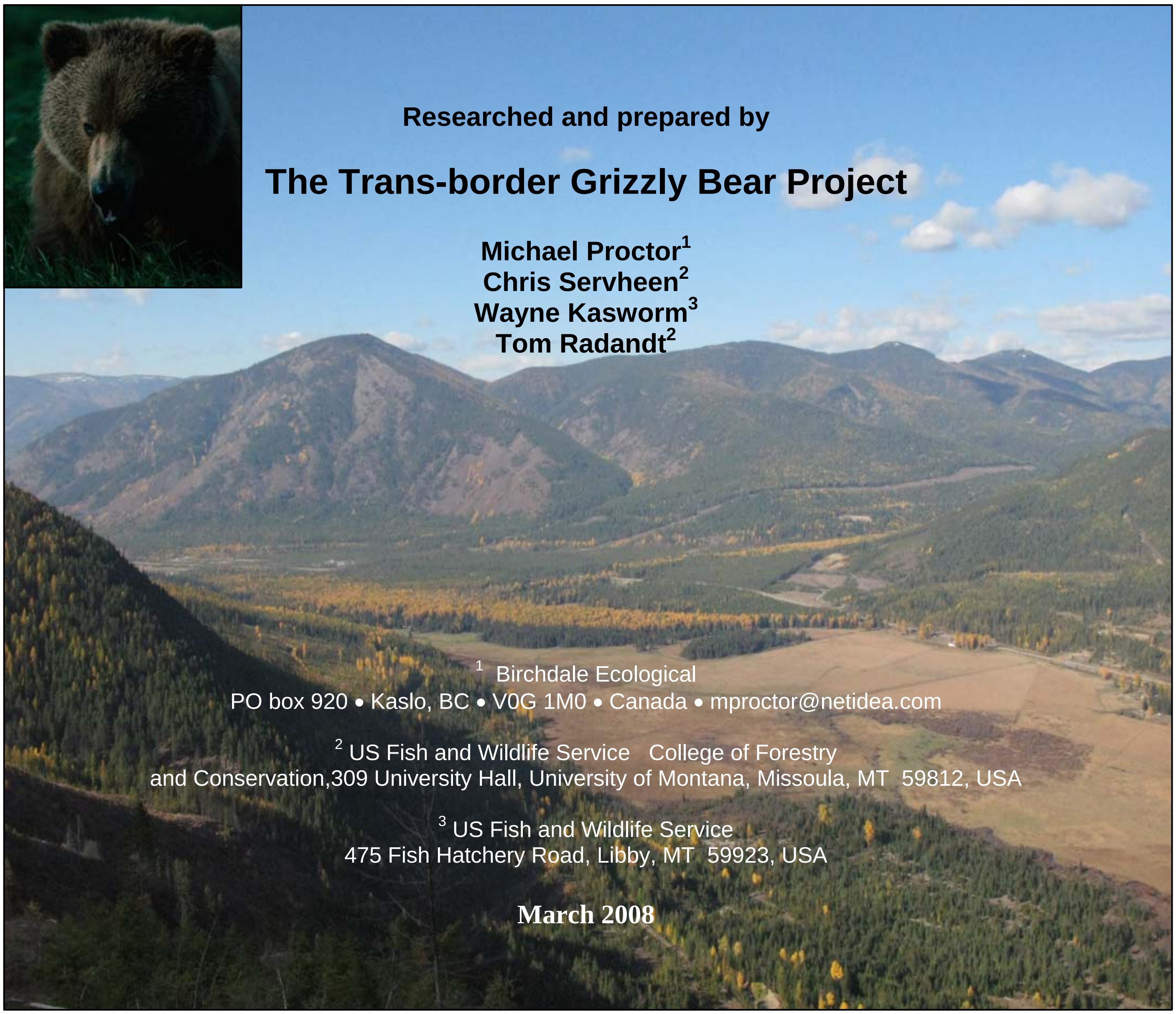
# Grizzly bear linkage enhancement plan for the Highway 3 corridor in the south Purcell Mountains of British Columbia



Researched and prepared by

## The Trans-border Grizzly Bear Project


**Michael Proctor[1]**
**Chris Servheen[2]**
**Wayne Kasworm[3]**
**Tom Radandt[2]**

[1] Birchdale Ecological
PO box 920 • Kaslo, BC • V0G 1M0 • Canada • mproctor@netidea.com

[2] US Fish and Wildlife Service College of Forestry
and Conservation,309 University Hall, University of Montana, Missoula, MT 59812, USA

[3] US Fish and Wildlife Service
475 Fish Hatchery Road, Libby, MT 59923, USA


**March 2008**

# ACKNOWLEDGEMENTS

This work is a component of our larger long-term research effort. We would like to thank the many funders who have contributed to this work and continue to support our overall project; we thank the BC Habitat Conservation Trust Fund, BC Ministry of Environment and Ministry of Forests, Tembec Industries, US Fish and Wildlife Service, U.S. National Fish and Wildlife Foundation, and Liz Claiborne & Art Ortenberg Foundation. We thank the University of Alberta, and especially Dr. Mark Boyce and Dr. Scott Nielsen for statistical and study design guidance; and Parks Canada for collaboration in the field. Additionally we thank Gillian Sanders and Cori Lausen for helping to compile and edit this report.

# Table of Contents



## Figures and Tables

## Appendices

## Preface

The aim of this report is to address solutions to the grizzly bear population fragmentation that is occurring in the southern Purcell Mountains of southeast BC. Herein we detail the evidence for this fragmentation, the implications for the region's grizzly bear population, and a set of research-derived solutions aimed at enhancing inter-population connectivity. This report has been written for a wide range of audiences. Questions should be directed to Dr. Michael Proctor.

## Introduction

Fragmentation of wildlife habitat and populations is one of this century's primary threats to biodiversity (Wilcox & Murphy 1985). Large carnivores are particularly affected because they require large areas for populations to thrive (Woodroffe and Ginsberg 1998). Fragmented systems yielding small isolated populations suffer increased extirpation or extinction probabilities primarily from demographic processes (Lande 1988; Woodroffe & Ginsberg 1998), and secondarily from more gradual genetic processes (Frankham et al. 2002).

Habitat fragmentation occurs when a contiguous habitat becomes divided into smaller components and animals become isolated from each other by unsuitable habitat, including highways or/and commercial and residential development. Extensive habitat fragmentation develops into population fragmentation when groups of animals become divided into separate populations with minimal inter-breeding. The worst case scenario is when a small number of animals (< 100) become isolated and mortality rates become unsustainable and a population becomes at risk of extirpation. For example, early in the mid and late 1900s, every isolated population of less than 50 bighorn sheep in the conterminous USA (more than 70 such populations) went extinct (Berger et al. 1999). Conservation biology theory recommends that management of species has the goal of securing a network of higher quality "core" habitat patches that are connected with corridors, or "linkage zones". This strategy recognizes the reality that habitat fragmentation is ubiquitous in much of our modern world and is designed for a balanced coexistence between human and wildlife.

The integrity of connected networks of secure core areas of habitat is vital for healthy, naturally-distributed wildlife populations. Linkage zones connect areas of larger productive habitat that frequently span human developments such as highways and provide for the movement of animals. Development of linkage zones may focus on threatened species and large carnivores (grizzly bears) although all wildlife is affected by habitat fragmentation. Game animals such as deer and elk rely on access to wintering areas; migratory fish depend on spawning access, and birds on nesting and feeding habitats. Linkage zones can also act as 'fire escapes' if a core area undergoes dramatic environmental change. Linkage zones are not simply travel corridors, but are habitats that support carnivores' feeding and behavioural activities in intervening areas between core regions of habitat. They tend to support low density populations of resident wildlife that have seasonal movements.

Reasons for habitat fragmentation include, but are not limited to residential, commercial, and industrial development, dense road networks and highways, railroads, and the loss of visual cover associated with timber harvest. Linkage zones counteract fragmentation, and require the support of local human residents and communities to be effective. To promote the success of linkage zones these areas must be managed to maintain favourable wildlife habitat such as visual cover for safe movement, foraging opportunities, proximity to productive habitats and low levels of human use. Human tolerance of wildlife in the area, and appropriate management of properties to avoid conflict with wildlife is necessary.

Grizzly bears in North America have experienced a contracted distribution over the past century; south the Canada/US border they have decreased by 98% due to habitat loss and conflicts with humans. While they once extended south to northern Mexico, they now exist south to Yellowstone National Park in the Rocky Mountains (Mts.), and just south of the Canada-US border in the Purcell (and Cabinet) Mts. and Selkirk Mts (Figure 1a). Canadian and US trans-border grizzly bears in the south Purcell and Selkirk Mts. are considered “Threatened” in the US (USFWS 1993) and BC (Hamilton et al. 2004).

This report will focus on connectivity for grizzly bears in the south Purcell Mts. across BC Hwy 3 (Fig. 1b). The bears living south of Hwy 3 make up a small, fragmented, and threatened population of less than 50 individuals (Proctor et al. 2007; Kasworm et al. 2006) and is declining at a rate of 3.7% per year (Wakkinen and Kasworm 2004). This population experiences little to no immigration of females from the adjacent areas to the north across Highway (Hwy) 3, creating to the south of the highway, an “island” of bears experiencing no female interchange (i.e. demographic isolation; Proctor et al. 2005). There is evidence of some male movement of bears across this highway which appears to be maintaining some gene flow and genetic diversity. This demographic isolation may have serious implications for long-term population stability, because a reduction in the female dispersal process diminishes the possibility of natural population augmentation (replacement of lost females), or re-colonization in the event of population extirpation (Lande 1988).

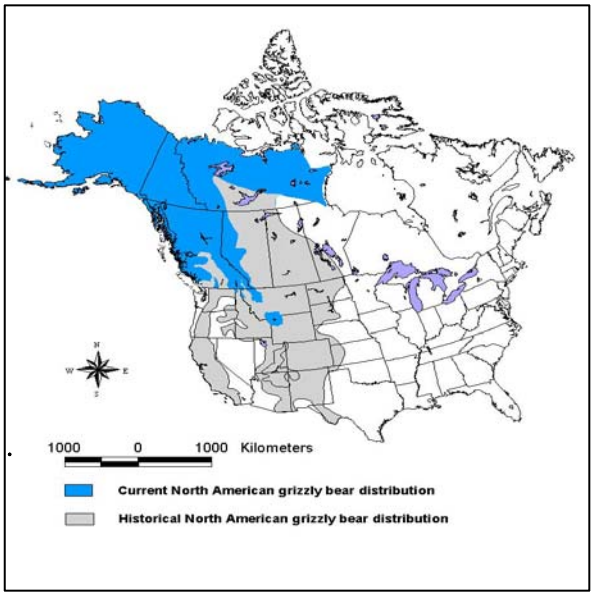
Figure 2 is a display of the genetic separation of bears in adjacent populations that illustrates the fragmentation occurring in the trans-border region. Figure 2a presents the complete genetic separation of the bears in the South Selkirk Mts. across BC Hwy 3A. This population has experienced complete isolation (no male or female connectivity) for several generations. Figure 2b, shows the other extreme where bears freely interbreed across the large and undisturbed Flathead Valley in the Rocky Mts. of southeast BC. Figure 2c shows the partial fragmentation across Hwy 3 in the Purcell Mts. There is separation (but not complete) of the bears north and south of the highway, and there is evidence of several male migrants that have primarily moved from north to south across the highway.

