WCS CANADA CONSERVATION REPORT NO. 3 | SEPTEMBER 2007

WILDLIFE CONSERVATION SOCIETY
CANADA

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CORE AREAS AND CONNECTIVITY ACROSS THE CROWSNEST HIGHWAY

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WILDLIFE CONSERVATION SOCIETY
CANADA

WCS Canada Conservation Reports:
ISSN 1719-8941 Conservation Report Series (Print)
ISSN 1719-8968 Conservation Report Series (Online)
ISBN 978-0-9784461-0-9 Conservation Report No. 3 (Print)
ISBN 978-0-9784461-3-0 Conservation Report No. 3 (Online)

Copies of WCS Canada Conservation Reports are available from:
Wildlife Conservation Society Canada
720 Spadina Avenue, Suite 600
Toronto, Ontario M5S 2T9 CANADA
Telephone: (416) 850-9038
www.wcscanada.org

Suggested Citation:
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.

Cover Photo:
Front Cover photo: Clayton Apps. View of Crowsnest Highway (Highway 3) and Crowsnest Pass looking northwest from Alberta into British Columbia. Back Cover photo: Clayton Apps. View looking north of Crowsnest Highway at Fernie, British Columbia. Lynx: John Weaver. Grizzly bear: Joe Lederer.

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ACKNOWLEDGEMENTS

We thank the Wilburforce Foundation for their vision of conservation in North America and their generous funding of our project on carnivores and connectivity in this strategic area of the Rocky Mountains. We especially thank Gary Tabor and Jennifer Miller at Wilburforce for their support and encouragement (and patience!), and their outstanding leadership in conservation from Yellowstone to the Yukon. We appreciate a grant from the Sage Foundation that enabled additional field reconnaissance at an important time. We thank the Woodcock Foundation and the Y2Y Conservation Initiative Society for funding the printing of this report and associated communications.

The Wildlife Conservation Society/ Wildlife Conservation Society Canada administered this project. We appreciate the vital support of Bill Weber, Jodi Hilty, Martha Schwartz and Ingrid Li of the Wildlife Conservation Society and Gillian Woolmer and Justina Ray of Wildlife Conservation Society Canada.

We also salute the conservation leadership by Harvey Locke; Jan Garnett, Dave Hillary, Larry Simpson, and Ron Montgomery - Nature Conservancy of Canada, and Dennis Rounsville of Tembec Forest Management for their collaborative efforts to secure key wildlife habitat in the Elk Valley and Crowsnest Pass area.

Members of the Alberta Conservation Officer Service, Frank DeBoone and Joe Caravetta of the British Columbia Conservation Officer Service, and Carla Fraser and Kari Stuart-Smith of Tembec Forest Management helped to coordinate our field activities with other land uses. Bighorn Helicopters provided safe and proficient helicopter services. Michael Proctor and Bruce McLellan provided indispensable advice on design and logistics related to DNA hair-snag sampling for bears. David Paetkau and his staff at Wildlife Genetics International conducted the DNA analyses with their customary competence and diligence.

Carnivores can be difficult species to study in the field, and data comes slowly. We wish to acknowledge and honor the many field biologists who have collected data on carnivores throughout the southern Canadian Rockies and northwestern Montana. Their impressive accomplishments and contributions are evident in the Literature Citations of this report. We also thank Trevor Kinley and Nancy Newhouse (badgers) and John Krebs (wolverines) who shared their valuable expertise in development of species-specific models.

SUMMARY

The 'southern Canadian Rocky Mountains' — between Banff National Park and Glacier National Park at the U.S. border — support an assemblage of carnivores that appears unique in North America for its intact diversity. Due to their particular geographic position, the southern Canadian Rockies also represent one of the most strategically important sections in maintaining broad ecological connectivity in the western mountains of North America.

The predominant orientation of mountains and valleys in the southern Canadian Rockies provides natural north↔south movement conduits for wide-ranging carnivores. However, this natural connectivity is vulnerable to fracture by the Crowsnest Highway (Hwy 3) transportation and development corridor that runs mostly east↔west. Expanding human developments and activities — along the Crowsnest Highway but also throughout the region — pose a threat to maintaining the security and connectivity of habitats and populations across this landscape. The increasing extent and intensity of this network may fragment carnivore populations into smaller and more vulnerable units, reduce gene flow, and restrict options for ecological and geographic shifts in response to climate change.

To address this problem of habitat and population fragmentation, we conducted modeling and field research during 2001-2004 to provide critical information pertaining to the viability, security, and connectivity of carnivore populations across the southern Canadian Rockies.

In stage 1, we selected a suite of six carnivore species — grizzly bear, lynx, badger, bobcat, wolf, and wolverine — that represent a broad variety of ecological conditions. For each of these landscape species, we developed and applied regional models of distribution and vulnerability across the entire southern Canadian Rockies (30,000 km^2). In stage 2, we used hair-snaring and DNA analysis to sample the actual distribution of two species (grizzly bear and lynx) within a zone (10-20 km wide) that paralleled and included the Crowsnest Highway. We collected these field data to assess and refine the regional models and to determine occurrence and general movements relative to the highway.

Our modeling projected rather high landscape suitability for grizzly bears in the mountains and higher foothills throughout much of our study region, both south and north of the Crowsnest Highway. Landscapes of high suitability include the following areas: (1) the lower Flathead basin (BC) and adjacent Castle drainage (AB), (2) east side of the Wigwam basin (BC), (3) the upper

reaches of the Flathead basin (BC) and adjacent Carbondale area (AB), (4) Michel Creek (BC) and adjacent Ptolemy Creek area (AB), (5) Alexander drainage (BC) and upper Oldman River basin (AB), (6) upper Elk River basin (BC) and adjacent upper Highwood River drainage (AB), (7) west side of the upper Elk River (BC), and (8) Lizard Range (BC).

Our model of landscape suitability for lynx projected a patchy distribution of highly suitable habitat along major ridge complexes and valleys at higher elevations. This patchy distribution indicates that the stability of the regional lynx population likely is dependent on the productivity, security, and connectivity of several key areas. Important landscapes include: (1) ridges east of Fernie and south of Sparwood and the upper Flathead River basin in British Columbia, (2) upper Elk River drainage and confluence of the upper branches of the White River in BC, and (3) a narrow band of habitat in Alberta just east of the Continental Divide extending from upper Racehorse Creek northward to upper Highwood River. In some areas, young conifer regeneration following natural fire or logging has provided suitable habitat at present for snowshoe hare and lynx. Habitats along the primary highways in the major valleys usually provide lower suitability.

Landscapes with potential to support badgers coincide with low elevations and relatively dry and open conditions. Our modeling suggested that the most extensive landscapes with high suitability for badgers occurs primarily in the dry, open grasslands of the Rocky Mountain Trench along Highway 93 in British Columbia and the Rocky Mountain foothills north and south of Lundbreck in Alberta.

Given that bobcats in this region currently are near the limit of their geographic range, their habitats coincide with low elevation forested landscapes associated with relatively dry and mild climatic conditions in winter. Distribution of bobcats tends to be somewhat peninsular in this region, occurring mostly along the flanks of the Rocky Mountain Trench parallel to Highway 93 in British Columbia as well as forested plains and foothills in Alberta.

