*
2) *Evaluate movement patterns outside of home ranges and compare these to within-home range movement patterns.*

3) *Provide observations concerning fine-scale response of wolverine to transportation corridors and putative linkage zones.*

By studying how wolverines traverse landscapes, our understandings can be integrated with results from research on other species to allow for a more complete systems approach for addressing wildlife considerations (Evink [1]). In addition to movement related objectives, our capture and monitoring of wolverines during the 5-year project also provided data regarding general wolverine ecology, reproduction, and mortality. To make this report as comprehensive as possible, each of these topics was addressed in detail. Information and findings, such as wolverine crossings of the Pioneer Mountain Scenic Byway, which did not change since the 2003 Final Report, were referenced to the published report; however, findings that have continued to evolve through additional data collection, such as home range estimates, were reanalyzed and reported from project inception to project completion.

## STUDY AREA

The large spatial requirements and low density of wolverines required that an extensive study area be selected to maximize both the number of wolverines and the number of major paved roads present. Our study area was located on the Beaverhead-Deerlodge National Forest including the Pioneer and Flint Creek mountain ranges, as well as large portions of the Beaverhead and Anaconda-Pintler mountains (Figure 1). Wolverines in the study area potentially interact with State Highways 1, 43, and 278 as well as Interstates 15 and 90.

Elevations in the study area ranged from approximately 1,800 m (6,000 ft) to 3,500 m (11,500 ft). The dominant forest cover was lodgepole pine (*Pinus contorta*). At lower elevations, Douglas-fir (*Pseudotsuga menziesii*) and sagebrush (*Artemisia* spp.) steppe dominated south-facing slopes. Mixed Engelmann spruce (*Picea engelmanni*)/ subalpine fir (*Abies lasiocarpa*) forests were found on wet aspects at higher elevations. Whitebark pine (*Pinus albicaulis*) occurred at the highest elevations near timberline. Riparian communities were dominated by willow (*Salix* spp.) that often transitioned into sagebrush-dominated meadows.

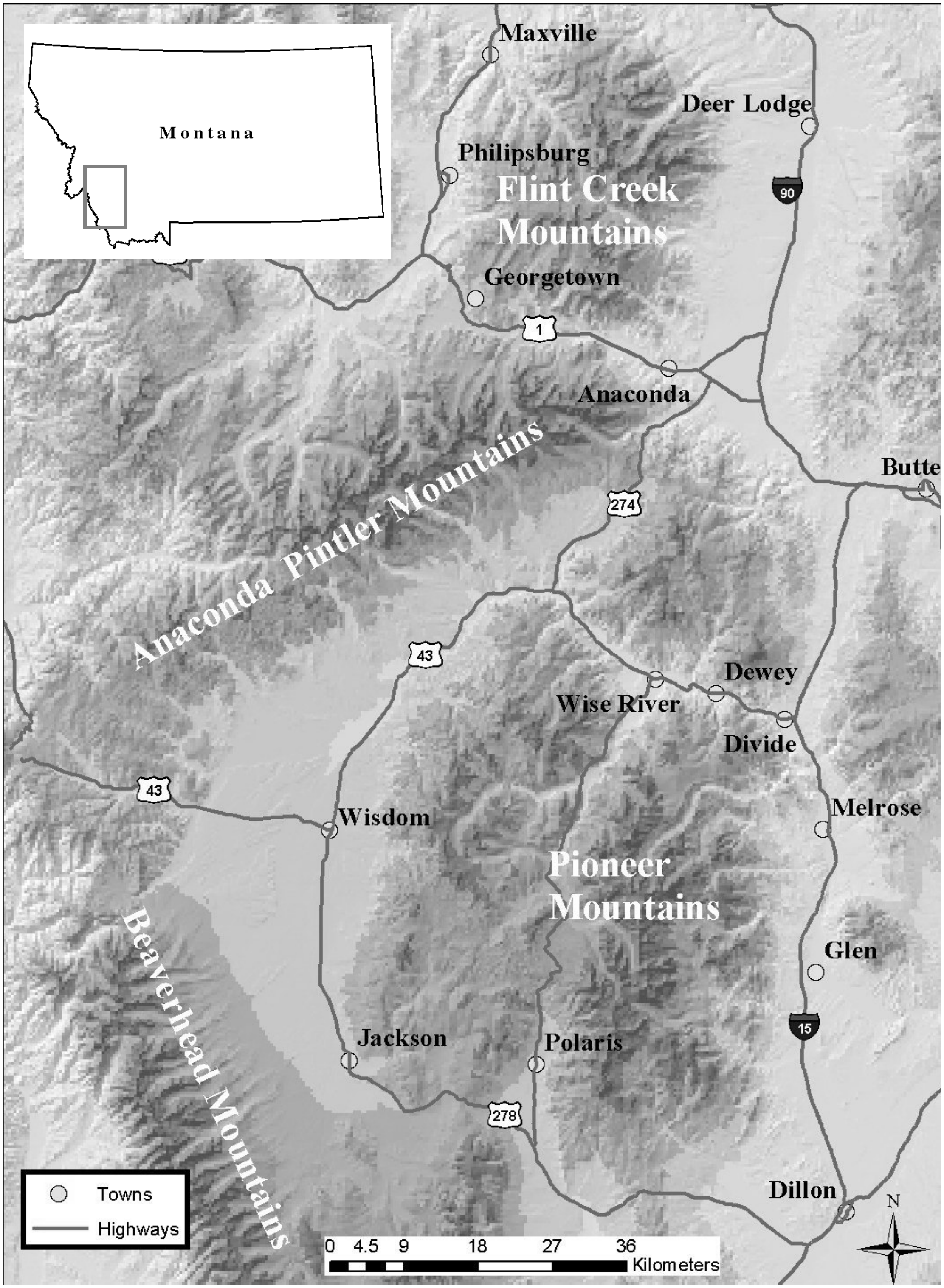


**Figure 1: Map of study area for Pioneer Wolverine Project in southwest Montana; 2001-2005.**

## METHODS

### Presence and Distribution Surveys

We developed an intensive survey framework (Squires et al. [21]) and conducted winter snow track surveys to detect the presence of wolverines and lynx and to delineate their core areas of use. We established a representative survey by overlaying a survey grid across the entire study area, with each unit within the grid measuring 8 km x 8 km (5 mi x 5 mi). Survey units were randomly selected each day, without replacement, until a census of all units was completed. This census was then repeated 2-3 times each winter. We used a hand-held GPS (Trimble Geoexplorer 3) to record survey routes and species detection locations, and our minimum survey effort in each survey unit was 10 km (6.3 mi). Most surveys were conducted by traveling existing roads and trails on snowmobile. In areas that precluded snowmobile access, we searched for tracks on skis or snowshoes. During 2000-2003, surveys documented all mid- to large-sized mammal species to provide baseline distributional data. During 2004-2005, these surveys were limited to large carnivores (wolverine, lynx, mountain lion, and wolf). Comparisons of survey data across years were used to identify shifts in wolverine distribution and to identify new individuals over the course of the study.

### Capture and Instrumentation of Wolverine

We instrumented wolverines with radio telemetry for monitoring their movements and status of individuals. All wolverines were captured using log-box traps (Copeland et al. [22]) built in areas of historical wolverine sightings or where our winter surveys had detected wolverine presence. Traps were operated each winter from 2002 through 2005. We focused on the Pioneer, Anaconda-Pintlers, and Flint Creek mountain ranges during 2002 and 2003; however, small population sizes and the harvest of study animals by trappers required an expansion to the Beaverhead Mountains during 2004 and 2005. Traps were baited and set in late December and operated until April 15$^{th}$ or the melting snow pack prevented access. We physically inspected traps every 2 – 3 days from December through February, and performed daily trap checks in March and April to mitigate the risks associated with capturing denning females with new-born kits.

We immobilized all captured individuals using a syringe jab-stick with a 0.8 cc of Capture-All (Wildlife Pharmaceuticals, Fort Collins, Colorado), which was a pre-mixed dose of Ketamine (160mg/ml;) and Medetomidine (4mg/ml). A licensed veterinarian implanted all wolverines with a VHF transmitter (Telonics IMP-400, Mesa, Arizona) in the field. In addition, large individuals were also outfitted with Argos satellite or GPS collars. Vital signs were monitored throughout the immobilization and morphometric measurements were collected.

**Wolverine Monitoring**

We monitored the status, location, and movement of individuals using aerial telemetry flights once every two weeks, weather and funding permitting. However, relocating animals with aerial telemetry is difficult when individuals make long movements outside of their home ranges. To reduce the number of "lost" individuals, we deployed various satellite technologies to enable us to track movements. Satellite collars for wildlife applications is an emerging field, so finding suitable collars for this project was difficult. In 2002, we investigated all the possible options and decided none of them fit the needs of the project; therefore, we opted to use only VHF for the first year until new-collar technology came online. In 2003, we contracted with HABIT Research (Vancouver, Canada) to develop combination GPS/Argos collars that could collect accurate daily locations and transmit them through the ARGOS satellite to an established email account. Three collars were purchased and deployed in 2003. In 2004, we purchased and deployed 4 ARGOS collars (Sirtrack LTD, New Zealand) on 4 wolverines weighing > 11kg. These collars were programmed to obtain 2 locations a day, and only those locations with quality codes of 1, 2 or 3 were used in analysis (i.e. ARGOS location codes, in order of quality, are 3,2,1,0,A,B,Z,; so only the 3 highest quality codes were used). ARGOS is older technology with an established track record, but determining locations from doppler-shift has much larger errors than GPS-based locations. Therefore, ARGOS collars were aimed at delineating general areas of road crossings and tracking inter-mountain range movements. In 2005, we switched to GPS collars (Lotek Wireless, Ontario, Canada) to concentrate on fine-scale movement questions, and deployed 1 collar on the only male wolverine captured that season. As a result, we returned to aerial telemetry as our sole method for monitoring large-scale movements within and between mountain ranges.

**Wolverine movements at various spatial scales**

We used snow tracking to address our first objective, which was to characterize wolverine movement paths relative to vegetation type, topography, streams, roads, and linkage zones. We attempted to follow all wolverine tracks detected during our surveys for 8-12 km (5-7.5 mi) using snowshoes. We recorded the animal's route using a hand-held GPS unit (Trimble

GeoExplorer 3) and collected data on land cover, forest stand composition, stand structure, daybed locations, foraging sites, and investigative sites. New line segments within a track were created each time a change in habitat occurred; therefore, different habitats could be assigned along different portions of the same track. GPS error associated with these track files was minimized using an ArcView (ESRI, Redlands, California) smoothing process (DeCesare et al. [23]). Elevation gain and loss were factored into track distance using the ET Geowizard extension (ET Spatial Techniques, Pretoria, South Africa) for ArcGIS 8.8 (ESRI, Redlands, California). Data on elevation, slope, and aspect were extracted from track routes overlaid on a GIS Digital Elevation Model.

We evaluated wolverine movements from snow tracks relative to landscape features by first evaluating broad-scale habitat selection of wolverine to determine if they exhibit a strong affinity towards certain landscape features. If wolverine were constrained to specific habitat types in their general movement, this information may be useful when planning and managing transportation corridors. We compared habitat-use variables quantified on *use* to those randomly available; random tracks were established at random start point and orientation within the same mountain range the *use* track was sampled. Thus, random tracks had the same general shape as actual wolverine tracks to control for potential internal correlations due to track geometry.

The broad-scale features we considered were limited to general forest-cover variables delineated in the Forest Service SILC 3 database (Wildlife Spatial Analysis Lab, Montana Cooperative Wildlife Research Unit, Missoula, Montana), and topographic characteristics as calculated from digital elevation models using ARCGIS. The specific broad-scale, habitat-use variables we quantified included: Douglas fir, lodgepole pine, spruce/fir, whitebark pine, open habitat, landscape curvilinearity (Apps et al. [24]), elevation, slope, solar radiation (Fu and Smith [25]), and surface roughness (Dickson et al. [26]). Habitat variables for actual tracks were derived from GPS routes, while habitat for random tracks were extracted by overlaying these tracks on SILC 3 vegetation layers. Data for non-vegetative variables were extracted from Digital Elevation Models for both actual and random tracks.

We then used logistic regression (SAS-Proc Logistic) to model habitat selection of wolverine by comparing broad-scale variables quantified on *use* and *random* tracks (Alldredge et al. [27], Hosmer and Lemeshow [28], Manly et al. [29], Keating and Cherry [30]). The aptness of the logistic model was evaluated using Hosmer-Lemeshow goodness-of-fit test. We initially evaluated each variable by itself in univariate framework, before important ($P < 0.25$) variables were analyzed together in a multivariate framework (Hosmer and Lemshow [28]). A final, multivariate model was then constructed using only significant ($P < 0.05$) variables.

In the second analysis, we compared *use* versus *availability* of the same 9 environmental variables using ArGIS (Jenness et al. [31]) within the area surrounding the actual track. Tracks were broken into segments at 4 different scales (500m [1,640 ft], 1000m [3,281 ft], 2000m [6,562 ft], and 4000m [13,123 ft]), and 35 random segments were then created for each original segment by spinning the segment around the origin (Figure 2). Actual *use* for each original segment was then compared to *availability* along the associated 35 random segments. Selection of environmental variables was analyzed using SAS GLIMMIX (SAS Institute, Cary, NC) to account for covariance within tracks.