The Trans-border Grizzly Bear Project was initiated by research biologists in both Canada and the US to expand the ongoing recovery efforts within the US. It is our goal to use scientific research to understand conservation issues surrounding the trans-border populations, and then develop and implement internationally integrated workable management strategies to return these populations to self-sustaining status. The USFWS has been working to recover these populations from within the US for the past 15 years (Kasworm et al. 2006). While they have made great progress, we realized that half of their populations, problems, and solutions lie within Canada. As part of a comprehensive strategy we are concentrating on necessary management issues to improve the conservation status of grizzly bears in the south Purcell/Yahk and south Selkirk Grizzly Bear Populations Units (GBPUs).

This report details our research concerning the evidence for fragmentation across Hwy 3, and presents our results in a solutions-oriented framework aimed at conservation of grizzly bears in this area. We identify specific linkage zones and adjacent core habitats that might be managed for wildlife movements, and offer recommendations on that management.

**Figure 1.a)** Current and historic distribution of grizzly bears in North America. b) western North American scale grizzly bear distribution (shaded grey) with BC Hwy 3 (red line).

a.




b.

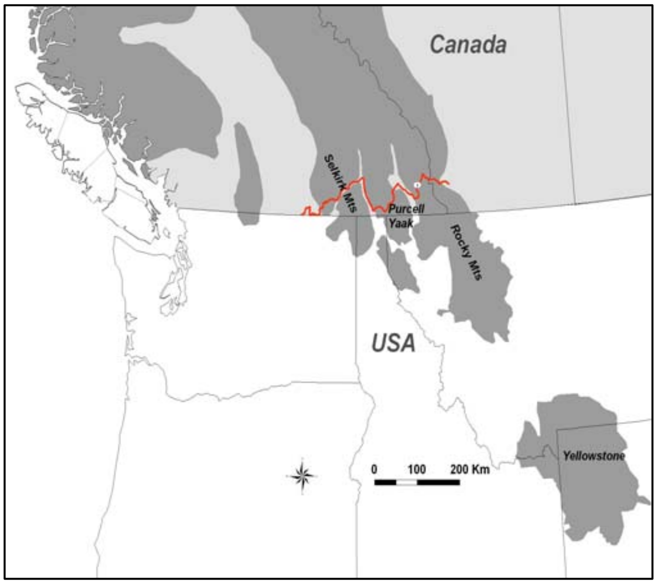
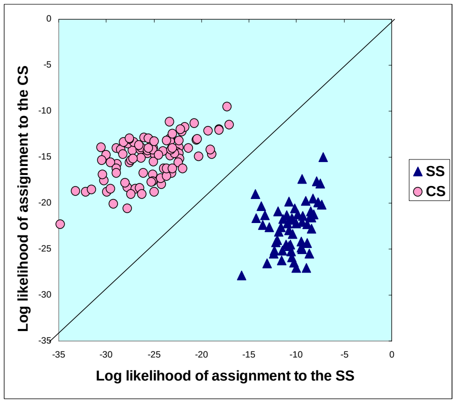
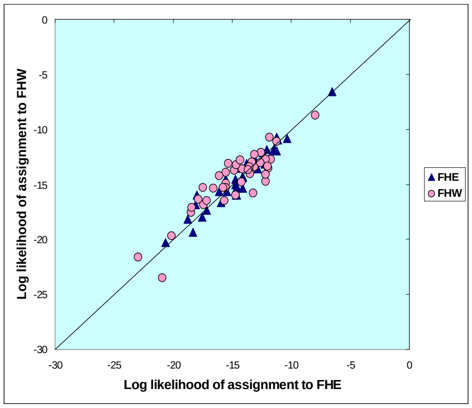



**Figure 2.** Population assignments that depict the level of genetic separation of grizzly bears in adjacent areas in SW Canada, in three mountain ranges: **a.** Selkirk Mts.( SS – CS), bears sampled on either side of Hwy 3 **b.** Rocky Mts., bears sampled on either side of the Flathead River valley (FHE – FHW) and **c.** Purcell Mts., (PS – PC) bears sampled on either side of Hwy 3. The numbered arrows are animals that have moved across Hwy 3 within the Purcell Mts. M = Male and F = Female. Adapted from Proctor et al. (2005).

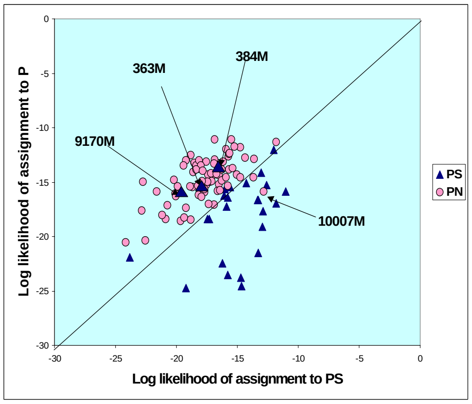
**a.**




**b.**




**c.**



## Research Identifying Linkage Zones

As mentioned above, the bears living in the south Purcell Mts. have been fragmented by BC Hwy 3. Proctor et al. (2005) found no movement of females across Hwy 3, but did find evidence of male movements. The resulting population to the south is small, threatened, and declining. It clearly needs enhanced management to return to a self-sustaining status, which would allow it to be legally hunted once again. Our approach is to work simultaneously on reducing human-caused mortality to allow for population increase (or at least prevent further decrease), providing for habitat security for females to allow productivity in rearing cubs, and enhancing inter-population connectivity to allow for functional inter-breeding with adjacent areas to resist risk of extirpation. In reality, all these solutions are interrelated. Here we focus on the enhancement of inter-population connectivity.

In determining linkage zones, our approach was to let the bears show us the best places to cross Hwy 3. Once we could identify these "linkage zones" we could develop management plans to provide security for bears attempting to move through human-disturbance environments. Proctor (2003) found that human settlement, traffic volumes, and human-caused mortality were causing fragmentation. Therefore management plans should highlight efforts to reduce human-caused mortality, which is not generally from vehicle collisions, but from the killing of bears after they are attracted to human food resources and subsequently get into trouble. Linkage zones should be in areas where humans are at a low density to minimize the potential for human-bear conflict that often results in bear deaths. And finally, this information can be used by the Ministry of Transportation for future planning of any relevant highway structures that could facilitate the movements of animals.

Linkage zone identification is challenging in areas where bears are sparse and movement across a major highway is limited; as such several approaches are needed to piece together an overall picture of habitat quality, use and possible movement corridors. We used three methods to identify linkage zones along Hwy 3 and core (higher quality) habitat in the adjacent mountains. First, we used DNA hair sampling combined with a variation of Resource Selection Function (RSF) modeling (probability of occurrence modeling) that uses systematic DNA survey results to estimate core and linkage habitat (Manley et al 2002; Apps et al. 2004). Second we used Geographic Positioning Systems (GPS) radio telemetry to identify where bears (likely males) are actually crossing Highway 3. And third, we used RSF (Manley et al. 2002) modeling using GPS radio locations to predict linkage habitat. These predictive models are built from real bear location data. RSF models have been used for predicting grizzly bear occurrence and habitat use in relation to many types of ecological and management questions (Mace et al. 1996, 1999, Boyce and Waller 2000; Nielsen et al. 2002; 2004a; 2004b; 2006) including ones very similar this effort. Once our models are built, we identify linkage zones by areas of higher quality habitat that pass through human-disturbance environments, in this case, across Hwy 3. Then we can compare these model predictions with any real bear crossing locations that might have been found with the GPS radio telemetry. Below we detail each method and their accompanying results.

### Methods

#### *DNA sampling and probability of occurrence modeling*

In 2004 and 2005 we carried out DNA surveys of wild grizzly bears in the south Purcell Mountains between Creston and Cranbrook, BC, and combined these results with those of a less intense but broader-based DNA survey in 2001 to underpin a DNA-based probability of occurrence model. We used the spatial capture information and landscape habitat, terrain, and human-use variables to develop a predictive map of where to expect grizzly bears on the landscape.

DNA surveys involve use of hair snags to collect hair samples from grizzly bears (DNA material is in the hair follicle; Woods et al. 1999). The DNA was used to develop "DNA fingerprints" to identify species and individual bears. Sampling was systematic across cells within a grid that paralleled Hwy 3 between Creston and Cranbrook and stretched approximately 20 km north and south of Hwy 3. Field methods were standardized within each grid and followed protocols detailed in Woods et al. (1999) which entailed use of rotted blood and fish scent lure at barb wire hair-snag stations to collect bear hair. Genetic identification of individual bears (carried out at Wildlife Genetics International, Nelson, BC) facilitates the development of capture histories of individuals from repeated sample collections. Genetic errors were minimized according to Woods et al. (1999) and Paetkau (2003). All surveys used 4 two-week hair collection sessions and sites were not moved between sessions. Grids were 5km x 5km ($25km^2$) cells (1 site / cell).

In total, we sampled 170 sites within the study area, where we recorded the number of bears captured at each site over a 2 month survey. In a multiple logistic regression we correlated the detection of bears with several ecological, terrain, forest cover, and human-use variables (Table 1) to predict grizzly bear occurrences across the whole study area (Manley et al. 2002; Nielsen et al. 2002; Apps et al. 2004). Because grizzly bears select habitat and home ranges at multiple scales (Johnson 1980; Manley 2002; Apps et al. 2004; Nams et al 2005), we modeled grizzly bear occurrence at 3 scales as in Apps et al. (2004). The finest scale was characterized by averaging each variable over a 2.4 km radius, the ~ average daily movement of a grizzly bear (B McLellan, unpub. data). The medium scale averaged each variable over a 6.8 km radius (~ female home range size) and the coarse scale was over an 11.2 radius (~ male home range). Our final model represents a multi-scale analysis. For each scale we assessed collinearity of explanatory variables and removed one of the two correlated variables when Pearson's correlations were >0.7. Univariate analyses regressing the detection of grizzly bears against each explanatory variable were performed. All significant (probability less than 10%, $p < 0.1$) uncorrelated variables were considered during multivariate model development. We used the principles of Hosmer and Lemeshaw (1989) for model building where individual variables were added sequentially based on their univariate level of significance (from most significant to least significant), retaining only those variables that were significant ($p < 0.1$) in the multivariate model. Essentially this process answers the question of what habitat characteristics attract grizzly bears, and what characteristics bears avoid.

### *GPS radio collaring*

Since 2004 we have put out 15 GPS radio collars on grizzly bears in the Canadian portion of the Purcell/Yahk ecosystem. Most collars have been designed to stay on bears through 2 non-denning seasons (although 3 were for only 1 season) and take hourly GPS locations. Collars are programmed to automatically drop off in the fall of the 2nd season at which time we retrieve them and download the data. Several collars allowed uploading on a monthly basis while remaining on the animals. All capture work was carried out in accordance with Canadian Council on Animal Care. We analyzed data from 8 males and 4 females (one female was captured and collared by Jesse Lewis, University of Idaho, during a black bear project in NW Idaho).

### *RSF modeling*

The radio telemetry RSF habitat model is a spatially-explicit multiple logistic regression integrated with GIS (Manley et al. 2002; Nielsen, et al. 2002). It associates grizzly bear habitat use as determined through GPS radio telemetry locations, with ecological, terrain, forest cover, and human-use variables (Table 1) to predict grizzly bear habitat use across the whole study area (Nielsen et al. 2002). This process is similar to the DNA modeling process described above, except that bear occurrence data points are from telemetry locations rather than hair collection locations.

The model variables were obtained from a variety of BC government sources, including Ministry of Forest TRIM (Terrain Resource Information Management), BTM (Baseline Thematic Mapping), and VRI (Vegetation Resource Inventory). The *highway* and *human occurrence* points (developments) layers were digitized from 1:50,000 topographic maps and ortho-photos, *greenness* was derived from Landsat imagery using a TassleCap transformation (Crist and Ciccone 1984), and *slope*, *solar radiation,* and *terrain ruggedness* were derived from a digital elevation model. Data was modeled at the100m x 100m pixel size.

