Eastern Bow Valley Wildlife Corridor Study: An Analysis of Winter Tracking and Monitoring Final Report

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Table of Contents

List of Tables

List of Figures

Executive Summary

The Eastern Bow Valley Wildlife Corridor Study is a multifaceted effort aimed at identifying wildlife corridors, habitat patches, and impediments to animal movement in the Bow Valley between the Town of Canmore in the west and Bow Valley Provincial Park in the east. The goal of the study is to provide land managers with science-based information and recommendations to ensure the viability of a network of wildlife corridors linking secure habitat patches within the Eastern Bow Valley. This study emerged from a formal conservation partnership established between World Wildlife Fund (WWF) Canada and Lafarge North America in 2004 as the conservation of wildlife movement corridors throughout the Rocky Mountains has been a long-term priority for WWF. Alberta Tourism, Parks and Recreation (ATPR), Parks Division, and Alberta Sustainable Resources Development (ASRD), Fish and Wildlife Division, joined this partnership to provide technical and analytical expertise for this study.

Initially planned as a five-year study focusing on winter field work involving survey transects and snow tracking, the project has expanded to include year-round field work utilizing remote wildlife cameras, monitoring of wildlife crossing structures across the Trans Canada Highway (TCH), human-use monitoring along trails using passive infrared trail counters, and monitoring fine-scale elk movements using GPS collars. **This report deals only with the results of the five-year winter transect and snow tracking portion of the greater Eastern Bow Valley Corridor Study.**

Recommendations from this report include:

1) Continue to collect further data to determine how human use affects carnivore habitat use and movement patterns in the Eastern Bow Valley:
    a. Use GPS and/or remote cameras to address the spatio-temporal effects of trail use on carnivore movements;
    b. Examine species variability in response to humans;
    c. Collect human-use data on trails with the use of infrared trail counters.

2) Tailor land use to provide secure movement opportunities in the following areas and pinch points where we have corroborating tracking data and predicted habitat quality from resource selection models:
    a. Bow River corridor west of Dead Man's Flats (pinch point);
    b. Three Sister's Campground at Dead Man's Flats (pinch point);
    c. McGillivray Slabs area (corridor);
    d. Jura Creek (corridor);
    e. Quaite Valley (corridor);
    f. Bow Valley rock cut east of Lac des Arcs.

3) Consider enhancements to increase landscape connectivity in the following regions:
    a. Wildlife movement corridors north of, or across, the Lafarge quarry at Exshaw;
    b. Wildlife movement corridors across/around the Burnco quarry in the western portion of the study area;

c. Build additional wildlife highway crossing structures in high-use wildlife areas such as at Quaite Valley.

4) Extending Cooperation:

   a. Work collaboratively with other stakeholders in the Bow Corridor Rock Industry Group to restore movement corridors and protect critical habitat patches.

Eastern Bow Valley Wildlife Corridor Study
Winter Transect and Snow Tracking

1.0 Introduction

The Bow Valley is widely recognized for its extremely high value to both resident and migratory wildlife (Paquet 1993; Paquet et al. 1994; Gibeau 2000; Callaghan 2002). The valleys northwest/southeast orientation and relatively low elevation have resulted in its success as a major wildlife linkage zone, connecting habitat in the Kananaskis and Spray valleys to the south, with Banff National Park and the Ghost Wilderness Area to the north. It is considered a regionally significant wildlife corridor, and facilitates the long distance dispersal of wide ranging carnivores throughout the Front ranges of the Rocky Mountains. Maintaining landscape connectivity throughout the Rocky Mountains is essential for genetic dispersal and the long term sustainability of these species (Noss et al., 1995).

Present and anticipated levels of human development within the Bow Valley threaten, and in some cases have already curtailed habitat connectivity and effectiveness for many species (Paquet et al. 1996, BCEAG 1999, Serrouya 1999, Gibeau 2000, Duke 2001, Percy 2003). The Bow Valley is considered a potential fracture zone to large carnivore movements and genetic exchange in the central Rocky Mountains (Servheen et al. 1998). A concurrent increase in highway and railway traffic, recreational use of trails, and a general increase in human visitation may result in the permanent loss of large mammalian and sensitive species from the Bow Valley ecosystem. The cumulative effects of human expansion throughout the valley have resulted in habitat loss and alteration, increased sensory disturbance to wildlife, and an overall increase in habitat fragmentation and alienation.

A 1994 report to the Bow Valley Wildlife Corridor Task force identified the importance of developing high levels of coordination between government agencies, landowners and non-government organizations in order to successfully implement a strategy for the conservation and restoration of habitat and vital linkage zones throughout the Bow Valley (Paquet et al. 1994).

In July 2004, Lafarge North America and World Wildlife Fund (WWF) Canada entered into a conservation partnership aimed at protecting large carnivores and other wildlife in the Bow Valley. Alberta Tourism Parks and Recreation (ATPR), Parks Division, and Alberta Sustainable Resources Development (ASRD), Fish and Wildlife Division, became involved in the partnership due to the similarities between conservation partnership goals and surrounding land management goals. ATPR is undertaking the data collection and analytical components of this project, and when required, supervising local contract biologists in collecting field data. Specifically, this joint initiative focuses on identifying wildlife movement corridors, critical habitat patches, and potential impediments to wildlife movement in the Eastern Bow Valley between Stewart Creek (near the east boundary of the town of Canmore) and Bow Valley Provincial Park. Identified patterns of movement and habitat use will be used to develop recommendations to guide land use planning and management in the Eastern Bow Valley. The study was initially intended as a five year winter transect monitoring and snow tracking project, but has expanded in scope to include an intensive remote wildlife camera component, monitoring fine scale elk movement patterns using GPS collars, monitoring of human use of trails, and monitoring wildlife crossing structures along the Trans Canada Highway (TCH).

This report summarizes winter transect monitoring and snow tracking in the Eastern Bow Valley between November 2004 and March 2009. A final report detailing the results of all field work and specific management recommendations will be written following the completion of the remaining components of the greater Eastern Bow Valley Wildlife Corridor Study (EBWCS) including the remote wildlife camera project, and the collection, download and analysis of the elk GPS collar data. Analyses will focus on identified goals and study objectives and will be available to all jurisdictions for consideration in management decisions related to the Bow Valley and to stakeholders in the larger regional landscape.

2.0 Study Area, Project Goals, and Species of Interest

2.1 Study Area

The study area is located in the Bow River Valley, approximately 85 km west of the city of Calgary, Alberta, along the front ranges of the Canadian Rocky Mountains (Figure 1). The study area includes lands in the Bow River Valley from the Stewart Creek wildlife underpass on the east edge of the Town of Canmore, to the Yamnuska area north of the Bow River, and Bow Valley Provincial Park south of the Bow River (Figure 2).

2.2 Project Goals

The overall goal of the EBWCS is to identify a network of wildlife corridors linking secure habitat patches within the Eastern Bow Valley using empirical data and the most current scientific information.

Surveying winter track transects and conducting follow-up snow tracking provides detailed information on wildlife movement patterns, habitat use, and potential impediments to landscape connectivity.

Figure 1. Location of the Bow Valley within Alberta, Canada.

2.3 Species of Interest

Species of interest for winter transect monitoring and snow tracking include:

Cougar (*Puma concolor*), wolf (*Canis lupus*), lynx (*Felis canadensis*), bobcat (*Felis rufus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), elk (*Cervus elaphus*), moose (*Alces alces*), bighorn sheep (*Ovis canadensis*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), river otter (*Lutra canadensis*) and any species known to be rare to this area. As this report summarizes winter research only, grizzly (*Ursus arctos horribilis*) and black (*Ursus americanus*) bears are not included due to their winter denning period coinciding with the snow tracking period.

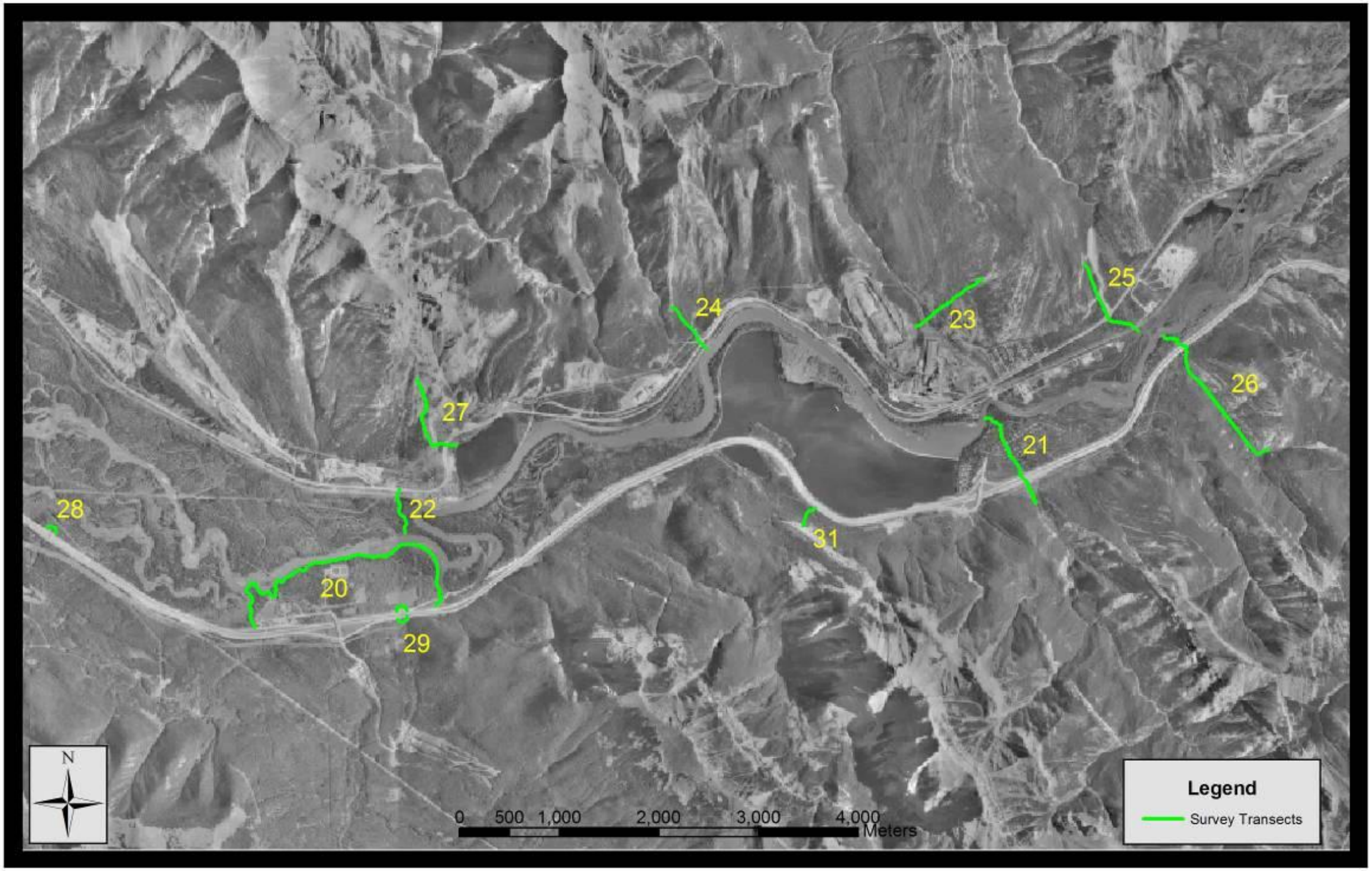

Figure 2. Eastern Bow Valley Study Area and Transect Locations, 2004 to 2009.