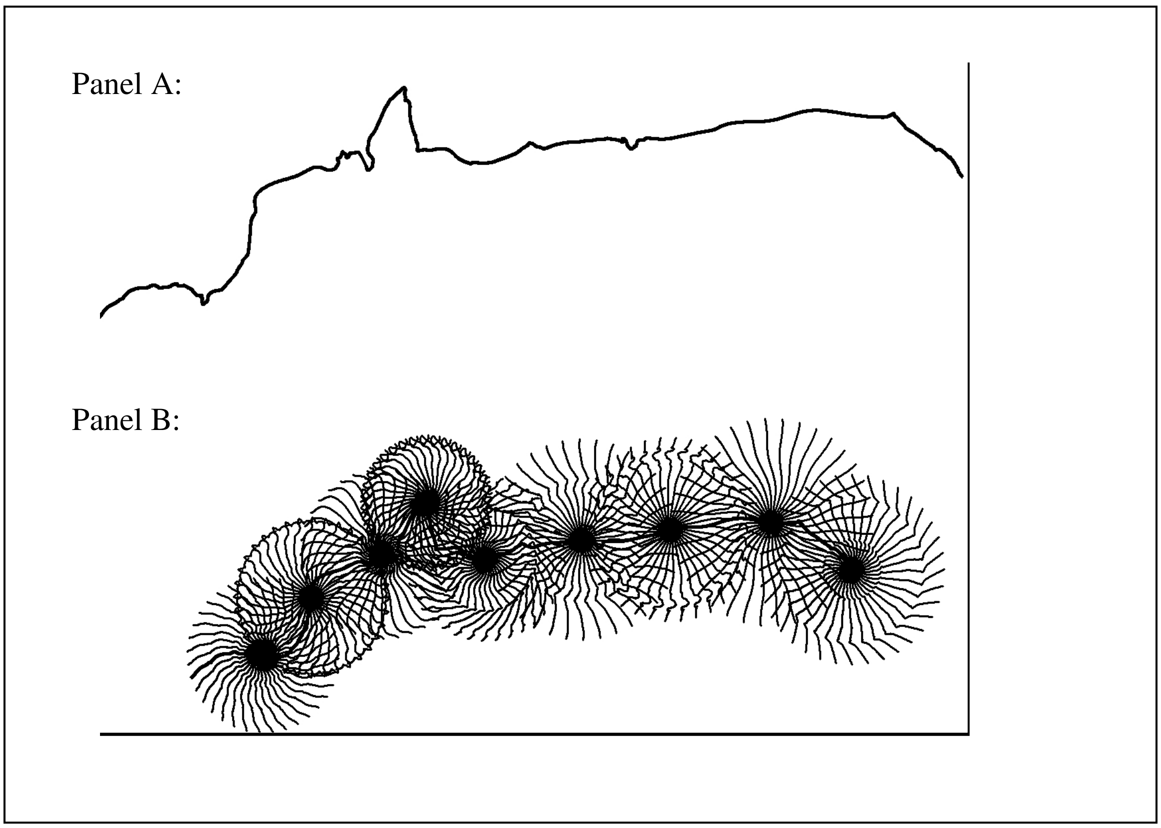


**Figure 2: Visual depiction of original wolverine snow track (panel A) relative to the same track broken into nine 500 m (1,640 ft) segments with 35 associated random tracks for each segment used to compare *use* versus *random* for 9 environmental variables.**

At the finest scale, we examined if wolverines traveled with greater tortuosity in one forest type compared to another. More tortuous or circuitous travel in a given forest type could indicate wolverines either foraged or spent more time in that type, which could help identify important habitat types relative to highway planning. Technicians recorded the track as segments on the GPS unit at each change in forest vegetation. We used the ratio of the animal's actual travel distance to the straight-line distance in segments relative to forest type (Turchin [32]). We analyzed differences in tortuosity within an ANOVA statistical framework; we used SAS Proc MIXED to account for potential within-track correlation from multiple segments being from a single track.

**Linkage Zones**

Ideally, empirical data on wolverine interactions with transportation corridors and wildlife linkage areas would be primarily based on the analysis of wolverine "tracks" collected through our snow tracking method and our GPS collars. However, the potential exists for road crossings or interactions with transportation corridors to go undetected by our formal methods due to timing, collar failure, or movements made by non-instrumented animals; therefore, we recognized the importance of factoring anecdotal reports and sightings from sources we deemed reliable. Any reports made by local residents or USFS employees were followed-up by field personnel to verify tracks (in winter) or to get exact locations and descriptions from sources. These anecdotal reports were combined with any crossings documented by telemetry or satellite collars to identify key linkage areas. We used USFS SILC3 vegetation layers, orthophoto quads, and hillshade topography layers for ArcGIS to identify commonalities between crossing locations. We then performed a linkage area analysis (Ruediger [33]) by applying these general characteristics to orthophoto imagery of the study area to identify other potentially important linkage areas that did not have documented crossings during our study.

**Home Range**

To understand wolverine spatial arrangement across the landscape and relative to transportation infrastructure, we calculated 90% adaptive kernel estimates of home range size using the HRE software for ArcView 3.2 (Rodgers and Carr [34]). Telemetry locations were screened or truncated to adjust for rare exploratory movements or shifts in home ranges due to the death of neighboring individuals, and we used all Argos locations with location code qualities of 1, 2, or 3. While our sample sizes were inadequate to reach the point of asymptote, we believe all individuals with more than 20 locations provide reasonable estimates of coarse-scale spatial requirements (Seaman et al. [35]). Home ranges were plotted on Digital Elevation Model-based maps using ArcGIS to show spatial arrangement and overlap of individuals.

**Survival**

Long distance movements of wolverines are most commonly associated with dispersal of young individuals. To better understand the population dynamics that drive dispersal, as well as to monitor the general status of the population, we used aerial telemetry to monitor wolverine survival on a monthly basis. Wolverines are wide-ranging animals with large home ranges that occur at low densities (Quick [36], Magoun [37], Banci [38], Copeland [12]), factors which make it difficult to obtain and monitor large sample sizes over extended periods of time for estimating survivorship rates with narrow confidence intervals. However, known fate models can provide valid survival estimates, even when based on small sample sizes (White and Burnham [39]). Telemetry data and harvest reports were used to classify individuals as alive, dead, or censored (i.e. status uncertain due to lack of contact) each month in a staggered entry design (Pollock et al. [40]). These data were then used to calculate annual survivorship rates in Program MARK (White and Burnham [39]). While basic survival rates are reported in this document, a more comprehensive discussion of survival rates based on a cooperative research agreement with other wolverine studies in western Montana is in preparation (Squires et al. [41]).

**Population Estimates**

Understanding wolverine population sizes and dynamics allows for a more informed discussion of the potential impacts and risks that transportation infrastructure has on this species. Given the lack of field-tested protocols for sampling wolverine numbers and our limited knowledge of wolverine density and spatial distribution, we determined a minimum population number on the Pioneer Study by counting known individuals identified through capture and genetic analyses, and corroborated this number with a population estimate based on a Lincoln index.

We counted the number of known individuals by simply tallying the number of research animals captured in traps and other individuals present on the study area identified based on nuclear DNA collected on backtracks according to Ulizio et al. [42]. This method is consistent with Squires et al. [21] and McKelvey et al. [43] in using the snow track as device for collecting genetic samples. Given that wolverine are territorial with exclusive male territories overlapping those of 1-3 females (Banci [38]), knowing the sex, relatedness, and spatial use of individuals helps in determining the maximum number of individuals that plausibly occupy the study area as constrained by wolverine social structure. We also assumed a priori that some wolverines might avoid live traps. Incorporating genetic methods allowed us to "capture" trap-shy individuals and collared animals with failed transmitters. We compared the dates of these identifications and determined the maximum number of individuals that were known to be present in the study area at any one time. This maximum number represents the minimum known population.

The Lincoln Index and associated standard error were also calculated to estimate the population on the Pioneer study area according to White and Garrott (1990 [44]). Instrumented individuals comprised the initial marked population with individuals "recaptured" using DNA from backtracks. A combined population from the Pioneer, Flint Creek, and Anaconda-Pintler Ranges was estimated in 2003 and a second estimate was calculated for the same ranges plus the Beaverhead Mountains in 2004. In 2005, the population estimate included only the Pioneer and Beaverhead Range due to an inconsistent snow cover in the other ranges.

**Reproduction**

Additional telemetry flights were conducted on a weekly basis, funding and weather permitting, during March-May in 2003, 2004, and 2005 to determine if adult females were localizing at den sites. Technicians followed up any series of points collected in approximately the same location during successive flights by going in on the ground and investigating the location. Technicians determined if the female was still present and attempted to follow snow tracks to locate possible den sites.

We also addressed reproduction by performing parentage analysis of genotypes produced from the nuclear DNA of samples from individual wolverines on the study area. Genetic samples for 17 individuals, including 14 captured animals, 1 harvested non-instrumented animal, and 2 non-instrumented animals identified from DNA off of snow tracks, were used to produce individual genotypes at 19 loci using standard multi-tube protocols (Taberlet et al. [45]). We manually performed pair-wise comparisons to determine parent/offspring relationships using absolute exclusion tests (Marshall et al. [46]). We also used CERVUS software (Marshall et al. [46]) to calculate the probability of parent/offspring relationships, and KINSHIP software (Queller and Goodnight [47]) to calculate maximum likelihood tests of the pedigree relationships between pairs of individuals in the population to determine overall relatedness among individuals.

**Foraging Activity**

Technicians collecting movement data from wolverine snow tracks, as explained in the Fine-Scale Movement section above, also collected foraging information from sites along the track.  The location of visible prey remains or holes in the snow pack created by wolverine were recorded with a GPS unit.  Holes were inspected for prey remains and genetic samples were collected, if present, for laboratory identification of prey species.  In cases where prey remains were readily identifiable in the field, such as skulls or entire carcasses, identifications of species were made on site.  Holes in the ground with no prey remains present were recorded as investigative sites, while areas with prey remains present were recorded as foraging sites.

We also investigated foraging behavior through dietary analysis of all scats collected along backtracks during 2003 and 2004.  All scats verified as wolverine through genetic analysis were submitted to the University of Wyoming for physical analysis of dietary contents using standard protocols for washing, inspecting, and identifying prey remains with a dichotomous key (T. Moore, University of Wyoming, personal communication).  Due to issues regarding prey size and persistence in the gastrointestinal tract, we described dietary items based on the proportion of total scats in which they were present, and not by their proportion within each scat.

## RESULTS

### Landscape Surveys

We completed approximately 17,950 km (11,220 mi) of surveys and trap route checks during the winters of 2001-2005 (Figure 3), during which time we detected a total of 402 wolverine tracks (Table 1). During 2001-2003, our surveys were focused on the Pioneer, Flint Creek, and Anaconda-Pintler mountain ranges. Due to study animal mortality in these areas, we expanded our surveys in 2004 and 2005 to access new study animals in the portion of the Beaverhead Mountains ranging from Hamby Creek north to Lost Trail Pass. Wolverines were detected in the Pioneer, Anaconda-Pintler, and Beaverhead mountains during all years they were surveyed, while the Flint creek range had detections in 2001-2004, but not during 2005 (Table 1).

**Table 1: Number of wolverine snow track detections in 4 mountain ranges in southwest Montana during the winters of 2001-2005.**

| | -----------------------Detections by Year------------------- | | | | | |
|---|---|---|---|---|---|---|
| **Location** | **2001** | **2002** | **2003** | **2004** | **2005** | **Total** |
| Flints | 8 | 6 | 25 | 4 | 0 | **43** |
| Pintlers | 12 | 5 | 26 | 5 | 11 | **59** |
| Pioneers | 43 | 101 | 47 | 60 | 25 | **276** |
| Beaverheads | N/A | N/A | N/A | 20 | 4 | **24** |
| **Total** | **63** | **112** | **98** | **89** | **40** | **402** |

Aside from a putative detection of a lynx track in 2001, no other lynx tracks were detected anywhere in the study area during the subsequent 4 years. Results and discussion of detections for other species during 2001-2003 were presented in the 2003 Final Report (No. 00-A-17-0031).