The potential distribution of wolves coincides mostly with major valley networks throughout the region — specifically the grasslands and foothills flanking the east side of the Canadian Rockies in Alberta and the larger montane valleys in British Columbia such as the Elk, Flathead, Kootenay, and Columbia River valleys. However, the actual distribution of this species has undoubtedly been impacted by human efforts to reduce wolf numbers. Currently, the regional wolf population likely is dependent on the productivity and somewhat higher security of landscapes such as the Flathead River basin and the upper Elk Valley. Wolf research within the region supports the conclusion that major valleys parallel to the Continental Divide from Glacier National Park up to Banff National Park and associated passes along the Continental Divide are conduits for wolf movements. In particular, the Flathead River, upper Carbondale-Castle River, and upper Elk River valleys appear to be important areas for wolves.

Our model of landscape suitability for wolverines predicted rather high suitability in the mountains and higher foothills throughout much of the regional study area. Many of the areas of high suitability for grizzly bear also appear good for wolverines.

Not surprisingly, our modeling suggested that this suite of carnivores are most vulnerable where suitable landscapes occurred proximal to settlements, highways, and primary roads in the region that facilitate high-intensity recreation and motorized access. These include Hwy 3 (Crowsnest Highway), Hwy 43 (Elkford Highway), and Hwy 93 in British Columbia, and Hwy 3, Hwy 22 (Chain Lakes Highway), Road 940 (Forestry Trunk road) and Road 774 (Castle River road) in Alberta.

Through our summer field surveys in the vicinity of Crowsnest Pass, we detected 38 grizzly bears in 29 (81%) of the 36 grid cells (900 km^2 total size). Grizzly bears were common both north and south of the highway in terms of occupancy, occurrence, and relative density. We found grizzly bears concentrated in several areas. One area occurred south of the Crowsnest Highway near Crowsnest Pass itself and along both sides of the Continental Divide. Another concentration occurred north of the Crowsnest Highway and along either side of the Continental Divide in the upper reaches of Alexander Creek and the Oldman River. We detected one female and two males on both sides of the Crowsnest Highway and several others on both sides of the Continental Divide.

Within the same survey grid, we detected a minimum of seven lynx (6 males and 1 female) at 17 sites in 13 cells. North of the Crowsnest Highway, lynx detections clustered in upper Alexander Creek. South of the Highway, lynx were detected primarily west of Michel Creek. Although we did not detect any lynx individual on both sides of the highway, the Alexander-Michel Creek linkage appears to be a likely north↔south connector. For lynx, west↔east linkages across the Continental Divide are likely to include Racehorse Pass north of Crowsnest Highway and Tent Mountain and Ptolemy Passes south of the highway.

Within the lower Elk Valley grid, we detected 52 grizzly bears in 29 (73%) of the 40 cells during various survey sessions. We detected two males on both sides of the Crowsnest Highway. Grizzly bears were more common west of the Crowsnest Highway in terms of occupancy, occurrence, and relative density. We found grizzly bears to be concentrated in the ranges west of the Crowsnest Highway, including the Lizard Range between Elko and Fernie, the Island Lake and Iron Creek drainages west of Fernie, and the environs of Hartley Pass to the northeast. Although grizzly bear density abundance appeared to be lower east of the highway in the lower Elk Valley, we did detect several individuals within the Coal Creek and Morrissey Creek drainages east of Fernie.

On the same grid, we detected a minimum of seven lynx (4 males and 3 females) at 22 sites in nine cells. All of the lynx detected in this grid occurred in the upper drainages <u>east</u> of the Crowsnest Highway primarily between Sparwood and Fernie. This clumped distribution was consistent with predictions of our regional population distribution model. Although we detected no individual lynx on both sides of the Crowsnest Highway, optimal habitat did not occur directly adjacent to the highway in the valley, and major features such as highways often represent home range boundaries for lynx.

A review of scientific studies along other major highways in the region indicates that highways with high traffic volume strongly restrict carnivore movements and have the potential to fragment populations. Grizzly bears are particularly vulnerable to these effects, with reproductive females being especially susceptible. Trains running on railroads that parallel major highways have been a major source of mortality. However, perhaps the greatest impact of highways is the cumulative human activity and spin-off development that they have facilitated over decades; current settlement and development patterns continue to proliferate along highways and associated access. These broader-scale impacts may well be the ultimate factor fracturing some carnivore populations. Through systematic sampling focused on the Crowsnest Highway, we confirmed that the highway and associated development has reduced the potential for movement by grizzly bears and perhaps lynx.

Two robust principles in conservation science are fundamental to a successful conservation strategy for carnivores, particularly in multiple-use landscapes such as the southern Canadian Rockies:

- ➢ safeguard against excessive mortality via a network of core areas of security with appropriate regulations, and
- ➢ maintain connectivity across the region with landscape linkages that connect core areas.

We identified and mapped 15 core areas in the southern Canadian Rockies and rated them in terms of conservation significance and current level of relative security with consideration for grizzly bear, lynx and wolverine. The following areas warrant special attention because they were rated as having *high to very high conservation significance* and *low to moderate levels of security* at present:

- Lower Flathead (BC),
- Michel (BC) – Ptolemy (AB),
- Upper Elk (BC) – Upper Highwood (AB), and
- Lizard Range – Hartley Pass (BC).

In addition, the West Elk – Upper Bull (BC) was rated as having high conservation significance, but security appears high at this time.

We identified and mapped 11 landscape linkages and movement corridors relative to the Crowsnest Highway and rated them in terms of conservation significance and level of vulnerability. We identified these connections based upon the modeling of key habitats for the focal species, empirical data from the hair-snagging surveys (grizzly bear and lynx), preliminary radio-tracking data (grizzly bear), and current mapping of existing human developments and activities. The following linkages warrant special attention because they were rated as having *high to very high conservation significance* and *moderate to high level of vulnerability*:

- Fernie to Morrissey
- Lizard Basin to Elk Valley
- Coal Creek to Elk Valley
- Mount Fernie slopes
- Hartley across Elk Valley
- Hosmer to Sparwood
- Michel Ck to Alexander Ck
- Crowsnest Municipality West

Several mountain passes provide crucial passage across the Continental Divide in the vicinity of Crowsnest Pass where connectivity across Highway 3 is quite limited: Ptolemy Pass, Tent Mountain Pass, Deadman Pass, and Racehorse Pass.

We urge land and resource managers, in concert with key stakeholders and the public, to implement the following recommendations toward conserving carnivores and other wildlife in the southern Canadian Rocky Mountains and ensuring that their populations are connected across the Crowsnest Highway.

✓ 1. Maintain a network of core areas with a high level of security through appropriate management practices. Important considerations include access management (implementing the Southern Rocky Mountain Access Management Plan), and avoiding excessive mortality through appropriate hunting and trapping regulations.

✓ 2. Develop a proactive conservation plan to provide connectivity across and around the Crowsnest Highway. This plan should consider assessment and planning of possible highway expansion, incentives for land-use covenants, and other practices.

In the context of expanding human population and developments and climate change, time is running out on these options.

SOMMAIRE

Les « Rocheuses canadiennes du Sud » – situées entre le parc national Banff et le parc national des Glaciers à la frontière américaine – assurent la survie d'un groupe de carnivores dont l'intégrité de la diversité semble unique en Amérique du Nord. En raison de leur positionnement géographique particulier, les Rocheuses canadiennes du Sud représentent également une des régions les plus importantes sur le plan stratégique pour maintenir un niveau élevé de connectivité écologique des montagnes de l'ouest de l'Amérique du Nord.