3.0 Methods

We used winter transect surveys to detect wildlife movements through suspected pinch points, and subsequent snow-tracking across the entire study area to identify winter habitat use by a variety of species. For the statistical analysis of the transect and wildlife snow-tracking data, ATPR commissioned an independent analysis and report (Whittington and Forshner 2009) which comprises most of the content of this document.

3.1 Winter Survey Transects

In 2004, eight wildlife survey transects were established in potential movement pinch points in the study area (Figure 2). Three additional transects were added in the winter of 2005/06 to further detect movement through pinch points, and one original transect was extended. Movement through these areas is constrained as a result of human developments, including linear features such as the TCH and the 1A highway, and natural barriers such as steep cliff faces and rivers. Unlike the survey transects established in 1999 for the Canmore Benchlands Study (Callaghan and Jevons 2001), the Eastern Bow Valley transects do not follow a uniform direction or line, but are located between known natural or anthropogenic barriers. As the primary purpose of the transects was to detect tracks for subsequent snow tracking throughout the study area, this design was intended to maximize track detection ability while minimizing survey length.

Transects were numbered consecutively beginning at 20 to avoid duplicating transect numbers from the concurrent Canmore Benchlands Study. All transects with the exception of Transects 20, 28 and 29 were divided into 50-metre segments (intervals) and labeled with flagging tape and small plastic identification markers denoting transect and interval number. Transect 20 was used to detect large mammal river crossings around the hamlet of Dead Man's Flats, while transects 28 and 29 are short, semi-circular transects surrounding the entrance to the two wildlife crossing structures under the TCH (Wind Valley Underpass and Stewart Creek Underpass). Transect identification number, number of intervals, and a brief description of transect location is summarized in Table 1.

Transects were surveyed between 24 and 72 hours after a significant snowfall (>1 cm), and were randomly assigned to trackers to minimize observer bias. During each survey, the presence of all species larger than (and including) American marten (*Martes americana*) was recorded for each transect interval. For all recorded species other than marten and snowshoe hare (*Lepus americanus*), the total number of crossings per 50m transect interval was recorded. The presence or absence of marten and snowshoe hare was recorded for each interval.

Table 1. Description of Survey Transects for the Eastern Bow Study Area, 2004 to 2009.

Transect ID	# of Intervals	General Location
20	1	Dead Man's Flats – follows river around perimeter of hamlet
21	21	Heart Creek – follows pedestrian trail from Bow River to cliffs at base of Heart Creek Trail
22	10	Dead Man's North – between Bow River and 1A north of DMF
23	17	Exshaw Creek – from mine tailings west of pedestrian bridge over Exshaw Ck. to cliffs on east ridge of Exshaw Ck valley
24	12	Grotto Pond – from Bow River to cliff bands above Grotto Pond picnic area
25	18	Jura Creek – from Bow River just west of Continental Lime to first cliffs on west side of Jura Ck
26	22	Quaite Valley – from Bow River across TCH to first cliffs on east side of Jewel Pass/Quaite Valley trail
27	18	Gap Lake – from Gap Lake picnic area up to cliffs above 1A on base of Grotto Mountain
28	1	Stewart Creek Underpass (North side only)
29	2	Wind Valley Underpass (North and South)
31	6	McGillivray Slabs – from TCH to climbing area

The following data was collected during each transect survey:

- Date of survey
- Transect number
- Observer
- Survey start time
- Time since last snow (number of hours)
- Tracking conditions
- Transect segment number
- Snow depth (centimeters)
- Species detected
- Number of animals detected
- Direction of animal travel
- In the case of transect #20, river/ice conditions were noted and whether or not a river crossing was involved

When snowfall was inadequate to conduct complete transect surveys, or if tracking conditions between snowfalls were favorable, carnivore surveys were conducted solely to detect the tracks of cougar, wolf, lynx, bobcat and fox for the purpose of tracking. Ungulate tracks were not recorded during carnivore surveys.

Using the snow transect data, we statistically tested for changes in the relative abundance of each species and for factors affecting where carnivores crossed transects. We then spatially mapped the probability of carnivore occurrence within transects across the study area.

We summed the number of animals recorded per transect session and tested changes in the relative abundance of each species using generalized linear mixed effects models (Pinheiro and Bates 2000). Mixed effect models account for the repeated nature of the data (each transect checked several times per winter over several winters) by including *transect* as a random effect and *bioyear* (i.e. tracking year) as the fixed effect of interest. Some species were relatively rare within the study area (cougar, lynx, moose) so we considered them as “present” or “absent” on a given transect and used a binomial link in the generalized linear model (glmm). The number of tracks per transect were affected by transect length and days since snow so we used an offset term of log(days_snow*transect_length) to account for those factors in the models. We determined whether or not elevation, slope or distance from the start of the transect influences where rare carnivores (cougar, lynx, bobcat, and fox) crossed transects.

3. 2 Winter Snow Tracking

Upon completion of the transect surveys, tracks of large and medium-sized carnivores (except coyote) detected during surveys were tracked to the edge of the study area, or until snow or topographic conditions precluded further tracking. Tracks were followed in the opposite direction to animal travel to avoid displacing the animals. Tracks were only followed in the direction of animal travel when tracks were > 2 days old. Tracking was conducted with hand-held GPS (Global Positioning System) units, programmed to collect spatial coordinates every 10 metres. Data was collected in UTM Zone 11 projection, NAD 83 datum, with an accuracy of 25m or better. GPS units were also used to record spatial coordinates of notable features of animal behaviour such as actual or attempted road or river crossing sites, bedding sites, denning sites, prey-kill sites, hunting sequences, and food caches. Upon completion of each tracking session, GPS data was downloaded into Arc GIS (Esri Inc., Redlands CA.) for analysis.

In the case of Transect 20, both carnivore and ungulate tracks were followed toward the Bow River to identify potential river-crossing points. Carnivores were tracked away from the river upon completion of the survey.

Snow conditions were sub-optimal during the five year study period. Due to the paucity of snow tracking data obtained through our transect surveys as well as the relative absence of wolves from the study area between 2004 and 2009, we supplemented our snow tracking data with data from the Central Rockies Wolf Project (CRWP, 1997 – 2003) and the Canmore Benchlands Study (1999 – 2009) when tracking vectors (or portions of tracking vectors) occurred within the defined EBWCS study area. Although the means of detecting tracks varied by study (Canmore Benchlands parallel transect system versus the pinch point transect system of the EBWCS, CRWP use of VHF wolf collars and road-based wolf track surveys to determine pack location), these methods are unlikely to create biases in the data as all tracking vectors crossed through the study area, and would likely have been detected on one or more of our transects or during opportunistic carnivore track surveys had all three studies been running simultaneously.

Animal movements, especially in winter, are affected by topography, vegetation, human infrastructure, and snow conditions. We determined what factors affect carnivore movements and resource selection during winter in the Eastern Bow Valley by comparing habitat-related attributes of carnivore snow-tracking data to random locations using conditional logistic regression, also known as discrete choice models or matched-case control logistic regression (Hosmer and Lemeshow 2000, Johnson et al. 2004, Mao et al. 2005, Whittington et al. 2005, Boyce 2006, Shepherd and Whittington 2006, Bakker 2009). These models isolate the "choices" made by animals by comparing habitat and resources selected by animals during travel to the habitat and resources available to the animals in the immediate area.

The snow-tracking sessions consisted of successive point locations each separated by approximately 30m. We simplified the tracking sessions into 500m step lengths. We then created ten random locations for each carnivore location using a 500m step length and a random turn angle ($\pm$ 90°) from the previous location and direction of travel (Whittington et al. 2005, Shepherd and Whittington 2006). This pairing of random locations to a carnivore location allowed us to determine what habitat-related features the carnivores selected given the features available in the immediate area.

We determined what topographic and vegetative factors affected carnivore use of the landscape by using the following variables: elevation, slope, aspect, distance to water, distance to stream, vegetation class (conifer (reference), conifer-open, deciduous, grass), and terrain ruggedness (standard deviation in elevation within 500m radius). We tested explanatory variables for multi-collinearity (one explanatory variable is highly correlated with one or more other explanatory variables) and removed variables with correlations >0.7 and variance inflation factors >3.0 (Fox 2002). We used a forward stepwise model selection procedure and tested for non-linearity for elevation and slope and tested for interactions between aspect-slope and aspect-elevation. We assessed model performance using k-fold cross-validation with Spearman's rank correlation (Boyce et al. 2002, Mao et al. 2005). We randomly selected and removed 20% of the data, fit the model to calculate new resource selection coefficients, determined the predicted values for the omitted data, and calculated Spearman-ranked correlation coefficients between the frequencies of observed and predicted values of the omitted data. We repeated the process 1000 times and calculated the mean correlation coefficient as a measure of model performance. High correlation coefficients with a maximum value of one indicate strong model performance.

We created predictive maps of carnivore occurrence based on these models to identify patches of high quality habitat and potential pinch points to movement. We did not assess the effects of human activity on carnivore movements because we lacked data for levels of human activity on trails.

For this report, all GIS analyses and mapping were performed in the open source programs QGIS 1.3 (http://qgis.org/) and GRASS 6.4 (http://grass.itc.it/). Statistical analyses and spatial modeling were conducted in R 2.10 (R Development Core Team 2008) using the package "Survival" for conditional logistic regression (Therneau and Lumley 2009), "lme4" for mixed effects modeling (Pinheiro and Bates 2000, Bates and Maechler 2009), "SP" for spatial overlays (Bivand et al. 2008), and "Raster" for creating predictive maps of carnivore occurrence (Hijmans and van Etten 2009).