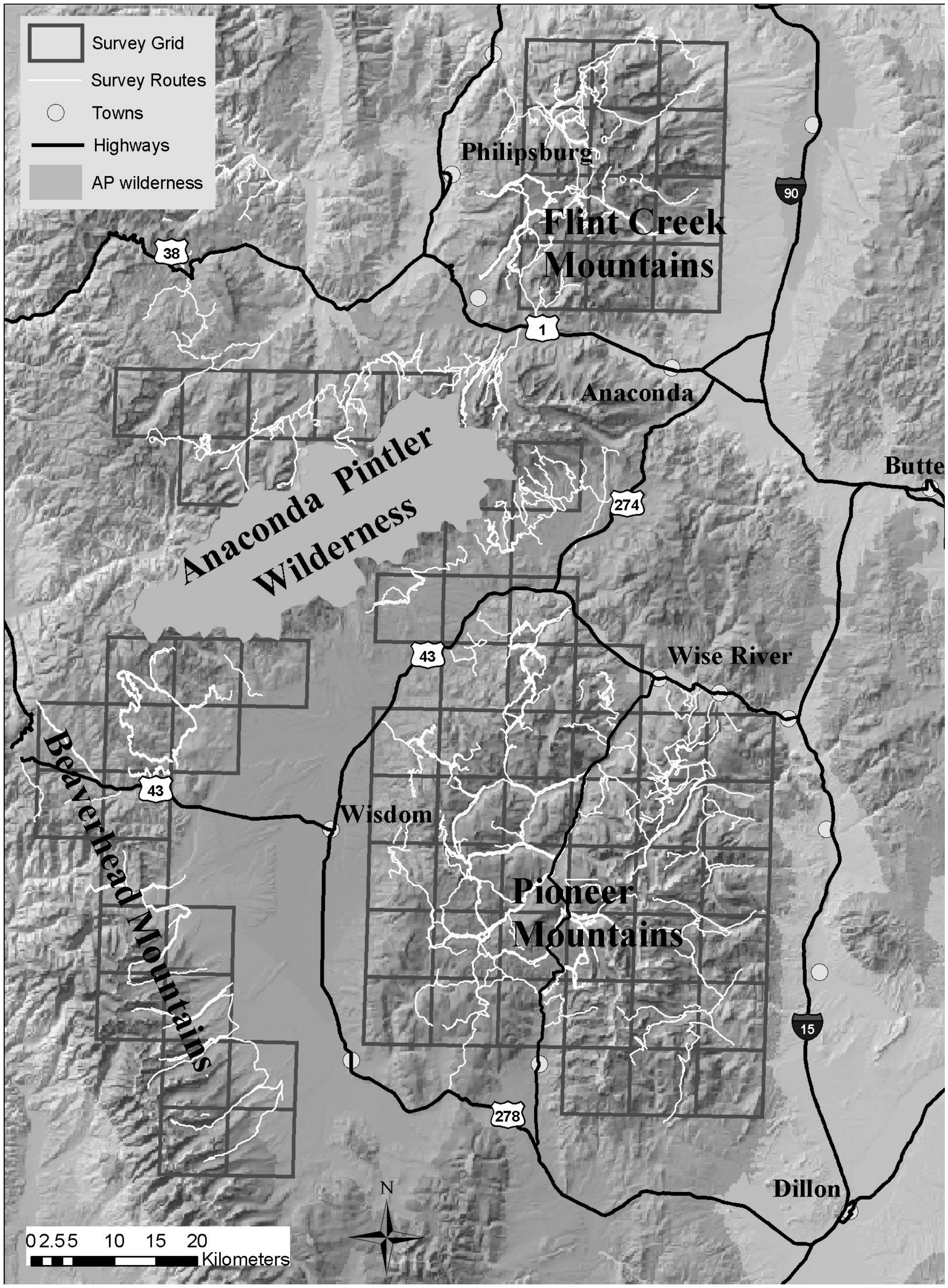


**Figure 3: Wolverine survey grid and completed survey routes during the winters of 2001-2005 in southwest Montana.**

**Wolverine Capture**

We captured and implanted 14 individual wolverines with radio transmitters during 4 years of trapping (Table 2). We trapped in the Pioneer, Anaconda-Pintler, and Flint Creek mountains during 2002 and had 9 captures of 5 individuals. We captured 1 adult male (M2), 2 juvenile males (M1 & M3), and an adult female (F4) in the Pioneers and 1 adult male (M5) in the Anaconda-Pintler Mountains. In 2003, we had 12 total captures of 4 new individuals and 2 recaptured individuals. New individuals consisted of 2 adult females (F6 & F8) and 1 adult male (M9) in the Pioneers and an adult male in the Flint Creek range (M7). We received combination Argos/GPS satellite collars in late winter 2003 and were able to recapture M1, M5, and M9 for instrumentation. We expanded our trapping in 2004 to include the Beaverhead Mountains, where we captured 2 adult males (M10 & M11) and an adult female (F12), all of which were instrumented with VHF implants and Sirtrack ARGOS collars. In addition, we captured 1 new adult female (F13) in the Pioneer Range. For the year, we had 12 total captures of 4 new individuals and 1 recaptured individual. In 2005, we expanded our trapping to include the southern Anaconda-Pintler Mountains, based on new track detections in this area. We captured our only new animal, an adult male (M14), in this area and instrumented him with a Lotek store-on-board GPS collar. We also recaptured F13 and F8, for a total of 3 captures during 2005.

Our trap effort per capture was lowest during the first year in a new area (2002 and 2004), and increased by more than 2-fold in subsequent seasons (2003 and 2005; Table 2) due to trap-shy behavior and population declines.

**Table 2: Total captured wolverines and the associated trapping effort in southwest Montana during the winters of 2002-2005.**

| Year | Trap Nights | New Captures | Trap nights per new individual | # of unique individuals captured | Total # of captures | Trap nights per capture |
|---|---|---|---|---|---|---|
| **2002** | 350 | 5 | **70** | 5 | 9 | **39** |
| **2003** | 855 | 4 | **214** | 6 | 12 | **71** |
| **2004** | 595 | 4 | **149** | 5 | 12 | **50** |
| **2005** | 448 | 1 | **448** | 3 | 3 | **149** |

**Wolverine Monitoring**

We relocated instrumented wolverines a total of 250 times from April 2003 through June 2005 using radio telemetry. Monitoring time for each individual ranged from 1 week (F6) to 25 months (F8). The monitoring period ended when the animal died or when the battery life of the transmitter expired and the animal could not be recaptured for transmitter replacement. We documented multiple long distance movements of adult males within their respective home ranges using telemetry and trapping, but only detected 2 movements between mountain ranges. On December 5, 2002, wolverine M1 was located in the Fishtrap drainage in the Anaconda Pintler range, before returning to his home range in the Pioneer range, where he was located on December 17, 2002. The second movement was detected on April 25, 2005, when M14 was located during a telemetry flight in the forest between Highway 93 and the new expansion of Lost Trail Ski Area, across the highway from where he had been captured (see "Linkage zones and movements across highways" section below for further results).

The 3 combination Argos/GPS collars from HABIT Research (Vancouver, Canada) deployed in 2003 failed immediately after deployment and were removed from the study animals in 2004. The 4 Argos satellite collars from Sirtrack Limited, LTD (Havelock North, New Zealand) deployed in 2004 produced a total of 72 useable relocations that were included in home range calculations, none of which revealed movements between mountain ranges (Figure 4). The Lotek GPS collar deployed in 2005 could not be located and recovered.

**Home Ranges and Spatial Arrangement**

The average home range sizes for adult males and females with >20 locations were 1,044 $km^2$ [648 $mi^2$] (SD 296, n = 4) and 339 $km^2$ [211 $mi^2$] (SD 182, n = 4), respectively (Table 3; Figure 4). The average home range size for the 2 sub-adult males was 196 $km^2$ [122 $mi^2$]. Adult females overlapped adult male home ranges in all instances; however, overlap was minimal between adults of the same gender. While adult males have home ranges exclusive of other adult males, we did identify 3 instances where the resident male shared his home range with his male offspring, as determined through comparison of genetic genotypes. Wolverine M11, who we believe was 2 years old, had a 854 $km^2$ [530 $mi^2$] home range almost completely embedded in the home range of his father (M10; Figure 4). Likewise, wolverine M1 and M3, who we believe were true sub-adults (<2 years old), often traveled together and shared similar home ranges that were embedded in the home range of their father (M2; Figure 4). While the four females in the

Pioneer Mountains appeared closely related, the death of the oldest female (F6) shortly after her initial capture precluded us from determining how her home range overlapped those of F4 and F8, who both lived close to the area in which F6 was captured.

**Table 3: Ninety percent adaptive kernel home range estimates for all instrumented wolverines in southwest Montana during 2002-2005.**

| ID | Home range ($km^2$) | # of relocations |
|---|---|---|
| ***Adult Males*** | | |
| M2 | 1215 | 28 |
| M5 | 739 | 42 |
| M7 | 296* | 10* |
| M9 | 336* | 15* |
| M10 | 1368 | 24 |
| M11 | 854 | 23 |
| ***Subadult Males*** | | |
| M1 | 213 | 40 |
| M3 | 178 | 22 |
| ***Adult Females*** | | |
| F4 | 178 | 39 |
| F8 | 200 | 29 |
| F12 | 556 | 28 |
| F13 | 423 | 20 |

* Home range sizes are likely underestimated for these individuals due to small sample size of telemetry locations.

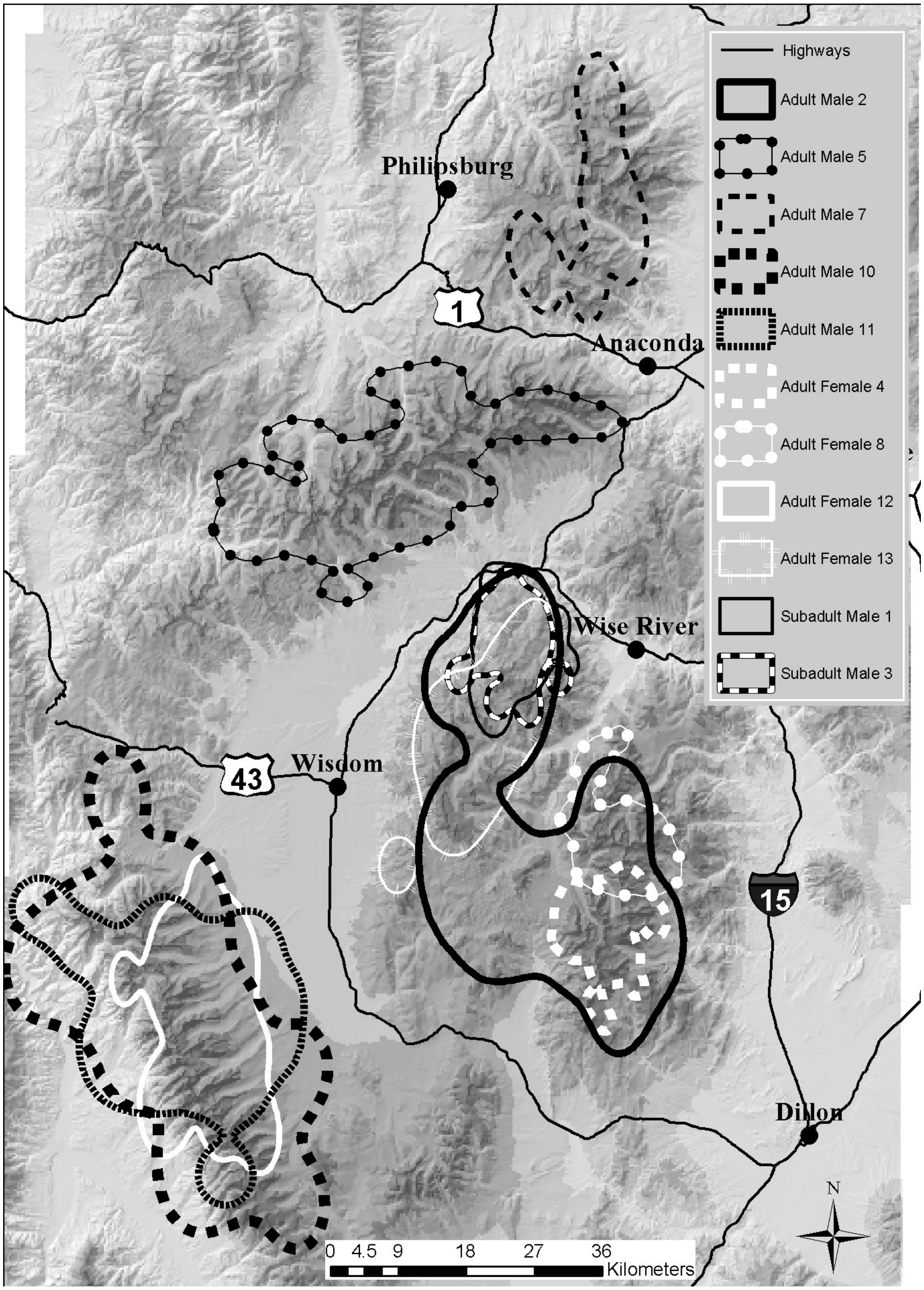


**Figure 4: Spatial arrangement of wolverine 90% kernel home ranges in southwest Montana during 2002 and 2003.**

**Population Estimates**

A total of 22 wolverines were detected in the 4 mountain ranges comprising the Pioneer Study area from 2002-2005; 14 of these individuals were marked as instrumented animals for research, 3 were detected based on DNA collected during surveys, and 5 were non-instrumented individuals harvested by recreational trappers during the state-sanctioned trap season; the 5 non-instrumented animals lived in areas immediately adjacent to, but not within, areas trapped or surveyed for research. However, not all detected individuals were present at any one time due to mortality and dispersal. We estimated based on instrumented individuals and DNA from surveys that a minimum of 16 individuals resided on the Pioneer Study area from 2003-2004, for an ecological density of 1 wolverine / 450 $km^2$ [1wolverine / 279$mi^2$]. Although individuals could have been missed, it appeared based on DNA collected on backtracks and instrumented individuals, that wolverine declined to a minimum of 6 individuals by 2005. A general decline in 2005 was further substantiated by a 77 % increase in the distance surveyed per detection (93.2 kilometers [58 mi] surveyed / track detection) compared to the observed detection rate from 2002-2004 (52.6 kilometers [33 mi] surveyed / track detection, 3-yr average 2002-2004) and a sharp increase in trapping effort required to instrument new individuals (Table 2).

A high proportion of instrumented wolverine were subsequently "recaptured" by collecting DNA from backtracks. In 2003, 5 of 7 marked individuals in the Pioneer, Flint Creek, and Anaconda-Pintler Ranges were later detected through DNA collected on backtracks, with an estimated population based on Lincoln Index of 8.3 ± 0.9 (95% CI) wolverine. In 2004, 7 of 9 individuals recaptured with an estimated population of 12.8 ± 2.9 (95% CI) in the same ranges, including the Beaverhead Range. In 2005, all 5 marked individuals marked in the Pioneer and Beaverhead Ranges were redetected in genetic samples.

**Wolverine Survival**

Of the 14 wolverine captured and instrumented, we were able to monitor 12 individuals for a minimum of 6 months, and 7 individuals for at least 1-year (range 1-24 months). Annual survivorship on our study area over the 4-year study was 0.51. As of June 31, 2005, we documented 2 natural mortalities and 6 mortalities of instrumented wolverines from trapper harvest. A predator killed wolverine M3 in September 2002 in the northwest Pioneers. A halo of plucked hair surrounded the carcass suggested the predator was a mountain lion (*Felis concolor*), however, massive hemorrhaging around the neck and base of skull was consistent with the animal being shook, possibly by a wolf or bear; mountain lions kill lynx with a single, precise bite to the head and the wound lacks much hemorrhaging (J. Squires unpublished data). Wolverine M11 died of blunt trauma to the head and chest, and was recovered in Big Swamp Creek in the Beaverhead Mountains in July 2004. One possible theory on the cause of death includes being kicked by an ungulate while hunting , although no conclusive evidence was found. The resident male (M2) in the Pioneers was harvested in January 2003, and the adult male (M9) that moved in to take over his former home range was harvested in December 2005. F6, a pregnant female, was initially captured by the project in February 2003, and was harvested by trappers the following week. The lone animal captured in the Flint Creek Range (M7) was harvested in December 2004. Lastly, the resident male (M10) and the only female (F12) captured in the Beaverhead Mountains were harvested in the same drainage during the same week in February 2005. In addition to these instrumented study animals, 4 non-marked wolverines were harvested from areas of the Anaconda-Pintler Mountains where we did not have project trapping coverage. Of the remaining 6 study animals, 3 are alive and were monitored through June 2005, while the status for the other 3 individuals was unknown (Table 4).