The cumulative radio collar data were used to develop Resource Selection Function (habitat use) models for the study area. Because our sample sizes were low, we elected to pool both sexes and all individuals into one model for each season. We defined two seasons: pre-berry – den emergence until July 14, and berry – July 15 until den entrance. We compared grizzly bear telemetry locations ("used") to an equal number of random locations ("available"). Model selection followed protocols in Hosmer and Lemshaw (1989).

### *Model validation*

We tested the ability of our DNA survey-derived models to classify the DNA occurrence results using a confusion matrix (McGarigal et al. 2000). We determined a cut-off probability (a threshold score where the model predicts the occurrence of a bear) using a sensitivity/specificity analysis (Liu et al. 2005). The cut-off probability was then used to classify presences of grizzly bears. A confusion matrix was generated and the overall classification accuracy determined as the ratio of correct classifications (absences and presences) to the total number of classifications.

Because we have radio collared bears in the Purcell south study area, we validated our best multi-scale DNA model using GPS radio location data. Here we used a Spearman's rank correlation test (Sokal and Rohlf 1995) to compare the similarity of our model in predicting DNA captures (that were used to build the model) and independent GPS radio location data for the same area. The correlation test was performed on the two data sets where RSF scores were categorized in equal bins and adjusted for area (Boyce et al. 2002).

To validate our RSF models derived from GPS data we built our models using 80% of our GPS locations and tested their predictive ability using the remaining 20% of the data (Boyce et al. 2002). This was accomplished in a similar fashion as described above testing for correlations between binned and area-adjusted RSF scores (Boyce et al. 2002).

## Results

### *DNA sampling and probability of occurrence modeling*

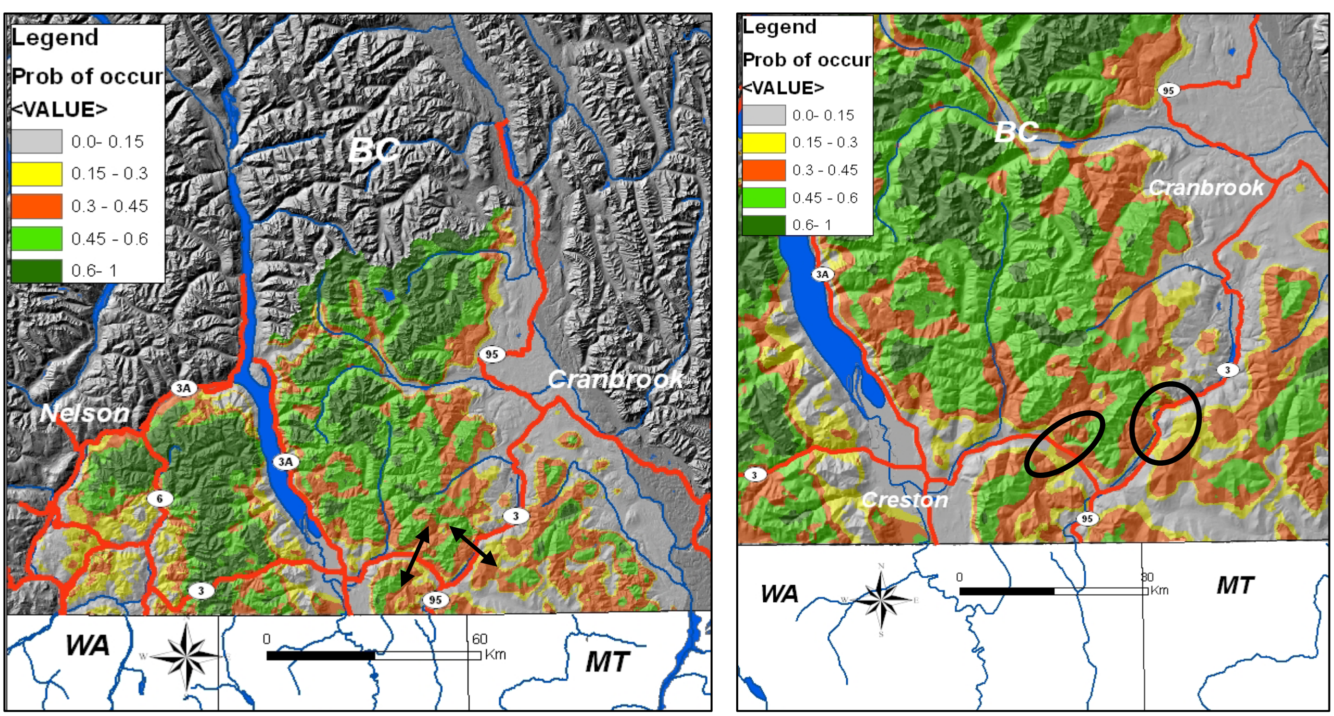
In total (in the 2001, 2004, and 2005 surveys) we captured 65 individual grizzly bears with multiple captures for many individuals (totaling 124 capture events). These captures occurred at 55 of our 170 sampling stations. The selection or avoidance of specific habitat variables is summarized in Table 1. Our best regional multi-scaled predictive linkage models identified two general linkage zones along BC Highway 3 (Fig 3a & b).

**Table 1**. Significant variables from uni-variate analyses using DNA capture data that indicate grizzly bear selection (+) or avoidance (--) of specific habitat characteristics. These variables were consistently selected or avoided across all study areas within this project.

| Selection Variable | sign | Avoidance Variable | |
|---|---|---|---|
| | | roads | -- |
| elevation | + | highways | -- |
| avalanche | + | human development | -- |
| alpine | + | deciduous forest | -- |
| slope | + | lodgepole pine | -- |
| terrain ruggedness | + | cedar-hemlock | -- |
| old forests | + | young forest | -- |
| Douglas fir | + | curvature - wetness | -- |
| greenness | + | riparian | -- |
| park | + | riparian-roads | -- |
| riparian-park | + | forest age | -- |
| | | greenness-human develop | -- |
| | | greenness-highways | -- |

**Figure 3.** DNA survey and ecological modeling estimated linkage zones across BC Highway 3 in the Purcell Mts. a) Arrows indicate linkage zones. b) Close-up view of areas predicted by model as linkage habitat (black ovals). Higher probability of occurrence values depict areas of better habitat. Note habitat along Hwy 3 generally has low values, except in a few locations indicated with arrows or black ovals.

**a.** **b.**

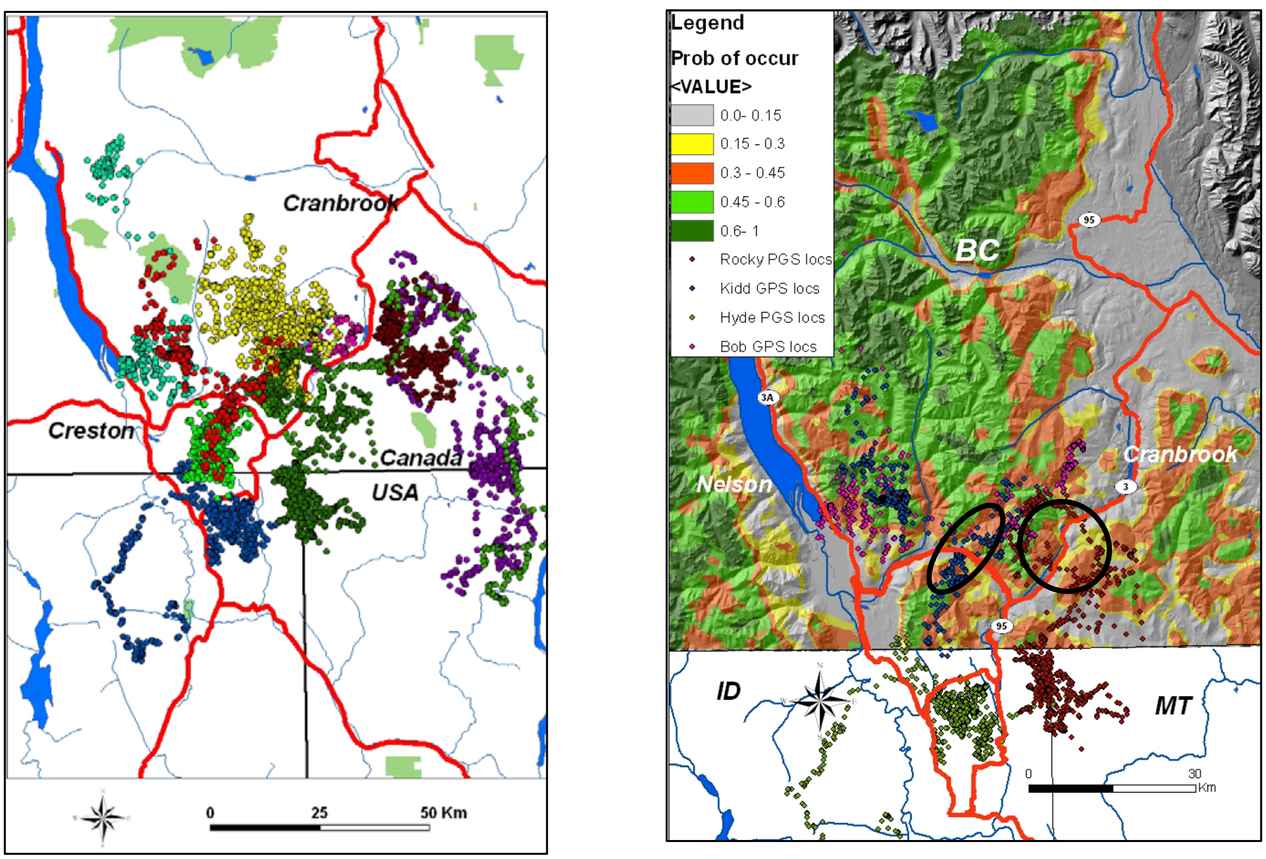


***Radio telemetry***

We used GPS location data from 12 grizzly bears along BC Hwy 3, collared between 2004 – 2007. In total we had over 18,000 bear locations (Fig. 4a). We had 2 male grizzly bears that crossed BC Hwy 3 in the Purcell Mts. There is a high degree of match between the predictive model based on DNA surveys and highway crossing locations determined with the GPS collared bears (Fig. 4); this is of particular interest given that the two data sets are completely independent of each other, and thereby validate each other. This comparison provides reasonably strong support for the identified linkage zones.

**Figure 4.** GPS radio locations from grizzly bears over 4 years (2004 – 2007). **a**. 12 bears, **b**.4 males Note in (b) the overlay of the DNA-derived habitat model and the two males that crossed Hwy 3 within Canada at the linkage areas that were predicted by the DNA-derived linkage habitat model (ovals).

**a** **b**



***RSF modeling***

For the preberry season within a multiple logistic regression, our best model found *elevation*, *greenness*, *alpine*, *roads*, and *Douglas fir forests* to be significant and positively correlated to bear habitat use, and *human development* (building), *old forests*, and *terrain ruggedness* to be negatively associated with grizzly bear habitat use. For the berry season we found *elevation*, *greenness*, *alpine*, and *Douglas fir forests* to be significant and positively correlated with grizzly habitat use, while *human development. old forests*, and *terrain ruggedness* were negatively correlated with grizzly bear habitat use. In the model validation process, the training model (built from 80% of locations) was highly predictive of the remaining 20% of locations. Mean RSF scores in each data set were essentially identical at 0.621 and the predictive ability of bear locations across the range of habitat quality was highly correlated.