L'orientation prédominante de montagnes et de vallées dans les Rocheuses canadiennes du Sud crée des corridors de déplacement nord↔sud naturels pour les carnivores à distribution étendue. Cependant, cette connectivité naturelle est vulnérable au morcellement par le corridor de transport et de développement de l'autoroute Crowsnest (autoroute 3) qui s'étend principalement d'est en ouest. L'expansion des développements et des activités anthropiques – le long de l'autoroute Crowsnest et dans la région tout entière – met en péril le maintien de la sécurité et la connectivité des habitats et des populations sur ce territoire. L'accroissement de l'étendue et de l'intensité de ce réseau risque de fragmenter les populations de carnivores en unités plus petites et plus vulnérables, de réduire le flux génétique et de limiter les transferts écologiques et géographiques en réaction aux changements climatiques.

Pour nous attaquer au problème du morcellement des habitats et des populations, nous avons mené de la modélisation et des études sur le terrain entre 2001 et 2004 afin de recueillir des données critiques sur la viabilité, la sécurité et la connectivité de populations de carnivores dans les Rocheuses canadiennes du Sud.

Au cours du premier stade, nous avons examiné six espèces de carnivores – grizzli, lynx, blaireau, lynx roux, loup et carcajou – qui tiennent compte d'une grande diversité de conditions écologiques. Pour chacune de ces espèces sur le territoire, nous avons élaboré et appliqué des modèles régionaux de distribution et de vulnérabilité sur l'ensemble du territoire des Rocheuses canadiennes du Sud (30 000 km^2). Au cours du deuxième stade, nous avons eu recours à la collecte de poils et à l'analyse d'ADN pour échantillonner la distribution réelle de deux espèces (grizzli et lynx) à l'intérieur d'une zone d'une largeur variant entre 10 et 20 kilomètres qui longeait et incluait l'autoroute Crowsnest. Nous avons recueilli ces données sur le terrain afin d'évaluer et de peaufiner les modèles régionaux et de déterminer les occurrences et les déplacements généraux relativement à l'autoroute.

Notre travail de modélisation a projeté une compatibilité relativement élevée du territoire pour les grizzlis dans les montagnes et les contreforts plus élevés sur la vaste majorité de la région à l'étude, à la fois au sud et au nord de l'autoroute Crowsnest. Les territoires de compatibilité élevée incluaient : (1) la partie inférieure du bassin de la rivière Flathead (CB) et le bassin versant de la rivière Castle adjacent (AB); (2) la partie est du bassin de la rivière Wigwam (CB); (3) la partie supérieure du bassin de la rivière Flathead (CB) et la région Carbondale adjacente (AB); (4) le ruisseau Michel (CB) et la région adjacente du ruisseau Ptolemy (AB); (5) le bassin versant du ruisseau Alexander (CB) et la partie supérieure du bassin de la rivière Oldman (AB); (6) la partie supérieure du bassin de la rivière Elk (CB) et la partie supérieure du bassin versant adjacent de la rivière Highwood (AB); (7) la partie supérieure ouest de la rivière Elk (CB); et (8) la chaîne Lizard (CB).

Notre modèle de compatibilité du territoire pour le lynx a extrapolé une distribution éparse d'habitats très compatibles le long des principaux complexes de crêtes et dans les vallées à des élévations supérieures. Cette distribution éparse permet de conclure que la stabilité des populations de lynx dans la région dépend probablement de la productivité, la sécurité et la connectivité de plusieurs régions clés. D'importants territoires incluent : (1) les crêtes à l'est du bassin de Fernie et au sud de Sparwood ainsi que la partie supérieure du bassin de la rivière Flathead en Colombie-Britannique; (2) la partie supérieure du bassin versant de la rivière Elk et la confluence des embranchements supérieurs de la rivière White en Colombie-Britannique; et (3) une étroite bande d'habitats en Alberta tout juste à l'est de la ligne continentale de partage des eaux qui s'étend de la partie supérieure du ruisseau Racehorse vers le nord jusqu'à la partie supérieure de la rivière Highwood. Dans certaines régions, la régénération de jeunes conifères à la suite d'un feu d'origine naturelle ou de l'exploitation des forêts a créé des habitats compatibles pour des populations de lièvres d'Amérique et de lynx. Les habitats le long des autoroutes primaires dans les principales vallées s'avèrent habituellement moins compatibles.

Les territoires pouvant supporter des populations de blaireaux se trouvent à basse élévation et y règnent des conditions relativement sèches et ouvertes. Notre modélisation indique que les territoires les plus vastes qui sont très compatibles pour les blaireaux se trouvent principalement dans les pâturages secs et ouverts du sillon des Rocheuses qui longe l'autoroute 93 en Colombie-Britannique et le contrefort des Rocheuses au nord et au sud de Lundbreck en Alberta.

Compte tenu que les lynx roux dans cette région se trouvent actuellement près des limites de leur aire de distribution géographique, ils habitent des terrains forestiers à basse élévation où règnent des conditions relativement sèches et tempérées en hiver. La distribution des lynx roux affiche une tendance quelque peu péninsulaire dans cette région, principalement le long des versants du sillon des Rocheuses parallèles à l'autoroute 93 en Colombie-Britannique ainsi que le long des plaines et contreforts forestiers de l'Alberta.

La distribution potentielle des loups coïncide principalement avec les réseaux de grandes vallées de la région, spécifiquement les pâturages et les contreforts qui flanquent le versant est des Rocheuses en Alberta et les plus grandes vallées montagnardes en Colombie-Britannique telles les vallées des rivières Elk, Flathead, Kootenay et Columbia. Cependant, la distribution réelle de cette espèce a été sans doute modifiée par les efforts humains de réduction des populations de loups. À l'heure actuelle, la population de loups dans la région dépend probablement de la productivité et la sécurité relativement supérieure de territoires tels le bassin de la rivière Flathead et la partie supérieure de la vallée de la rivière Elk. Les études menées sur les loups dans la région appuient la conclusion que les loups se déplacent dans les principales vallées qui longent la ligne continentale de partage des eaux du parc national des Glaciers vers le nord jusqu'au parc national Banff et les cols associés. En particulier, les vallées de la rivière Flathead, de la partie supérieure de la rivière Carbondale-Castle et de la partie supérieure de la rivière Elk semblent être des régions importantes pour les loups.

Notre modèle de compatibilité du territoire pour les carcajous a prédit une compatibilité relativement élevée dans les montagnes et les contreforts à plus haute élévation dans la majeure partie de la zone d'étude. Il appert que plusieurs régions très compatibles pour les grizzlis le sont également pour les carcajous.

Sans surprise, notre modélisation indique que ces carnivores sont les plus vulnérables lorsque des territoires compatibles se trouvent à proximité d'établissements humains, d'autoroutes et de routes principales dans la région, des conditions qui sont favorables à une forte intensité d'activités récréatives et qui facilitent l'accès par véhicule motorisé. On y trouve notamment les autoroutes 3 (autoroute Crowsnest), 43 (autoroute Elkford) et 93 en Colombie-Britannique. En Alberta, il s'agit des autoroutes 3 et 22 (autoroute Chain Lakes) et des routes 940 (Forestry Trunk) et 774 (Castle River).