**Table 4: Status and fate of all radio-instrumented wolverines monitored in southwest Montana from 2002-2005.**

| Animal ID | Date of Capture | Status | Date of Mortality | Monitoring Duration | Comment |
|---|---|---|---|---|---|
| M1 | 2/02 | Unknown | | 17 mo. | Implant lasted 2 years. Snow track ID in 2004. |
| M2 | 2/02 | Dead | 1/03 | 10 mo. | Trapper harvest |
| M3 | 3/02 | Dead | 9/02 | 6 mo. | Natural mortality |
| F4 | 3/02 | Unknown | | 17 mo. | Implant lasted 2 years. Snow track ID in 2005 |
| M5 | 4/02 | Unknown | | 18 mo. | Implant lasted 2 years. Snow track ID in 2004 |
| F6 | 2/03 | Dead | 2/03 | 7 days | Trapper harvest |
| M7 | 3/03 | Dead | 12/03 | 10 mo. | Trapper harvest |
| F8 | 3/03 | Alive | | 25 mo. | |
| M9 | 4/03 | Dead | 12/04 | 7 mo. | Trapper harvest |
| M10 | 1/04 | Dead | 2/05 | 13 mo. | Trapper harvest |
| M11 | 1/04 | Dead | 7/04 | 6 mo. | Natural mortality |
| F12 | 1/04 | Dead | 2/05 | 13 mo. | Trapper harvest |
| F13 | 3/04 | Alive | | 15 mo. | |
| M14 | 3/05 | Missing | | 1 mo. | Lost during long-distance movement |

**Wolverine Movement: Analysis of Snow Tracks**

We completed 30 snow tracks for a total of 183 km (range 1.2–16 km). The broad-scale variables of lodgepole pine ($P = 0.16$), surface roughness ($P = 0.08$), slope ($P = 0.16$), landscape curvilinearity ($P = 0.02$), open ($P = 0.06$), and whitebark pine ($P = 0.22$) were sufficiently important ($P < 0.25$) to warrant inclusion in multivariate models of wolverine habitat use. The multivariate logistic regression model of these variables was predictive (Likelihood Ratio = 12.55, df = 5, $P$=0.028) of wolverine habitat use as quantified on *use* compared to *available* tracks within mountain ranges (Table 5); the logistic model was appropriate based on the Hosmer and Lemeshow Goodness-of-fit test ($X^2 = 9.84$, df = 8, $P = 0.28$). Landscape curvilinearity was the most significant variable ($P = 0.029$) in the multivariate model; habitat openness was not significant (0.204), but did exhibit a weak relationship to the model. The logistic regression model was improved based on parsimony and a stronger statistical relationship (Likelihood ratio = 10.492, DF = 2, P = 0.005) compared to the full model in predicting wolverine habitat use (Table 5). Based on the reduced model, wolverine preferred habitat with lower curvilinear (i.e., convex drainage bottoms) and less open compared to random expectation.

The analysis of *use* versus *availability* at 4 scales along backtracks (500m, 1000m, 2000m, and 4000m [(Jenness et al. [31]) found wolverine use of forest cover types did not differ from expected. Areas with low curvature (concave drainage bottoms), lower elevation, lower slope, and lower roughness were all used more than *availability* would have predicted at all 4 scales (Table 6). The tortuosity of wolverine backtracks was similar (*P* = 0.307) across forest types with low (0.17) within track covariance. Wolverines did not travel differently or search more in any given forest type and tortuosity was similar between forest types (Figure 5).

**Table 5: Logistic regression model of wolverine (n = 30 pairs of use and random tracks) habitat use with associated maximum likelihood estimates.**

| Variable | Coefficient | SE | Wald Chi-square | *P*- value |
|---|---|---|---|---|
| | | Full model [1] | | |
| Intercept | 1.476 | 1.374 | 1.154 | 0.283 |
| Curvilinearity | -7.769 | 3.555 | 4.778 | 0.029 |
| Lodgepole pine | -0.477 | 1.410 | 0.115 | 0.735 |
| Open | -2.572 | 2.03 | 1.61 | 0.204 |
| Slope | -0.065 | 0.070 | 0.859 | 0.354 |
| Whitebark pine | -1.447 | 2.0134 | 0.516 | 0.473 |
| | | Reduced model [2] | | |
| Intercept | 0.298 | 0.398 | 0.561 | 0.454 |
| Curvilinearity | -7.424 | 3.327 | 4.979 | 0.026 |
| Open | -3.045 | 1.801 | 2.858 | 0.091 |

[1] = Full Model (Likelihood ratio = 12.546, DF = 5, P = 0.028)

[2] = Reduced Model (Likelihood ratio = 10.492, DF = 2, P = 0.005)

**Table 6: Wolverine selection of 9 environmental variables at 4 different segment lengths from 30 snow tracks in southwest Montana; 2003-2005.**

| Variable | Scale (m) | Covariance Parameter | Intercept | SE | DF | T_value | P_value |
|---|---|---|---|---|---|---|---|
| Curvature | 500 | 0.2557 | -0.040 | 0.012 | 29 | -3.36 | 0.002 |
| Curvature | 100 | 0.2232 | -0.044 | 0.014 | 29 | -3.2 | 0.003 |
| Curvature | 2000 | 0.2257 | -0.047 | 0.017 | 26 | -2.84 | 0.009 |
| Curvature | 4000 | -0.00234 | -0.048 | 0.021 | 21 | -2.32 | 0.031 |
| Elevation | 500 | 0.381 | -7.650 | 2.513 | 29 | -3.04 | 0.005 |
| Elevation | 100 | 0.3365 | -18.682 | 5.426 | 29 | -3.44 | 0.002 |
| Elevation | 2000 | 0.1557 | -31.103 | 10.620 | 26 | -2.93 | 0.007 |
| Elevation | 4000 | 0.0581 | -29.220 | 16.535 | 21 | -1.77 | 0.092 |
| Lodgepole pine | 500 | -0.1098 | 0.002 | 0.010 | 29 | 0.18 | 0.857 |
| Lodgepole pine | 100 | 0.0057 | 0.018 | 0.015 | 29 | 1.24 | 0.227 |
| Lodgepole pine | 2000 | -0.04476 | 0.029 | 0.021 | 26 | 1.36 | 0.186 |
| Lodgepole pine | 4000 | -0.3037 | 0.006 | 0.029 | 21 | 0.2 | 0.847 |
| Open | 500 | -0.04155 | 0.008 | 0.009 | 29 | 0.88 | 0.388 |
| Open | 100 | 0.1127 | 0.003 | 0.014 | 29 | 0.24 | 0.815 |
| Open | 2000 | 0.0997 | 0.006 | 0.020 | 26 | 0.33 | 0.748 |
| Open | 4000 | 0.009988 | 0.027 | 0.028 | 21 | 0.96 | 0.347 |
| Slope | 500 | 0.1439 | -0.841 | 0.239 | 29 | -3.52 | 0.002 |
| Slope | 100 | 0.09692 | -1.231 | 0.373 | 29 | -3.3 | 0.003 |
| Slope | 2000 | 0.008104 | -1.273 | 0.479 | 26 | -2.66 | 0.013 |
| Slope | 4000 | 0.392 | -1.298 | 0.645 | 21 | -2.01 | 0.057 |
| Solar | 500 | -0.07158 | 498.930 | 811.110 | 29 | 0.62 | 0.543 |
| Solar | 100 | -0.2133 | 1037.430 | 1157.630 | 29 | 0.9 | 0.378 |
| Solar | 2000 | -0.07961 | 1319.720 | 1953.990 | 26 | 0.68 | 0.505 |
| Solar | 4000 | -0.09741 | 1157.270 | 3378.740 | 21 | 0.34 | 0.735 |
| Spruce / fir | 500 | -0.04792 | -0.009 | 0.010 | 29 | -0.86 | 0.398 |
| Spruce / fir | 100 | -0.0107 | -0.012 | 0.015 | 29 | -0.75 | 0.457 |
| Spruce / fir | 2000 | -0.07705 | -0.021 | 0.020 | 26 | -1.04 | 0.310 |
| Spruce / fir | 4000 | -0.182 | -0.015 | 0.025 | 21 | -0.59 | 0.563 |
| Surface roughness | 500 | 0.141 | -0.005 | 0.002 | 29 | -3.34 | 0.002 |
| Surface roughness | 100 | 0.0487 | -0.008 | 0.002 | 29 | -3.14 | 0.004 |
| Surface roughness | 2000 | -0.07363 | -0.009 | 0.003 | 26 | -2.69 | 0.012 |
| Surface roughness | 4000 | 0.2734 | -0.008 | 0.004 | 21 | -1.82 | 0.083 |
| Whitebark pine | 500 | -0.2685 | -0.004 | 0.005 | 29 | -0.77 | 0.448 |
| Whitebark pine | 100 | -0.1291 | -0.010 | 0.007 | 29 | -1.43 | 0.163 |
| Whitebark pine | 2000 | 0.06768 | -0.019 | 0.011 | 26 | -1.7 | 0.101 |
| Whitebark pine | 4000 | 0.6398 | -0.026 | 0.020 | 21 | -1.27 | 0.217 |

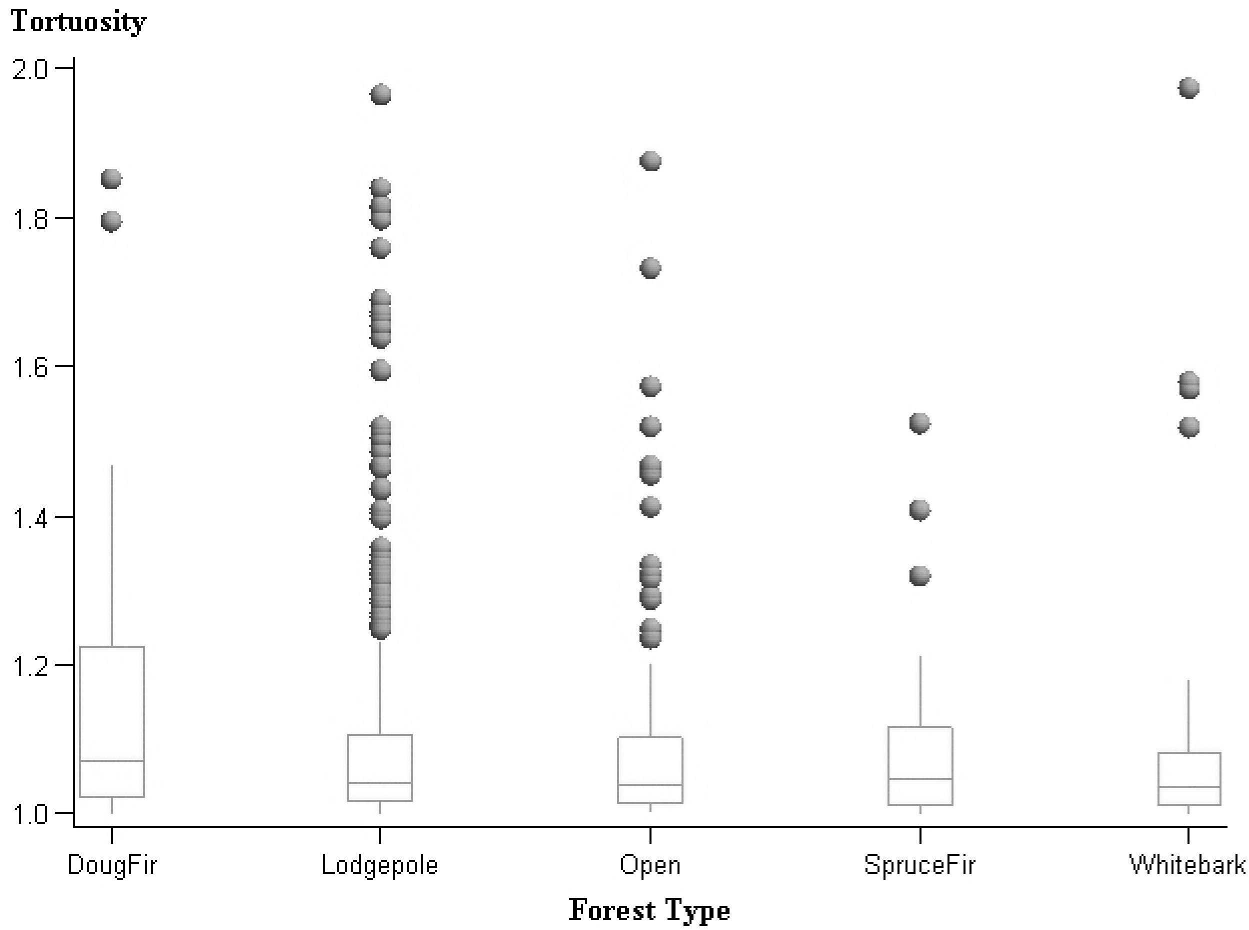


**Figure 5: Median tortuosity within 5 habitat categories for wolverine movements collected during 2004 and 2005 in southwest Montana. Whisker length is 1.5 times the inter-quartile range, while spheres indicate outliers.**

**Linkage zones and movements across highways**

Major road crossings by wolverine were documented through telemetry flights (n=2 crossings), snow tracking (n=1 crossing), and anecdotal reports (n=5 crossings). On December 5$^{th}$, 2003, we located a young male that had crossed State Highway 43 in the vicinity of Lamarche creek, traveling from the northwest corner of the Pioneer Mountains to Fishtrap creek in the Anaconda Pintler range. A subsequent flight 2 weeks later documented that the animal had returned to the Pioneer Mountains, where he remained for the next 9 months until his implant battery expired. We believe the general area of the crossing was Lamarche Creek, although the data does not allow for a more specific delineation of the crossing location (Figure

6). On April 25, 2005, an adult male crossed Highway 93 from the Anaconda Pintler range a few miles north of Lost Trail Pass and was located near the base of the new ski trail expansion at Lost Trail Ski area. We performed a search flight for this individual covering 5 National Forests in Idaho and Montana, and were unable to locate him again. Our study ended a few months after this location, so we were unable to continue monitoring this animal to determine if he returned to his original home range. A backtrack performed in the same area during 2004 documented a different unmarked animal traveling from East to West towards the same general area on Highway 93. The track was lost temporarily when it became obscured on the hillside approximately 300 m above the road, but tracks were again detected on the snowy road cut crossing Highway 93 (Figure 7).