3.3 Regional Movement Patterns

Animal movement patterns, pinch points to animal movement, fragmentation effects, and habitat quality were assessed around Dead Man's Flats, Lac des Arcs, Exshaw, and the East end of Grotto Mountain, including Gap Lake and Grotto Pond as these are all areas of potential movement constraints. We assessed animal movements by using a combination of wildlife snow-tracking data, resource selection maps, and knowledge of topographical features. Shallow snow depths and strong winds made snow-tracking difficult in many regions of the study area, which may affect the quantity of snow tracking, the distribution of snow-tracking, and the strength of the resource selection models. Therefore, we used a hierarchical approach to identifying important regions for carnivore movement. We had the most confidence in areas defined as high quality habitat when they contained animal tracking data and high probabilities of carnivore occurrence. Similarly, we had the most confidence in areas that obstructed animal movements when a lack of snow-tracking data was corroborated by very low probabilities of carnivore occurrences, topographic features, and developments. In this way, we identified important carnivore habitat and pinch points to movement.

4.0 Results

4.1 Winter Survey Transects

Winter survey transects in the Eastern Bow Valley were sampled an average of 7.0 times per winter for a total of 368 sampling sessions. A total of 4488 animal tracks were recorded on the snow transects (Table 2). Coyote, lynx, and cougar were the most commonly detected carnivores while sheep and deer were the most commonly detected ungulates. Wolves were not detected on the EBCS snow transects between 2004 and 2009. We did not include the underpass transects in the trend analysis because of their short length. We tested for an increase or decrease in each species over time. Over the 5-years of monitoring, there was no change in the probability of detecting carnivores (combined), cougars, bobcat or moose, but there was a slight increase in the probability of detecting lynx (Figure 3). Similarly, there was no change in the probability of detecting elk. The relative abundance of deer and sheep did not change in the study area, but there were significant changes on individual transects. The largest increases in the relative abundance of deer occurred at the Dead Man's Flats and Lac des Arcs transects while the largest decreases occurred at the Graymont and Dead Man's Flats North transects. The largest increases in the relative abundance of sheep occurred at Exshaw and Gap Lake transects while the largest decrease occurred at Grotto Pond transect. The relative abundance of coyotes decreased overall also, but with variability in trends among individual transects. It is important to note that trends observed over the five year period do not necessarily indicate increases or decreases in population size or a long-term shift in habitat-use patterns of focal species.

4.2 Wildlife Snow-Tracking

Since 1997, 203 km of wildlife tracking has occurred in the defined Eastern Bow Study Area (Figure 4 and 5). Cougars, wolves, and lynx were the animals most frequently tracked (Table 3). Wolves rarely used the study area from 2004 to 2009, and cougar tracking increased over that same time period. Bobcats, which are rare in the Bow Valley, were documented using the study area consistently since 2004. Thus, the study area has three wild felid species (cougar, lynx, and bobcat). All species concentrated their winter movements in the valley bottoms, especially when using the south side of the valley, where the snowpack is deeper on north aspects at higher elevations.

Compared to other species, cougars used higher elevations and steeper slopes. Ninety-five percent of cougar movements occurred on slopes less than 30.1^{o}, whereas 95% of the movements of the other carnivore species occurred on slopes below 25^{o}, which is an important metric for defining wildlife corridors in the Bow Valley (BCEAG 1999).

Table 2. Number of animal tracks detected on all transects in the Eastern Bow Valley from Fall 2004 to Spring 2009. Track transects were sampled 320 times.

Species	Number of Tracks Detected
Bobcat	15
Cougar	81
Coyote	1332
Red fox	14
Lynx	153
Deer	1015
Elk	101
Moose	30
Sheep	1599
Total	**4340**

Table 3. Kilometres of animal tracks recorded by snow tracking in the Eastern Bow Valley from 1997 to 2009 as well as the 95th percentile of elevation (metres) and slope (degrees) used by five species. For example, 95 percent of cougar movements occurred on slopes below 30.1 degrees.

Species	Length (km)	95th percentile: elevation (m)	95th percentile: slope (degrees)
Cougar	120.1	1580	30.1
Wolf	90.5	1513	21.3
Lynx	40.7	1477	23.4
Bobcat	8.2	1326	14.4
Deer	8	1305	3.7
Coyote	5	-	-
Elk	4.9	-	-
Moose	2	-	-
Red fox	1	-	-
Otter	0.9	-	-
Wolverine	0.5	-	-
Total	**281.8**		

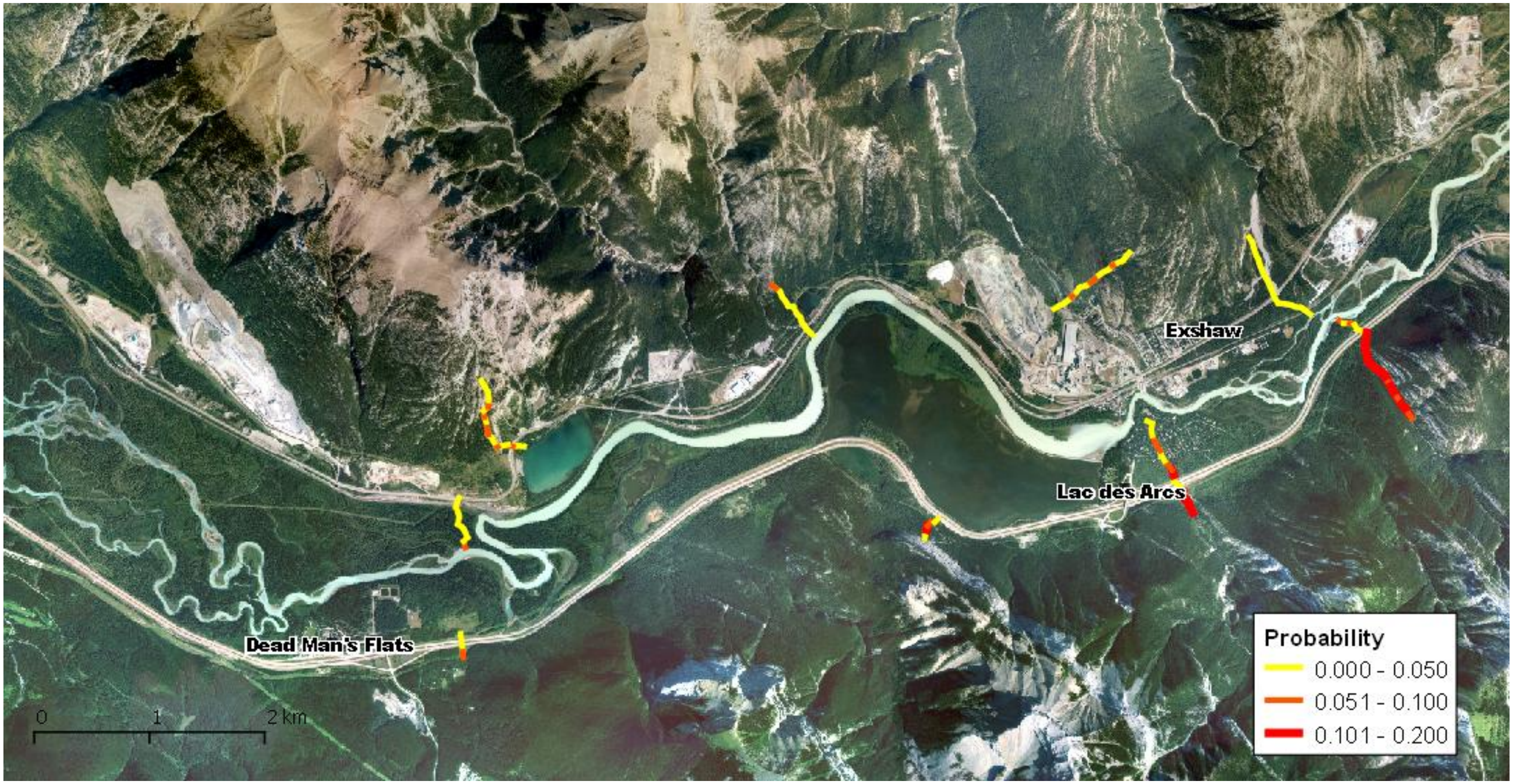

Figure 3. Map indicating the probability of detecting a carnivore (cougar, lynx, bobcat, or fox) within each 50m transect interval.

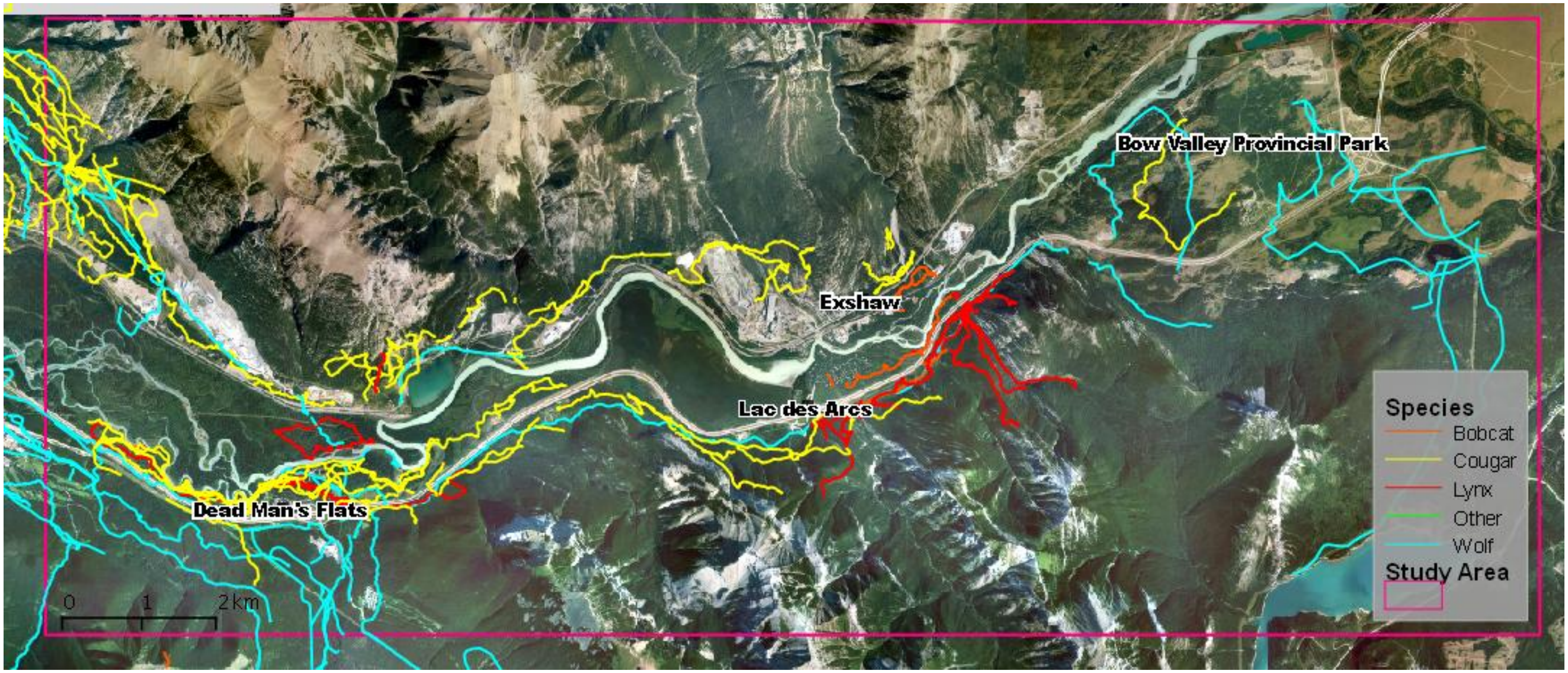

Figure 4. Eastern Bow Valley study area as defined for the analysis of snow-tracking data.