Durant nos études sur le terrain menées au cours de l'été à proximité du col Crowsnest, nous avons répertorié 38 grizzlis dans 29 (81 %) des 36 cellules de grille (superficie totale de 900 km^2). Des grizzlis ont été couramment répertoriés au nord et au sud de l'autoroute en termes d'usage, d'occurrence et de densité relative. Nous avons identifié une concentration de grizzlis dans plusieurs régions, dont au sud de l'autoroute Crowsnest près du col Crowsnest lui-même ainsi que le long des deux côtés de la ligne continentale de partage des eaux. Ils étaient également concentrés au nord de l'autoroute Crowsnest et le long de chaque côté de la ligne continentale de partage des eaux dans la partie supérieure du ruisseau Alexander et de la rivière Oldman. Nous avons répertorié une femelle et deux mâles des deux côtés de l'autoroute Crowsnest et plusieurs autres des deux côtés de la ligne continentale de partage des eaux.

Dans la même grille de levées, nous avons répertorié un minimum de sept lynx (6 mâles et 1 femelle) à 17 emplacements dans 13 cellules. Au nord de l'autoroute Crowsnest, les lynx répertoriés étaient regroupés dans la partie supérieure du ruisseau Alexander tandis qu'au sud de l'autoroute, ils ont été répertoriés principalement à l'ouest du ruisseau Michel. Bien que nous n'ayons pas répertorié de lynx individuels des deux côtés de l'autoroute, il appert que la liaison des ruisseaux Alexander-Michel soit un corridor nord↔sud probable. Dans le cas du lynx, des liaisons ouest↔est qui franchissent la ligne continentale de partage des eaux incluent probablement le col Racehorse au nord de l'autoroute Crowsnest et les cols du mont Tent et Ptolemy au sud de celle-ci.

Dans la grille de la partie inférieure de la vallée de la rivière Elk, nous avons répertorié 52 grizzlis dans 29 (73 %) des 40 cellules dans le cadre de divers levés. Nous avons répertorié deux mâles des deux côtés de l'autoroute Crowsnest. Les grizzlis étaient plus nombreux à l'ouest de l'autoroute Crowsnest en termes d'usage, d'occurrence et de densité relative. Nous avons trouvé des concentrations de grizzlis dans les chaînes à l'ouest de l'autoroute Crowsnest, dont la chaîne Lizard entre Elko et Fernie, les bassins versants du lac Island et du ruisseau Iron à l'ouest de Fernie et les environs du col Hartley vers le nord-est. Bien que la densité des grizzlis semble moins forte à l'est de l'autoroute dans la partie inférieure de la vallée de la rivière Elk, nous avons répertorié plusieurs grizzlis individuels aux bassins versants des ruisseaux Coal et Morrissey à l'est de Fernie.

Dans la même grille, nous avons répertorié un minimum de sept lynx (4 mâles et 3 femelles) à 22 emplacements dans neuf cellules. Tous les lynx répertoriés dans cette grille l'ont été dans la partie supérieure de bassins versants à l'est de l'autoroute Crowsnest, principalement entre Sparwood et Fernie. Cette distribution agglomérée était conforme aux prédictions de notre modèle de distribution des populations régionales. Bien que nous n'ayons répertorié aucun lynx individuel des deux côtés de l'autoroute Crowsnest, les meilleurs habitats n'étaient pas directement adjacents à l'autoroute dans la vallée et le domaine vital du lynx est souvent circonscrit par des ouvrages majeurs tels des autoroutes.

Un examen d'études scientifiques menées le long d'autres grandes autoroutes dans la région indique que les autoroutes très achalandées limitent fortement les déplacements des carnivores et ont le potentiel d'en fragmenter les populations. Les grizzlis sont particulièrement vulnérables à ces effets, surtout les femelles en âge de se reproduire. La circulation de trains sur des voies parallèles aux principales autoroutes représente une importante source de mortalité pour les ours. Cependant, le principal impact des autoroutes est peut-être l'activité humaine cumulative et les retombées sur le plan du développement que ces axes routiers ont facilitées au cours des décennies. En effet, les types actuels d'établissement et de développement continuent de proliférer le long des autoroutes et des axes auxquels elles donnent accès. Ces impacts de plus grande étendue peuvent représenter l'ultime facteur de fragmentation de certaines populations de carnivores. Notre échantillonnage systématique le long de l'autoroute Crowsnest a confirmé que l'autoroute et le développement qui est y associé ont limité le potentiel de déplacement des grizzlis et possiblement des lynx.

Deux principes robustes de la science de la conservation sont fondamentaux pour assurer l'efficacité d'une stratégie de conservation des carnivores, particulièrement sur des territoires utilisés à de multiples fins tels les Rocheuses canadiennes du Sud :

- prévenir une mortalité excessive en établissant un réseau de zones sécuritaires clés adéquatement réglementées;
- maintenir la connectivité du territoire en mettant en place des corridors reliant les zones clés ainsi établies.

Nous avons identifié et cartographié 15 zones clés dans les Rocheuses canadiennes du Sud et les avons évaluées en fonction de leur importance pour la conservation et leur niveau actuel de sécurité relative pour les grizzlis, les lynx et les carcajous. Les zones suivantes méritent une attention particulière puisqu'elles s'avèrent *très importantes pour la conservation* et offrent *un niveau de sécurité faible à modéré* à l'heure actuelle :

- Partie inférieure du bassin de la rivière Flathead (CB),
- Ruisseaux Michel (CB) et Ptolemy (AB),
- Partie supérieure des bassins des rivières Elk (CB) et Highwood (AB)
- Chaîne Lizard et col Hartley (CB)

Par ailleurs, la partie ouest du bassin de la rivière Elk et la partie supérieure du bassin de la rivière Bull, en Colombie-Britannique, sont importantes pour la conservation, mais elles semblent offrir un niveau de sécurité élevé en ce moment.

Nous avons identifié et cartographié 11 corridors interterritoriaux et de déplacement en lien avec l'autoroute Crowsnest, que nous avons évalués eu égard à leur importance pour la conservation et leur niveau de vulnérabilité. Nous avons identifié ces corridors sur la base de la modélisation des habitats clés des espèces focales, de données empiriques recueillies dans le cadre des levés de poils de grizzlis et de lynx, de données préliminaires de radio-repérage de grizzlis et de cartes actualisées des développements et activités anthropiques existants. Les corridors suivants méritent une attention particulière puisqu'ils s'avèrent *très importants pour la conservation* et présentent *un niveau de vulnérabilité modéré à élevée* :

- Entre Fernie et Morrissey
- Entre Lizard Bassin et Elk Valley
- Entre Coal Creek et Elk Valley
- Pentes du mont Fernie
- Entre Hartley et Elk Valley
- Entre Hosmer et Sparwood
- Entre les ruisseaux Michel et Alexander
- Partie ouest de la municipalité de Crowsnest

Plusieurs couloirs de montagne constituent des corridors essentiels traversant la ligne continentale de passage des eaux près de Crowsnest Pass, où la connectivité des deux côtés de l'autoroute 3 est plutôt limitée : col Ptolemy, col du mont Tent, col Deadman et col Racehorse.