In 2002, we received 2 reports of wolverine crossings during the summer. The first was a crossing of I-15 near the Divide exit, headed towards the Pioneer Mountains from the Highland Mountains, although no more specifics could be gathered. The second was a wolverine crossing Highway 43 near Thompson's Corner, traveling from the Pioneer to the Fleecer Mountains. Two additional crossings were reported by USFS personnel in 2005 of a single wolverine crossing the road in the Divide Canyon, traveling between the Fleecer and Pioneer mountains. Interviews of personnel provided a more specific location (Figure 8). While no wolverine tracks were detected in the Fleecer Mountains during limited formal surveys, tracks were twice detected during other activities east of the Jerry Creek drainage above where the crossings were reported. Lastly, a MFWP employee documented a wolverine crossing the Mill Creek road approximately 400 m (.25 mi) west of the continental divide between the Anaconda-Pintler range and the Fleecer mountains (Figure 9), which further suggests that wolverine were using the Fleecer range.

In addition to actual crossing locations, our linkage analysis identified other areas that could potentially provide connectivity based on environmental attributes (Figure 10). Primary examples of these areas include the Big Hole Pass area of Highway 278 that connects the Pioneer Mountains with the Beaverhead range to the south; the portions of Highways 43 and 274 that link the Pioneers, Fleecers, and Anaconda-Pintler mountains; the section of Highway 1 between Anaconda and Highway 38, which links the Anaconda-Pintler mountains to the Flint Creek range; and the section of Highway 1 in the canyon between Maxville and Phillipsburg that provides potential connectivity between the Flint Creek Range and the national forest lands to the west.

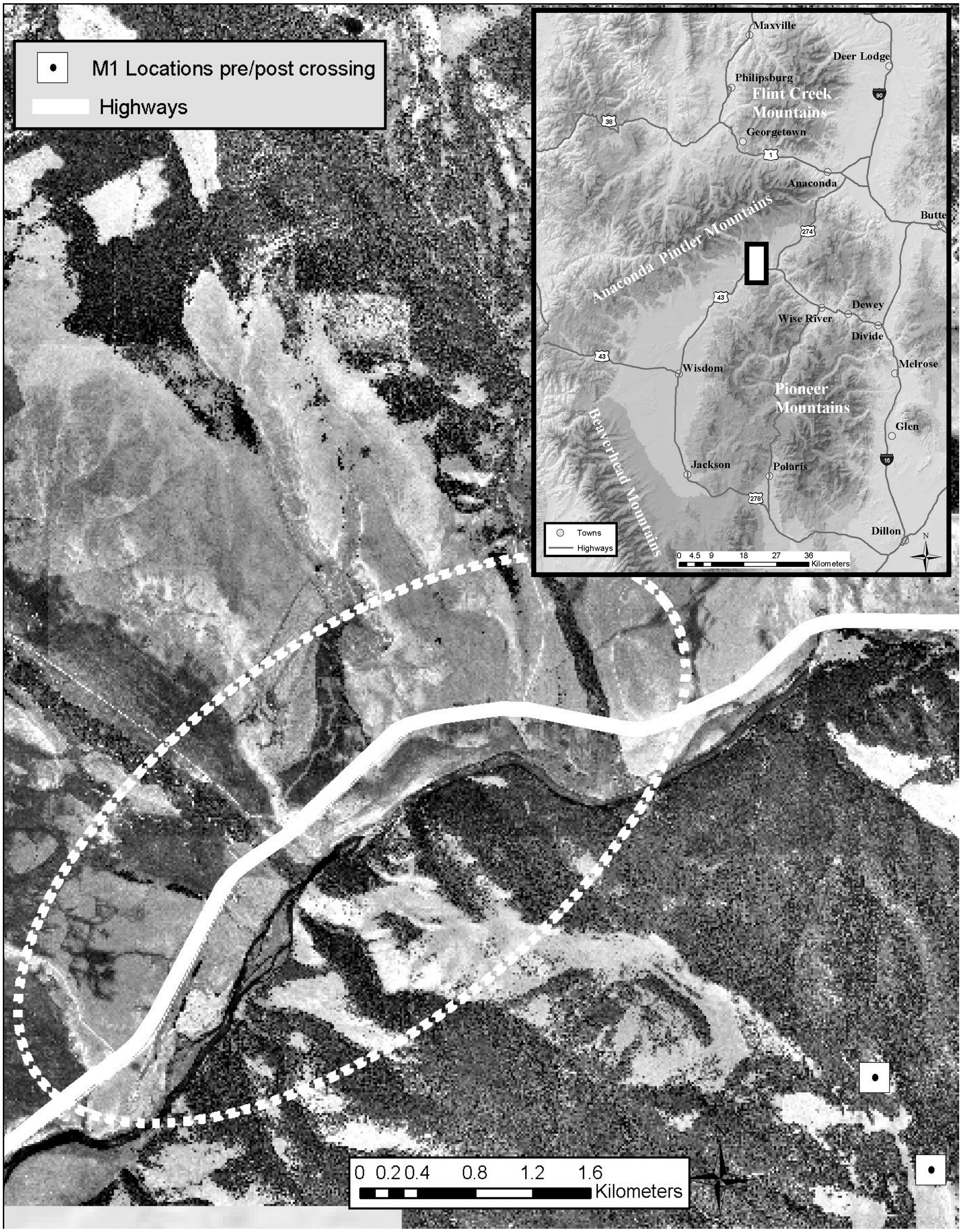


**Figure 6: General crossing location of wolverine M1 on Highway 43 between the Pioneer and Anaconda-Pintler Mountains in December 2002.**

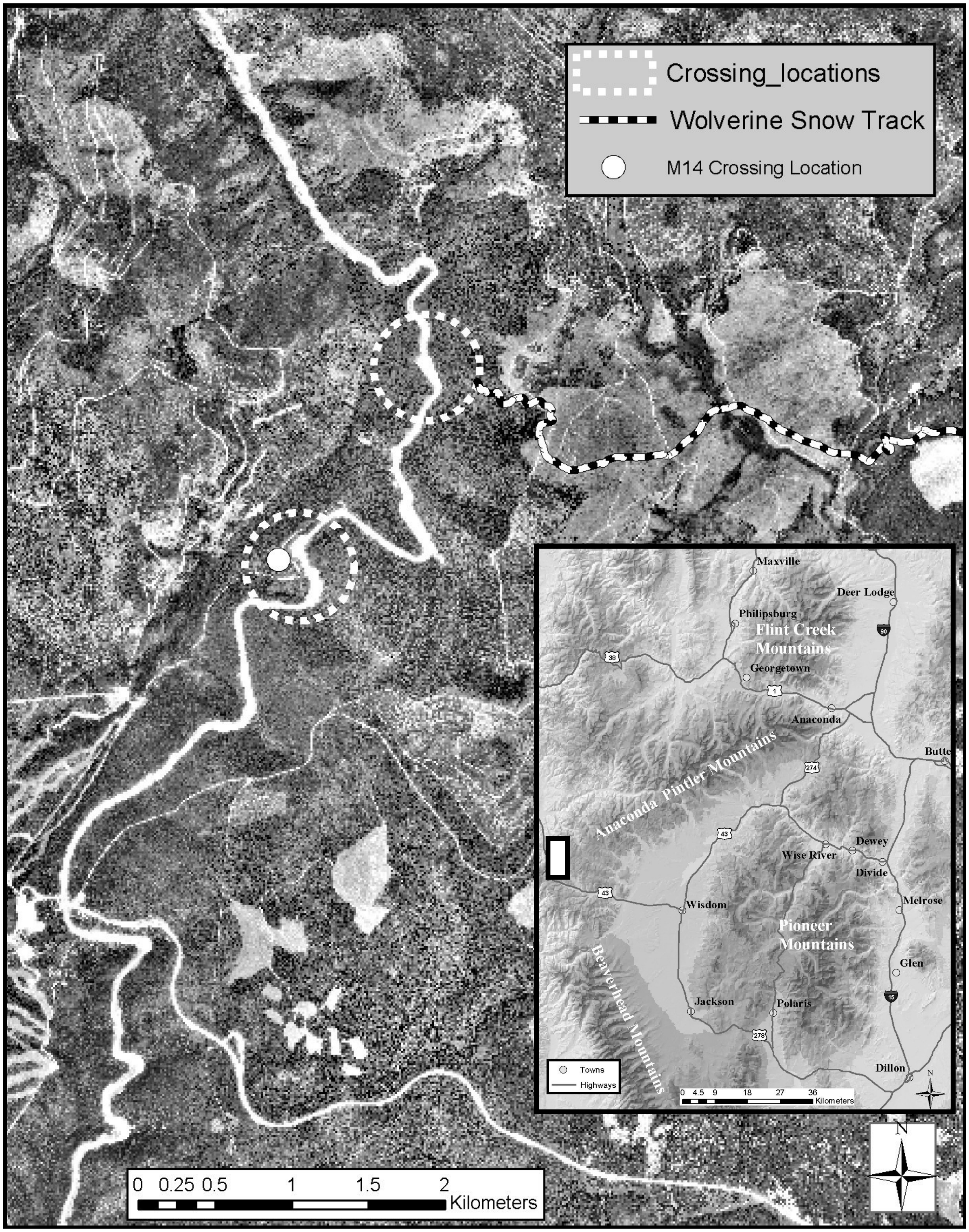


**Figure 7: Estimated locations of 2 wolverine crossings of Highway 93 between the Anaconda-Pintler and the Bitterroot Mountains in southwestern Montana; 2003-2005.**

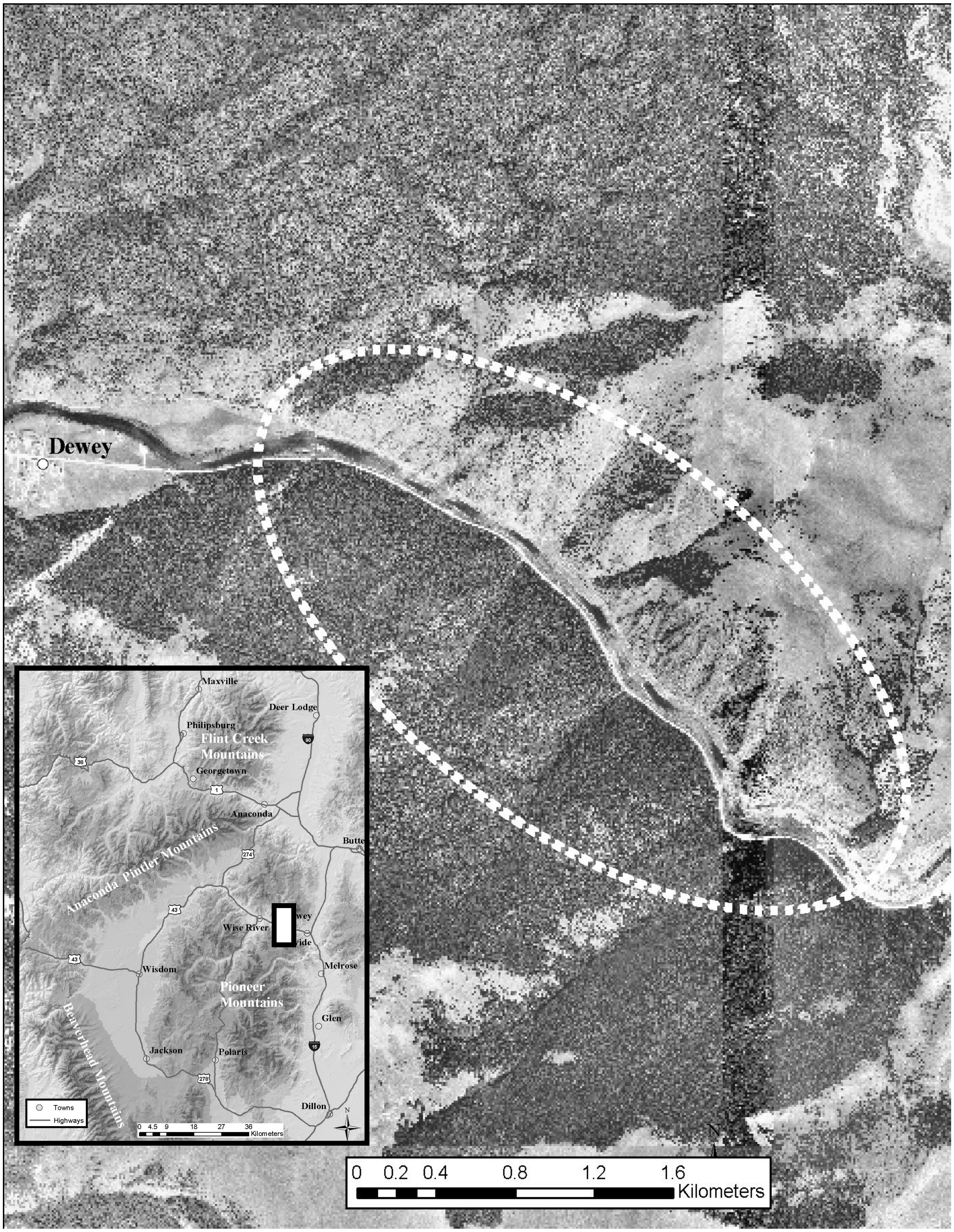


**Figure 8: General location of 3 wolverine crossings of Highway 43 in the Divide Canyon between the Pioneer and Fleecer Mountains during 2002 – 2004 based on reports from USFS personnel.**