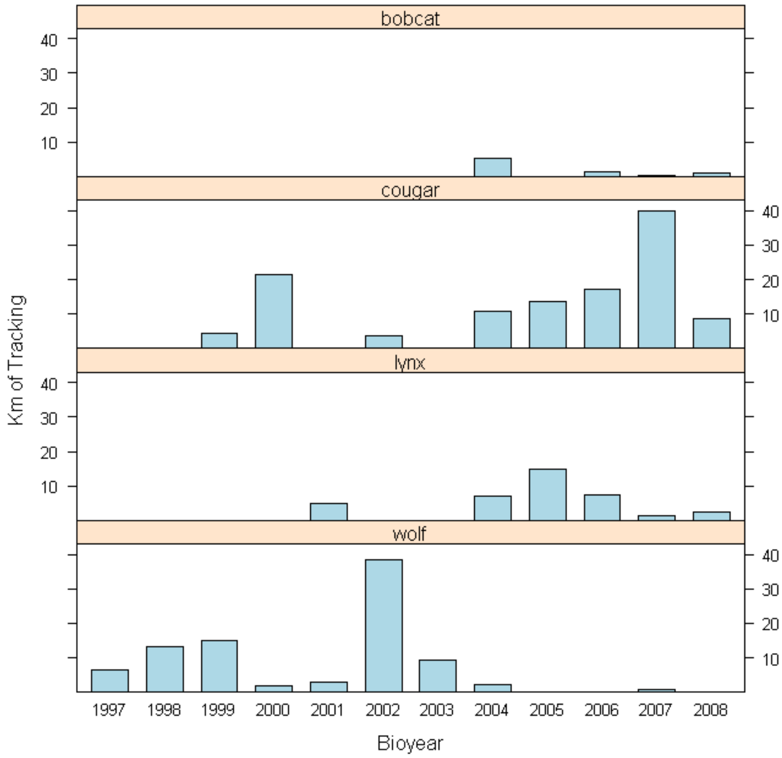

Figure 5. Kilometres of snow-tracking in the Eastern Bow Valley by year and species, from the EBWCS, the Canmore Benchlands Study and the Central Rockies Wolf Project.

Wolf movements in the study area were both limited and fragmented as they rarely used the valley bottom between the TCH and the 1A. Most wolf tracking occurred prior to 2004 when the large and relatively bold Fairholme wolf pack accessed the study area across the south side of Canmore. Between 2004 and 2009, wolves were not detected during surveys of the Eastern Bow Corridor Study transects, but groups of one or two animals were snow-tracked by the Canmore Benchlands Study in 2004 (2.4 km) and in 2007 (0.7 km) when they accessed the study area across the north side of Canmore. The Peter Lougheed Wolf Pack also accessed the study area over Skogan Pass and used the eastern portion of the study area in Bow Valley Provincial Park prior to 2004.

Lynx were most commonly tracked on the south side of the valley southeast of Lac des Arcs. Bobcat were most commonly tracked east of Lac des Arcs and Exshaw (Figure 3).

We modeled the habitat preferences of cougars, wolves and lynx by comparing the topographic and vegetative features used by each species along tracking vectors to features in the surrounding 500m (i.e. we compared what was "used" to what was "available") (Table 4). The predictor variable "terrain ruggedness" was excluded due to correlation with slope and elevation. Cougars selected areas with steeper slopes on southern aspects and slightly avoided steep slopes on northern aspects (Figure 6). Wolves selected for low to moderate slopes and strongly avoided steep slopes (Figure 7).

Cougars also selected areas close to large water bodies. Closed coniferous forests dominated the study area and were thus the reference category for the resource selection analysis. Cougars and lynx avoided grassland relative to closed coniferous forests. Most grassland occurred along the TCH. Wolves selected for open coniferous forests, grassland, and deciduous forests (in order of selection strength) relative to closed coniferous forests. Models for habitat selection in cougar and wolves were found to be robust, but the model for lynx was relatively weak, perhaps because there was less lynx tracking data compared to the other two species (Figure 8). We lacked sufficient data to create predictive habitat use models for bobcat.

The statistical strength of each explanatory variable on resource selection can be roughly estimated by the p-values (Table 4). However, the p-values do not reflect effect sizes or the deviance explained by the variable, which was tested using likelihood ratio tests. Similarly, while coefficients for a given explanatory variable can be compared among species, variables with different scales cannot be compared. Elevation was clearly one of the important predictors as all species showed strong selection for low elevations.

Table 4. Resource selection function models for cougar, wolf, and lynx. β, SE, & p represent the regression coefficient, standard error, and associated p-value for each explanatory variable included in the model. Closed coniferous forests were the reference category for the vegetation-related covariates. "n" indicates the number of carnivore locations with a separation distance of 500m used in the analysis. K-fold cross validation reflects the correlation between presence-absence and the probability of carnivore occurrence and high values indicate better model performance (maximum value = 1.0).

	Cougar			**Wolf**			**Lynx**		
Variable	β	**SE**	**p**	β	**SE**	**p**	β	**SE**	**p**
elevation	-9.282	1.833	<0.001	-5.456	2.221	0.014	-10.12	2.802	<0.001
slope	0.042	0.016	0.007	0.148	0.037	<0.001			
slope^2				-0.006	0.002	<0.001			
aspect.s	-0.493	0.193	0.011				-1.149	0.259	<0.001
dwater	-1.253	0.491	0.011						
elev:aspect.s									
slope:aspect.s	0.049	0.016	0.001						
conifer-open	0.269	0.257	0.294	1.476	0.325	<0.001	-0.646	0.579	0.264
deciduous	-0.005	0.23	0.982	0.377	0.218	0.083	0.072	0.285	0.802
grass	-0.935	0.269	0.001	0.489	0.206	0.017	-1.681	0.547	0.002
n	277			288				130	
k-fold	0.856			0.873				0.479	

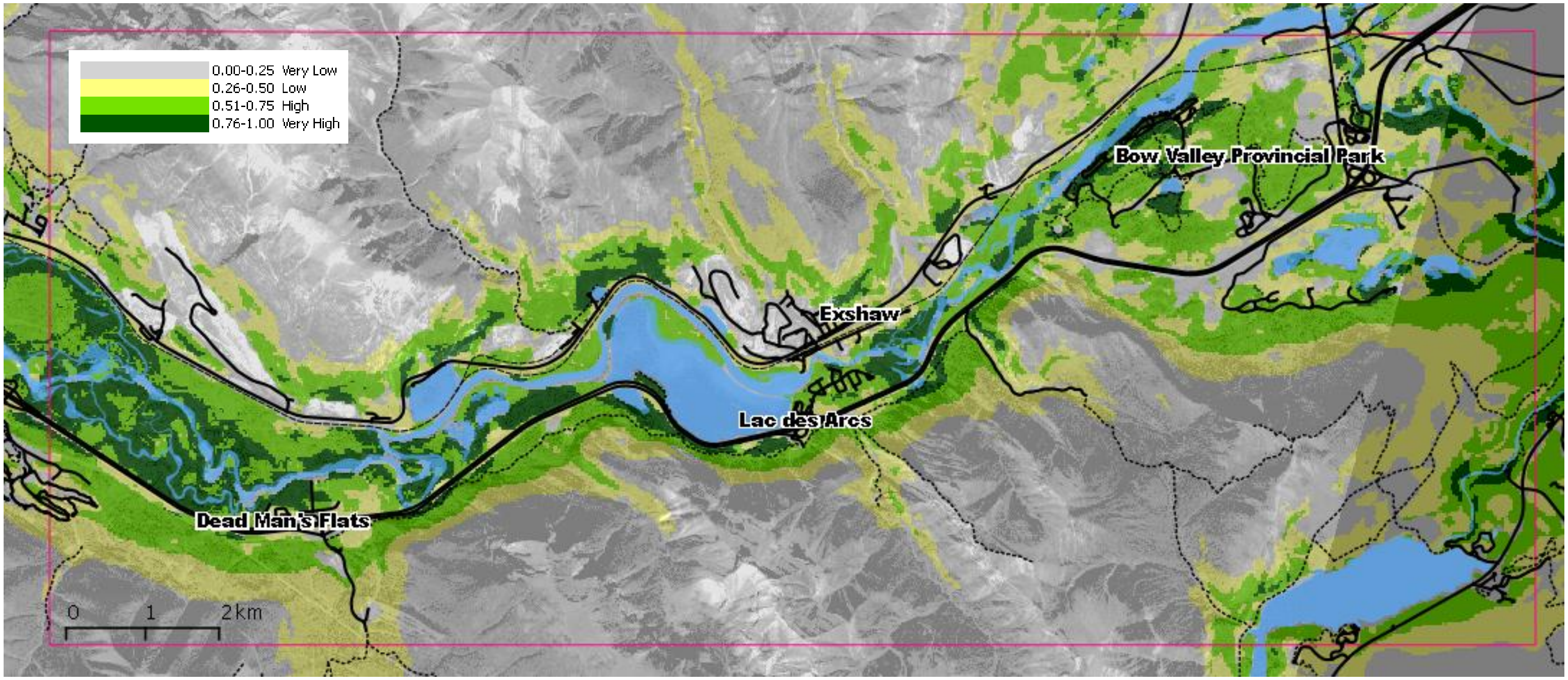

Figure 6. Resource selection maps for cougar in the Eastern Bow Valley study area. Maps show relative probability of species occurrence.