Nous incitons les gestionnaires du territoire et des ressources, de concert avec des intervenants clés et le public, à mettre en œuvre les recommandations suivantes pour assurer la conservation des carnivores et d'autres espèces fauniques dans les Rocheuses canadiennes du Sud et la connectivité de leurs populations le long de l'autoroute Crowsnest.

✓ 1. Maintenir un réseau de zones clés de sécurité élevée par l'adoption de pratiques de gestion appropriées. L'importance doit être accordée entre autres à gérer les accès (mise en œuvre intégrale du plan de gestion des accès aux Rocheuses du Sud) et à prévenir une mortalité excessive par l'adoption d'une réglementation adéquate des activités de chasse et de trappage.

✓ 2. Élaborer un plan de conservation proactif visant à assurer la connectivité le long de l'autoroute Crowsnest et à proximité de celle-ci. Ce plan doit tenir compte de l'évaluation et la planification de possibles prolongements de l'autoroute, d'incitatifs à négocier des ententes sur l'utilisation du territoire et d'autres pratiques.

Vu l'expansion des populations humaines et des développements anthropiques ainsi que les changements climatiques, le temps presse d'exercer ces options.

1. INTRODUCTION

Background and Conservation Issues

The Canadian Rockies are renowned throughout the world for their spectacular scenery, natural features, and wildlife. However, the 'southern Canadian Rockies' — the section between Banff National Park and Glacier National Park at the U.S. border — has received less public attention than many other regions from a conservation perspective.

The southern Canadian Rockies exhibit a broad array of ecological conditions that, in turn, support the most diverse, intact system of carnivores in North America. Seventeen species are included: gray wolf (*Canis lupus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), ermine (*Mustela erminea*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vision*), American pine marten (*Martes americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), American badger (*Taxidea taxus*), striped skunk (*Mephitis mephitis*), river otter (*Lontra canadensis*), cougar (*Puma concolor*), Canada lynx (*Lynx canadensis*), and bobcat (*Lynx rufus*). In addition, there are six ungulate species: moose (*Alces alces*), elk (*Cervus elaphus*), white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), and mountain goat (*Oreamnos americanus*) (caribou [*Rangifer tarandus*] have recently been extirpated).

Several ecological and geographic factors contribute to this rich assemblage of carnivores. First, the Continental Divide cleaves the southern Canadian Rockies into two climatic regimes: (1) warmer, moister (maritime) climate and diverse forests on the Pacific side in British Columbia, and (2) colder, drier (continental) climate and more grassland in the front ranges and foothills of Alberta. Elevations range from 900 m in the valleys to more than 3000 m at mountain peaks. The combination of varying climate, elevation, and vegetation results in an extraordinarily diverse landscape. In addition, several species of carnivores reach the margins of their geographic range across North America in or near the southern Canadian Rockies. For example, southerly species like badgers and bobcats occur near their northern limit here, whereas northern or boreal species like Canada lynx occur near their southern limit. For the northern species, the southern extent narrows to a 'peninsular tip', which increases their vulnerability to additional population fragmentation. Grizzly bears and wolves once ranged much further east across the Great Plains, but human developments and persecution have shrunk the southeast boundary of their range in Canada to the eastern slopes of the southern Canadian Rockies (Hummel and Pettigrew 1991, Paquet and Hackman 1995). Convergence of these natural and human factors has yielded a collection of carnivores in the southern Canadian Rockies that is unique on the continent.

Carnivores are vital members of ecological communities and wild landscapes. They can serve as useful focal species in conservation planning for several reasons (Carroll et al. 2001). First, carnivores reflect lower levels of ecosystems due to their position atop different ecological pyramids or food chains. In addition, carnivores typically require large areas where a mosaic of different plant communities occurs. By conserving a suite of different species of carnivores, managers may also conserve many other plant and animal species in a region. Finally, these predators may influence the behavior of their prey and interactions among other species (Ray 2005). For example, a carnivore may alter the relative composition of the prey community which can influence the vegetation which, in turn, can influence other organisms such as invertebrates. The successful reintroduction of wolves to Yellowstone National Park has revealed some of these fascinating relationships (Smith et al. 2003). Thus, carnivores enact a vital and irreplaceable role in maintaining the integrity of ecosystems.

Although individual carnivores can be formidable, their *populations* may be quite vulnerable. Several species of carnivores lack resiliency to persist in the midst of intense human pressures (Weaver et al. 1996). Over the past 150 years, many carnivore populations across North America have declined due to loss of habitat or prey and over-killing, which led to smaller, more isolated populations that did not persist (e.g., grizzly bears: Mattson and Merrill 2002). More recently, the steadily expanding network of roads, major highways, railroads and associated human developments across the landscape has added another threat to wildlife populations: fracturing of landscape connectivity which fragments or divides populations into smaller and more vulnerable units (Forman and Alexander 1998, Lindenmayer and Fischer 2006).

In addition, updated projections of climate change (IPCC 2007) portend significant changes in ecosystems as plants and animals attempt to shift their distribution to stay within their preferred range of ecological conditions (Lovejoy and Hannah 2005). Indeed, shifts in distribution have already been documented of a wide variety of species (Parmesan 2006). A warming of 2° C, for example, would require moving 200 km north in latitude or 250 m upward in elevation to remain at the previous temperature (MacArthur 1972). When the planet warmed by several degrees during past millennia, plants and animals in North America tracked changes by moving north toward higher latitudes and/or upward in elevation (Pielou 1991). Of course, there were not four-lane highways, cities, or vast stretches of agriculture back then. The problem now is that the ubiquitous human 'wheelprint' has fragmented landscapes and may hinder movements as plants and animals attempt to locate new areas of suitable conditions. The combined effects of climate change and habitat fragmentation will be especially problematic for wild life. Thus, in the context of climate change, connectivity through the southern Canadian Rockies takes on added importance. Providing connectivity through changing landscapes will not be a panacea for all affected wildlife, but it will ensure better options for many (Hannah and Hansen 2005).

Connectivity of habitats and populations is important in wildlife conservation to: (1) provide coherent habitat and secure space for populations of resident animals (Bennett 1998), (2) prevent or reverse local extirpations by recolonization of depleted areas ('rescue effect': Brown and Kodric-Brown 1977, Fahrig and Merriam 1994), (3) minimize human-caused mortality from vehicles, especially during dispersal (Beier 1993), (4) maintain gene flow and diversity among historically-connected populations (Schonewald-Cox et al. 1983), and (5) facilitate ecological and geographic shifts in response to changing environmental conditions wrought by climate change (Hannah and Hansen 2005, Parmesan 2006). Due to their large home ranges and wide-ranging movements, large carnivores are particularly vulnerable to deleterious effects of roads and associated human development and activity (Woodroffe and Ginsberg 2000).

The predominant orientation of mountains and valleys in the southern Canadian Rockies provide natural north↔south movement conduits for most large mammals. However, this natural connectivity is vulnerable to fracture by three major highways and railroads running mostly east↔west: Hwy 1 (Trans-Canada Highway), Hwy 3 (the Crowsnest Highway), and Hwy 2 (U.S.) along the south boundary of Glacier National Park. Previous studies have documented the restrictive effect of highway traffic and associated human developments on the movements or gene flow of grizzly bears (Hwy 1: Chruszcz et al. 2003, Hwy 2: Waller and Servheen 2005, Hwy 3: Proctor et al. 2005) and other carnivores (Percy 2003, Alexander et al. 2005, Apps 2007).

