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Abstract

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IDENTIFICATION AND MANAGEMENT OF LINKAGE ZONES FOR GRIZZLY BEARS BETWEEN THE LARGE BLOCKS OF PUBLIC LAND IN THE NORTHERN ROCKY MOUNTAINS

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Abstract: The fragmentation of carnivore habitat in the Rocky Mountains on both sides of the U.S.-Canada border is an ongoing threat to the survival and recovery of these populations. Human developments are the cause of this fragmentation. Major developments causing fragmentation include private land conversion into homesites and highway construction and improvement. If carnivores such as grizzly bears (*Ursus arctos horribilis*), wolves, (*Canis lupus*), wolverines (*Gulo gulo*), lynx (*Lynx lynx*), and fishers (*Martes pennanti*) are to survive and recover to healthy population levels in the Rocky Mountains, the issue of fragmentation must be addressed in a proactive and effective manner.

The grizzly bear (*Ursus arctos*) is an opportunistic omnivore that readily adapts to a wide range of habitats. Historic distribution of grizzly bears spanned the Northern Hemisphere. However, expanding human populations have reduced or eliminated grizzly bear populations from most of their former range throughout the world. In the conterminous United States, grizzly bears were indiscriminately killed by Anglo-American settlers beginning in the early 1800's and continuing through the mid-1900's. By 1970, grizzly bears had been reduced to approximately 2% of their historic range (Servheen 1990; Servheen 1999; USFWS 1993). In 1975 the grizzly bear was listed as threatened under the Endangered Species Act (ESA: 16 U.S.C. 1531-1544). Although healthy populations of grizzly bears persist in Alaska and Canada, some Canadian populations appear threatened by continued development (McLellan and Banci 1999).

Grizzly bears in the lower 48 United States are currently limited to 5 areas in portions of the states of Wyoming, Montana, Idaho, and Washington (Figure 1). Reestablishment of grizzly bears in a sixth area, the Bitterroot Mountains of Idaho and Montana, is planned. This area has ample habitat but no viable grizzly bear population. Despite ESA protection, grizzly bears continue to face human threats. These include mortality, displacement, and habitat fragmentation. If not addressed through appropriate management and mitigation, they will decrease the probability of the grizzly bear's persistence.

Humans continue to exact a heavy toll on grizzly bear populations by intentionally or accidentally killing them. Intentional killing includes illegal forms of mortality such as poaching, malicious killing, or mistaking grizzly bears for legal game. It also includes removal of nuisance bears by management agencies and bears killed by individuals in defense of life or property. Accidental killing is most often the result of collisions between bears and motor vehicles or trains.

Human activities can displace bears from important habitats such as denning or foraging sites. Displaced bears are forced to limit their use of portions of their habitat, and seek life requisites in less favorable habitats. This can result in reduced reproduction by displaced bears, higher mortality rates due to food stress or lower security, and smaller bear populations due to reduced carrying capacity of remaining habitat. Some bears may choose to continue foraging within close proximity to human developments. These bears suffer much higher mortality rates (Mace and Waller 1998).

What is a linkage zone?

The area between larger blocks of habitat where animals can live at certain seasons and where they can find the security they need to successfully move between these larger habitat blocks.

Linkage zones are broad areas of seasonal habitat where animals can find food, shelter, and security.

Habitat fragmentation occurs when contiguous blocks of habitat are broken into pieces, with the pieces being separated from one another by unsuitable habitats. Habitat fragmentation is usually accompanied by habitat loss, that is, the area of the remaining parcels sum to less than the area of the original contiguous block (Forman 1995). Recent advances in the science of island biogeography have led to the development of ecological principles that are relevant to our management of public lands (MacArthur and Wilson 1967). First, the number of species in an area of habitat is proportional to its size. As the area of a habitat is reduced, the number of constituent species is concurrently reduced. Second, the species that disappear first tend to be the largest and rarest (Soule 1983). Populations that are dramatically reduced in size and isolated from one another on small habitat "islands" are at risk of extinction. Extinction risk is elevated because small populations are less able to absorb losses caused by random environmental, genetic, and demographic changes (Gilpin and Soule 1986). Examples of negative environmental changes are catastrophes (e.g. fires or floods), disease epidemics, habitat changes due to climate change, or cyclical food shortages. Random genetic changes include variations in gene frequencies due to genetic drift, population bottlenecks, or inbreeding (Mills and Smouse 1994). Random demographic changes include deleterious shifts in sex and age ratios.

Most species exist as a series of geographically isolated populations separated from each other by habitats having limited support capability and/or higher levels of mortality risk. Such species exist in the landscape as a population of populations, which has been termed a metapopulation (Levins 1970). Lande and Barrowclough (1987) further define metapopulations as geographically separated populations whose range is composed more or less of isolated patches, interconnected through patterns of movement between them. Such a situation describes grizzly bear populations in the Northern Rocky Mountains of the United States and adjacent areas of Canada. The survival and persistence of such metapopulations is dependent upon some level of movement and gene flow between them, especially in environments where demographic challenges exist.

When a species exists as geographically separate populations, as the grizzly does in the Northern Rockies, some level of movement and gene flow between them decreases their probability of extinction (Soule 1987; Harrison 1994; Hanski 1999). The reason for this is that natural environments and pressures from human activities vary over time and such variation can impact survivorship and other demographic variables. When multiple populations exist, there are more chances of differences in natural environmental variation and human pressures between these populations, thereby increasing the probability that some populations will survive environmental and human-induced threats that may result in tinction of some populations exist.

The need for linkage consideration:

The long-term health of populations of carnivores will benefit from linkage wherever possible.

Linkage areas can likely serve multiple carnivore species as well as other wildlife species such as ungulates.

Dramatic changes are occurring in the remaining possible linkage areas due to ongoing human development.

Time to maintain connection opportunities is growing short due to the pace of development on these lands.