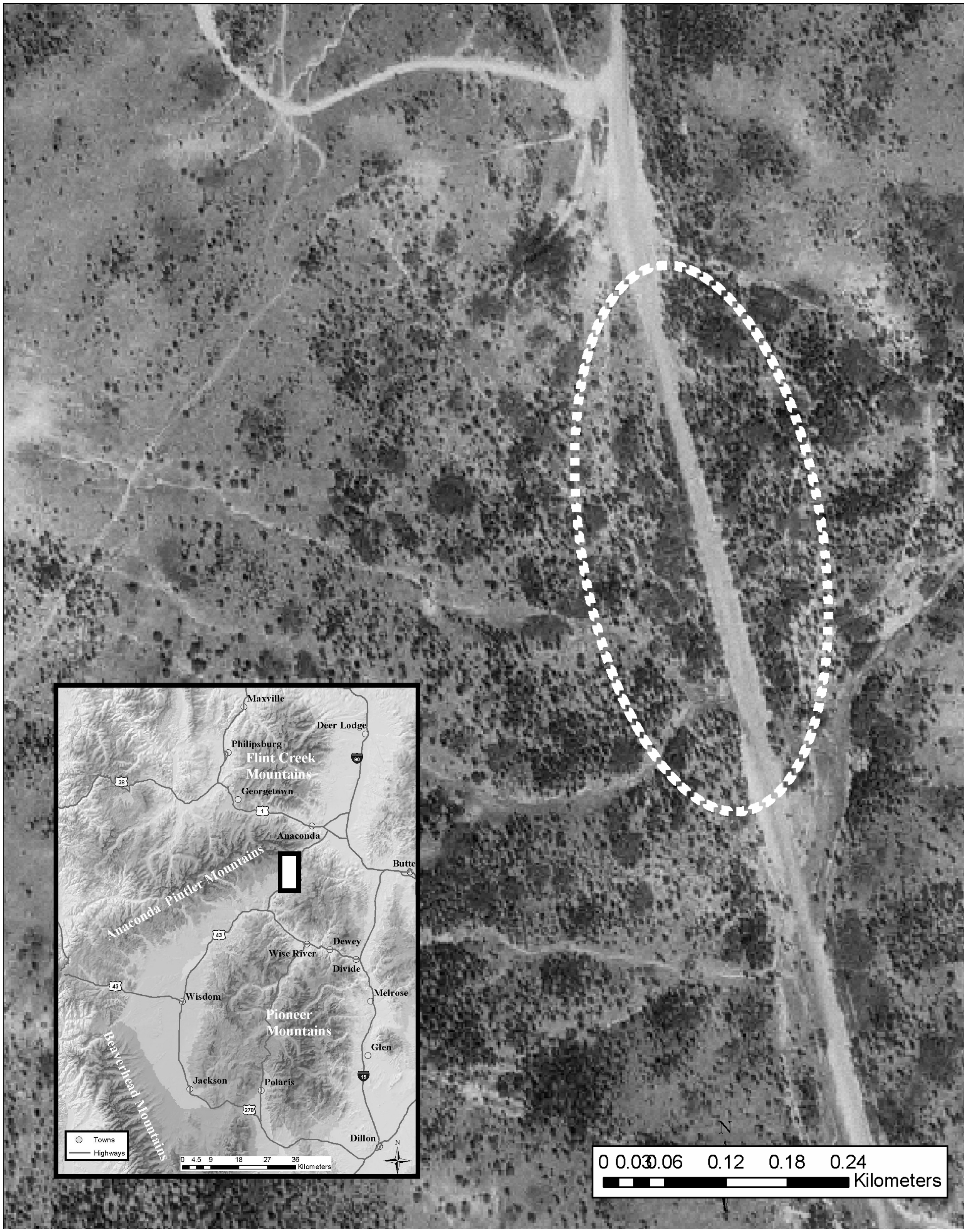


**Figure 9: General location of wolverine on Highway 274 documented in February 2004 between the Anaconda-Pintler and Fleecer Mountains in Montana.**

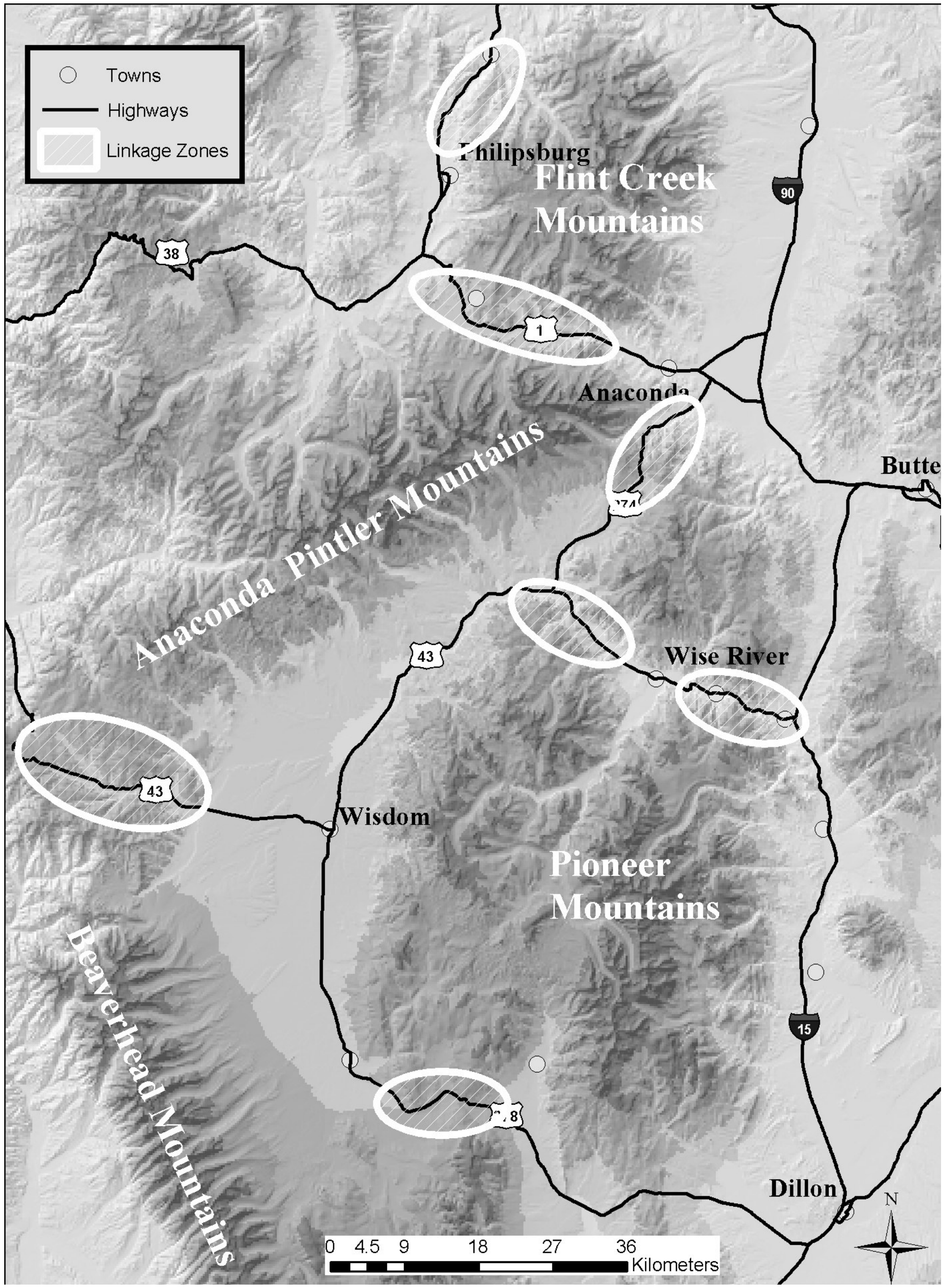


**Figure 10: Putative wildlife linkage zones in southwest Montana identified based on distance between wolverine habitat; 2005.**

**Reproduction**

We documented pregnancy in 3 of the 5 female study animals between 2003-2005. Female F4 was not pregnant upon her capture in 2002, was never recaptured over the course of the study, and we never documented her localized at a den site. Female F6 was pregnant upon her initial capture in 2003, but was harvested by a trapper the next week. Female F8 was not pregnant upon her initial capture in 2003, was too young to have given birth in previous years, but was deemed pregnant by a vet upon her recapture in 2005. However, flights during the denning period documented frequent movement and no localizations at den sites were observed. Female F12 was not pregnant upon initial capture in 2004, but was verified to be pregnant by MFWP personnel upon submittal of her carcass by a trapper in 2005. Female F13 was not pregnant upon her initial capture in 2004, but had given birth to a previous litter (genetic paternity test), and appeared to localize repeatedly during the spring of 2005. Project personnel made 3 separate trips into the areas where she localized and found areas of intense use, but no indication of kits. Scats and hairs were collected from one potential den site, but DNA quality did not allow for confirmation.

**Foraging and Diet**

We documented 38 foraging sites and 86 investigative sites on 255 km (158 mi) of snow tracks conducted between 2003-2005. The average distance between successful foraging sites was 6.5 km (4 mi), while the average distance between investigative holes was 3 km (1.9 mi). Combined, wolverine made foraging attempts an average of once every 2.1 km (1.3 mi). At the 38 successful foraging sites prey consisted of elk (*Cervus elaphus*; N=18), mule deer (*Odocoileus hemionus*; n=6), moose (*Alces alces*; n=1), snowshoe hare (*Lepus americanus*; n=1), beaver (*Castor canadensis*; n=1), and coyote (*Canis latrans*; n=1). The remaining 10 prey items could not be identified in the field or through genetic analysis.

Twenty-seven scats from snow tracks were delivered to the University of Wyoming for physical analysis of contents. The most common prey items found were ungulates, which were present in 74% of scats (Table 7), followed by plant, wolverine, domestic cow, squirrel, chipmunk, and mouse. We assume that wolverine hair in scats was from grooming rather than feeding on other individuals.

**Table 7: Contents of wolverine scats collected during 2003 and 2004 from snow tracks in southwest Montana, according to the frequency of scats in which each item was present.**

| Family | Species (common name) | Freqency in Scats | Total (by family) |
|---|---|---|---|
| **Cervidae** | Elk | 0.11 | |
| | Deer | 0.56 | |
| | Uncertain | 0.07 | 0.74 |
| **Plant** | Primarily pine needles and grass | 0.56 | 0.56 |
| **Mustelidae** | Wolverine | 0.33 | 0.33 |
| **Bovidae** | Domestic Cow | 0.14 | 0.14 |
| **Sciuridae** | Squirrel | 0.07 | |
| | Chipmunk | 0.07 | 0.14 |
| **Cricetidae** | Mouse | 0.03 | 0.03 |

Other feeding events include 1 mule deer and 1 moose carcass located during a telemetry flight on May 15, 2002 and investigated by technicians on the ground. Both carcasses were in close proximity and heavily scavenged by wolverines and a black bear.

## DISCUSSION

Mitigating the effects of roads on wildlife by making roads more permeable is difficult given the limited tools available to achieve this objective. Fences, number of traffic lanes, right-of-way clearances, Jersey barriers, cut slope grade, and line of sight are highway design elements that can add or detract to wildlife's ability to cross safely (Ruediger [19]), and therefore are the focus of many mitigation efforts. More expensive, but often necessary, options include retrofitting bridges or constructing new wildlife passages (i.e. culverts, overpasses, underpasses), or preventing private development along important wildlife linkage areas using land swaps, land purchases, and conservation easements. The scope of highway projects and the available funding all affect the number and breadth of options available to transportation agencies. Ruediger [19] and Evink [1] both provide excellent overviews of the key carnivore conservation issues, planning and mitigation options, research needs, and general recommendations for the future.

We understood entering this project, based on previous research studies and wolverine life history traits, that studying wolverine movements relative to transportation corridors would be a difficult proposition requiring maximum use of the limited number of wolverines present on the study site. While our annual capture rate of wolverines was commensurate with other research efforts in the United States (Hornocker and Hash [11], Copeland [12]), our ability to monitor these animals was significantly compromised by high harvest rates by trappers and failed GPS technology. Not only did the harvest of 10 wolverines from our study area limit our sample sizes, but it also disturbed the population dynamics of the resident wolverines, thereby limiting the probability of density-related dispersals. While these issues limited our ability to address some of our primary objectives, our research activities still yielded valuable information on wolverine movements relative to roads, distribution, and population dynamics that will be helpful to transportation planning. The general population dynamics and ecology of wolverine affect the reasons and manner by which wolverines move across the landscape, which in turn affects the manner that wolverine interact with roads.

### Wolverine movements relative to landscape

A primary factor affecting a species' direct mortality from vehicle collisions is the adjacency of use areas to transportation corridors. Wolverines in our study area occupied home ranges that were separate from major roads and highways; thus, they were at a low risk of vehicle-caused mortality. While we found that wolverines did not overtly avoid open habitats in the landscape matrix encountered above the lower tree line, our telemetry data strongly supported that wolverines did not use non-forested habitats at low elevations, namely valley bottoms. Infrequent crossings of valley bottoms by wolverines all occurred in areas where there were numerous forested "stringers" or narrow distances between forested habitats. We suspect these areas of increased cover help facilitate movement across such areas, although empirical data are lacking. So, the range of wolverine habitat in our study area was roughly bounded between lower tree line and mountaintops. Within this habitat range, and at all scales, wolverines did not select for specific forest cover types. However, wolverines did select for lower elevations, lower slopes, lower roughness, and lower curvature relative to *availability*. At the broadest scale that compared use to what was available throughout the entire mountain range, this result may have been biased by the inability of technicians to follow tracks into some of the most severe topography for safety considerations. However, the same relationship held in the 2 finer-scale analyses that only compared use to what was directly adjacent to the track; therefore, we believe the relationship was biologically meaningful and not an artifact of sampling.