The Crowsnest Highway (Hwy 3) poses a particularly difficult challenge to maintaining carnivore population connectivity due to several factors (Apps 1997): (1) the breadth of the Rocky Mountains narrows considerably here, (2) management of the surrounding landscape provides scant protection for carnivores, (3) most of the land along the highway is in private or corporate ownership and subject to potential development, and (4) the highway carries relatively high-volume traffic and is associated with considerable human settlement and development. Despite these factors, there has been less scientific scrutiny of connectivity here than for the other two major highways.

The southern Canadian Rockies represent one of the most important and strategic sections for carnivores in the entire interior mountain bioregion stretching from Yellowstone National Park to the Yukon and beyond (Apps 1997, Weaver 2001, Carroll et al. 2003). Yet, expanding human developments and activities — especially along the Crowsnest Highway — pose an obvious threat to maintaining the integrity and connectivity of habitats and populations across this area (Apps 1997, Carroll et al. 2004). Hence, from the perspective of conservation science, the challenge is to discern and map core areas and landscape linkages that will contribute to the viability, security, and connectivity of carnivore populations across this vital area.

Research: Goals, Objectives and Approaches

In developing conservation strategies for wide-ranging carnivores, two concepts are particularly relevant to landscape planning: (1) core areas of habitat quality and security that are connected by (2) landscape linkages. Core areas, where habitat productivity is maximized and human disturbance minimized, represent source areas that can 'anchor' a regional population. Linkages are connecting zones where animals can reside temporarily or move through — even where habitat quality may be lower or levels of human activity higher, compared to core areas. Linkage zones maintain connectivity among core habitat and population areas, thereby facilitating genetic and demographic flow and promoting persistence of the regional population. Integrity of a connected network of secure core areas is vital for a healthy, naturally-distributed population. In applying these concepts, it is important to consider a range of spatial scales (Noss 1991).

The overall goal of this research was to identify important core areas and linkage zones for carnivores across the southern Canadian Rockies, with emphasis on landscapes bisected by the Crowsnest Highway. To accomplish this goal, we derived information and developed models and maps at different scales, ranging from the entire southern Canadian Rockies (30,000 km^2) to localized sites along the Crowsnest Highway. Such a multi-scale, hierarchical approach has proven effective in other regional conservation strategies because it combines perspective and context from a higher level (region) with insights about ecological mechanisms that operate at lower levels (local) (O'Neill et al. 1986). To obtain information and perspective at various scales, we proceeded through three integrated stages of research.

In stage 1, we selected a suite of six carnivore species to focus our research on the landscape of the southern Canadian Rockies. This <u>suite</u> of species is chosen considering area requirements, heterogeneity of habitats, ecological functionality, and socioeconomic significance. We selected the following species — grizzly bear, lynx, badger, bobcat, wolf, and wolverine — that range widely, represent a broad variety of ecological conditions, and appear sensitive to human activities. For each of these landscape species, we developed and applied regional models of distribution and vulnerability to identify likely areas of core habitat and security throughout the southern Canadian Rockies as well as potential zones of population linkage across the Crowsnest Highway.

In stage 2, we sampled the actual occurrence of two species (grizzly bear and lynx) within a zone (10-20 km wide) that paralleled and included the Crowsnest Highway. We collected these field data to (1) determine occurrence adjacent to the highway and possible crossings, and (2) assess and refine the regional models. In stage 3, GPS radio-collars were placed on several grizzly bears to track more precisely their movements and use of habitat relative to the Crowsnest Highway and other human developments.

In this report, we describe the results and conservation implications of the first two stages; we will issue a companion report based on finer-scale grizzly bear tracking data once that stage is completed.

Regional Study Area

Our regional study area encompassed 30,000 km^2 of the southern Canadian Rocky Mountains (Figure 1). It extended approximately 200 km from Kootenay and Banff National Parks south to the Montana border. It stretched about 160 km from Highway 22 in the Alberta foothills west to Highway 93 in the East Kootenay Trench, a broad and flat glacial plain. Both landscapes on the flanks of the study region are dominated by permanent human settlements, agriculture, and other developments. The BC portion of the study area lies within the traditional territory of the Ktunaxa First Nation.

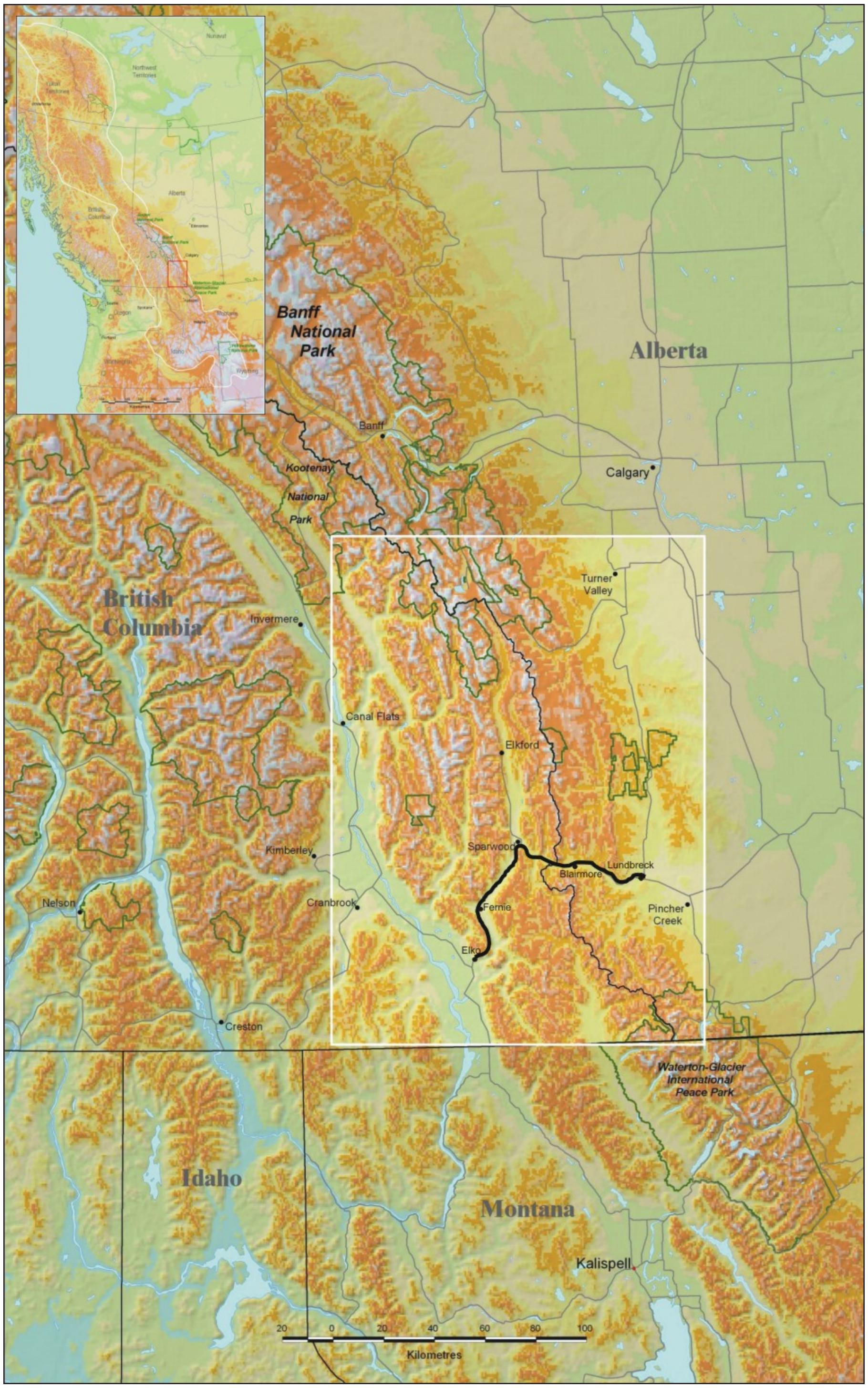
The study area is comprised of three major physiographic units, or ecosections (Demarchi 1996). In the northwestern part, the ‘Southern Park Ranges’ ecosection contains the upper Kootenay, White and Bull River watersheds. The terrain is rugged, spanning elevations of 1100-3500 m, and includes some of the highest peaks in the Canadian Rockies. Major rivers drain through U-shaped glaciated valleys, with long and narrow tributaries. To the south and east, the ‘Border Ranges’ ecosection encompasses landscapes drained by the Elk, Flathead and Wigwam Rivers in British Columbia, and the Highwood, Oldman, and Castle Rivers in Alberta. There, mountains are more subdued, with occasional steep, rugged ridges, and elevations of 1100-3200 m. These ranges are underlain by folded and faulted sedimentary rocks that include prominent bare limestone ridges and major coal deposits. The southeastern portion of the study region includes the ‘Crown of the Continent’ ecosection — a rugged, mountainous area that rises abruptly from the Interior Plains in Alberta to the east and the Flathead Basin to the west. Elevations span 1100-2900 m. In general, mountain ranges and most major valleys orient north↔south through the study region. Both Pacific weather systems and Arctic air masses influence the local climate. Most of the study region falls within the rain shadow of the Columbia Mountains and exhibits a cool, dry, continental climate. The eastern slopes, however, are notably drier than western ranges.