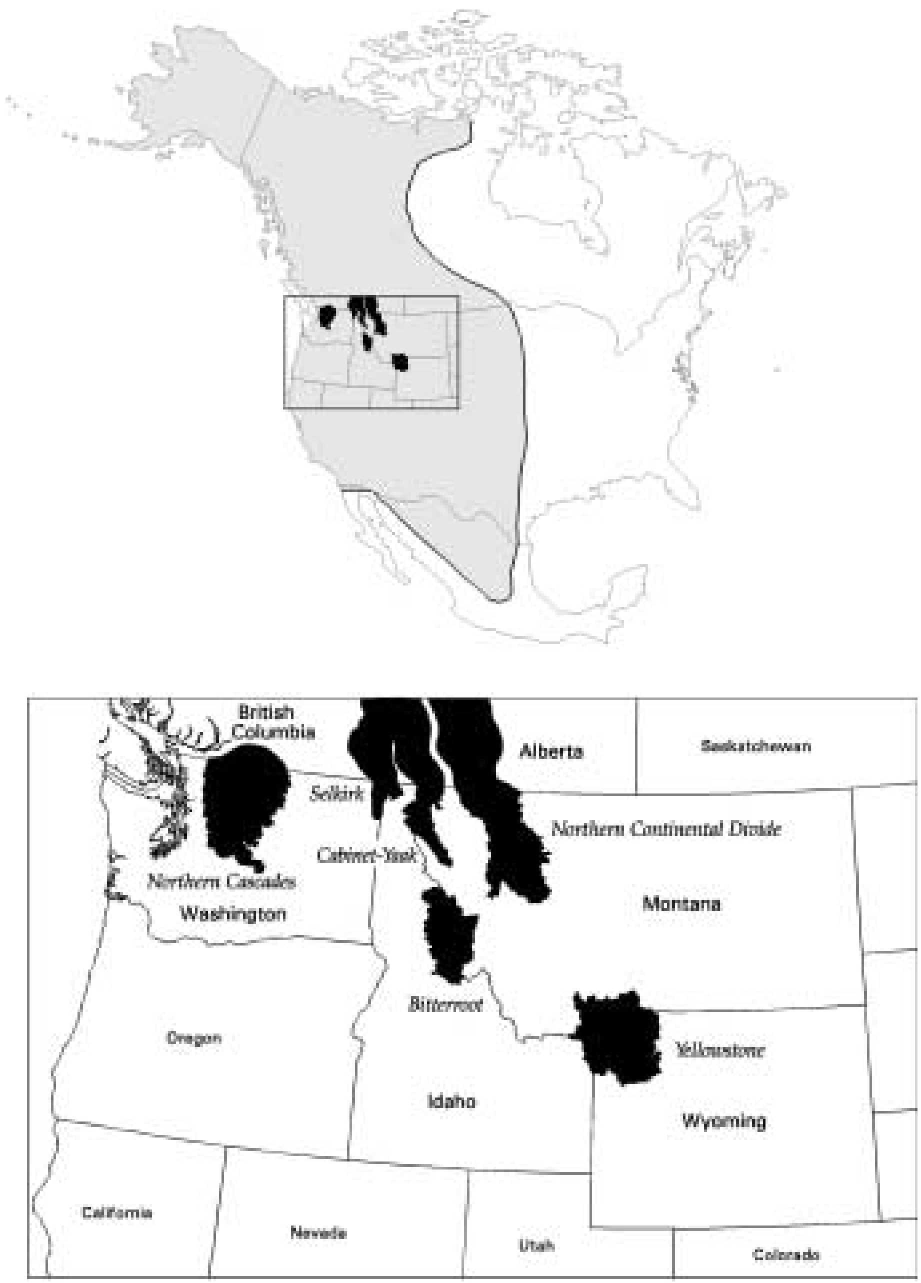

Fig. 1. Historical distribution of grizzly bears in North America and the location of the six grizzly bear recovery areas.

Boyce et al. (2001) have demonstrated the value of multiple populations with some dispersal between them to the survival of the grizzly in the Northern Rockies. For multiple populations to act to minimize the probability of extinction of the entire population of grizzly bears in the Northern Rockies, dispersal between different populations must have some acceptable probability of success. The probability of successful movement between grizzly bear populations depends on what is happening in the intervening areas between them. Thus, management of linkage zones to maintain and enhance movement opportunities is a critical part of the successful application of metapopulation theory to grizzly bear conservation.

Why is a linkage zone not a "corridor"?

A "corridor" implies an area just used for travel; however movement between ecosystems by carnivores rarely occurs this way.

For carnivores to get between ecosystems they require habitats that can support their feeding and behavioral needs in these intervening areas.

Linkage zones are areas that will support low density carnivore populations often as seasonal residents - they are not just travel areas.

Habitat Fragmentation and Grizzly Bears

The primary causes of grizzly bear habitat fragmentation are human activities such as road building, and residential, recreational, and commercial developments. The negative effects of human developments and the degree of habitat fragmentation are influenced by the spatial arrangement of the developments. In the Rocky Mountain west, human developments usually occur in linear fashion along valley floors. When development reaches a certain concentration, grizzly bears can no longer cross the valley floor or use it as habitat. These areas have been termed "habitat fracture zones" (Servheen and Sandstrom 1993).

Maintaining connectivity or "linkage" between small isolated populations could prevent many of the detrimental consequences of habitat fragmentation. Immigrants from unaffected populations can bolster populations reduced due to catastrophic events or negative environmental conditions. Connected populations function as one "metapopulation" where local population processes are balanced by immigration and emigration (Hanski and Gilpin 1991). Linkage zones can serve as "fire escapes" that animals can use to avoid temporary catastrophic events. Maintaining linkage between populations can also preserve gene flow, reducing chances of inbreeding and lessening the effects of genetic drift.

Grizzly bear habitat has been fragmented into 6 pieces constituting 2% of their former range. Five grizzly populations exist in the remaining habitat. Valleys containing human developments of varying intensity separate each of these pieces. As human development continues in these intervening areas, they become increasingly effective barriers to grizzly bear movement. Task number 37 in the Grizzly Bear Recovery Plan (USFWS 1993) calls for an evaluation of potential linkage zones within and between grizzly bear recovery areas. This document describes the methods and results of that evaluation.

The Issue of Scale for Linkage Zones and Crossing Sites

The identification of linkage zones is a way to stratify areas where opportunities for movement still exist between large blocks of habitat. Each linkage zone is from one to several miles or more in width. The Linkage Zone Prediction (LZP) model is not designed to predict the most likely locations within each linkage zone that may be used by wildlife to get across each zone. Various scales exist at the landscape level to view the distribution and linkage of wildlife populations. These scales vary from the general distribution of species to site-specific locations where movement routes or sites occur across highways and through linkage zones. Our current level of knowledge does not yet allow us to predict specific crossing routes or sites, or to predict what combinations of topographic features, vegetation characteristics, road structures, or other values that may be most likely to be used by wildlife to select areas to get across linkage zones. Work is now progressing on ways to attempt to predict such crossing sites (Servheen et al. 1998). If it were possible to predict characteristics for crossing sites for grizzly bears and other wildlife species, these would be of great value to highway engineers for placement of crossing structures in the most important locations. This report does not identify these specific crossing sites within each linkage zone. Such identification is a future effort that should be attempted in each linkage zone based on further research.