While rugged and mountainous high-elevation areas appear critical for female denning (Banci [8]) and wolverines were often detected foraging in rock or talus fields above tree line, the daily movements of wolverines were not limited to these areas. Rather, lower elevation areas (above lower tree line) were used more than would be expected based on *availability*. Similarly, while many instances were documented of wolverines traveling on ridgelines, up steep couloirs, and in extremely rough habitats, wolverines selected for lower slope and roughness areas more than expected. As suggested by Banci [8], these results may be a function of the fact that wolverines are not constrained by habitat, but rather select areas based on food availability and a lack of human disturbance. Another theory regarding habitat selection is that wolverine females seek out high elevation areas with persistent spring snow pack and a lack of disturbance for denning; their spatial requirements are then dictated by food availability surrounding these denning areas (J. Copeland, personal communication). Under this scenario, the spatial arrangement and habitat use of male wolverines would be dictated by the need to maintain multiple females within a home range. Regardless of the ecological reason, wolverines appeared to select for forested cover in areas of lower slope, roughness, curvature, and elevation, while at the same time being fully capable of traversing the steepest and highest regions they inhabit. In other words, while wolverines showed preference in where they traveled, they were not constrained by topographical features.

This means from a highway planning perspective that while wolverines moved non-randomly through the landscape, they were not strongly constrained by topography, habitat, or other environmental characteristics aside from an avoidance of low-elevation valley bottoms. This complicates our ability to create predictive crossing models for wolverine that are useful to highway planners. The generality of their movement patterns suggests that building specific features (overpasses, underpasses, culverts) to facilitate movement may be ineffective, because wolverines were not highly predictive in their response to landscape features. Our observations along backtracks of wolverines walking through USFS road culverts and rock tunnels (n=7), jumping off large boulders (n=3), frequently digging through frozen surfaces while foraging, and ascending near vertical cliffs (n=3) suggest that concrete road barriers and road cuts would not hinder wolverine movement; yet, by the same reasoning, mitigation tools such as fencing to funnel movement may also be ineffective for this agile species. The wolverine's proclivity to travel in forest cover, coupled with their general movement patterns, suggest the most appropriate mitigation for maintaining connectivity and facilitating broad-scale movements would be to purchase land easements that protect putative linkage zones from urbanization rather than constructing physical structures. Had wolverines been highly stylized or predictive in their movements, then these understandings could have been used to properly site physical structures.

Secondary highways were not barriers to wolverine movements, as evidenced by observations and anecdotal reports of successful crossings. However, our study was not designed to detect crossing attempts or evidence of road avoidance behavior. All wolverine home ranges in our study area included varying densities of unpaved USFS roads, but none included any major highways. Based on a study of 20 wolverines, Hornocker and Hash [11] also concluded that the sizes and shapes of home ranges of wolverines in NW Montana were independent of the presence of highways. In our study area, the absence of highways from home ranges could be the result of highways primarily traversing the low-lying agricultural areas in our study area, whereas wolverines tend to inhabit the higher elevations. However, Ruediger [19] suggested that wolverines live adjacent to highways, and not overlapping them, as a result of avoidance behavior.

Provided that highways are permeable to wolverine dispersal movements, a secondary consideration is to understand how forest roads affect wolverine habitat use and population distribution. Banci [8] surmised that wolverine populations across their distribution are negatively affected by human activity and alteration of habitat; therefore, proposals to limit new road building or to rehabilitate USFS roads to benefit grizzlies and aquatic species may also benefit wolverines by decreasing general disturbance as well as reducing trapper harvest.

**Linkage zones**

While major roads and transportation corridors had low adjacency to home ranges, wolverines must encounter these linear features when moving between mountain ranges during exploratory and dispersal movements. We recorded 8 anecdotal observations of wolverine crossings secondary highways. High harvest rates on our study area reduced the density of animals, and therefore likely reduced the need for density-dependent dispersal. Therefore, the frequency of documented crossings may underestimate the crossing frequency that may exist for higher-density wolverine populations. For example, research in areas of Canada and Montana with higher traffic volumes has documented collisions with vehicles as a source of wolverine mortality (Krebs and Lewis [48]; Bob Inman, Co-Principal Investigator, Greater Yellowstone Wolverine Project, personal communication). The example from Montana demonstrates the vulnerability of wolverines to collisions with vehicles not only during crossing, but also while scavenging road-killed ungulates. The data we collected did not allow us to investigate whether all attempts were successful or whether road avoidance reduced wolverine interactions with roads.

The anecdotal observations we documented of wolverines crossing roads varied in precision, with some providing specific locations, while others provided only general areas (Figures 6, 7, and 8). The crossing locations at Lost Trail Pass, Mill Creek road, and in the Divide Canyon were relatively precise, while the crossing of I-15 near Divide and of Highway 43 between the Pioneers and Pintlers could only be delineated at a general level. Seven of the 8 documented wolverine crossings, excluding the I-15 crossing, occurred in areas where the roads left open agricultural lands and entered more constricted forested or river canyon landscapes, and where human development was minimal. Lost Trail Pass is the natural intersection of the Beaverhead, Anaconda-Pintler, and Bitterroot mountain ranges, as well as the border between Montana and Idaho. This high elevation area contains relatively continuous tree cover and narrow road corridors along Highways 93 and 43. Mill Creek road , which connects Highways 43 and 1, travels between the Anaconda-Pintler and Fleecer mountains. While the northern and southern end of the road are generally open agricultural land, the portion in the area of the Continental Divide where this crossing occurred is heavily forested with a narrow road right-of-way. The Divide Canyon also provides the narrowest crossing points between the Pioneer and Fleecer mountain ranges, where vegetated "stringers" reach down to the river on both sides. We acknowledge that sample sizes were too small for quantitative analysis, but the major commonality between crossing areas appears to be a narrow distance between wolverine habitat on either side compared to the surrounding landscape. This general understanding is corroborated by Austin [18], who concluded that wolverines crossed the Transcanada highway at the narrowest points between wolverine habitat and typically traveled the minimum distance possible between cover at these locations.

From a large landscape perspective, our delineation of Lost Trail Pass as an important linkage zone was corroborated by a least-cost analysis conducted by American Wildlands (Bozeman, MT) that recognized the Lost Trail and Lemhi Pass area as one of the 12 most important linkage zones for carnivores in western Montana. According to the American Wildlands analysis, the remainder of the study area was considered to have intact connectivity due to relatively low vehicular traffic rates and lower levels of development compared to elsewhere in Montana. However, we identified putative linkage zones in our study area regardless of traffic and urbanization because these conditions may change in the future. Ideally, these understandings of linkage zones for wolverine will be integrated with research on other species in Montana to allow transportation agencies to identify and prioritize linkage areas.

**Spatial Arrangement**

Home range requirements for wolverines in our study area were similar to other studies in the contiguous United States (Hornocker and Hash [11], Copeland [12]). The visual depiction of these adult home ranges (Figures 3, 4, & 5) juxtaposed on available habitat helps one to understand why wolverine populations tend to be small and occur at low densities. The Beaverhead, Anaconda-Pintler, and Pioneer Mountains all appear to have had a single resident adult male whose home range encompassed the vast majority of each mountain range. We believe the same pattern would have held true in the Flints as well had we been able to collect more relocation data before M7's death. While we cannot rule out that other unrelated adult males were also present in these mountain ranges, the likelihood is low given the lack of available space. The patterns of home range overlap within and between genders (Powell [49], Magoun [37], Banci [38]), as well as between adults and immatures (Banci and Harestad [50]), appear typical of wolverines.

For example, trapping, survey, and telemetry activities in 2002 and the majority of 2003 identified M2 as the resident adult male in the Pioneer Mountains, with no other adult males detected. M2 was harvested in the winter of 2003, and within 2 months a new adult male wolverine (M9) was captured in the East Pioneers, where he established a large home range that would have previously overlapped M2 to a large extent. Genetic comparison of alleles showed that M9 contained many rare alleles compared to other wolverines in the Pioneers, suggesting that he was not born in the Pioneers, but rather immigrated into the range. During his 2 winters in the Pioneers, no other adult males were captured. M9 was harvested in 2005, after which point we again found no adult males occupying the Pioneers. While these data were limited to a short time period (4 years), we suggest that it is likely that the Pioneer Mountains, based solely on the size of available wolverine habitat, do not support more than 1 adult male at any one point in time. How this affects the breeding activities of females within the Pioneers and the degree to which individuals are related to one another is unknown.

The population in the Beaverhead Mountains based on surveys, trapping, and DNA snow tracking from 2003-2005 also provides insight into the population dynamics of wolverines. Three individuals were captured in the first 2 weeks of trapping in 2003 and recaptured repeatedly in 2003 and 2004, yet no other individuals were ever captured during this time. All genotypes collected off of independent snow tracks throughout the Beaverhead Mountains belonged to 1 of these 3 known individuals. Genetic analysis confirmed these three individuals were a family group consisting of the mother (F12), father (M10), and one offspring (M11). M11 died of natural causes in 2004, and M10 and F12 were both harvested in 2005. Subsequent to this event, no other wolverine tracks were detected in the entire portion of the Beaverhead Mountains ranging from Hamby Lake to Lost Trail Ski Area during 2005. Determining whether other animals still exist, and if not, whether this area is recolonized, and how quickly, would require future monitoring.

**Population Status and Distribution**

The ability of wolverines to travel widely over short periods of time has led to a general misperception regarding wolverine abundance (Hornocker and Hash [11]). The ability to monitor and enumerate wolverine numbers is hindered by their low densities, small population sizes, and remote habitats. When we initiated our study in 2001, there were no monitoring programs or population estimates for our study area. Informal "guesstimates" by trappers, state and federal employees, and the general public varied widely. Estimating the number of individuals that comprised local populations was important for putting the issues of road mortality and connectivity into the proper context. Although we did not have a formal study objective to estimate population numbers, our survey, trapping, and backtracking methods were designed to be representative and intensive, which increased the probability of detecting most individuals present on the study area, excluding the Anaconda Wilderness Area. We believe the 8 animals in the Pioneers and 3 animals in the Beaverhead Mountains represented almost all individuals present in these ranges at that time. The Flint Creek Range also had adequate access, but wolverines were less common in this range. Two animals were identified over 5 years of surveys and trapping, with 1 of these individuals being harvested in 2003. A lack of track detections and harvest by local trappers corroborated the fact that wolverine in the Flints were exceedingly rare. The Anaconda-Pintler range provided only limited access due to a large federal Wilderness area at its core. We trapped the fringes in certain areas in hopes of improving our sample size for movement objectives, but such limited access likely results in a much lower minimum population size than would have been detected given full access.

Results from our study corroborated other published findings that wolverine populations exhibit low densities and low reproductive rates. High mortality rates, especially of reproductive females, appeared to be the major issue facing wolverine populations. Krebs et al. [51] reported that harvest greater than 7% of a population, in addition to natural mortality, were not sustainable. Given that wolverine dispersal is male-mediated (Banci [8]), the risk of female wolverine being negatively affected by transportation corridors, either through road-kill or the barrier effect, may be lower than the risk posed to males. We also acknowledge that harvest pressure may have increased on our study simply because our research confirmed the presence of wolverine. However, although anecdotal observations suggest that isolated mountain ranges may have received similar high harvest rates in the past, we were unable to evaluate harvest on a state-wide basis.

## RECOMMENDATIONS & IMPLEMENTATION

Understanding species-specific responses to roads is an ongoing process that will require the cumulative findings of many research projects. Much of the recent literature on wildlife and major highways considers only direct impacts of roadways such as road kill statistics and monitoring species use in areas of mitigation projects on highways. However, the more pressing issue for wolverine may relate to how connectivity of the larger landscape affects the ability of these meta-populations to persist. As a result, wildlife mitigation by transportation agencies should be a progressive process that begins at the broad landscape-scale to develop ecosystem-wide planning, then identifies important general linkage zones, and finishes by prescribing site-specific mitigation if necessary. Based on our research, we provide the following recommendations for transportation planners:

### 1) Linkage Zone Identification

Identifying habitat linkage zones for wolverine is a more complex task than for species such as ungulates. Where ungulates have clear habitat associations, live adjacent to roads, live in large populations, and have a long history of road kill data, wolverines are the opposite. While wolverines did not avoid open areas juxtaposed within the forested landscapes or above tree line, open habitats in low elevation valley bottoms were not contained within home ranges. These valley bottoms, however, were crossed infrequently during exploratory movements and dispersal. Because roads in our study area primarily occur in these valley bottoms, our anecdotal observations suggested that wolverines cross roads in areas where the distance between forested habitats is most narrow compared to the surrounding landscape or in areas where forested "stringers" are present. These associations suggest that current efforts to delineate linkage zones and create "green maps" (Ruediger [33]) using distance between habitat as a primary criteria may work for wolverine. That said, our tortuosity and "*use vs. availability*" analyses found that wolverines did not show a preference for any specific forest type, such as lodge pole or spruce/fir forests; nor did they travel differently in different forest cover types. Thus, forest cover types do not appear to be an important criterion in selecting linkage zones. These conclusions must be viewed as tentative due to the weak habitat associations and small sample sizes.