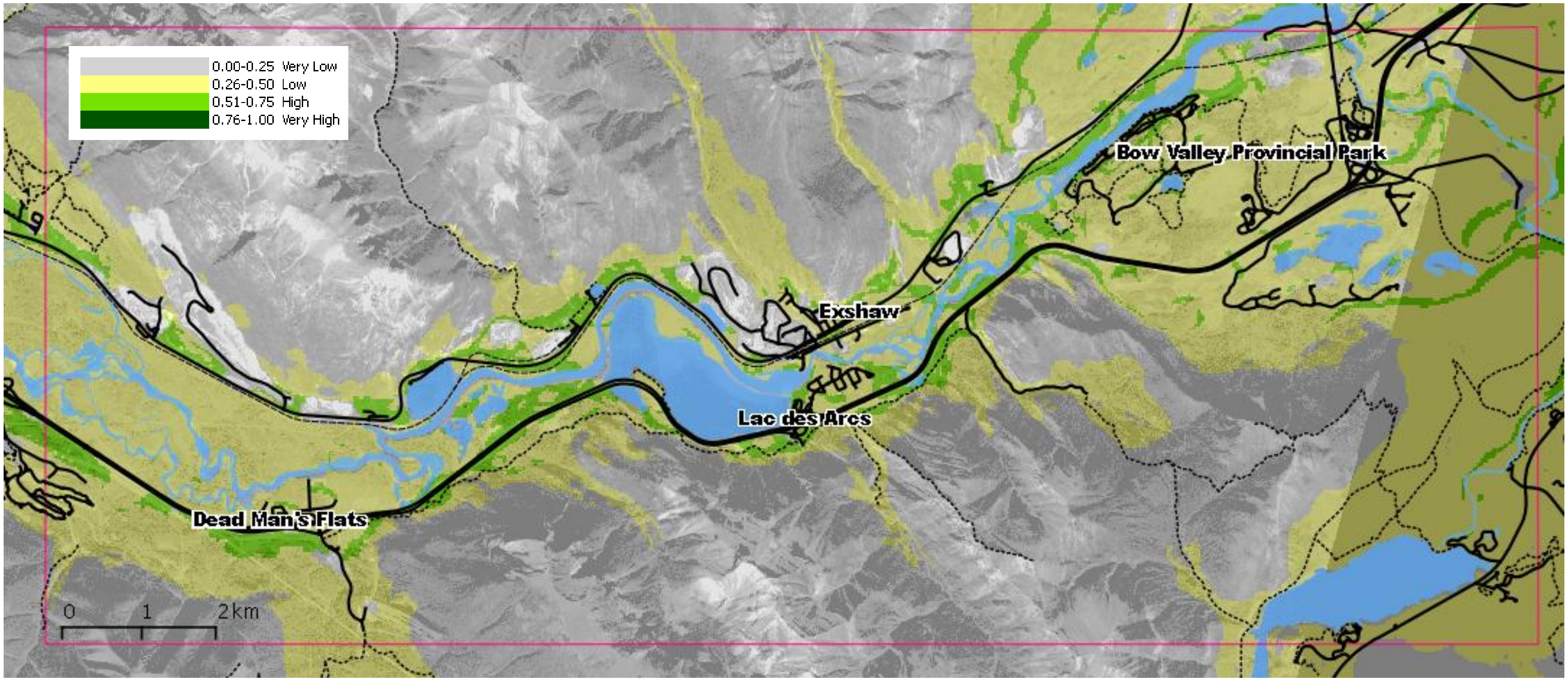

Figure 7. Resource selection maps for wolves in the Eastern Bow Valley study area. Maps show relative probability of species occurrence.

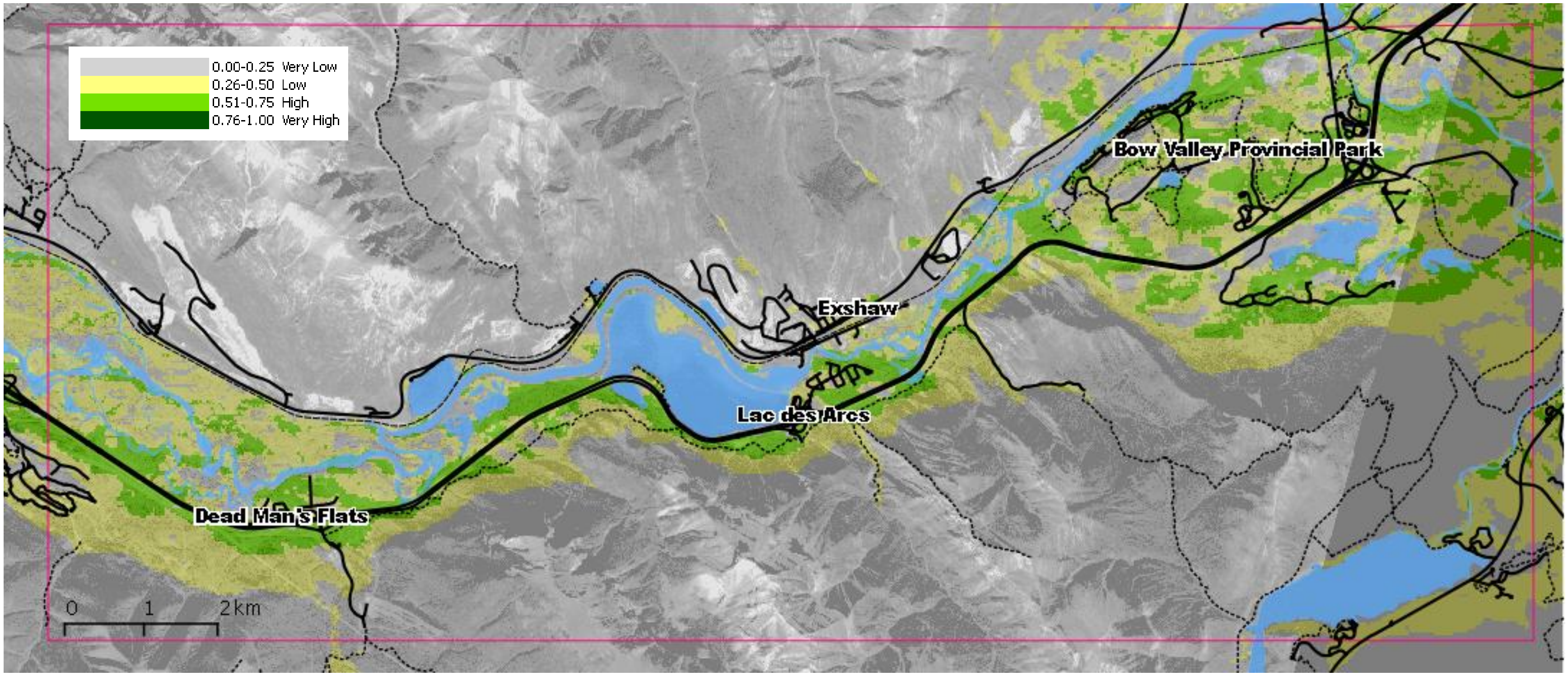

Figure 8. Resource selection maps for lynx in the Eastern Bow Valley study area. Maps show relative probability of species occurrence.

4.3 Regional Movements

4.3.1 Dead Man's Flats – Regional Movements

Wildlife tracking data clearly illustrate the importance of the Dead Man's Flats area for wildlife movement (Figure 9). Cougar, lynx, and wolf have all used the area. Cougars and lynx in particular seem to spend more time in the area north of the TCH, while wolves used the area south of the TCH prior to 2004. Wolves have rarely used the Dead Man's Flats and Wind Valley area since 2004 and have not been detected using the wildlife underpasses, nor during surveys of the Eastern Bow Corridor Study transects. Although relatively few cougar or lynx tracking sessions occurred south of the TCH at Dead Man's Flats, these species likely use the area. Unfortunately, there were no wildlife transects located south of the TCH near Dead Man's Flats except the short transects around the Stewart Creek and Wind Valley underpasses. The Stewart Creek Underpass transect melted out very quickly and there were only a few tracking sessions initiated from that location. Since few cougars and no lynx used the Wind Valley Underpass, there were limited data from this location also. The habitat selection maps for cougar, lynx, and wolf indicate the area south of the TCH is an important travelling area for these three species (Figure 9). Unlike more fragmented habitat patches on the north side of the Bow Valley, the continuous stretch of high quality habitat south of the TCH is more conducive to large scale carnivore movements, albeit on northern aspects and generally in deeper snows.

In order to travel between the two underpasses, carnivores and especially cougars primarily travelled along the Bow River. In this area they encounter two pinch points. The first pinch point occurs between Dead Man's Flats and the Bow River. Here the carnivores must travel through this narrow corridor and through the Three Sisters Campground. The second pinch point occurs approximately 1.5 kilometres west of Dead Man's Flats where the Bow River is within 50 meters of the TCH fencing. Carnivore movements are less constrained in the forested area east of Dead Man's Flats. Carnivores and ungulates often crossed the berm east of Dead Man's Flats to access habitat towards Lac des Arcs.

South of the TCH, it is unclear how carnivores moved between the underpasses because there were few tracking sessions. Wolves used the area south of the TCH broadly and their movements were less confined than the area along the Bow River. However, the wolf data was collected prior to the construction of the Wind Valley Underpass. Cougars occasionally used the powerline area near the Stewart Creek Underpass. In the Wind Valley Underpass area, they used forested cover to move further south and east at the base of Pigeon Mountain.

Few ungulates and carnivores crossed the Bow River near Dead Man's Flats between 2004 and 2009. In that time, 17 crossings were recorded (Table 5). Most crossings occurred during November and December, with only two occurring in February and March. These crossings occurred primarily at the eastern end of the transect. Elk, deer, and coyote were most frequently observed crossing the Bow River, while cougars only crossed tributaries of the Bow River. Flood ice may have obstructed wildlife crossings in this area. The lack of crossings further emphasizes the importance of the area between Dead Man's Flats and the Bow River for wildlife movement.