Analysis Areas

For this paper, we evaluated the extent of habitat fracture and potential for linkage between the Cabinet/Yaak and Bitterroot recovery areas. We have also evaluated the potential for linkage between the Cabinet/Yaak and Selkirk recovery areas; NCDE and Bitterroot recovery areas; and between the NCDE and Cabinet/Yaak recovery areas. We also examined the potential for linkage between the Cabinet Mountains and the Yaak River drainage within the Cabinet/Yaak recovery area. An evaluation of habitat fracture and potential linkage between the Yellowstone recovery area and the NCDE and Bitterroot recovery areas will be addressed in a future document. No movement of grizzly bears between any of these recovery areas south of the Canadian border has been documented to date.

Cabinet/Yaak to Bitterroot - This linkage evaluation area encompassed 3,606 square miles and contained 5 primary transportation corridors: Interstate 90 and Montana state highways 28, 56, 135, and 200. Two of these highways, Interstate 90 and Montana 200, formed potential barriers to grizzly bear movement between the Cabinet/Yaak and Bitterroot recovery areas. Approximately 88% of the area was public land, primarily within the Kootenai, Clearwater, Idaho Panhandle, and Lolo National Forests. The area was mountainous with elevations ranging from 2047 ft. in the Clark Fork river valley to 7928 ft. in the higher peaks of the Bitterroot Range. Most private land and development occurred in the valleys formed by the Clark Fork and St. Regis rivers and paralleling the 5 primary highways. Timber harvest was the primary use of surrounding National Forest lands, thus forest road densities were relatively high.

Methods

We used a computerized geographic information system (GIS) to model and graphically display the opportunities for grizzly bear movement between recovery areas. GIS allows numerous thematic layers to be combined into one graphic display. Each theme represents a feature of the environment, for example elevation, vegetation type, road networks, etc. Because these themes are combined using a computer algorithm, the process is repeatable over large landscapes.

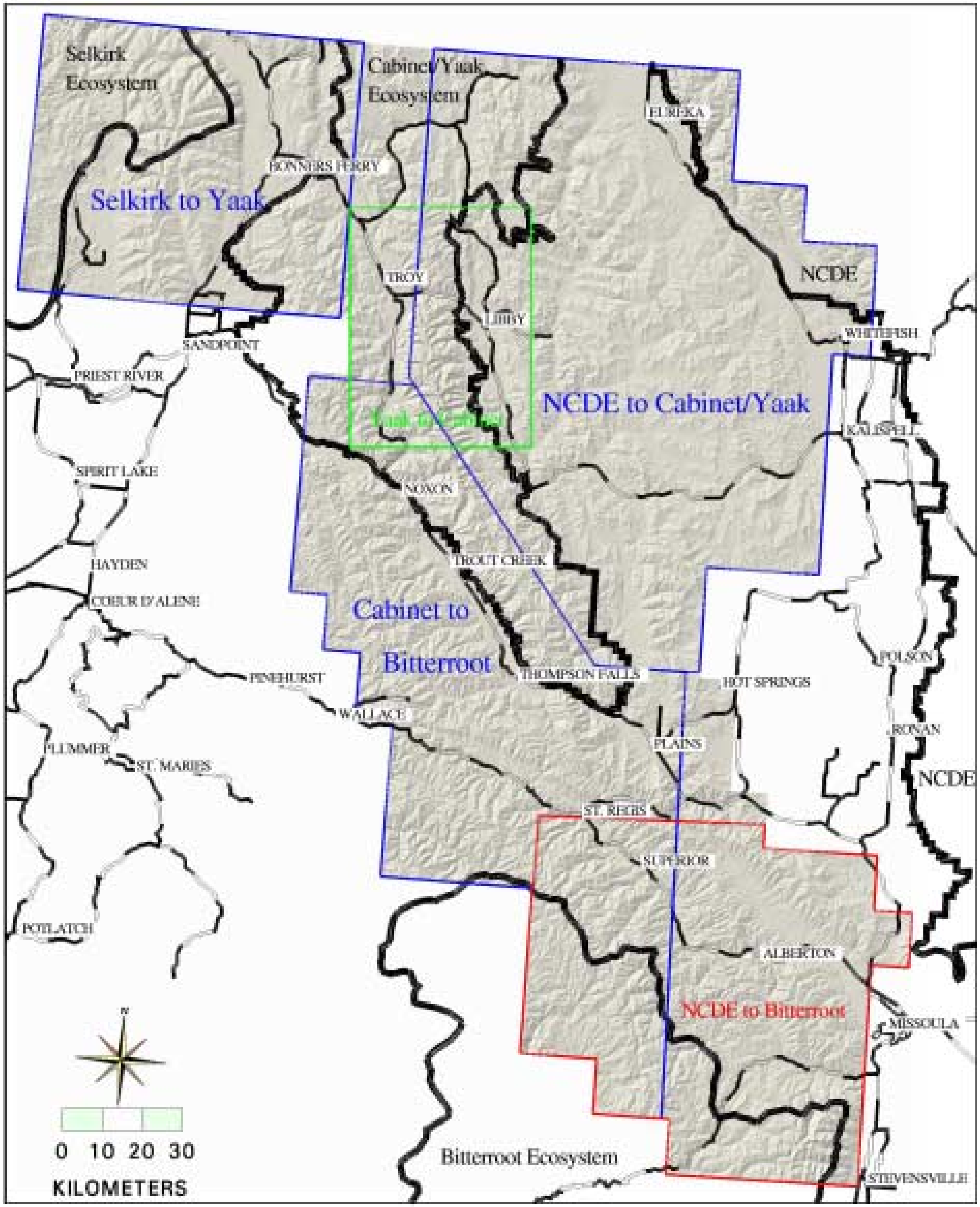

Fig. 2. Five Linkage Zone Prediction Model evaluation areas with terrain, cites, recovery area boundaries, and major highways shown.

The linkage zone prediction model (LZP) was developed to quantify, in repeatable fashion, the extent to which human development has limited the potential for grizzly bear movement between recovery areas. This model was developed by Mietz (1994) and Sandstrom (1996) and applied to the Evaro Hill and Swan Valley areas of Montana. A derivation of this model was used by Apps (1997) to define linkage areas in Southeastern British Columbia and Southwestern Alberta, Canada.

Previous evaluations of grizzly bear habitat focused on describing vegetation, particularly as potential food resources (Mace and Jonkel 1980, Craighead et al. 1982). More recent research has demonstrated that human activities can also have profound effects on distribution of grizzly bears (Mace et al. 1999). Our LZP model evaluated the potential for bear movement between recovery areas by scoring the landscape based upon 4 data layers: roads, human-developed sites, vegetative cover conditions, and riparian habitat.

<u>Linkage zone prediction</u>

Depends on a GIS model to predict the broad areas of highest potential for linkage between habitat units for various carnivores.