For multi-season fine-scale linkage zone identification we present a combined preberry/berry habitat selection map (Fig. 5). In general, this composite RSF model predicted lower quality grizzly bear habitat along the Hwy 3 corridor. However, there were several locations where higher quality habitat extends down to and across Hwy 3 (ovals in Fig. 5). Several of these locations were also predicted by the DNA-derived model (Fig. 3). When overlaid with actual GPS location data where male bears actually crossed Hwy 3, there was a good match (Fig. 6).

To solidify the predictions for linkage zone identification from our suite of methods, we needed to identify the patches of higher quality habitat in the mountains adjacent to the Hwy 3 corridor – core habitat. The logic is that linkage zones would connect these core areas north and south of Hwy 3. To do this we used our telemetry-based RSF models. We combined three RSF models -- one model predicting female habitat, another predicting preberry habitat of both sexes, and a third predicting berry habitat for both sexes -- into one composite model. We selected the top 40% of habitat quality (areas with RSF scores between 0.6 – 1.0). The resulting map depicts areas of the best “core” habitat in the mountains adjacent to Hwy 3 (Fig. 7). We also consolidated the model predictions for linkage habitat into polygons that connect and extend to the core areas. These linkage zones can be viewed as the blue polygons in Figure 7.

**Figure 5.** Linkage habitat as predicted by a Resource Selection Function (RSF) derived from GPS radio locations of 12 grizzly bears. Map is a composite of pre-berry and berry RSF models. Note the fine scale predictions as to linkage habitat across Highways 3 and 3A.

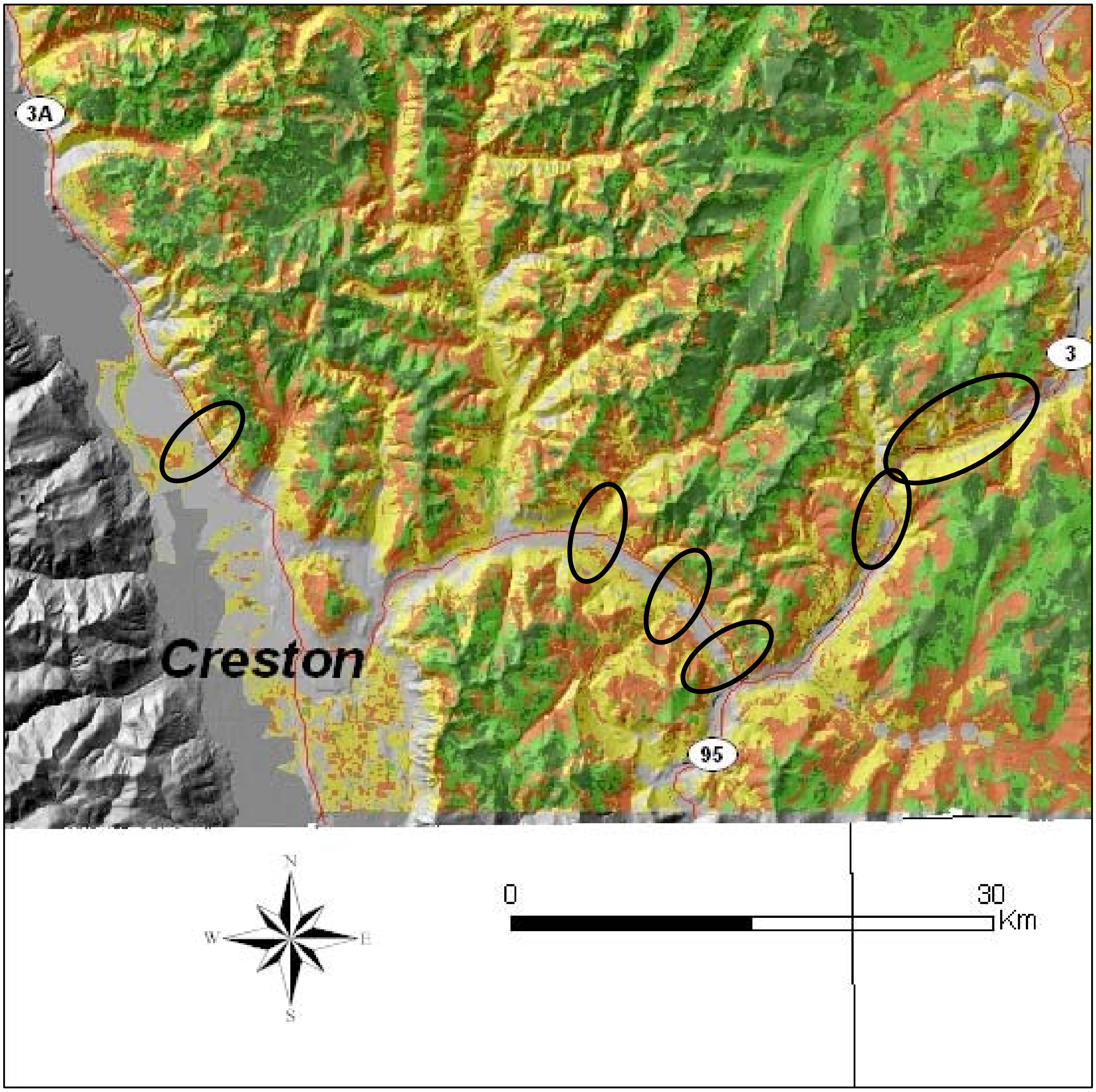


**Figure 6.** Identical map as in Figure 5 (predicted linkage habitat from GPS locations of 12 grizzly bears) but with the addition of actual GPS locations from 3 males that crossed Hwys 3 and 3A.

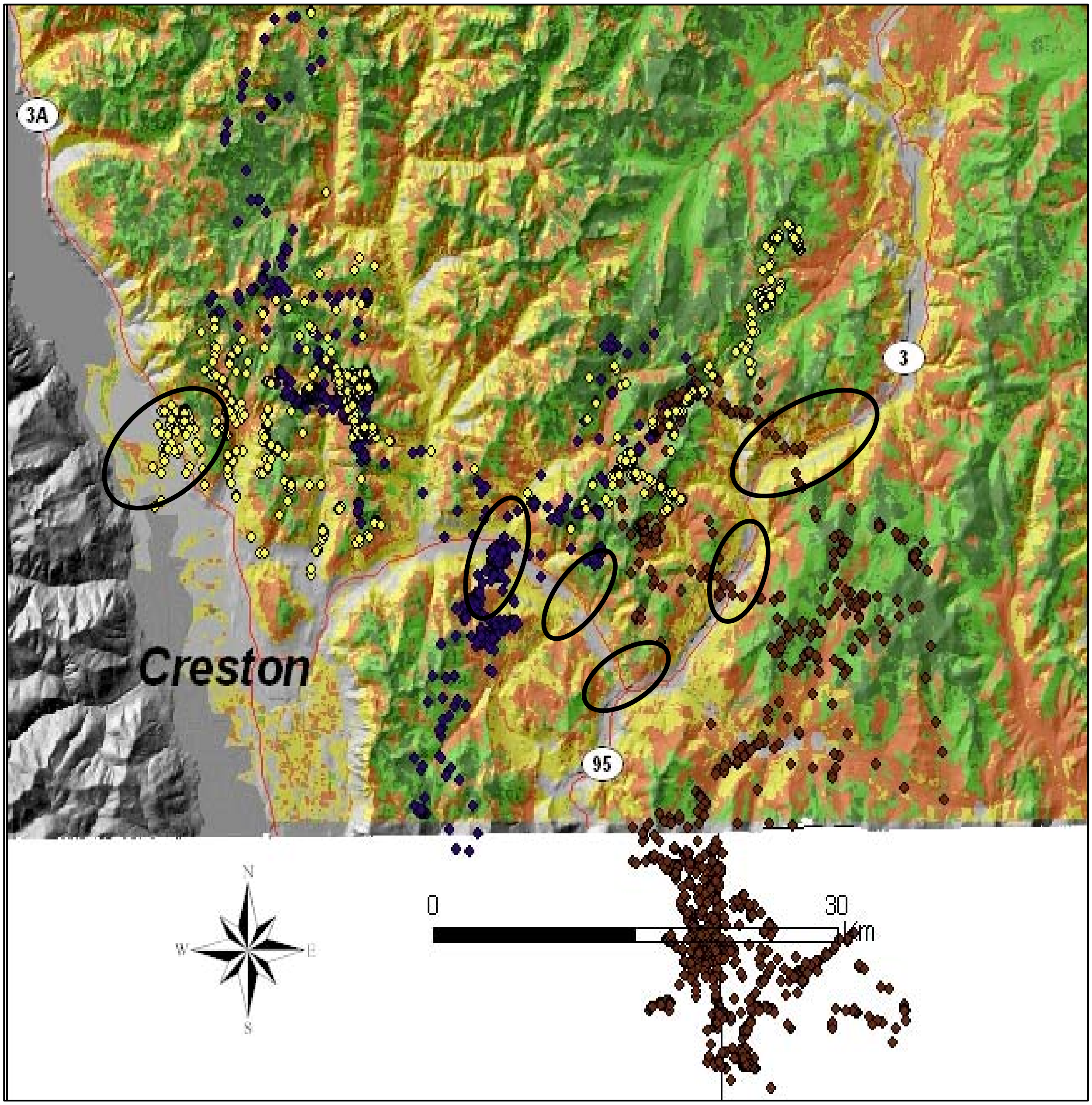
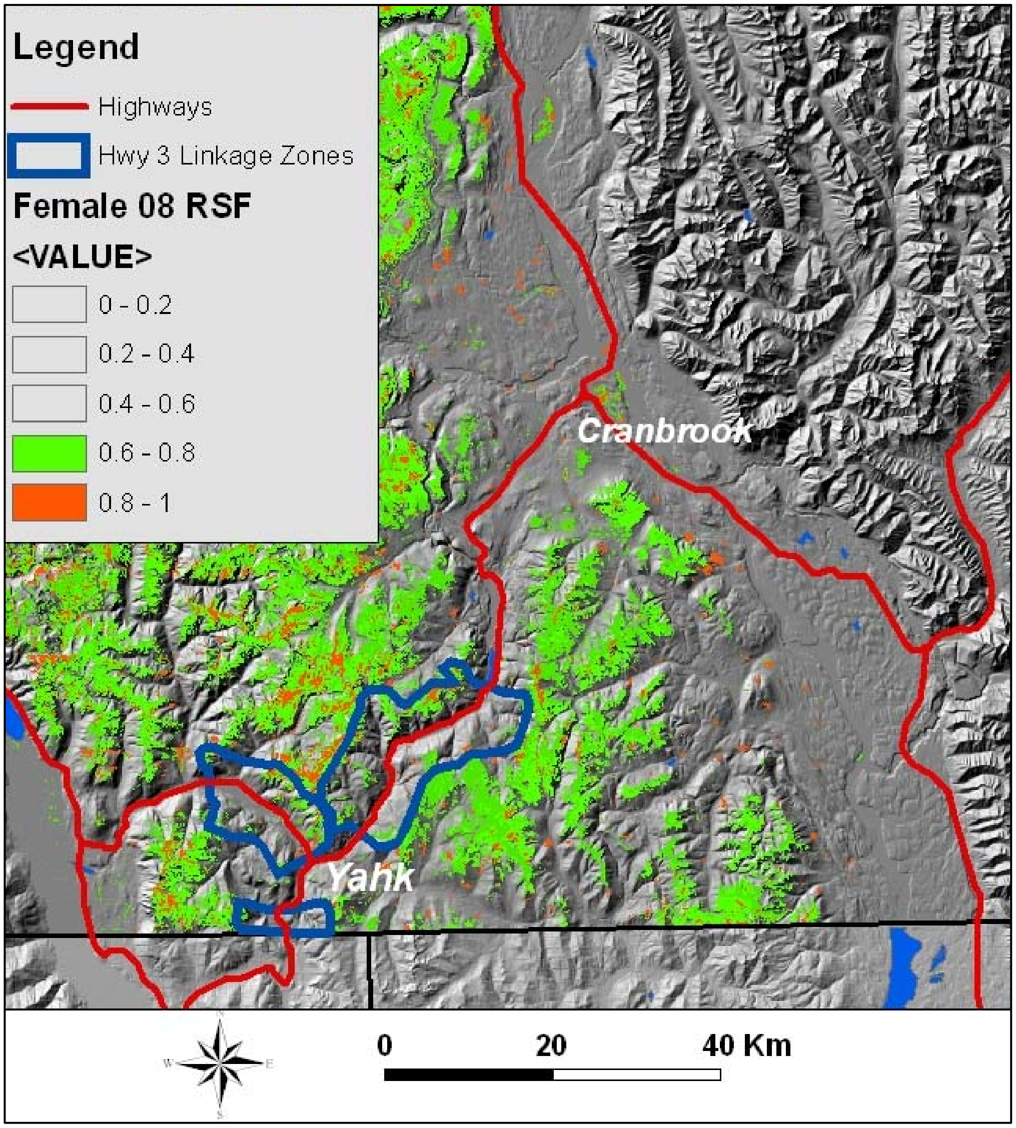


**Figure7.** Core grizzly bear habitat (green and orange areas) and linkage zones (blue polygons) in the S. Purcell Mts if southeast British Columbia.