The most common sequence of biogeoclimatic zones (Meidinger and Pojar 1991) here consists of Montane Spruce (MS) at low elevations, Engelmann Spruce-Subalpine Fir (ESSF) at middle elevations, and Alpine Tundra (AT) at high elevations; the Interior Douglas-fir (IDF) zone occurs in the driest valley bottoms. In the MS and ESSF zones, the climax overstorey is primarily hybrid Engelmann/white spruce (*Picea engelmannii* x *glauca*) with a greater composition of subalpine fir (*Abies lasiocarpa*) at higher elevations, while Douglas-fir (*Pseudotsuga menziesii*) is the primary climax species in the IDF. In the lower elevations of the Wigwam, Elk and Bull River basins, high levels of precipitation yield an Interior Cedar-Hemlock (ICH) zone, with climax stands of western red-cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) and hybrid spruce. Seral stands of lodgepole pine (*Pinus contorta*) occur at various elevations, in association either with western larch (*Larix occidentalis*), Douglas-fir and aspen (*Populus tremuloides*) at low elevations or with whitebark pine (*Pinus albicaulis*) at higher elevations. The AT is dominated by barren rock, with small patches of meadow and wind-swept alpine grasses.

Most land in the southern Canadian Rocky Mountains is subject to various uses, including oil and gas wells/pipelines, open-pit coal mining, timber harvesting, agriculture and livestock grazing, human settlements, and both motorized and non-motorized recreation. These activities currently fuel economic growth in this region which, in turn, results in a rapidly expanding human population. Moreover, many residents of Calgary, Alberta (pop. 1,000,000; distance: 225 km to Crowsnest Pass) travel along the Crowsnest Highway to reach recreation sites in the region.

We focused on the 115-km long section of Hwy 3 that extends from Elko, British Columbia, on the west to Lundbreck, Alberta, on the east (Figure 1). This highway was paved in the 1960s, and vehicular traffic increased 10-fold from 1980 to 2000 (Proctor 2003). Current traffic level along this section is approximately 7000 vehicles per day during summer, with 8-16 freight trains per day on the railroad that parallels the highway (BC Ministry of Transportation and Highways). The highway and railroad serve as a major transportation route for commercial/freight traffic heading between ports on the west coast and the interior, as well as connecting with major routes (Hwys 15 and 93) heading into the United States. Numerous communities — including Fernie, Sparwood, Crowsnest Pass municipality (six small hamlets), and several other minor settlements — are located along the highway. Within the study region, highway communities have a combined resident population of approximately 20,000 people. For ease of reference, we call this entire transportation corridor of highway, railroad, and human settlements from Elko, BC to Lundbreck, AB the 'Crowsnest Highway'.

Figure 1. Regional study area for the evaluation of carnivore core areas and connectivity across the southern Canadian Rocky Mountains, British Columbia and Alberta, Canada. The Crowsnest Highway is depicted in bold.



2. DISTRIBUTION AND VULNERABILITY OF SELECT CARNIVORES IN THE SOUTHERN CANADIAN ROCKY MOUNTAINS: REGIONAL MODELING

Introduction

To support regional conservation planning, we modeled the distribution and vulnerability for a suite of six carnivore species: grizzly bear, lynx, badger, bobcat, wolf, and wolverine. We selected these focal species to represent the diverse array of ecosystem conditions across the southern Canadian Rocky Mountains. For our regional study area, we compiled and assembled a spatial database of available biophysical, land cover (inventoried and remotely sensed), and human use data. Our approach was to develop knowledge-based models that reflect the best available understanding of species-environment relationships at scales relevant to population persistence. Our modeling framework conformed to a Bayesian belief network (Marcot et al. 2001, Root et al. 2002, Loiselle et al. 2003) for integrating relationships across spatial scales to predict population distribution and vulnerability for each species.

Profiles of Focal Carnivore Species

For our selected suite of carnivore species, we profile aspects of their ecology relevant to identifying core areas for source habitats and security, landscape linkages for connectivity, and overall resilience (*sensu* Weaver et al. 1996).

Grizzly Bear

Throughout their historic range, grizzly bears occupied a great diversity of ecosystem types and their probable requirements can vary considerably among regions. In the southern Canadian Rocky Mountains, most of what is known of grizzly bear ecology has come from a research project conducted by Dr. Bruce McLellan in the Flathead drainage. Here, grizzly bears fed on (1) ungulates (elk and moose) and hedysarum (*Hedysarum sulphurescens*) roots in the early spring, (2) grasses, horsetails (*Equisetum arvense*), and cow parsnip (*Heracleum lanatum*) in early summer, (3) huckleberries (*Vaccinium spp*) and buffaloberries (*Shepherdia canadensis*) in late summer, and (4) berries, ungulates, and hedysarum roots in the fall (McLellan and Hovey 1995). Although bears use a wide variety of foods, they rely upon berries in late summer and fall for weight gain and fat deposition necessary for successful hibernation and reproduction. The diversity of bear foods found in the region likely contributes to a relatively stable and high density grizzly bear population. Important habitats include riparian zones in river valleys, avalanche chutes, and sites where wildfires 50-70 years ago created huckleberry patches at mid-elevations (1700-2000m) and buffaloberries across elevations (McLellan and Hovey 2001a).