The main assumption is that human activities determine wildlife distribution in disturbed areas.

This model uses 4 digital layers:

- Road density (using a moving window approach)
- Human developed sites (i.e. houses, campgrounds, etc.) and the influence zone around them
- Presence of or lack of vegetative hiding cover
- Presence of riparian zones

Additionally, in some areas, livestock allotments may have an impact on linkage zones and may need special consideration.

Roads

Human transportation corridors and their associated developments can cause fragmentation of the habitats of many different species (Garland and Bradley 1984). Recent research has demonstrated the negative effects of roads on grizzly bears (Archibald et al. 1987; Mattson et al. 1987; McLellan and Shackleton 1988; Kasworm and Manley 1990; Mace et al. 1996' Mace et al. 1999). Although grizzly bears are occasionally killed by motor vehicles on roadways, the primary impact is displacement from preferred habitats (Mace et al. 1999). Conversely, bears not displaced by roads are at higher risk of mortality from hunters, poachers, and management removal.

We compiled digital road data from the US Forest Service and the US Geological Survey for each linkage area. The road network was represented in digital form as "vectors", and classified as either open to public travel or restricted in some manner. Two thematic layers were created from these data. The first depicted "total motorized access routes" (TMAR), and included all open roads, restricted roads, and motorized trails (IGBC 1994). Restricted roads included roads on which motorized use was restricted yearlong, or seasonally, by a physical obstruction (gate, berm, rocks, or logs). The second layer depicted all open roads, roads with motorized use restricted by a gate or a sign, and trails receiving high use (more than 12 parties per week, IGBC 1994). These "vector" files were converted to a "raster" format in which the landscape is portrayed as a grid of 30x30 meter cells. Each cell is coded as being a road (1) or not (0).

We calculated road density within each linkage zone evaluation area using the TMAR road layer in a "moving circle" analysis. A moving circle analysis assigns each pixel a road density in mi/mi^2 based on the number of road cells within a surrounding 1 mi diameter circle. The circle moves across the evaluation area, calculating road density, cell by cell. Road density values were then grouped into 4 categories: 0 mi/mi^2, 0.01 – 1.00 mi/mi^2, 1.01 – 2 mi/mi^2, and > 2 mi/mi^2. The categories were those used by Mace and Manley (1993) to measure and report effects of road density on grizzly bears.

The second road layer was used to create a map of secure core areas (SCA). All open roads, roads restricted by a gate or a sign, and trails receiving high use, received a 500 m buffer. All areas outside this buffer were considered SCA. Areas within a SCA are considered to be less impacted by human activity and where grizzly bears are at lower risk of displacement and mortality risk, thus are given a lower impact score (minimal), than areas outside SCA. The interaction between roads, SCA, developed sites, and vegetation were represented by an impact level ranking (Table 1).

Developed sites

Grizzly bear survival and habitat-use patterns are strongly influenced by the intensity of human activity around developed sites. Grizzly bears may respond negatively, neutrally, or positively. A negative response is avoidance of the area surrounding a developed site. A positive response is attraction to developed sites due to the presence of garbage or foods. Both negative and positive responses can be detrimental to grizzly bears.

Avoidance of developed sites may result in loss of important habitats while attraction may result in increased mortality. Developed sites usually become permanent features of the grizzly bear's environment, and therefore need to be accommodated by land managers charged with grizzly bear conservation.

Input data for this layer consisted of digital maps of developed sites represented as point and polygon features. Polygon features represented campgrounds, livestock operations, communities, and other places that cover an area too large to be represented by a point. Data were obtained from USFS and USGS cartographic feature files. Each developed site represented a "human influence zone" which was then buffered by 60, 120, or 210 m depending on the type of activity occurring at the site. Various types of activities occurring at developed sites were subjectively categorized as to their "danger" to grizzly bears based on the judgment of bear biologists (Table 2).

There was no empirical basis for establishing these categories, so we employed a "best judgment" methodology (USFS 1994). In the LZP model, we coded all human influence zones as having a "high" or the strongest impact level. Human developments often represent permanent human presence and reduced land management opportunities. Thus, a developed site has a long term, permanent, negative impact on grizzly bear habitat quality. We assumed that the influence of humans on bears declined as distance from a developed site increased. We incorporated this into the LZP model by creating two 120 m concentric zones around each human impact zone and classifying them as having moderate and low impact levels respectively. Distances greater than 240 m from the outer boundary of a human influence zone were considered neutral.

Cover conditions

Hiding cover is vegetation capable of shielding an animal from visual detection. Many definitions of hiding cover exist and tend to be specific to the species of interest. We used the Flathead National Forest definition of grizzly bear non-hiding cover (USFS 1992), which is "vegetation not capable of hiding 90% of an adult grizzly bear at 200 feet." These open areas occurred naturally as a result of recent fires, as a consequence of environmental factors (climatic, edaphic) that discourage vegetation growth, and as a result of human activities, such as logging.

Grizzly bears seldom venture far from hiding cover during daylight hours in areas with frequent human activity (Blanchard 1978; Schallenberger and Jonkel 1980; Aune and Kasworm 1989), but seem unaffected by cover conditions where human presence is minimal (Servheen 1981). Open areas where humans are present are usually associated with roads or trails. Bears in direct view of roads and vehicles usually flee, whereas grizzly bears in protective cover are less affected by human presence (McLellan and Mace 1985; McLellan and Shackleton 1989; McLellan 1990). We therefore assumed that open areas have a negative affect on habitat quality only if within 500 m of an open road, a road with use restricted by a gate or a sign, or a high-use trail outside SCAs.

Table 1
Estimated levels of impact on habitat quality from different categories of human activity and vegetation hiding cover conditions (Sandstrom 1996).

Category of condition	**Impact level**
Road Density (RD) 0 mi/mi^2, inside SCA[1]	Beneficial
Within riparian area	Beneficial
RD 0 mi/mi^2, outside SCA	Neutral
RD 0.01 – 1.00 mi/mi^2, inside SCA	Neutral
> 240 m from a human influence zone	Neutral
Area providing hiding cover	Neutral
Open area, inside SCA	Neutral
Outside riparian area	Neutral
RD 0.01 – 1.00 mi/mi^2, outside SCA	Minimal
RD 1.01 – 2.00 mi/mi^2, inside SCA	Minimal
Edge, outside SCA	Minimal
RD 1.01 – 2.00 mi/mi^2, outside SCA	Low
RD > 2.00 mi/mi^2, inside SCA	Low
120 – 240 m from a human influence zone	Low
RD > 2.00 mi/mi^2, outside SCA	Moderate
< 120 m from a human influence zone	Moderate
Open area, outside SCA	Moderate
Within a human influence zone	High

Secure Core Areas (SCA) are areas > 500 meters from open roads, or roads with motorized use restricted by a gate or a sign, and non-motorized trails receiving more than 12 parties per week. Roads with use restricted by berms, rocks, or logs could exist inside SCAs.
1SCA = secure core area

Table 2
Human influence zone buffer sizes, types, and danger categories (Sandstrom 1996).