## Discussion

### *Linkage*

Our goal was to use bear habitat models and movement data to predict relatively secure linkage habitat. We used three methods to identify potential linkage zones along Hwy 3 because bear densities are low and movement across the highway corridors is limited making them challenging to detect, characterize, and predict. The fact that our model predictions are corroborated by movements of GPS radio collared bears provides us with confidence that habitat variables are playing a role in these remnant secure locations where bears can move through human-dominated environments and survive. With these linkage habitats identified, we can now apply targeted management and education outreach to maintain and further improve security, facilitating inter-population movement of bears.

As expected, all of our documented highway crossings are male bears. Our ultimate goal, and what the population of bears south of Hwy 3 require, is secure linkage habitat for female movement to occur across the highway/settlements. This expectation is not unrealistic. Recent genetic analyses (not presented in this report) indicate a recent female migrant across Highway 3 in the Purcell Mts. A researcher from Idaho (J. Lewis, University of Idaho) put a radio collar on this particular female and when she was 5-6 years old she was shot by a landowner within 500m of Hwy 3, potentially moving back to her natal area north of Hwy 3. This example illustrates the problem and ultimate solution. The bear was attracted to human-food sources while moving near Hwy 3, got into trouble and was killed as a result. The solution is to minimize food attractants, reduce the human-bear conflict, keep the female bear alive, and let her move between populations.

Furthermore, if habitat security increases in the area of the linkage zone, resident females will reproduce successfully. Research by Proctor (2003) suggested that human-caused mortality is one of the primary factors driving fragmentation in the Purcell/Yahk population. Reduction and appropriate management of bear attractants improves several management problems impacting this ecosystem; by reducing human-bear conflicts and human-caused mortality, female bear productivity will increase, and even a modicum of inter-population movement of females will occur, both resulting in a positive influence on population size and viability. ,

## Management Options within Linkage Zones

### Minimizing Human-Caused Mortality

Minimizing human-caused mortality may be the single most important management goal within linkage zones. The Trans-border Grizzly Bear Project carried out a spatially-explicit mortality analysis for the trans-border region in 2005 (Proctor et al. 2005, Abstract and results excerpted in Appendix I, this report). We found that in the past decade, 75% of grizzly bear mortalities occurred from bears being attracted to human food sources on the periphery of these population units. It is in these perimeters where potential movement between adjacent population units takes place, and the places the mortality tends to occur.

Management options to minimize human-caused mortality within linkage zones include public education to reduce bear attractants and thus human-bear conflicts. This can be accomplished through the hiring of an area-specific Bear Aware Specialist from the existing and well organized BC Bear Aware program. This Bear Aware Specialist should focus a portion of their effort on assessing the bear attractant situation within the linkage zones, and work with local residents to control any bear attractants available to bears. The BC Bear Aware program is a professionally run organization with experience in these types of educational activities. Also, the Bear Aware Specialist should have information and access to electric fencing materials to loan to landowners requiring it, as an inducement to try proven methods for securing food resources (chickens, small orchards, etc). We also suggest a pamphlet be produced that briefly explains this program to land owners and requests their cooperation.

The Province of BC has recently put a temporary limit to grizzly bear hunting in the south portion of the South Purcell Grizzly Bear Population Unit (GBPU). This was mandated for several reasons. First, it was in response to recent data-based population estimates suggesting that numbers were markedly lower than expected (Proctor et al. 2007). Second, it was to allow linkage enhancement management a chance to work (Garth Mowat, pers. comm.). The hunting community is credited with voluntarily agreeing to these changes. These types of cooperative management efforts between researchers, managers, and resource-users are driving forces in a successful management strategy.

Another important component of reducing human-caused mortality is to intervene quickly when potential human-bear conflicts occur. This usually means the local Conservation Officer Service responding immediately to a call that a grizzly bear is approaching human settlement. Extensive experience in Montana, where they employ dedicated Problem Bear Specialists to react quickly, has proven very effective in reducing human-bear conflicts and mortality rates of grizzly bears (C. Servheen pers. comm). Techniques employed are dependent on each situation, and are specific to the "history" of the bear; techniques range from hazing a bear away from human communities, to live capture and a "hard" (lesson-teaching) on-site release, to destroying a bear that is not a good candidate for learning to avoid human environments. A program such as this requires training of Conservation Officers, specialized equipment, specific guidelines for management decisions and actions, and policy support.

### Access Management within Linkage Zones

It has been shown that there is a relationship between road densities, intensity of road use, and avoidance by grizzly bears (Mace et al. 1996, 1999, Proctor et al. 2008). It has also been shown that female bears have lower survival and reproductive output with increasing road densities (Boulanger 2005). Access management has been one of the cornerstones of grizzly bear management in the population recovery within the Yellowstone ecosystem (Schwartz et al. 2002; Pyare et al. 2004) that has taken place over the past 20 years. Bears respond to habitat security, particularly in higher quality habitat. Therefore, if we want grizzly bears to use linkage zones, then as much as reasonably possible, human access should be minimized.

We envision implementation of an access management plan in the area will be a multi-year process. Access management is a controversial issue and its effective establishment requires the cooperation of several levels and ministries of government, user groups, the public, and the timber industry. There are several access management working groups considering this issue within the south Purcell Mts. One is made up of representatives of a variety of citizen groups that use the backcountry, including hunters, recreationists, and guide outfitters. The other consists of representatives from the BC Ministry of Environment (MoE), Ministry of Forests (MoF), BC Timber Sales, and local timber companies. We suggest that the best avenue for the wider community discussion is within these working groups because of their organized nature and broad spectrum of representation. Therefore, the information within this report will be distributed to these groups for their consideration and integration.

### Timber Harvest Activities

Land use activities can be addressed through dialogue between timber companies operating in the region, BC Ministry of Forests, and biologists familiar with timber harvest guidelines designed to consider grizzly bears (and other species). Timber harvest and silviculture practices can be designed to maintain or improve habitat within linkage zones and core habitat. Also, following guidelines designed to develop and maintain linkage zones may be useful in attaining certification in some product certification systems.

Options for timber harvest protocols include the following:

***Human access control.*** Access management is a complex process that requires consultation between government agencies, industry, and the public (see access management section above).

- Options for access control include the following: road deactivation, benign neglect, remove culverts or bridges, Kelly humps, reclaim first 100-200 metres of a road, legal closures, gates, and signs explaining intention of closures.

***Retain cover for wildlife security.***

- Retain cover between major roads and cut blocks and high quality habitat (berry patches, riparian area, and productive avalanche paths).
- Cover can be maintained by retaining understory vegetation as much as possible. A guideline for cover retention is to leave vegetation twice the distance that an animal (or person) is visible through a forest.
- Combine cover retention with partial retention cutting methods.
- If clear-cut logging takes place, consider leaving cuts a maximum of 400m across, so most areas within the cut are within 200m of the edge.

***Harvest timber using methods to maximize retention of bear foods.***

- Retain forest integrity around any particular productive riparian/wetland areas and berry patches (*Vaccinium sp*., huckleberry; *Sheperdia canadensis*, buffalo berry).
- Maintain/promote bear foods by not using herbicides, scarification, or brushing in ways that would destroy or limit bear foods (*Vaccinium*, *Sheperdia*, and other important shrubs).
- Maintain a variety of seral stages when planning harvest in linkage zones. Avoid high percentage of stands of similar age because mid-age stands may contain a minimum of bear foods.
- Leaving large diameter stumps and non-merchantable wood on the ground to provide for decomposing insects that are an important food source for grizzly bears.
- Restricting new road development in critical habitats.

***Provide predictability for wildlife that are sensitive to disturbance.***

- When timber harvesting within linkage zones, carry out operations within one portion at a time. This provides a measure of predictability and leaves alternate routes undisturbed to provide options for bears to move. In other words, harvest in one section of a linkage zone at a time, complete the operation, then move to another section.

## Highway Infrastructure Mitigation

While high-speed, high-volume highways can fragment habitats and isolate wildlife populations, the use of crossing structures such as culverts, underpasses and overpasses can provide linkage across highways for various species. When considering expansion of highway development, linkage zone consideration and placement of highway crossing structures for wildlife will help connect potentially fractured populations. The use of these crossing structures by wildlife, combined with appropriate fencing, can mitigate and reduce the chances of vehicle-wildlife collisions. This conservation issue is also one of human safety and economics, as vehicle-wildlife collisions on highways result in human injuries and deaths and cost millions of dollars each year in property damage and insurance costs.

### ***Highway crossing structures***

In areas where crossing structures exist there have been comparison studies of which species prefer which structure type. Servheen et al. (2003) found that when comparing underpasses and culverts, ungulates and large carnivores utilizing crossing structures across Interstate 90 in Montana only used underpasses. This included species such as white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*) and black bear (*Ursus americanus*). Small carnivores such as skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), and domestic/feral cats (*Felis domesticus*) preferred to use culverts, though small carnivores also used underpasses. Culverts were physically large enough for large mammals to cross through (2 -- 4.6 m), yet it is thought the damp conditions and surface substrate were the limiting factors for large animal use. Underpasses were found to generally offer more natural lighting, vegetation, and favourable surface substrate to encourage large mammal use. Clevinger and Waltho (2005) found more open underpasses had higher use by both ungulates and carnivores in Banff National Park.

To encourage wildlife to use crossing structures, they should be placed within linkages where natural habitat is contiguous on either side of the highway. Servheen et al. (2003) found the highest use of crossing structures on I-90 in Montana where less disturbed habitat led directly to the structure, and the placement of the structure was remote from human use. When crossing structures are placed in areas already known to be travel routes of animals, they are more likely to be used (Bruinderind and Hazebroek 1996' Foster and Humphrey 1995; Land and Lotz 1996; Ruediger 2001). Fencing can be an effective tool in funneling wildlife to the crossing structure and preventing vehicle-wildlife collisions, yet crossing structures must be placed closely enough together so that fencing does not actually prevent wildlife from crossing the highway in general and furthering the fracture of contiguous habitat (Servheen et al. 2003).