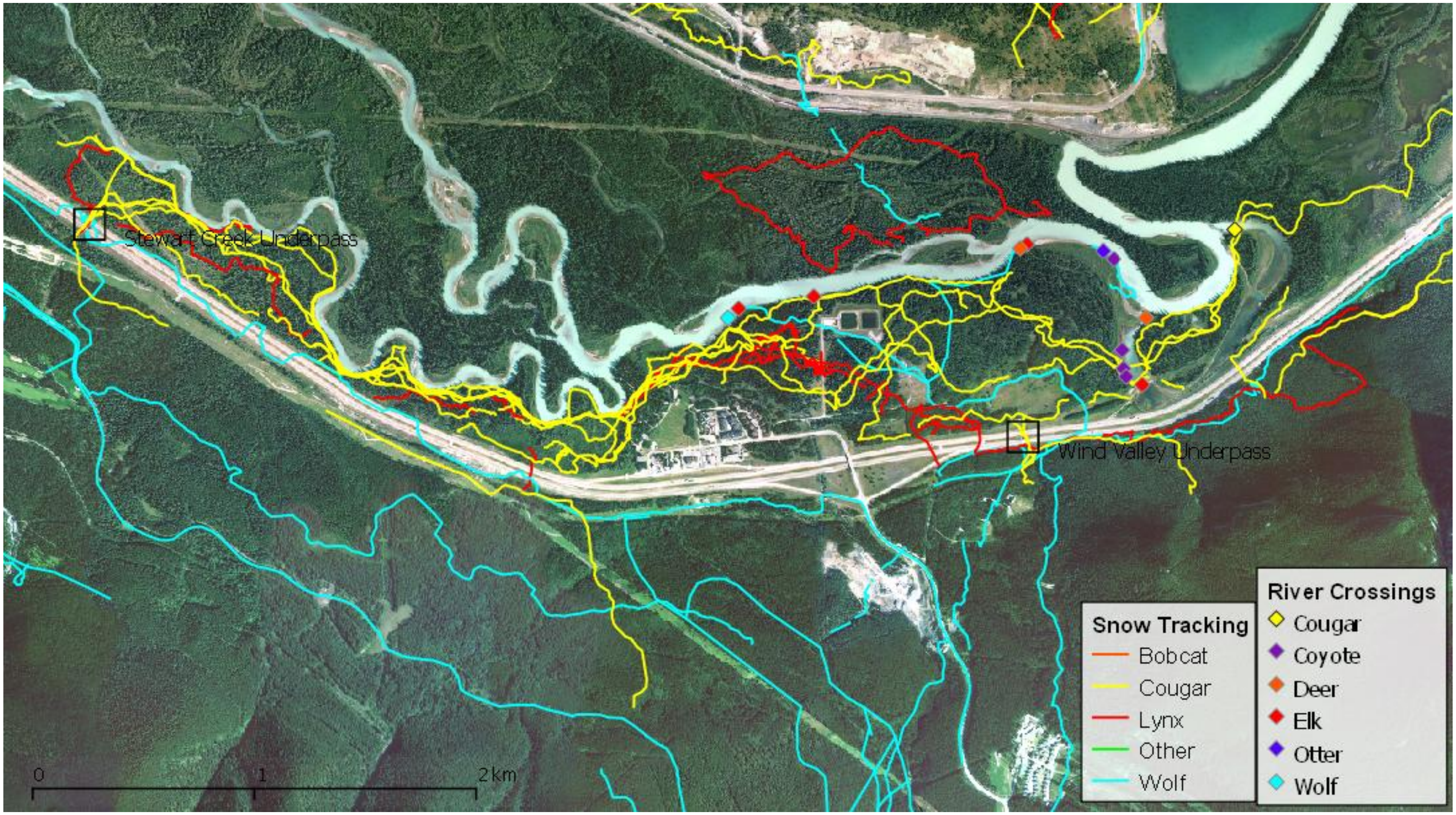

Figure 9. Wildlife snow-tracking data (1997-2009), highway underpass locations, and Bow River crossing locations near Dead Man's Flats.

Table 5. Wildlife crossings of the Bow River near Dead Man's Flats from 2004 to 2009.

Date	Species	Description
21-Nov-04	Elk	2 elk cross river
21-Nov-04	Deer	2 deer cross the berm
07-Feb-05	Elk	3-18 elk cross river
05-Mar-05	Deer	4 deer cross river at berm/causeway
30-Nov-05	Elk	10 elk cross on the berm
03-Dec-05	Coyote	1 coyote crosses river
14-Dec-05	Coyote	1 coyote crosses river ice
14-Dec-05	Coyote	2 coyotes cross on river ice
14-Dec-05	Deer	2 deer cross the berm
01-Feb-06	Coyote	1 coyote crosses river - completely open
30-Dec-06	Elk	3-4 elk cross open river n to s
30-Dec-06	Coyote	2 coyotes cross frozen side channel of river
06-Nov-07	Deer	3 deer cross
06-Nov-07	Elk	2 elk cross river
06-Nov-07	River Otter	4 cross river
06-Nov-07	Deer	2 deer cross tributary
07-Dec-07	Coyote	2 coyotes cross tributary at east end of transect

4.3.2 Gap Lake and East Grotto Mountain – Regional Movements

Cougar, lynx, and wolf all used the area around Gap Lake and the east end of Grotto Mountain. Most of the cougar tracking in the Gap Lake area occurred on the slopes above the private residence and the big bend. Therefore, this area contains important habitat for cougar as corroborated by the resource selection function maps.

There were few tracking sessions west of Gap Lake and it is difficult to generalize how animals travel throughout this region (Figure 10). When travelling east or west, the tracking data suggest cougar and wolves travelled between the mine and Burnco Pit, which is a very narrow area. Alternatively, they crossed the 1A west of the Burnco Pit. The tracking data and the resource selection models suggest the mine and the Burnco Pit are difficult for carnivores to navigate. The mine extends from the 1A to high up on the mountain side and thus bisects patches of high quality habitat with no easy movement route between the two areas. Terrain modification and vegetation enhancements through the mine could greatly improve connectivity for carnivore movements on the north side of the Bow Valley.

Surprisingly, cougar tracks were not detected south of the 1A toward Dead Man's Flats (Figure 10). This area was predicted to contain large patches of high quality habitat from the resource selection analysis and maps (Figure 6).

Few tracking sessions occurred between the big bend and Grotto Pond. Prior to 2004, a wolf used the 1A to travel between the two areas; during the Eastern Bow Corridor Study period, a cougar used the cliffs west of the Howling Dogs kennel facility and the Baymag pit to access the Grotto pond area; and cougars travelled between the Baymag plants and the Baymag pit. Despite the lack of tracking data, the resource selection map for cougars suggests the most important travel corridor for movement extends from the cliffs west of

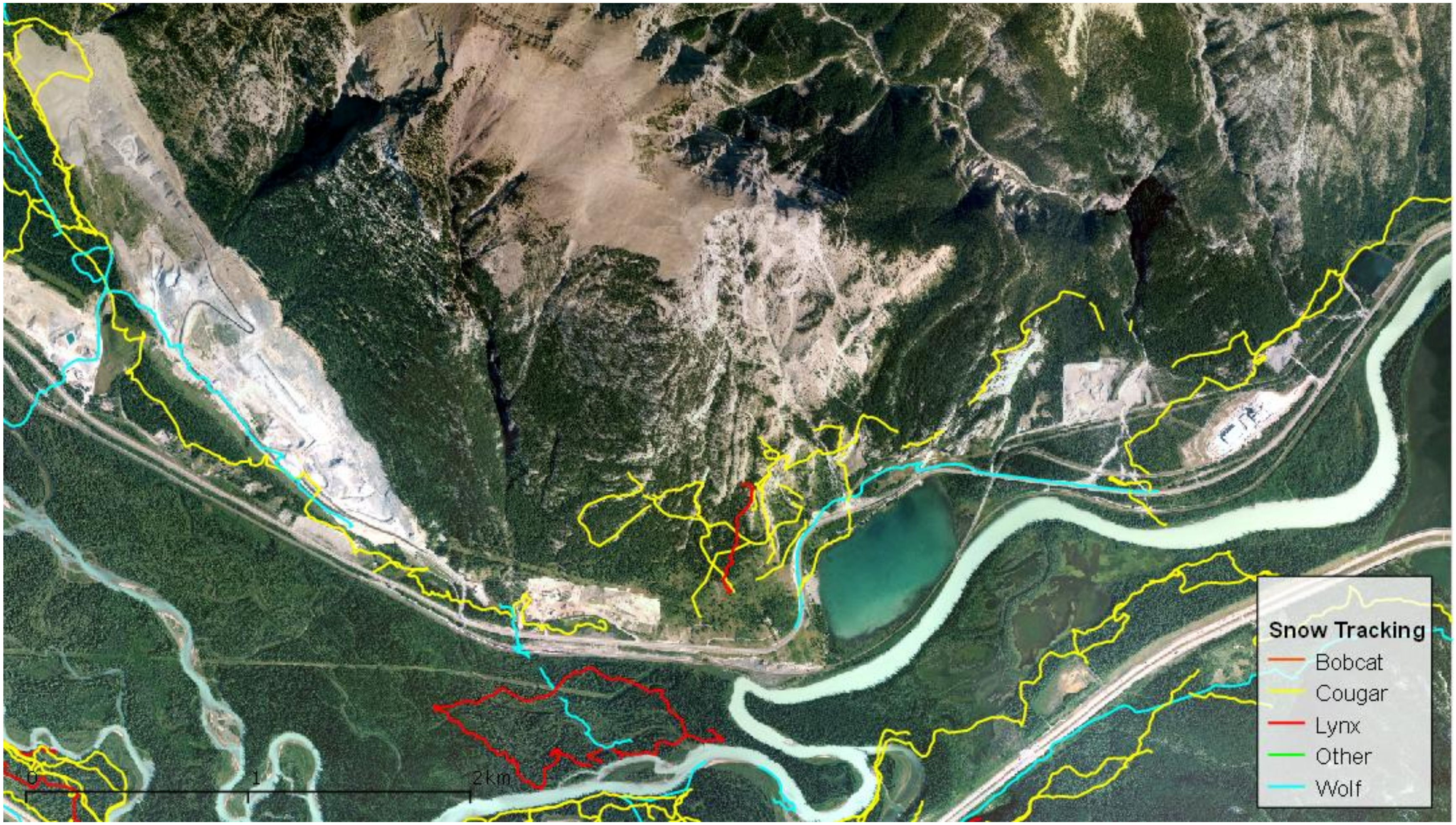

Figure 10. Wildlife snow-tracking data (1997-2009) near Gap Lake and the eastern end of Grotto Mountain.

the Howling Dogs kennel facility, behind the Baymag plant and pit, to the Grotto Pond area. According to resource selection maps, the Grotto Pond area is a very important area for cougars with sizeable patches of high quality habitat running both east and west (Figure 6).