Influence zone radius		*Type of developed site*	*CEM Danger Category*
Meters	*# of cells*		
60	2	Fishing access, boat launch, trailhead, Miscellaneous structure	low
120	4	Campsite, picnic site, work station, Outfitter camp, viewpoint	medium
210	7	Residence, livestock operation, Community, school, manufacturing business, church, campground, garbage dump, restaurant, summer camp, guest lodge	high

We used LANDSAT Thematic Mapper satellite imagery and unsupervised classification (Ma 1994) to delineate areas of hiding cover. Open cover/non-cover edges were delineated with a 30 m buffer to represent use of forest edges by grizzly bears. In the LZP model, open areas were classified the same as cover areas within SCAs, but were assigned a “moderate” impact when outside SCAs. Edge areas outside SCAs were assigned a “minimal” impact.

Riparian areas

Previous research has shown that riparian areas are important to grizzly bears and generally provide more food and security than other cover types (Mealey et al. 1977; Mace and Jonkel 1979; Servheen 1983; Craighead 1982; Aune et al. 1984; Kasworm 1985; Almack 1986). In many cases, riparian areas run perpendicular to the linear arrangement of human developments along higher-order waterways, thus facilitating grizzly bear movement through developed areas.

We developed a computer model to predict the occurrence of riparian areas because detailed vegetation mapping was not available in most of the LZP model evaluation areas (Sandstrom 1996). This model mapped the potential for riparian vegetation based on the slope of land adjacent to waterways. Using digital hydrography and elevation data from USGS (USGS 1987a, b), we buffered existing waterways by an amount proportional to the change in elevation out to a maximum of 210 m. Two caveats apply to this riparian model. First, this predictive riparian model was developed for use at landscape scales and where little field mapping has occurred. Small, but important, micro-sites such as seeps were excluded because of the spatial resolution of the mapping process. The riparian model should not be considered a replacement for site-specific field mapping. Second, the model does not determine specific vegetation types within the riparian area, which may include open water, rocks, wet meadows, deciduous shrubs, and coniferous forest.

Land ownership

In the western U.S., much of the land useful for human development lies within valley bottoms. Here, soils and terrain are suited for agriculture and transportation systems, and water is available for drinking and irrigation. These desirable and productive valley bottoms are primarily privately owned. However, because of their linear nature, they serve to further fragment remaining grizzly bear habitat. Thus, land ownership patterns can indicate areas of habitat fragmentation. Land ownership information was not directly incorporated into the LZP model, but was used to help identify areas where linkage zone opportunities might best be preserved. Digital land ownership files denoting either publicly or privately owned lands were obtained from the Wildlife Spatial Analysis Lab at the University of Montana, Missoula.

Highway structure and volume

The LZP model does not include highway features, form, or traffic volume in its scored map output. Highways are important habitat fragmentation factors and must be accounted for in any management scheme that seeks to facilitate linkage for bears and other wildlife species. The purpose of the LZP model is to identify areas where human activity levels still allow some opportunity for movement. Getting wildlife across the highways within linkage zone areas is important and recommendations on this issue are detailed in the section on management of linkage zones.

Final LZP model score

Each of the 4 input data layers (roads, developed sites, cover conditions, riparian areas) were combined into one new layer displaying the combined impact of each of these factors on habitat quality. The combined scores were then divided into 4 categories based upon subjective evaluation. In general, to be considered in the “minimal” combined impact category, the pixel had to have “neutral” or “beneficial” impact values for all 4 individual layers, or only one condition have a “minimal” or “low” impact value. To be considered in the “low” combined impact category, 2 conditions could be in the “minimal” or “low” category, or 1 condition in the “minimal” or “low” category and/or 1 condition in the “moderate” category while the others had to be “beneficial” or “neutral”. To be considered in the “moderate” or “high” combined impact category, individual impact values had to be different combinations of “low”, “moderate”, and “high” impact values. When interpreting these combinations it is important to acknowledge how different human impacts interact with each other. For example, residences in valley bottoms are nearly always associated with some level of road density and often with open areas. The model is indirectly driven by presence of developed sites, not because they were given the highest impact category, but because developed sites almost always occur in association with roads and open areas of limited visual cover (Table 1).

Delineation of linkage zones

Examining the maps showing combined impact scores allowed identification of Linkage Zones. The goal was to locate areas where grizzly bears could move between large blocks of habitat on public lands with the least conflict with people. To qualify as a linkage zone, an area had to be within the “minimal” or “low” combined impact categories and span an area between the large blocks of habitat on federal lands in a continuous fashion. Single, small areas in the “moderate” or “high” combined impact category surrounded by areas in the “minimal” and “low” combined impact categories (usually lone developed sites surrounded by forested areas) could also be included in linkage zones. Extensive areas within the “moderate” and “high” combined impact categories were excluded as linkage zones. Such areas were usually within human influence zones. To facilitate identification of linkage zones, developed corridors were displayed as yellow/black graphics, where yellow represented “low” and “minimal” combined impact categories and black represented “moderate” and “high” combined impact categories. LZP model outputs were also displayed as 3D surfaces viewed obliquely, thus giving the reader a “birds-eye” view of potential linkage zones.

Results

Each of the linkage zone evaluation areas had different amounts of habitat fragmentation, thus precluding movement between recovery areas to varying degrees. However, some common themes emerged. As stated in the introduction, most development occurred on private lands in valley bottoms. These developments generally were within human influence zones and thus ascribed “moderate” to “high” combined impact categories. Most of the public lands fell within the “minimal” or “low” combined impact categories. Some areas have a “moderate” score due to the presence of clearcuts and high road densities, or due to presence of a recreation site. Public lands scored as “moderate” were discontinuously distributed across the landscape, whereas private lands scored as “moderate” or “high” had a linear distribution along higher order waterways or primary transportation systems.

Example of the results – the Cabinet/Yaak to Bitterroot Linkage Area

The most severe habitat fragmentation between the Cabinet/Yaak and Bitterroot ecosystems occurs along Montana Highway 200 between Plains, Montana and the Idaho border. Some fragmentation also occurs along Interstate 90 (I-90), from east of Superior, Montana to Lookout Pass (Figures 3 and 4, end of paper), but this is mostly limited to the town sites along the route as most land adjacent to I-90 in this area is in Federal ownership (Figure 5, end of paper). Most remaining lands along the Interstate highway were “minimal” or “low” categories and did not appear to be an impediment to linkage, except for the fact that a four lane interstate highway runs through these areas. Little development has occurred in the I-90 corridor between St. Regis and Deborgia, offering ample opportunity for linkage (Figure 4).