While recorded Hwy 3 crossings by grizzly bears have all been male bears to date, it is thought that as population numbers increase, occasional female movement will occur. As mentioned above, one female did disperse across Hwy 3 where she lived for several years until being killed in a human-bear conflict event close to Hwy 3. In Banff National Park several female grizzly bears have utilized wildlife underpasses at different locations under Highway 1 (Trans Canada Highway; Clevinger and Waldo 2005).

In the Canadian Rockies Alexander et al. (2005) recorded cougar (*Felis concolour*), coyote (*Canis latrans*), marten (*Martes sp*.) lynx (*Lynx lynx*), wolf (*Canis lupus*) and wolverine (*Gulo gulo*) were all more likely to cross highways of low and moderate traffic volumes than those of high to very high traffic volumes. Female grizzly bears were twice as likely to cross low-volume versus high-volume roads (Chruszcz et al. 2003 ) in the Banff National Park area. Alexander et al. (2005) recommended that highways with greater than 5,000 vehicles per day are implemented with highway structures to facilitate safe wildlife crossings. However, wild animal crossings are consistently negatively correlated to human activity and therefore the best designed crossing structures may be ineffective if human activity is not controlled (Clevinger and Waltho 2005).

Highway 3 in the Purcell Mts. has average summer traffic volumes of approximately 4000 vehicles per day. We are not currently advocating wildlife crossing structures be built along Hwy 3 but envision that they be considered at some future time, particularly when highway upgrades are made. Because of the projected eventual increase in highway traffic along this important southern BC route (BC Ministry of Transportation), this report will be shared with the BC Ministry of Transportation.

***Private land management and human-wildlife coexistence***

Rural residents who live and work in grizzly bear habitat are the people who will ultimately be the most influential in plans for co-existence with large carnivores. It is therefore of utmost importance that they be included in the planning of and integrated into developing solutions to wildlife issues. Human tolerance of wildlife moving through human environments and management of private properties to avoid conflict with wildlife is a necessary component of reducing human-caused mortality, and facilitating wildlife linkage. Rural residents that develop personal investment and understanding of habitat linkages can help steward these linkage zones, particularly as rural populations increase. Community involvement will make linkage zones effective in the long term.

As mentioned earlier, our grizzly bear mortality analysis found that 75% of Canadian non-hunting mortalities in the south Purcell area occurred as a result of attractants at residences and small farms such as fruit trees, livestock and feed, and garbage (including 3 self-defense kills at residences and several unspecified causes at attractant sites).

***Private lands and resident/community involvement***

Private lands are often critical low elevation and riparian habitats for a variety of species. These areas may include critical winter ranges, spring breeding sites and fall foraging grounds. Wildlife is dependent on human tolerance for their survival in habitat adjacent to rural residents and communities. This is especially true for large carnivores, but also true for grazing animals and migratory waterfowl that may feed on crops. Wildlife protection measures that do not include rural residents may have the unintended result of increasing illegal mortality. While linkage zones may be planned for areas away from rural residents, it is not possible to keep all linkage zones out of private property and local resident acceptance and tolerance of wildlife is essential to the success of linkage zone planning. When rural communities are involved in developing linkage zones and local input is welcomed and solicited, residents understand and accept linkage zones, and human-caused mortality (either directly or indirectly) is reduced. In the Swan Valley area of Montana, successful linkage zones were created by involving the best local knowledge and best scientific information, providing a clearer understanding of the ecological and social landscape (Parker and Parker 2002). Key local leaders and concerned residents may be invited to sit on a steering committee to involve residents in conservation initiatives necessary for linkage habitats on private lands. Managing private lands in the area of linkage zones is essential for them to be effective. Different species may have distinct ‘social needs’ to coexist with humans and human development on the landscape. Rural residents generally understand ungulate needs to migrate between winter and summer ranges and are directly concerned with these species. If game animals such as deer and elk are included in the linkage zoning process, it may help to gain the support of local residents. Private lands also need to maintain cover for wildlife security and foraging. In the case of grizzly and black bears, all food attractants need to be managed in ways that bears are not encouraged to approach residences or commercial developments.

As mentioned earlier, the BC Bear Aware Program reduces human/bear conflict through education, innovation, and cooperation. Bear Aware Specialists provide outreach to residents and communities to manage bear attractants such as garbage, fruit trees, small livestock and feed, pet food, compost, and other food attractants. Bear Aware Specialists in linkage areas will provide specific knowledge of grizzly bears and encourage residents to report any sightings to the Conservation Officer (C.O.) Service. Any grizzly sightings should be reported immediately so Conservation Officers can employ methods to prevent conflict with residents and Bear Aware can ensure bear attractants are secure in the area. Recent policy shifts in the C.O. Service have highlighted a priority for Conservation Officers to respond as soon as possible to potential grizzly bear - human conflicts in the Kootenay region. Further, Conservation Officers and/or Bear Aware specialists may assist residents to protect fruit trees and small livestock from bears with electric fencing. When electric fencing is correctly installed and maintained, it is effective to prevent conflict between bears and small livestock such as chickens or pigs. Bear Aware provides various educational materials for schools and communities to use to increase understanding of bear biology and behaviour.

Pamphlets will be provided to local residents and visitors to help identify grizzly and black bears, and highlight the importance of connectivity of grizzly populations. Locals may be encouraged to become stewards of linkage zones and help educate new residents on preventing wildlife conflict.

Official Community Plans should incorporate land use planning in conjunction with wildlife security and foraging needs in linkage zones. Educational outreach to promote wildlife-human coexistence is needed for both municipal and regional local governments as well as communities to learn about the importance of linkage zones and appropriate management of these areas. Accordingly, this report will be provided to local communities.

### *Monitoring plan and community outreach*

Monitoring and measuring effectiveness of linkage zones presents some difficulties. It is recommended to implement a monitoring plan to gather baseline data that can be compared with future data to track the effectiveness of linkage zones. The following could be useful in this regard: telemetry data of focal species, harvest statistics (fishing, hunting, trapping), track surveys, local oral history, wildlife mortality stats due to conflict or road collisions, and remote camera data on over/underpasses of Hwy 3. Maintaining a local wildlife sighting page on a community website and involving these volunteers in scientific data collection may be helpful in generating support for the wildlife-human coexistence program. Such a program is underway in the Rocky Mts. along Hwy 3. Recording bear sightings and especially mothers with cubs may prove useful information and help to involve those living in and/or stewarding linkage zones. Meetings could be held annually or biannually to maintain stewardship of the plan for new and existing residents and to provide the opportunity for adaptive management. At such meetings residents and biologists can compare data collected and new management options can be discussed. Human developments and wildlife populations can be measured every 5-10 years to quantify changes

In any monitoring program, it is necessary to define what determines success. Our current definition of success includes, but is not limited to:

- Continued presence and movement of grizzly bears across Hwy 3
- Existence of naturally-viable grizzly population south of Hwy 3
- Decrease in illegal wildlife mortalities
- Decrease of human-wildlife conflicts and mortalities
- Increased tolerance of grizzly bears and other carnivores by residents
- Increase in secure core habitats through managing access

### *Land purchase for conservation values*

Another important option in the arsenal of management tools is the direct purchase of strategic properties where linkage values are very high, and no other suitable option exists. This includes direct purchase of private land or the purchase of “conservation easements.” Purchasing of conservation easements compensates residents for any lost opportunities after agreement to manage their land for conservation values that may preclude certain activities (e.g., sub-divisions) and be accompanied by a reduction in land value. There are several professional organizations that engage in these types of activities in the region including The Nature Conservancy, the Nature Trust of BC, Columbia Basin Compensation Program, Vital Ground. These organizations raise funds, purchase, hold, and manage land in trust for wildlife and biodiversity values. There also is significant interest within the ENGO community (such as the Yellowstone to Yukon Conservation Initiative) to facilitate these types of transactions by fund raising and connecting conservation-minded donors with wildlife and land trust organizations. We intend that the linkage zones identified within this report be integrated into regional land conservation strategies of local land trust organizations.

## Recommendations

### Public lands

#### *BC Ministry of Environment*

To maintain and enhance grizzly bear and other wildlife inter-population movements across BC Hwy 3 the BC Ministry of Environment can:

- Continue to support the Bear Aware program.
- Be a partner in a program that works with Bear Aware, Conservation Officers, and ENGOs whereby electric fencing is used to inhibit bear-human conflicts and landowners are compensated for livestock losses from large carnivores, if fencing is properly used.
- Take part in community-wide working groups that consider access management in linkage and adjacent core habitat. Support the integration of science-based solutions to access management issues. Work with the larger community to reduce open road densities with appropriate gates, deactivation, or semi-permanent closures, thereby limiting mortality risk, displacement and disturbance.
- Consider hunting-related vehicle access closures for appropriate portions of management units with linkage zones.
- Avoid constructing new recreation facilities or expanding existing facilities (e.g. campgrounds, visitor centers, lodges, etc.) within linkage zones.
- Manage dispersed recreation use to avoid conflict with identified target species.
- Avoid issuing new permits or additional use days for commercial recreation activities (e.g. outfitter and guiding permits) that may conflict with wildlife linkage objectives.
- Continue dialogue with research scientists and others to promote adaptive connectivity management.

#### *BC Ministry of Forests and Range*

To maintain and enhance grizzly bear and other wildlife inter-population movements across BC Hwy 3 the BC Ministry of Forests can:

- Include linkage habitat values in forestry guidelines that promote cover retention and foraging opportunities for wildlife in identified linkage zone areas. Promote the recognition of linkage habitat as a valuable resource across the landscape.
- Take part in community-wide working groups that consider access management in linkage and adjacent core habitat. Support the integration of science-based solutions to access management issues. Work with the larger community to reduce open road densities with appropriate gates or semi-permanent closures, thereby limiting mortality risk, displacement and disturbance.
- Restrict new road development in critical habitats within linkages to limit mortality risk, displacement and disturbance.
- Manage livestock grazing to maintain wildlife forage and hiding cover in identified linkage zones.

- Allow no increase in numbers of livestock and issue no new grazing permits within linkage zones.
- Pursue mitigating, moving and/or reclaiming developments and disturbed sites that conflict with the objective of providing wildlife linkage.
- Continue dialogue with research scientists and others to promote adaptive connectivity management.

### *Timber Industry*

To maintain and enhance grizzly bear populations (and other wildlife species) in their operating areas, timber companies can:

- **Human access control.** Access management is a complex process that requires consultation between government agencies, industry, and the public (see access management section above). Decisions for access management will ultimately be made by a diverse group of interests including government, industry and backcountry user groups. Government may have the mechanistic authority over backcountry public roads, but community-wide support will be necessary for implementation.
- Take part in community-wide working groups that consider access management in linkage and adjacent core habitat. Support the integration of science-based solutions to access management issues. Work with the larger community to reduce open road densities with appropriate gates or semi-permanent closures, thereby limiting mortality risk, displacement and disturbance. Consider options for access control include the following: road deactivation, benign neglect, remove culverts or bridges, Kelly humps, reclaim first 100-200 metres of a road, legal closures, gates, and signs explaining intention of closures.
- Consider timing in harvest schedules when operating near high quality habitat. For example, avoid spring work for important low elevation riparian areas that are within linkage areas.
- Continue dialogue with research scientists and others to promote adaptive connectivity management.
- Develop **silviculture protocols** that incorporate consideration for wildlife linkage areas. **These may include:**
    - Retain cover between major roads and cut blocks and high quality habitat (berry patches, riparian area, and productive avalanche paths).
    - Cover can be maintained by retaining understory vegetation as much as possible. A guideline for cover retention is to leave vegetation twice the distance that an animal (or person) is visible through a forest.
    - Retain understory vegetation to 3m tall.
    - Combine cover retention with partial retention cutting methods.
    - If clear-cut logging takes place, consider leaving cuts a maximum of 400m across, so most areas within the cut are within 200m of the edge.
- **Harvest timber using methods to maximize retention of bear foods.**
    - Retain forest integrity around any particular productive riparian/ wetland areas, berry patches (*Vaccinium sp.*, huckleberry;and *Sheperdia canadensis*, buffalo berry).
    - Maintain/promote bear foods by not using herbicides, scarification, or brushing in ways that would destroy or limit bear foods (*Vaccinium*, *Sheperdia*, and other important shrubs).