4.3.3 Grotto Pond, Exshaw, Jura Creek – Regional Movements

Cougar and bobcat were the only carnivores detected around the Lafarge plant, Exshaw, and the Jura Creek drainage east of Exshaw (Figure 5). Tracking data were difficult to obtain in these areas because of poor snow conditions, exposure to sun, and high winds that quickly obscured tracks. Cougars generally travelled around the northern limit of the Lafarge quarry and along Exshaw Mountain above the town of Exshaw. Resource selection maps for cougars near the Lafarge plant show disconnected high quality habitat patches, with low habitat quality above the quarry (Figure 6). The area above the quarry is an important movement corridor and development further upslope may obstruct carnivore movements. Habitat enhancements across the quarry could improve habitat connectivity.

Unfortunately, there were no tracking data to determine how cougars negotiate Exshaw Mountain to access the Jura Creek drainage. The area is dominated by steep terrain and cliffs and cougars may travel up and over the mountain. Limited tracking data suggest some cougars may travel from Jura Creek (near the 1A) to a few hundred meters east of Exshaw before heading up and over the mountain.

Resource selection maps for cougars suggest the lower slopes of Exshaw Mountain are important cougar travelling areas, and that lower portions of Jura Creek are not prime travelling areas (Figure 6). However, cougars were occasionally tracked along the lower portion of Jura Creek. This may not have been their preferred travelling habitat, but perhaps they utilize this area for connectivity. There was little tracking data further up Jura creek, mainly because the transect ended at the rock bands near the start of the Jura Creek canyon, and tracks rapidly deteriorated in this area, obscuring our ability to record animal movements.

Resource selection maps also suggest there are some important cougar habitat patches south of Jura Creek and the 1A near the Bow River (Figure 6). Interestingly, cougar were not detected in this area even though this area was checked regularly. Bobcat were tracked twice in this area.

4.3.4 Lac des Arcs – Regional Movements

All three felid species (cougar, bobcat, and lynx) were tracked regularly in the Lac des Arcs region (Figure 11). Very little wolf tracking occurred in the area prior to 2004. Bobcat were the only carnivore species tracked in the area around the hamlet of Lac des Arcs, even though the resource selection maps suggest there is high quality habitat for other species in the area (Figure 6 and 7).

The area south of the TCH toward Quaite Valley was the focus of concentrated cougar, lynx, and bobcat activity and is an important area for carnivores in the Eastern Bow Valley (Figure 11). Bobcat and lynx frequently used the area between Quaite Valley and Heart Creek. Cougar tracks were observed more often in the area south of the

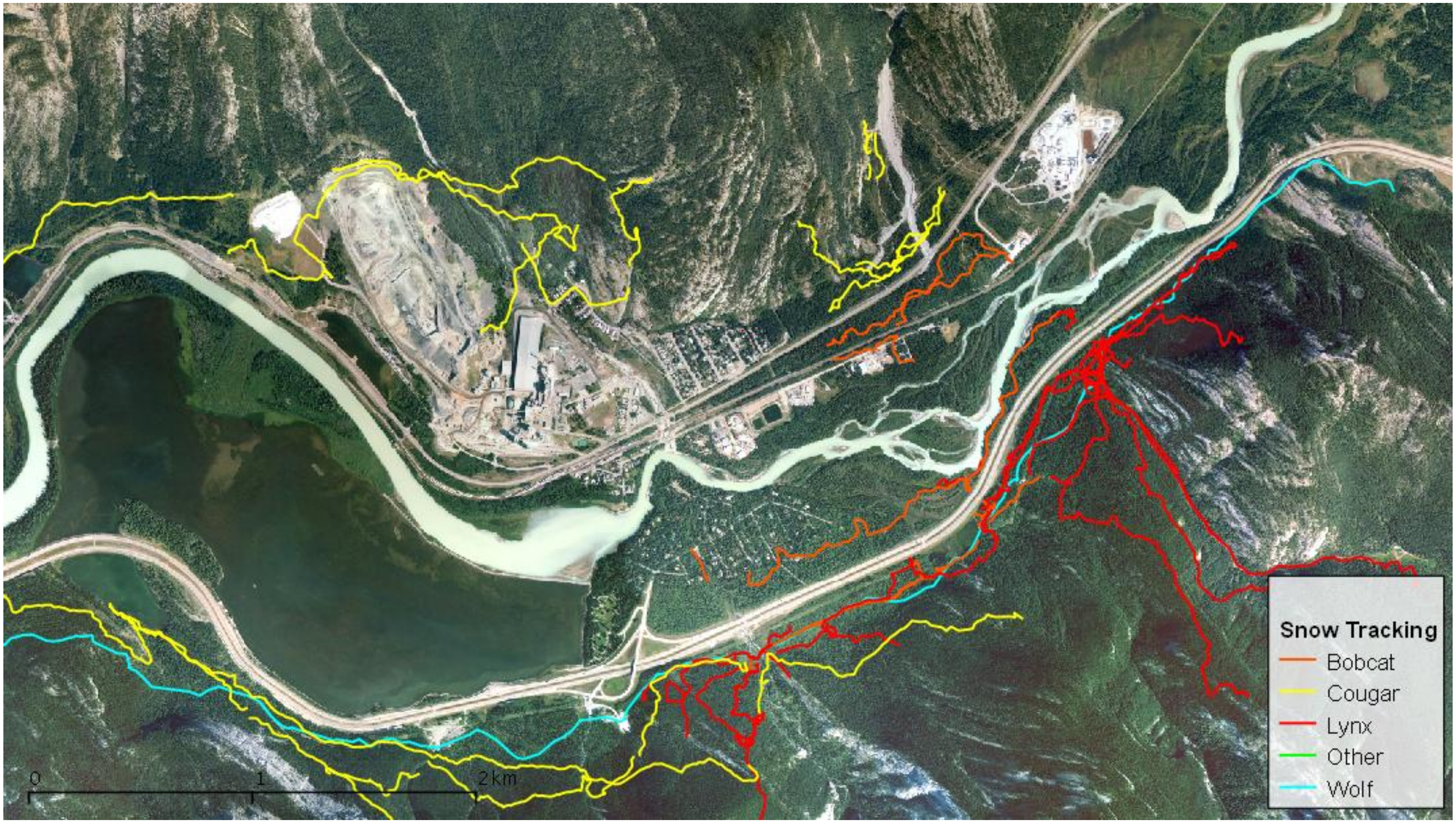

Figure 11. Wildlife snow-tracking data (1997-2009) near Exshaw and Lac des Arcs.

TCH between Heart Creek and the McGillivray slabs area. This long, narrow strip of habitat is another important pinch point for wildlife movement, and is confined by vertical cliffs, the TCH, and contains an alpine club hut and the Trans Canada Trail.

Interestingly, the McGillivray slabs area, and another area a few hundred meters west of the Quaite valley, are the only two sizeable habitat patches of very high quality for cougars south of the TCH in the Eastern Bow Study area (Figure 6).

Few carnivores travelled around the rock cut east of the Quaite Valley. One wolf passed through the rock cut near the TCH prior to 2004, but otherwise, there were no records of carnivores using the area. Tracking conditions east of the Quaite Valley transect were generally poor because of strong winds and shallow snows. Resource selection maps for carnivores suggest there is high quality habitat in the area and the map for cougars suggests there is high quality habitat west, but not immediately east of the rock cut.

5.0 Discussion

The Eastern Bow Valley between Canmore and Bow Valley Provincial Park appears to be a highly fragmented landscape. The movements of many wildlife species are confined to the narrow valley bottoms by cliffs, rugged topography, and deeper snows in winter. Yet, the narrow valley bottom contains several features that appear to obstruct animal movement both across and along the valley bottom. These features include the meandering Bow River, large water bodies, the TCH, the 1A, a railway, three residential areas, and several quarries/mines. Species that selected for steep topography (e.g. bighorn sheep and cougar) and species that were tolerant of human activity (e.g. white-tailed deer) were frequently found in the study area. Wary species that preferred the valley bottoms (e.g. wolves) have rarely been observed in the study area since 2003.

The study area can be divided into three distinct areas based on the snow-tracking data and resource selection function maps of carnivore occurrence. The area north of the 1A contains numerous patches of very high and high quality habitat given its southern exposure and lower snow depths. However, those patches are fragmented by a combination of topography, industrial development, and roads. This is the area most frequently used by cougars. The valley bottom between the 1A and the TCH contains the most very high and high quality habitat in the study area. However, the habitat is fragmented by large water bodies, the meandering Bow River, and two residential areas. Only the area near Dead Man's Flats was consistently used by both cougar and lynx. The area south of the TCH contains only two large patches of very high quality habitat (at the base of McGillivray Slabs and west of Quaite Valley), but it also contains a narrow, continuous strip of high quality habitat. Consequently, carnivores were able to travel continuously from the western end of the study area to Quaite Valley. This area was frequently used by bobcat, lynx, cougar, and wolves (the latter prior to 2004).

5.1 Winter Snow-Transects

While the Eastern Bow Valley is a fragmented landscape, it contains a wide diversity of large and mid-sized mammal species including all felids (cougar, lynx, and bobcat). Coyote, lynx, and cougar were the most commonly detected carnivores on survey transects while sheep and deer were the most commonly detected ungulates. The lack of wolves in the Eastern Bow Valley, in recent years, has likely affected the abundance and distribution of the other mammal species (McLaren and Peterson 1994, Hebblewhite et al. 2005, Kauffman et al. 2007, Kortello et al. 2007). Over the five years of transect monitoring, there was no change in the probability of detecting carnivores (combined), cougar, bobcat, or moose, but there was a slight increase in the probability of detecting lynx. There was no change in the probability of detecting elk, however elk were relatively rare because the snow transects did not overlap areas of high winter elk use near Canmore and Bow Valley Provincial Park. The relative abundance of deer and sheep did not change in the study area generally, but did change on individual transects, which may suggest annual shifts in their regional distribution. The relative abundance of coyotes decreased overall also, but with variability in trends among individual transects.

The snow transects were established primarily to detect carnivore movements for subsequent snow tracking, rather than to detect changes in relative abundance of species. This, combined with the high variability in the number of tracks detected on a survey and the number of transect sessions per winter likely resulted in low power for detecting changes in the relative abundance of each species.