Discussion

This assessment does not present a bright outlook for potential connectivity between recovery areas. Fragmentation was complete, or nearly so, between all the recovery areas. Development has continued at a record pace and it is likely that linkage areas we identified may become unavailable within the next decade. However, the following discussion of the LZP model may inject some cause for optimism.

A model is an abstraction of reality that simplifies natural processes into understandable components. The LZP model attempted to quantify those components most responsible for influencing grizzly bear movements, then use those components to identify places where grizzly bears were most likely to traverse human developments. The model operated with geographic data collected at landscape scales. Thus it was insensitive to fine scale environmental patterns. Grizzly bears, on the other hand, are well equipped to process information collected at fine scales. Model outputs reflected the quality of input data. Errors in digital maps of terrain, human developments, and roads were reflected in model results. Thus the LZP model may not accurately predict where grizzly bears will choose to cross-fractured habitat unerringly. Further, human development is a continuous process. Digital maps of roads and developments, that were accurate at the time we obtained them, may not show recent developments.

The LZP model should be considered a point of departure for more intensive and accurate mapping of potential linkage zones. Although we felt confident that the model accurately portrayed places where grizzly bears may cross-fractured habitat with the least risk, implementation of conservation strategies will require that the model be validated in the field. The LZP model also contains many assumptions about the relative risk of each of its components to grizzly bears. Some of these assumptions are poorly substantiated due to the lack of pertinent research, for example the strength of reaction to human developments in relation to cover conditions. In these cases, we used our best judgment to estimate risk and aversion.

As the number of linkage zones between recovery areas decreases, the likelihood of remaining linkage areas being utilized diminishes. The spatial extent of remaining linkage areas will become very small relative to movements of grizzly bears. Bears will then be more likely to attempt crossings in less safe areas, increasing their risk of mortality. There is no research concerning minimum required size of linkage zones or at what level linkage areas become ineffective for grizzly bears. Such information can only be obtained through long term and intensive monitoring of grizzly bears. Recent advancements in GPS technology may allow researchers to answer questions of this nature in the near future.

The LZP model, as applied here, does not consider habitat quality as an important factor governing bear movements. It does use presence of riparian areas, modeled from terrain data, as a factor, but this treatment is superficial at best. The reason for this is that classified and validated maps of grizzly bear habitat quality are generally non-existent. Creating them from field research is time consuming and expensive. However recent research into grizzly bear habitat selectivity using satellite imagery and radio telemetry data have found strong associations between telemetry locations and vegetation reflectance patterns (Manley et al. 1992; Mace et al. 1999).

It may be possible to map grizzly bear habitat quality across broad landscapes using satellite imagery. Such information could then be incorporated into a more habitat-specific linkage prediction model. Private landowners who have already worked cooperatively to implement linkage zones in local communities will write this protocol. This private lands protocol will describe the best ways to work with local landowners in order to obtain understanding, agreement, and ownership of the ideas necessary for linkage zone management. These task force reports can then be the template to implement management opportunities on public lands in the approach zones to each linkage zone, to implement planning and outreach with private landowners in each area, and to incorporate linkage zone crossing opportunities into highway planning in each linkage zone.

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current work, and that of his graduate students, focuses on the impacts of highways and human developments on habitat fragmentation for large carnivores in the Rocky Mountains. He also works with state and federal highway departments in understanding and developing ways to get animals across highways. Through Chris' international work, he maintains close cooperative relationships with IUCN, WWF, and other international conservation organizations. Chris holds a B.S. in Zoology/Wildlife Biology from the University of Montana, a M.S. in Wildlife Biology from the University of Washington, and a Ph.D. in Forestry/Wildlife Biology from the University of Montana.

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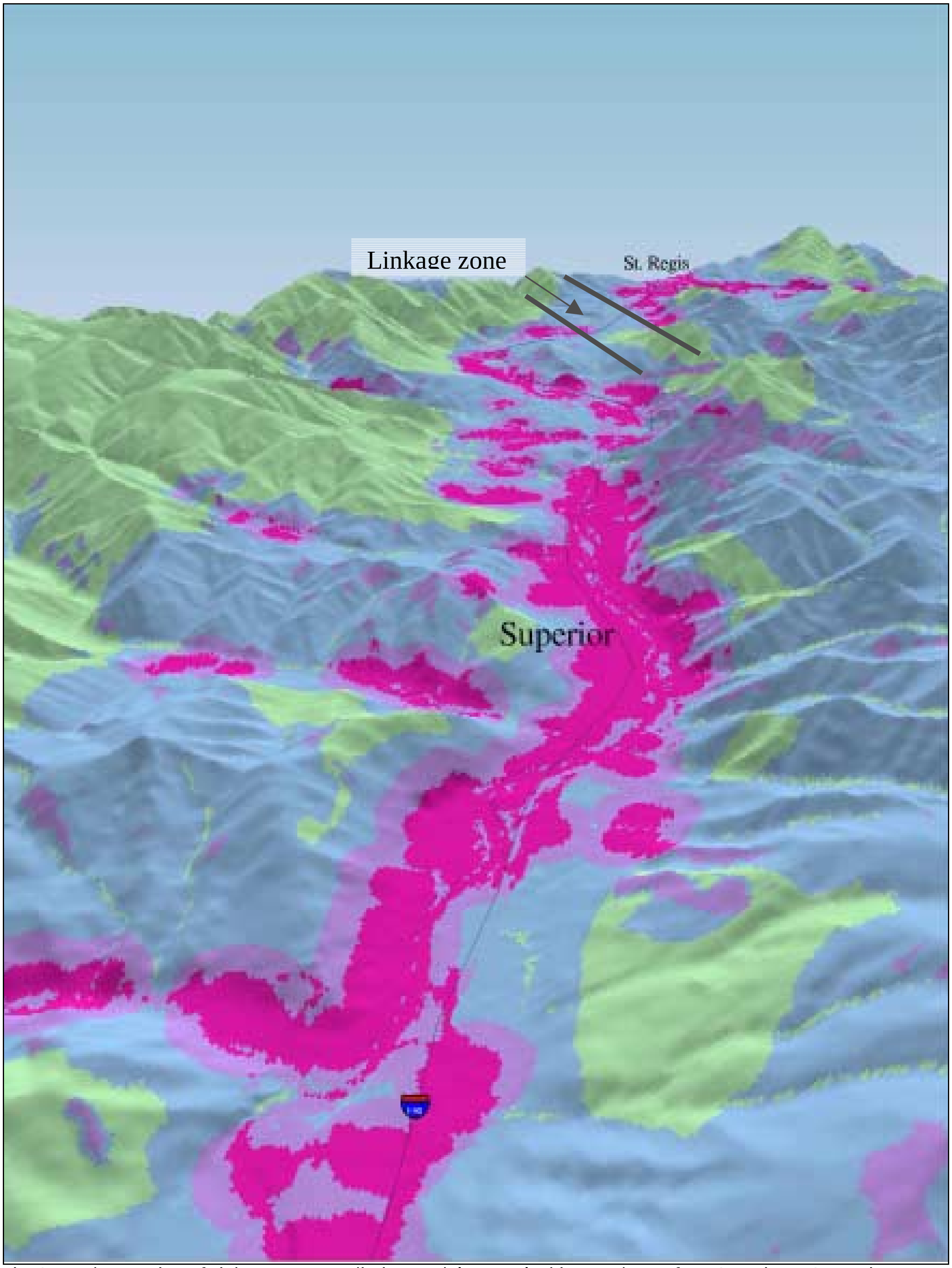