- Maintain a variety of seral stages when planning harvest in linkage zones. Avoid high percentage of stands of similar age because mid-age stands may contain a minimum of bear foods.
- Leaving large diameter stumps and non-merchantable wood on the ground to provide for decomposing insects that are an important food source for grizzly bears.

- **Provide predictability for wildlife that are sensitive to disturbance.**
  - When timber harvesting within linkage zones, carry out operations within one portion at a time. This provides a measure of predictability and leaves alternate routes undisturbed to provide options for bears to move. In other words, harvest in one section of a linkage zone at a time, complete the operation, then move to another section.

### *BC Ministry of Transportation*

To maintain and enhance wildlife linkage along the Highway 3 corridor, BC Ministry of Transportation can:

- Integrate linkage zone necessity into highway planning.
- Implement appropriate highway crossing structures for safe wildlife passage when highway volumes exceed 5,000 vehicles per day.
- Implement appropriate wildlife fencing in conjunction with highway crossing structures.
- Maintain hiding cover in areas leading to highway crossing structures.
- Avoid new site developments or expansions that are not compatible with the needs of target species in linkage zones (i.e. special use developments, gravel pits, etc.).
- Continue highway garbage management in methods consistent with preventing conflict with wildlife (i.e. Bear-proof containers).
- Continue dialogue with research scientists and others to promote adaptive connectivity management.

## Private Lands

To maintain and enhance wildlife habitat and secure linkage zones, private landowners and residents can:

- Control human, pet and livestock foods, garbage, fruit trees and small livestock and other potential wildlife attractants to minimize the risk of conflicts between people and wildlife.
- Manage livestock grazing to maintain wildlife forage and hiding cover.
- Allow no increase in numbers of livestock and accept no new grazing permits within linkage zones.
- Manage cattle calving grounds and slaughtering areas with electric fencing so as not to attract bears. Carcasses should be disposed of so as not to provide food for bears.
- Enhance habitat by increasing natural forage and cover and protecting riparian areas.
- Avoid active timber harvest during spring in critical low elevation grizzly bear habitats.
- Consider conservation easements on their land.
- Engage in dialogue with research scientists and others to promote adaptive connectivity management.
- Promote education on coexisting with wildlife.

***Environmental Non-governmental Organizations***

ENGO's can help provide funds to promote wildlife coexistence education and to encourage and enable local residents and landowners to:

- Restore hiding cover for wildlife.
- Maintain and restore safe foraging opportunities.
- Rehabilitate stream and river banks.
- Install electric fencing to prevent livestock-predator conflict.
- Take part in compensation programs for landowners who have lost livestock to large carnivores.
- Contribute to research and implement other activities promoting wildlife-human coexistence.
- Continue to partner with researchers, government, and the public in planning for strategic land acquisition and conservation easements on linkage habitat.

## Conclusions

Habitat fragmentation is a wildlife and biodiversity issue that can be solved. It is not an insurmountable problem. Awareness, education, and some changes in the ways we live, work and recreate in rural areas can bring about positive changes to allow our natural wildlife populations to coexist with a growing human population. British Columbians appreciate the immense and pervasive natural world in the Kootenay region and will likely rise to the challenges of coexisting with wildlife including large carnivores. Mobilization of society in response to global climate change is occurring at a rapid pace. Providing solutions to wildlife fragmentation is also part of the global climate change response. Allowing our natural world to adapt to changing climate by having the ability to move successfully across a landscape will be a very important component to society's effort to mitigate the far reaching and often unpredictable effects of climate change.

It is the belief of the researchers that make up the Trans-border Grizzly Bear Project that wildlife conservation and management is not just the responsibility of the government, but will require cooperation from many parts of society. The main responsibility lies with those of us who live, work and play in the rural areas of BC. That includes the forestry workers, hunters, hikers, quad-enthusiasts outfitters, farmers, ranchers, campers, RV-campers, government employees and homesteaders. Conservation management is usually carried out by these groups of people, and they should be an integral part of the discussion, decisions, and application of any management that occurs. We envision this current version of this linkage management plan to be the beginning of a wider community discussion. We tried to let science, as much as possible, guide our thinking and recommendations, but also realize that solutions must be practical and workable. We recognize that as people read this they may have better ideas, and we encourage those ideas to be brought forward for inclusion in future editions.

## Literature Cited

Alexander, S.M., N.M. Waters, and P.C. Paquet. 2005. Traffic volume and highway permeability for a mammalian community in the Canadian Rocky Mountains. The Canadian Geographer 49:321-331.

Apps, C. D., B. N. McLellan, J. G. Woods, and M. F. Proctor. 2004. Estimating grizzly bear distribution and abundance relative to habitat and human influence. Journal of Wildlife Management 68:138-152.

Apps, C.D., J.L. Weaver, P.C. Paquet, B. Bateman, and B.N. McLellan. 2007. Carnivores in the southern Canadian Rockies: Core areas and connectivity across the Crowsnest Highway. Wildlife Conservation Society Canada Conservation Report No. 3. Toronto, Ontario, Canada.

Berger, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology. 4:91-98.

Boulanger, J. 2005. Demography of Foothills Model Forest Grizzly Bears: 1999-2003. In, Foothills Model Forest grizzly bear research program, 1999-2003 final report. Eds. G. Stenhouse, and K. Graham. Foothills Model Forest. Hinton, Alberta.

Boyce, M.S. and J.S. Waller. 2003. Grizzly bears for the Bitterroot: predicting potential abundance and distribution. Wildlife Society Bulletin31:670-683.

Boyce, M.S., P.B. Vernier, S.N. Nielsen, F.K.A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281-300.

Bruinderink, G. and E. Hazebroek. 1996. Ungulate traffic collisions in Europe. Conservation Biology 10:1059-1067.

Clevinger, A.P. and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large carnivores. Biological Conservation 121:453-464.

Chruszcs, B, A.P, Clevinger, K. Gunson, and M.L. Gibeau. 2003. Relationship amonggrizzlybears, highways and habitat on the Banff-Bow valley, Alberta, Canada. Canadian Journal of Zoology 81:1378-1391.

Crist, E.P. and R.C. Ciccone. 1984. Application of the tasseled cap concept to simulate thematic mapper data. Photogrammetric Engineering and Remote Sensing 50:343-352.

Foster, M.L. and S.R. Humphrey 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Frankham, R., J.D. Ballou, and D.A. Briscoe. 2002. Introduction to Conservation Genetics. Cambridge University Press. Cambridge. 617 pp.

Hamilton, A.N., D.C. Heard, and M.A. Austin. 2004. British Columbia grizzly bear (*Ursus arctos*) Population estimate 2004. British Columbia Ministry of Water, Land, and Air Protection, Biodiversity Branch. Victoria, B.C. 7 pp.

Hosmer, D.W., Jr. and S. Lemshaw. 1989. Applied Logisitic Regression. John Wiley & Sons, New York, New York, USA.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

Kasworm, W.F., H. Carriles, and T.G. Radandt. 2006. Cabinet-Yaak grizzly bear recovery area 1999 research and monitoring progress report. United States Fish and Wildlife Service. Grizzly Bear Recovery Coordinator's Office. Missoula, Montana.

Land. D., and M. Lotz 1996. Wildlife crossings design and use by Florida panthers and other wildlife isn southwest Florida. In, Proceedings of the International Conference on Ecology and Transportation. Florida Department of Transportation, Tallahassee.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuring. 1996. Relationships among grizzly bears, roads, and habitat use in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

Mace, R.D., J.S. Waller, T.L. Manley, K. Ake, and W.T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in Western Montana. Conservation Biology 13:367-377.

Manly, B.F.J., L.L. McDonald, D.L. Thomas. T.L. McDonald, and W.P. Erickson 2002. Resource Selection by Animals. Kluwer Academic Publishers, Boston. 221 pp.

McGarigal K. S. Cushman, and S. Stafford. 2000. Multivariate Statistic for Wildlife and Ecology Research. Springer. New York. 283 pp.

Nams, V.O, G. Mowat, and M.A. Panian. 2005. Scale dependent habitat selection by grizzly bears. Biological Conservation 128:109-119.

Nielsen, S.E., M.S. Boyce, G.B. Stenhouse, and R.H.M. Munro. 2002. Modeling grizzly bear habitats in the Yellowhead ecosystem of Alberta: taking autocorrelation seriously. Ursus 13:45-56.

Nielsen, S.E., M.S. Boyce, and G.B. Stenhouse. 2004a. Grizzly bears and forestry I: selection of clearcuts by grizzly bears in west-central Alberta. Forest Ecology and Management 199:67-82.

Nielsen, S.E., S. Herroro, M.S. Boyce, R.D. Mace, B. Benn, M Gibeau, and S. Jevons. 2004b. Modeling the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies Ecosystem of Canada. Biological Conservation 120:101-113.

Nielsen, S. E., G. B. Stenhouse, and M. S. Boyce. 2006. A habitat-based framework for grizzly bear conservation in Alberta. Biological. Conservation 130:217–229.

Paetkau, D. 2003. An empirical exploration of data quality in DNA-based population inventories. Molecular Ecology 12:1375-1387.

Parker, M. and T. Parker. 2002. A guide to involving rural communities in wildlife linkage zone development. Interagency Grizzly Bear Committee. Missoula, Montana.

Proctor, M.F. 2003. Genetic analysis of movement, dispersal and population fragmentation of grizzly bears in southwestern Canada. PhD Thesis. University of Calgary. 147 pp.

Proctor, M.F., C. Servheen, S. Miller, W. Kasworm, and W. Wakkinen. 2004. A comparative analysis of management options for grizzly bear conservation in the U.S.-Canada trans-border area. Ursus 15:145-160.

Proctor, M., B.N. McLellan, C. Strobeck, and R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of the Royal Society, London 272:2409-2416.

Proctor, M., J. Boulanger, S. Nielsen, W. Kasworm, C. Servheen and T. Radandt. 2007. Abundance and density of Central Purcell, South Purcell and Yahk Grizzly Bear Population Units in southeast British Columbia**.** BC Ministry of Environment. Nelson, BC.

Proctor, M., C, Servheen, W. Kasworm, and T. Radandt. 2008. Habitat security for grizzly bears in the Yahk Grizzly Bear Population Unit of the south Purcell Mts. of southeast BC. The Trans-border Grizzly Bear Project. Kaslo, BC.

Pyare, S., S. Cain, D. Moody, C. Schwartz, and J. Berger. 2004. Carnivore re-colonization: reality, possibility and a non-equilibrium century for grizzly bears in the Southern Yellowstone Ecosystem. Animal Conservation 7:1-7.

Ruediger, B. 2001. High, wide, and handsome: Designing more effective wildlife and fish crossings for roads and highways. In, Proceedings of the International Conference on Ecology and Transportation, edited by G. Evink and K.P McDermott, Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Schwartz, C., M. Haroldson, K. Gunther, and D. Moody. 2002. Current distribution of grizzly bears in the Greater Yellowstone Ecosystem: 1990–2000. Ursus 13:203–213.