5.2 Snow Tracking and Resource Selection

The cougar, wolf, and lynx resource selection models varied in their performance and similarity to resource selection models from other areas. Cougars generally concentrate their movements in areas with high prey abundance, particularly deer which are their primary prey species (Kortello et al. 2007, Knopff et al. 2009) and which were abundant in this study area. In other studies cougars selected steeper slopes, moderate elevations, areas with moderate prey abundance, and riparian areas (Goh 2000, Duke 2001). Cougars in this study area selected for lower elevations and steeper slopes but only on southern aspects. These are the same areas with lower snow depths that are favoured by deer. Cougar may have been more prevalent than wolves in the study area because they are more tolerant of human activity (Bier 1991, Jalkotzy and Ross 1995, Weaver et al. 1996) and use steeper terrain. The cougars may also have benefited from less direct competition for prey with wolves and a reduced risk of mortality from wolves (Kortello et al. 2007).

Wolves in most areas of the Rocky Mountains select low elevations, shallow slopes, south-western aspects, and open forests (Paquet 1993, Duke 2001, Callaghan 2002, Whittington et al. 2005, Hebblewhite and Merrill 2007, Hebblewhite and Merrill 2008, Webb 2009). Based on data collected between 1997 and 2009, wolves in this study area showed similar patterns, except they strongly selected moderate slopes over shallow slopes. This selection for moderate slopes had a pronounced effect on the resulting resource selection maps that showed very little high quality habitat in the valley bottom. Our model likely reflects wolf movements in a fragmented landscape. Most wolf tracking occurred on moderate slopes either south of the TCH or north of the 1A and it appears that wolf access to the valley bottom is obstructed by developments in the valley. The Eastern Bow Valley does not contain enough habitat for even a single wolf pack, which generally require territories of approximately 1000 km^2 in the Rocky Mountains (Callaghan 2002). Thus, wolves may access the study area only as part of a larger home range. Wolves have traditionally entered the Eastern Bow Valley from the Bow Valley west of Canmore either on the north or south side of Canmore, or, from the Kananaskis Valley via Skogan Pass or through Bow Valley Provincial Park. Since 2004, only two wolves have been detected entering the west edge of the study area four times across the north side of Canmore. Currently, wolf use of the study area is very rare. Wolf packs, while generally wary, exhibit considerable variability in behaviour towards human activity (Hebblewhite and Merrill 2008). Given the amount of human activity and development within and around the study area, wolves will likely need to be relatively tolerant of human activity to use this area in the future.

The lynx resource selection model discriminated poorly between lynx locations and random locations, and the resources selected differed somewhat from other studies. Lynx in the broader southern Canadian Rocky Mountains selected for high elevations, moderate slopes, higher solar incidence, and young pine or spruce forests (Apps 2003), whereas lynx in this study selected for low elevations, northern aspects, and avoided grasslands. The results of the lynx model are questionable given the limited tracking data relative to other carnivores, poor model performance, and lack of corroboration with other studies.

The models may not generalize well to other areas because of the high levels of human activity in the study area. In other areas, species' may have selected different attributes in the absence of human activity (e.g. wolves may have selected shallow slopes rather than moderate slopes). The resource selection models are limited to winter movements and do not account for temporal effects of human activity on carnivore movements (Percy 2003, Hebblewhite and Merrill 2008) nor do they explicitly model the effects of human activity on habitat quality. More robust resource selection models would account for temporal movement patterns and would avoid potential biases associated with snow-tracking conditions. The resource selection models here do however highlight the importance of valley bottom habitat to carnivores.

5.3 Regional Movements

5.3.1 Dead Man's Flats – Regional Movements

The Dead Man's flats area is clearly an important area for wildlife movement in the Eastern Bow Valley. It is one of the only places along the valley bottom where extensive carnivore tracking data overlaps with large patches of high quality habitat as predicted by the resource selection function models. Even so, animals rarely crossed the Bow River in winter and their movements were confined between the Bow River and Dead Man's Flats, and the Bow River and the TCH. There was little carnivore activity through the Wind Valley Underpass. The high concentration of carnivore movements between the Bow River and Dead Man's Flats and the rarity of wildlife crossings across the Bow River suggest it is essential to maintain east-west habitat connectivity in the Dead Man's Flats area, since north-south carnivore connectivity may be limited by the Bow River and the TCH. Human activity in this area should be minimized to allow wary carnivores to travel safely through this pinch point. In addition, the wildlife underpasses should continue to be monitored for changes in use and a better understanding of factors affecting carnivore use of the Wind Valley Underpass is required.

5.3.2 Gap Lake and East Grotto Mountain – Regional Movements

The southern slopes of this region contain high quality habitat for many species, especially cougar. However, the quarry east of Canmore extends from the valley bottom to high up on Grotto Mountain and thus obstructs animal movements and fragments the landscape. Cougars frequently used the area above the big bend and Gap Lake, but surprisingly little use by any carnivore species occurred on the south side of the 1A. The resource selection models predict high quality habitat in the area, yet it is unclear whether carnivores avoided the valley bottom area or whether the transect received less use because it was situated where the Bow River potentially obstructed all valley bottom movements.

5.3.3 Grotto Pond, Exshaw, Jura Creek – Regional Movements

Cougars were the only carnivore species tracked on the north side of the 1A from Grotto Pond to Jura Creek. Cougars can currently travel above the Lafarge plant due to a narrow utility ledge built into the mountain at the back of the quarry. However, the concentration of cougar tracking at the edge of the quarry and the lack of high quality habitat above, suggests that connectivity is tenuous and reclamation work to facilitate east-west animal movements could be highly beneficial to many wildlife species, including cougars.

Carnivore movement south of the 1A and the town of Exshaw was likely precluded by the railway, human development and the Bow River. Limited tracking data show that bobcat were the only wary carnivore that made use of this fragmented habitat. The Jura Creek area is important for connectivity with Bow Valley Provincial Park. Cougar movements are confined to a narrow band when crossing Jura Creek in an exposed area of relatively poor quality habitat.

The Francis Cook landfill may obstruct animal movements. While no carnivore tracking occurred in the area, the resource selection function maps and topographical constraints indicate the landfill creates a pinch point that carnivores must navigate to access habitat toward Yamnuska. Based on resource selection function maps, there are disconnected patches of high quality habitat interspersed with low quality habitat in the area.

5.3.4 Lac des Arcs – Regional Movements

In the immediate vicinity of Lac des Arcs, bobcat were the only wary carnivore tracked in the area, despite the fact this area has patches of high quality habitat based on resource selection maps. That habitat patch is bounded by Lac des Arcs, the Bow River, and the TCH and is therefore relatively isolated from other habitat patches.

South of the TCH, tracks of cougar, lynx and bobcat were regularly found, and with spatial overlap. Lynx and bobcat were most often found around Quaite Valley, while cougar were more often found travelling between Heart Creek and McGillivray Slabs.

Based on snow tracking and the resource selection models, the McGillivray Slabs area appears to be an important area for future consideration. This area showed up as one of only two sizeable patches of very high habitat quality for cougars and to a lesser extent, carnivores, in the Eastern Bow Study Area south of the TCH.

6.0 Limitations & Recommendations for Future Research

For the entire study area north of the TCH, and to a lesser extent, south of the TCH, shallow snows coupled with high winds made it difficult to snow track carnivores. Although snow tracking has been found to be a highly effective method for identifying habitat use for mammals in many study areas, the scant snow and high winds of the Eastern Bow Valley resulted in a relatively small amount of data for relatively high effort. Other methods such as GPS-collared animals and remote wildlife cameras may be more effective methods for identifying habitat use, spatial, and temporal movement patterns. The snow-tracking data that was collected, however, clearly identifies how animals are travelling across the study area. While there are some biases associated with snow tracking, those biases were minimized by snow-tracking only after recent snowfalls and in the analysis by pairing random (available) locations with animal locations. The tracking data combined with the resource selection maps clearly show that the Eastern Bow Valley is a highly fragmented landscape.

Levels of human activity on trails and roads affect the spatial and temporal use of carnivores in the Eastern Bow Valley as most carnivores generally try to avoid encounters with people (Callaghan 2002, Gibeau et al. 2002, Percy 2003, Whittington et al. 2004, Whittington et al. 2005, Donelon et al. 2006, Hebblewhite and Merrill 2008). We lacked levels of trail use for the study area and examining the spatial effects of trail use on carnivores without accounting for seasonal and temporal effects could produce misleading results (Percy 2003, Hebblewhite and Merrill 2008), therefore we did not address the effects of human activity on habitat quality and animal behaviour in this analysis. Spatio-temporal effects can be addressed using data from ongoing remote camera research, GPS data from radio-collared animals, and concurrent human-use data from infrared trail-counter research. Similarly, more robust resource selection models would require GPS data from the species of interest. Cougar are the most common carnivore in the study area, yet they are generally more tolerant of human activity and select more rugged terrain than other carnivores. Resource selection functions would be stronger by including animal location covering a gradient of human use and habitat fragmentation and occurring both within and outside the current study area. Snow transects have relatively low power to detect trends, yet if change in the relative abundance of animals is of interest then each transect should be sampled approximately 10-12 times per year (Whittington, unpublished analyses). This may be unachievable in the study area due to weather patterns.

7.0 Recommendations

1) Collect further data to determine how human use affects carnivore habitat use and movements within the Eastern Bow Valley:
    a. Use GPS and/or remote wildlife cameras to address the spatio-temporal effects of trail use on carnivore movements;
    b. Examine species variability in response to humans;
    c. Continue to collect human use data on trails with the use of infrared trail counters.
2) Tailor land use to provide secure movement opportunities in the following areas and pinch points where we have corroborating tracking data and predicted habitat quality from resource selection models:
    a. Bow River corridor west of Dead Man's Flats (pinch point);
    b. Three Sister's Campground at Dead Man's Flats (pinch point);
    c. McGillivray Slabs area (Corridor);
    d. Jura Creek (Corridor);
    e. Quaite Valley (Corridor);
    f. Bow Valley rock cut east of Lac des Arcs.
3) Consider enhancements to increase landscape connectivity in the following regions:
    a. Wildlife movement corridors north of, or across, the Lafarge quarry at Exshaw;
    b. Wildlife movement corridors across/around the Burnco quarry in the western portion of the study area;
    c. Build additional wildlife highway crossing structures in high-use areas for wildlife such as at Quaite Valley.
4) Extending Cooperation:
    a. Work collaboratively with other stakeholders in the Bow Corridor Rock Industry Group to restore movement corridors and protect critical habitat patches.

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