Fig. 3. Landscape view of Linkage Zone Prediction Model output looking northwest from Superior to St. Regis, Montana along I-90.

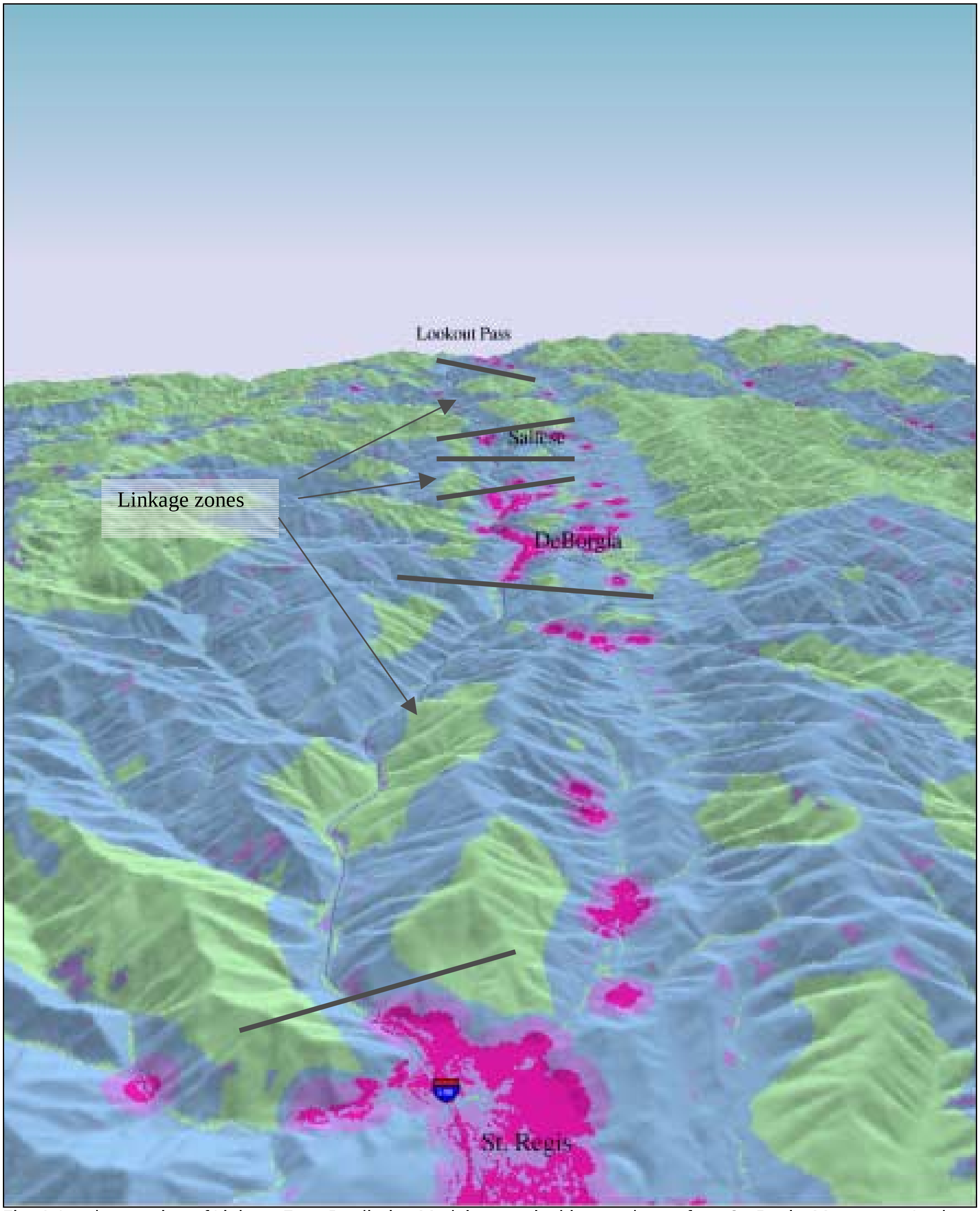

Fig. 4. Landscape view of Linkage Zone Prediction Model output looking northwest from St. Regis, Montana to Lookout Pass along I-90. This is a critical linkage connection, the success of which will be determined by the permeability of the highway and what Montana DOT does to address linkage in this area.