Servheen, C., R. Shoemaker, and L. Lawrence. 2003. A sampling of wildlife use in relation to structure variable for bridges and culverts under I-90 between Alberton and St. Regis, Montana. In, 2003 Proceedings of the International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garret, and K.P McDermott, Raleigh, NC: Center for Transportation and the Environment, North Carolina State University.

Sokal, R.R. and F.J. Rohlf. 1995. Biometry, 3rd Edition. W.H. Freeman and Company. New York. 887 pp.

Wakkinen, W.L., and W.F. Kasworm. 2004. Demographic and population trends of grizzly bears in the Cabinet–Yaak and Selkirk ecosystems of British Columbia, Idaho, Montana, and Washington. Ursus 15 Workshop Supplement: 65–75.

Wilcox, B.A. and D.D. Murphy. 1985. Conservation strategy: the effects of fragmentation on extinction. American Naturalist 125:879-887.

Woodroffe, R. and J.R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. Science 280:2126-2128.

Woods, J.G., D. Paetkau, D. Lewis, B.N. McLellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. Wildlife Society Bulletin 27:616-627.

## Appendix I. Abstract,Tables and Figures from Mortality Analysis Report

Canadian and US trans-border grizzly bears in the south Selkirk and Purcell-Yaak ecosystems live in small fragmented threatened populations. Reducing human-caused mortality where feasible is an important strategy for "recovery" of these populations. We examined patterns of human-caused mortality spatially and temporally in these ecosystems by reviewing 29 years of mortality records from the US Fish and Wildlife Service, Idaho Fish and Game, and the British Columbia Ministry of Environment (Table 1). This report crystallizes three important points:

1) human-caused mortality rates in these ecosystems are likely contributing to declines in the Purcell-Yaak area and may be limiting growth in the Selkirk Mountains
2) the vast majority of Canadian grizzly bears are being killed after being attracted to residences and small farms on the periphery of these ecosystems
3) actions focused on reducing bear attractants in settled areas may improve several bear management issues:
   - reducing human-bear conflicts,
   - reducing bear mortality and thus improving survival rates in and around these threatened populations, and
   - reducing attractants, allowing inter-population linkage without increasing human-bear conflicts in linkage zones.

We found human-caused mortalities to be increasing in both the Purcell-Yaak and south Selkirk ecosystems (Fig. 2), culminating in a known mortality rate averaged over the past 6 years of an estimated 4.0% of the Purcell-Yaak population and 3.0% of the south Selkirk population. Males were killed more often than females, sub-adults (1-5 yrs. old) more often than adults, and deaths were more likely to occur in the fall than the spring and summer combined (Table 1). In the recent decade, we found that 75% of Canadian non-hunting mortalities occurred as a result of attractants at residences and small farms from fruit trees, livestock and feed, and garbage (including 3 self-defense kills at residences and several unspecified causes at attractant sites) on the periphery of these ecosystems (Table 2, Fig.2). The other category was backcountry mortalities in the eastern portion of the Purcell-Yaak area which included mistaken identification, illegal kills, self-defense, black bear hound hunters, and several of unknown cause resulting in 11% of known mortalities (Table 2). We make recommendations for strategies to reduce these mortalities within Canada, as the US has on-going organized efforts aimed at minimizing grizzly bear mortalities. We recommend using the existing well organized BC Bear Aware program modified to encompass the rural scattered nature of on-site attractant-based grizzly bear mortalities occurring on the periphery of these ecosystems. We also recommend a committee of relevant interested community and government individuals be formed to guide these efforts. We further recommend that a member of this research team and a local conservation officer approach the local hunting community using the east Purcell-Yaak area for discussions on the solutions to the backcountry mortality occurring in that region. And finally, we recommend that hunting be eliminated south of Highway 3 in the Purcell Mountains (South Purcell Grizzly Bear Population Unit) and a no hunting buffer around these threatened populations be considered to facilitate population interchange.

**Appendix-Table 1**. Summary of human-caused grizzly bear mortalities in the south Selkirk and south Purcell / Yaak ecosystems from 1976 through 2004. Mortalities span both the US and Canada and include a 15 km perimeter.

| CATEGORY | | | Purcell/Yaak | S Selkirks | Both % of total | Total |
|---|---|---|---|---|---|---|
| **Total human-caused mortalities** | | | 110 | 84 | | 194 |
| **Human-caused morts, no hunting** | | | 52 | 47 | | 99 |
| | | **male** | 28 | 25 | 0.54 | 53 |
| | | **female** | 21 | 14 | 0.35 | 35 |
| | | **unknown** | 3 | 8 | 0.08 | 11 |
| **Hunting** | | **US** | 0 | 0 | | |
| | | **Canada** | 51 | 30 | 0.45 | 81 |
| **Age** | | **<1** | 4 | 6 | 0.15 | 10 |
| | | **1-5** | 18 | 16 | 0.52 | 34 |
| | | **>5** | 11 | 11 | 0.33 | 22 |
| **Season** | | **Spring** | 11 | 9 | 0.20 | 20 |
| | | **Summer** | 3 | 7 | 0.10 | 10 |
| | | **Fall** | 38 | 31 | 0.70 | 69 |
| **Private land** | | **US** | 5 | 1 | 0.06 | 6 |
| | | **Canada** | 25 | 21 | 0.46 | 46 |
| **Public land** | | **US** | 11 | 13 | 0.24 | 24 |
| | | **Canada** | 11 | 12 | 0.23 | 23 |
| **Within 500m of road** | | | | | | |
| | **US** | **yes** | 13 | 7 | 0.20 | 20 |
| | | **no** | 3 | 5 | 0.08 | 8 |
| | | **unk** | 0 | 2 | 0.02 | 2 |
| | **Canada** | **yes** | 29 | 27 | 0.57 | 56 |
| | | **no** | 7 | 3 | 0.10 | 10 |
| | | **unk** | 0 | 3 | 0.03 | 3 |
| **GENERAL CAUSES** | | | | | | |
| | | **Mistaken ID** | 7 | 3 | 0.10 | 10 |
| | | **Poaching/ Illegal** | 2 | 7 | 0.09 | 9 |
| | | **Unknown** | 0 | 2 | 0.02 | 2 |
| | | **Under Investigation** | 6 | 3 | 0.09 | 9 |
| | | **Self-defense** | 13 | 4 | 0.17 | 17 |
| | | **Train** | 2 | 0 | 0.02 | 2 |
| | | **Research** | 1 | 0 | 0.01 | 1 |
| **MANAGEMENT MORTALITIES** | | | | | | |
| | | **Fruit trees** | 0 | 7 | 0.07 | 7 |
| | | **Livestock** | 7 | 5 | 0.12 | 12 |
| | | **Garbage** | 3 | 1 | 0.04 | 4 |
| | | **Property** | 1 | 1 | 0.02 | 2 |
| | | **Unknown** | 9 | 17 | 0.26 | 26 |
| **TOTAL** | | | **51** | **50** | | **101** |
| **Known deaths / year*** | | | 1.76 | 1.72 | | |
| **Known deaths / yr last 6 years*** | | | 3.5 | 2.8 | | |
| **Known deaths / yr last 6 years**** | | | 2.2 | 3.0 | | |
| **Percent of population**** | | | 4.3% | 3.0% | | |

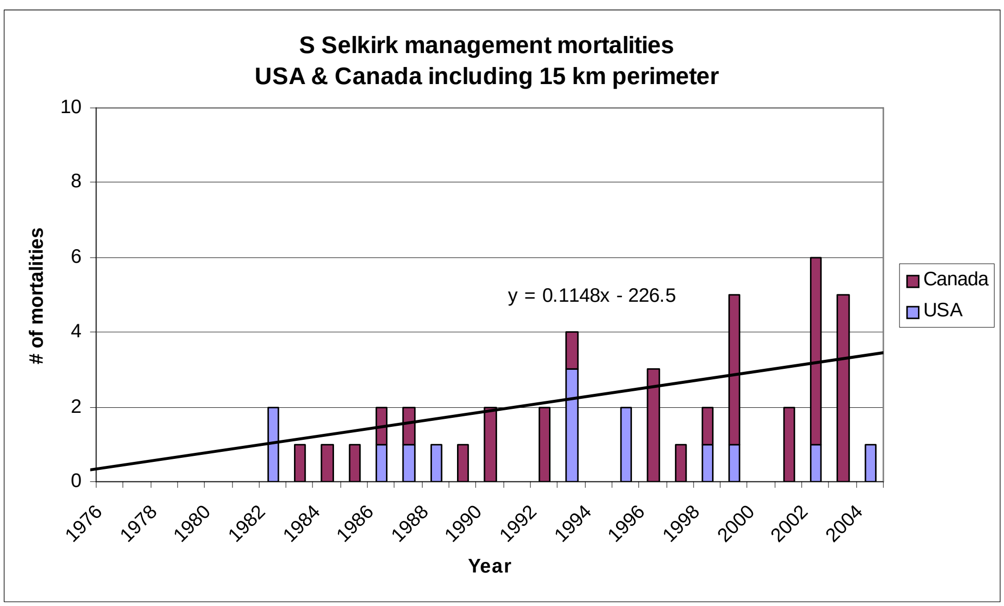
*** includes bears in ecosystem & periphery**
**** includes only bears within ecosystem**

**Appendix-Table 2.** Summary of human-caused mortality (non-hunting) in the south Purcell-Yaak and south Selkirk ecosystems in the most recent decade from 1995-2004. The Can : US column refers to the number of mortalities in each category that occurred in Canada or the US.

| Recent Decade 1995-2004 | Purcell/Yaak | S Selkirk | Total | Can : US | Proportion of total |
|---|---|---|---|---|---|
| **Human, unknown*** | 7 | 5 | 12 | 10 : 2 | 0.22 |
| **Under investigation** | 6 | 3 | 9 | 0 : 9 | 0.16 |
| **Livestock** | 4 | 4 | 8 | 7 : 1 | 0.15 |
| **Self defense**** | 6 | 2 | 8 | 7 : 1 | 0.15 |
| **Fruit trees** | 0 | 7 | 7 | 7 : 0 | 0.13 |
| **Mistaken ID** | 2 | 2 | 4 | 2 : 2 | 0.07 |
| **Garbage** | 2 | 1 | 3 | 3 : 0 | 0.05 |
| **Property damage** | 1 | 1 | 2 | 1 : 1 | 0.04 |
| **Train** | 2 | 0 | 2 | 2: 0 | 0.04 |
| **TOTAL** | | | 55 | | |

*All 10 of the Canadian unknown mortalities resulted from being attracted to a residence or farm
**Includes some BB hound hunters

**Appendix-Figure 1.** Human-caused grizzly bear mortalities in the south Purcell/Yaak ecosystem from 1976 through 2004. Mortalities span both the US and Canada and include a 15 km perimeter. Hunting and natural mortalities are not included.



**Appendix - Figure 2**. Map of human-caused grizzly bear mortalities in the south Selkirk (orange polygon) and south Purcell / Yaak (yellow polygon) ecosystems by decade. Mortalities span both the US and Canada and include a 15 km perimeter (white line). Included are: human-caused mortality between 1976-1984 (red dots), 1985-1994 (pink dots), 1995-2004 (yellow dots). Green shaded areas are protected; PWC is the Purcell Wilderness Conservancy, GRPP, KGPP, VPP, and WAPP are Goat Range, Kokanee Glacier, Valhalla, and West Arm Provincial Park respectively.