### 2) Mitigation within Linkage Zones

Based on observed movement patterns, we believe the most appropriate mitigation for wolverine is to identify putative linkage zones and then protect these areas from urbanization through land purchases and easements. Our fine-scale analysis of wolverine backtracks and anecdotal observations of broad-scale movements suggest that wolverines are generalists in their response to landscape features. Thus, it is difficult to create planning models that can predict *a priori* where wolverines will cross highways (Malo et al. [52]). Such models would be necessary before crossing structures (overpasses, underpasses, culverts) could be placed most effectively within a landscape context. Ng et al. [53] suggested that simple improvements such as habitat restoration near crossing points and animal-proof fencing that serves to funnel wildlife to passages could facilitate animal movement between fragmented habitats that are bisected by roads. However, we do not know how wolverine will respond to fencing and concrete barriers as means of funneling wolverine to crossing structures given their agility in climbing and digging. While structures at specific crossing areas may prove to benefit wolverines, we believe reducing disturbance and development in general linkage areas may be a more effective mitigation approach. Also, recommendations by Ruediger [33] suggested that crossing structures are warranted at daily traffic volumes exceeding 2,000 vehicles. MDT traffic counts throughout the study area (Appendix A) show that only I-15 and I-90 currently support traffic volumes at this level; therefore new projects specifically designed to install site crossing structures solely for wildlife may not be warranted at this time. That said, new construction or road improvement projects should consider incorporating wildlife mitigation structures given that installation costs would likely be lower when all road improvements are consolidated into one effort versus having to install wildlife mitigation at a later time.

**3) Monitor Mitigation Projects**

Highway mitigation projects planned for Highway 93 North and Bozeman Pass on I-90 provide an opportunity for monitoring the use of crossing structures for a variety of species, including wolverine. Ruediger [33] and Ng et al. [53] indicated that underpasses, overpasses, and culverts designed for other wildlife often facilitate the movement of large carnivores. We found that wolverines frequently traveled through small rock openings or caves. We also observed a wolverine traveling through a small (<36" wide) culvert under a USFS forest road, suggesting that wolverines may be able to take advantage of smaller crossing structures. We do not believe that wolverines would be constrained by concrete barriers or fencing, but mitigation projects provide an opportunity to better investigate this theory. Clevenger and Waltho [54] recognized that a multiple-year period is often required to allow for sensitive species to adapt to new structures and mitigation projects; therefore, both pre- and post-mitigation monitoring should be conducted to help identify whether permeability is improved and if certain mitigation characteristics are used by wolverines. These understandings can then be used to inform future mitigation projects.

**4) Research Needs**

Monitoring of road kill and species crossings at mitigation sites (Recommendation #3) provide important information in determining which species are most at risk and how they interact with roads; however, this information alone can be misleading. Road avoidance behavior for many species may manifest itself at distances much further away from roads than will be detected by the monitoring techniques mentioned. Determining whether the infrequent crossings of roads by wolverine are a function of roads being placed in habitats not used by wolverines, or as a function of wolverine avoidance of these areas can only be achieved by monitoring wolverine movements at larger scales. We recognized this fact in our initial proposal by designing our study to incorporate GPS collars to record broad-scale movements of wolverines. Throughout the study, GPS manufacturers claimed that existing technology was capable of addressing this objective for wolverine. Unfortunately, the reality was different, and many GPS collars from multiple manufacturers were flawed. These technical issues prevented us from collecting data as planned. Collar technology has improved over this time through cooperation between manufacturers and multiple wolverine research projects, and we believe it is now useful for researching the issue of road avoidance.

Given the magnitude of trapping mortality documented on our study, we think it is important to gather additional information regarding the size and distribution of wolverine across the state. The noninvasive genetic techniques developed during this study show promise in providing a means of conducting mark-recapture surveys to estimate populations. We would be interested in working cooperatively with Montana Fish, Wildlife, and Parks to develop protocols and to seek funding for conducting additional broadscale surveys for wolverine.

**5) Wolverine Population Dynamics Relative to Movement**

Our trapping and monitoring activities over a 4-year period found that wolverine populations in southwest Montana consist of relatively few individuals. Low populations numbers, extremely low reproductive rates, and yearly harvest of individuals indicate that wolverines are arranged in a meta-population framework that requires dispersal and exchange to maintain populations. The population characteristics of wolverines, combined with findings that wolverine populations in Montana are becoming fragmented and isolated (Cegelski et al. [55]), reaffirms the importance that maintaining connectivity has on the distribution and persistence of wolverines in Montana. Despite the difficulty of collecting empirical data on wolverine connectivity between populations, the issue of highway permeability for wolverines and other rare carnivores should remain a high priority for transportation agencies.

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Appendix A: Average annual daily traffic volumes, by county, from 1990-2004 for roads in or surrounding the Pioneer Wolverine Project study area in southwestern Montana

## Granite County

| | | | | | AADT | | | | | | | | AADT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Route** | **Location Description** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
| P-19 | MT 1, MP 31.5, E of MT 38 (Skalkaho Pass Rd) | 600 | 570 | 560 | 670 | 680 | 710 | 750 | 780 | 490? | 690 | 1050 | 1060 | 800 | 750 | 1190 |
| P-19 | MT 1, MP 32, N of MT 38 (Skalkaho Pass Rd) | 600 | 630 | 610 | 690 | 780 | 810 | 620 | 910 | 870 | 810 | 1070 | 1120 | 890 | 930 | 1340 |
| P-19 | MT 1, MP 38, S of Approach Rd to Phillipsburg | 580 | 540 | 490 | 520 | 600 | 750 | 650 | 930 | 870 | 680 | 860 | 880 | 710 | 700 | 1110 |
| P-19 | MT 1, MP 39.5, 1 mi N of FAS 348 (loop site) | 830 | 770 | 830 | 860 | 800 | 970 | 910 | 1020 | 1000 | | | 890 | 1050 | 970 | 1050 |
| P-19 | MT 1, MP 49, .5 mi N of Maxville | 560 | 510 | 510 | 660 | 660 | 670 | 800 | 1200 | 960 | 880 | 1040 | 940 | | | 1030 |
| P-19 | MT 1, MP 58, N of Hall | 860 | 810 | 770 | 810 | 980 | 970 | | 1280 | 940 | 810 | 1000 | 2090 | 1010 | | 1280 |
| P-96 | MT 1, MP 64.1, N of Front St (Drummond) | 1410 | 1370 | 1280 | 1500 | | 1300 | 1280 | 1560 | 1440 | 1470 | 1380 | 1250 | 1620 | 1300 | 1790 |
| P-96 | MT 1, btwn 1st & Main (Drummond) | 1550 | 1570 | 1590 | 1620 | 1700 | 1510 | 1540 | 1790 | 1680 | 1720 | 1580 | 1490 | 1720 | 1680 | 2270 |
| P-96 | MT 1, btwn A & B (Drummond) | 2070 | 2390 | 2160 | 2200 | 1890 | 1950 | 2000 | 2150 | 1940 | 1900 | 1820 | 1840 | 2120 | 1920 | 2300 |
| P-96 | MT 1, NW of FAS 271 (Drummond) | 1420 | 1590 | 1250 | 1300 | 1190 | 990 | 770 | 1020 | 1140 | 1030 | 1120 | 1040 | 1270 | 1110 | 1150 |
| P-19 | MT 1, at W city limits (Drummond) | 750 | 960 | 930 | 810 | 880 | 850 | 890 | 1190 | 1050 | 1090 | | 960 | 1250 | 1010 | 1510 |

## Silver Bow County

| | | | | | AADT | | | | | | | | AADT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Route** | **Location Description** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** |
| I-15 | I-15, MP 119.6, .3 mi S of Victor Int (Buxton) | 2870 | 3000 | 3150 | 3600 | 3280 | 4010 | 3910 | 3530 | 3610 | | 3590 | 4140 | 4460 | | 3670 |
| I-15 | I-15/90, MP 123.6, 1.2 mi E of Rocker Int | 11170 | 11570 | 12490 | 12990 | 14030 | 14240 | 13870 | 15020 | 15650 | 15400 | 15190 | 15230 | 15260 | 15620 | 15790 |
| I-15/90 | I-90, MP 218.3, 1 mi W of Nissler Int | 8210 | 8300 | 10000 | 10620 | 10040 | 9370 | 10610 | 10580 | 11060 | 10420 | 9930 | 10450 | 11450 | 11440 | 12090 |
| I-15/90 | I-15/90, MP 121.7, .7 mi W of Rocker Int | 10300 | 9760 | 11080 | 11310 | 13550 | 11410 | | 12860 | 12270 | 12190 | 11610 | | 13670 | 15800 | 16860 |
| I-15 | I-15, S of I-90 Nissler Int | 3970 | 4080 | 4080 | 4000 | 3910 | 3900 | 5220 | 5200 | 5130 | 4110 | 4140 | 4150 | 4890 | 4390 | 4480 |
| I-15 | I-15, MP 101.5, 1 mi SE of Divide Int | 1970 | 2180 | 1940 | 2360 | 2130 | 2660 | 2120 | 2800 | 3150 | 2770 | 2620 | 2950 | 2970 | 3310 | 3080 |
| P-46 | MT 43, MP 77, 1 mi W of I-15 Divide Int | 530 | 620 | 540 | 610 | 630 | 680 | 400 | 560 | 620 | 670 | 520 | 820 | 560 | 940 | |
| P-46 | MT 43 , W of Divide Intch | | 410 | 510 | 510 | 470 | 630 | | 470 | 520 | 560 | 410 | 660 | 460 | 760 | 550 |
| I-15 | I-15, N of Divide Intch | | | 2530 | 2510 | 2790 | 2850 | 3430 | 3490 | 3470 | 3060 | 2830 | 3040 | 3260 | 3540 | 3310 |

Appendix A (continued): Average annual daily traffic volumes, by county, from 1990-2004 for roads in or surrounding the Pioneer Wolverine Project study area in southwestern Montana

## Beaverhead County

AADT

| Route | Location Description | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P-46 | MT 43, RP 15, W of Big Hole Battlefield | 250 | 270 | | 240 | 230 | 380 | 420 | 260 | 250 | 390 | 280 | 420 | 290 | 570 | 290 |
| P-46 | MT 43, RP 26, W of FAS 278 | 460 | 420 | | 380 | 460 | 650 | 570 | 340 | 330 | 500 | 360 | 500 | 380 | 690 | 380 |
| S-278 | FAS 278, RP 60, 1 mi S of MT 43 | 350 | 420 | | 370 | 390 | 330 | 500 | 310 | 260 | 450 | 350 | 370 | 430 | 430 | |
| P-46 | MT 43, RP 27, N of Wisdom | 350 | 250 | | 370 | 270 | 340 | 330 | 210 | 190 | 340 | 360 | 330 | 300 | 520 | 440 |
| P-46 | FAP 46, btwn Pine & Main (Wisdom) | | | | | | | | | NEW | | 510 | 730 | 600 | 850 | 670 |
| P-46 | MT 43, RP 61, W of Wise River | 370 | 360 | | 360 | 370 | 490 | 310 | 330 | 220 | 450 | 280 | 490 | 400 | 720 | |
| P-46 | MT 43, RP 75, County Line | 440 | 450 | | 500 | 470 | 610 | 520 | 420 | 590 | 580 | 480 | 690 | 510 | 910 | |
| S-278 | FAS 278, RP 44, 1 mi N of Jackson | 300 | 350 | | 350 | 360 | 350 | 470 | 300 | 280 | 420 | 370 | 330 | 350 | 430 | 290 |
| S-278 | FAS 278, RP 41, 2 mi S of Jackson | 250 | 260 | | 250 | 300 | 310 | 420 | 260 | 290 | 340 | 300 | 350 | 280 | 470 | 240 |
| I-15 | I-15, RP 60.5, btwn S Dillon & FAS 278 Intch | 2990 | 2860 | 3140 | 3740 | 3740 | 3470 | 4090 | 4030 | 4130 | 5000 | 3590 | | 4450 | 4190 | 4240 |
| I-15 | I-15, RP 57.5, S of FAS 278 Intch | 2460 | 2200 | 2620 | 3010 | 2440 | 2940 | 3560 | 3750 | 4300 | 4160 | 2920 | | 3640 | 3380 | 3350 |
| S-278 | FAS 278, RP 6, 7 mi SW of Dillon | 490 | 450 | 650 | 590 | 640 | 650 | 710 | 740 | 770 | 780 | 780 | 780 | 810 | 850 | 850 |
| S-278 | FAS 278, RP 18, 18 mi W of I-15 | 450 | 430 | | | 420 | 430 | 600 | 270 | 330 | 570 | 530 | | 490 | 550 | 390 |
| I-15 | I-15, RP 62.5, btwn N & S Dillon Ints | 2380 | 2070 | 2510 | 3060 | 2390 | 3570 | 3620 | 3680 | 3060 | 4210 | 3140 | | 3620 | 3530 | 3690 |

## Deer Lodge County

AADT

| Route | Location Description | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P-19 | MT 1, RP 1.5, 1.5 mi W of Anaconda Int on I-90 | 2580 | 2470 | 2470 | 2640 | 2710 | 2930 | 2800 | 2690 | 3220 | 3480 | 3420 | 3260 | 3500 | 3520 | 3610 |
| P-19 | MT 1, RP 5.3, .3 mi SE of MT 48 | 4130 | 3890 | 3820 | 3930 | 4370 | 4630 | 4710 | 4000 | 5080 | 5020 | 5240 | 4890 | 4480 | | 4960 |
| P-19 | MT 1, W of Jct MT 48, E of Anaconda | | 5400 | 5180 | 5330 | 5850 | 5790 | 5560 | 5480 | 6310 | 7160 | 6310 | 6660 | 6810 | 6470 | |
| P-19 | MT 1, E of old FAS 274 (Silica Rd), W of Opportunity | | 3780 | 3680 | 3750 | 4040 | 4310 | 4470 | 3800 | 4780 | 4800 | 4480 | 4710 | 4610 | 5540 | 5000 |
| P-46 | On MT 43, MP #54, 0.5 mile west of FAS 274 | 380 | 320 | | 290 | 310 | 290 | 370 | 230 | 170 | 360 | | 400 | 320 | 590 | |
| P-46 | On MT 43, MP #55, 0.5 mile east of FAS 274 | 340 | 340 | | 250 | 280 | 270 | 340 | 180 | 180 | 340 | 240 | 350 | 300 | 530 | |

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