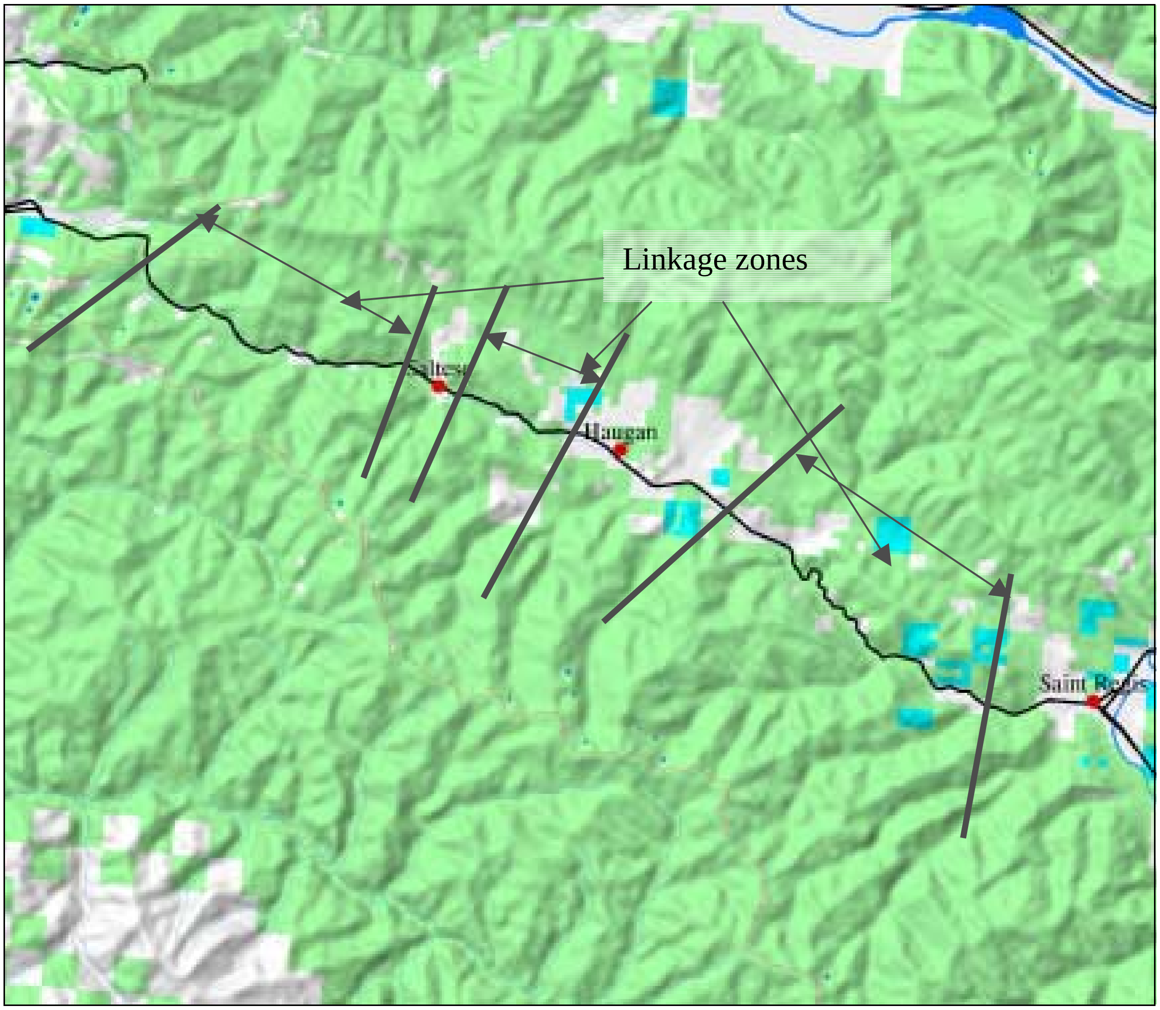

Fig. 5. Land ownership and linkage zones along I-90 from St. Regis, Montana to Lookout Pass on the Idaho line. Linkage zones are within the red arrow areas. Green is USFS, blue is state, white is private.

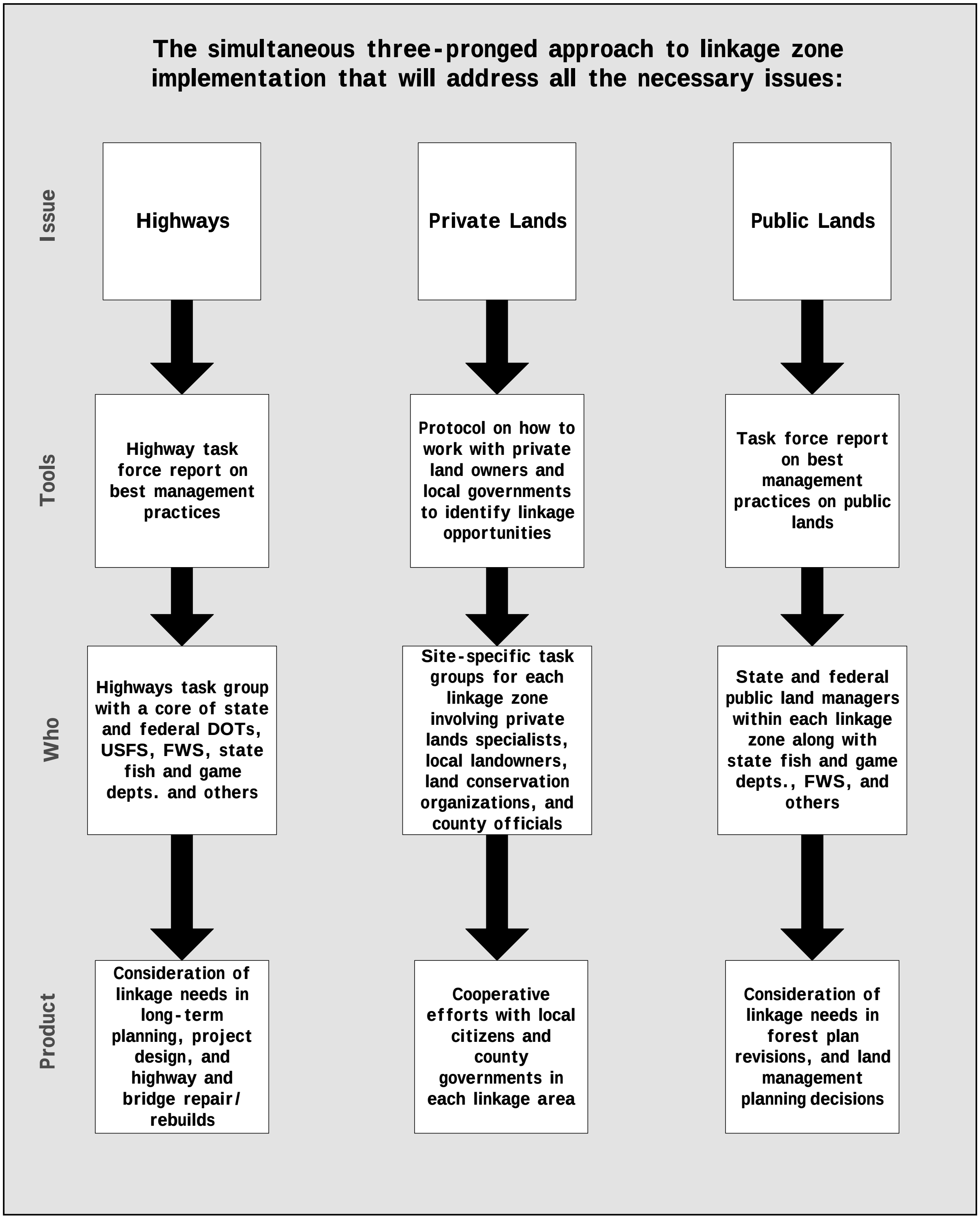

Fig. 6. The three issues that need to be addressed to implement linkage zones.