Grizzly bears exhibit very low reproductive potential, with females producing their first litters at approximately six years of age and then producing only 0.5 – 0.8 cubs per year after that. Consequently, their populations cannot absorb high mortality levels, and low total mortality of adult females (<8%) is critical for the continued persistence of grizzly bears. Dispersal by young grizzly bears appears to be a gradual process over months or even years (McLellan and Hovey 2001b). Relative to many other carnivores, adult bears reside relatively close to their natal range (females: 10 km, males: 30 km — on average), and sub-adult females usually establish home ranges that overalap their mother's.

The distribution and persistence of grizzly bears is a function of habitat quality and the level of human-caused mortality. A high survivorship (>0.92) of adult female grizzly bears is essential for population stability. The risk of such mortality depends upon accessibility for people (frequency of encounter) and the behaviour of those people (lethality of encounter) (Mattson et al. 1996). Grizzly bears tend either to (a) avoid human settlements and busy roads, or (b) become habituated to the human activity or conditioned to human food and garbage, resulting in higher risk of mortality (Mattson 1990, Mace et al. 1996, Gibeau et al. 2002, Apps et al. 2004). Provision of 'security areas', where bears can meet their energetic requirements while minimizing contact with people, has emerged as a critical component of contemporary management for grizzly bears (e.g., Gibeau et al. 2001). We rate the resilience of grizzly bears as low.

Lynx

As specialized predators of snowshoe hares (*Lepus americanus*), lynx exhibit little flexibility in foraging behaviour, and virtually every aspect of their demographic, spatial, and behavioural ecology is tied to snowshoe hare abundance (Koehler and Aubry 1994). Highest hare densities are associated with landscapes dominated by regenerating (10 – 50 year) conifer stands, but hares can also be abundant in late-successional stands with a dense understory. In the southern

Canadian Rockies, populations of snowshoe hare occur at low densities in a patchy distribution that appears to result in low reproduction, low population recruitment, and large home ranges for lynx (Apps 2007). Lynx distribution is also limited by climatic and physiographic factors, and resident animals are generally associated with upper MS, upper ICH and ESSF landscapes.

Owing to the narrow range of habitat conditions with which they are associated, lynx are expected to be regionally distributed as a metapopulation consisting of several small subpopulations. Some of these may represent "source" landscapes where population recruitment exceeds mortality, and immigrants are supplied to other "sink" landscapes where lynx may persist intermittently but are not self-sustaining. Lynx have considerable dispersal potential, and several examples of adult movements >500 km are known (Mowat et al. 2000). Hence, the regional population may be reliant on a few highly productive core habitat areas, but lynx persistence may also depend on immigration from more distant regions, likely to the north (Schwartz et al. 2002). Lynx likely persist in the southern Canadian Rockies due to continued immigration from such connected local and distant source areas (Apps 2007). It follows that the regional population may be sensitive to habitat degradation or high mortality rates within a relatively small number of core habitats. For example, expanding access for humans (roads) in productive lynx habitat could lead to increasing hunting and trapping pressure, which could have resounding consequences at the regional level. Considering their specialized habitat and prey adaptations, low productivity of local populations, and the continued importance of regional-scale movements to population persistence, we consider the resilience of lynx in the southern Canadian Rockies to be low.

Badger

The subspecies of badger (*T. t. jeffersonii*) in the study region is *endangered* in British Columbia due to habitat loss, alienation, and persecution of badgers and their prey (Cannings et al. 1999, COSEWIC 2000). Here, near the northern extent of their range in North America, badgers are associated with low elevation, open, dry habitats that are valued for agriculture and human development. Our knowledge of local badger ecology and probable requirements is based on a nearby study in the East Kootenay Trench (Newhouse and Kinley 2001). Badgers depend on the availability of fossorial prey and soils conducive to prey pursuit and burrow construction. Locally, badgers prey almost exclusively on Columbian ground squirrels (*Spermophilus columbianus*), and badger habitat associations are closely tied to the distribution of ground squirrel colonies (Apps et al. 2002). In our study area, badgers are mostly restricted to the IDF, lower ICH and lower MS biogeoclimatic zones, although there is both permanent residence and forays into the AT and logged or burned portions of the ESSF. They are expected to occur at very low densities and have large home ranges. If not harassed, badgers will occupy habitats in close proximity to humans, but human activity translates to high mortality risk for badgers primarily due vehicle collisions, shooting, and direct and indirect poisoning. In this region, badger reproduction appears to be extremely low, with litter sizes of 1-2 being typical. Although little is known of badger dispersal ability, movements of up to 110 km have been documented (Messick and Hornocker 1981). We consider the overall resilience of badgers to be low in this region.

Bobcat

In the southern Canadian Rockies, bobcats are also at a northern range limit. Here, potential bobcat habitat is restricted to low elevation, forested landscapes with relatively dry, mild winters. Within our study area, bobcat distribution is thus restricted primarily to the IDF, lower MS, and lower ICH ecosystems. Our knowledge of the local ecology and probable requirements of this species is based on a seven-year research effort that took place partially within our study area (Kinley 1992, Apps 1996). Bobcats are more flexible in their foraging behaviour than lynx, and are thus expected to be more resilient to population fluctuations of various prey species. Bobcat distribution is restricted by winter snow and temperature conditions and is somewhat peninsular in the southern Canadian Rockies. Important attributes of forest structure provide for snow interception, prey availability and stalking cover, while terrain attributes provide for security and escape cover and sunning/resting microsites (Apps 1996). Relative to most other populations, bobcats in this region occur at low densities and have large home ranges; individuals here have dispersed upwards of 155 km. We consider the overall resilience of bobcats to be moderate in this region.

Wolf

Several wolf studies have been conducted in and around the southern Canadian Rockies, including northwestern Montana and the Flathead drainage (Boyd-Heger 1997, Kunkel 1997) and the central Rocky Mountain ecosystem to the north (Paquet et al. 1996, Hebblewhite 2000, Callaghan 2002). Wolves have the potential for widespread distribution throughout the southern Canadian Rockies. However, if human-caused mortality is minimal, wolves are more likely to occur at lower elevations and subdued terrain where their ungulate prey tend to be concentrated. Locally, in the southern Flathead drainage, wolves have preyed mostly on white-tailed deer (*Odocoileus virginianus*), secondarily on elk (*Cervus elaphus*), and thirdly on moose (*Alces alces*) (Boyd-Heger 1997, Kunkel 1997). In the central Rockies, however, wolves killed elk more often than other species (Hebblewhite 2000). Attributes associated with wolf distribution and habitat selection in the region have been explained as relatively low elevation, flat terrain, and proximity to both water and roads; security cover provided by closed coniferous forests may also be important (Boyd-Heger 1997, Callaghan 2002). Wolves show high reproductive potential, with litters of 4-7 pups annually, and they can withstand annual mortality rates of 30%. Wolves also have excellent dispersal ability, with movements of 732 – 917 km documented (Weaver et al. 1996, Boyd and Pletscher 1999). Wolf distribution is most likely to be influenced by human activity as it pertains to hunting, trapping, and predator control programs (Paquet et al. 1996, Callaghan 2002). Due to their exceptional vagility and relatively high reproductive potential, we consider wolves to exhibit a high degree of ecological resilience.

Wolverine

There has been little to no published study of wolverines in or proximal to the southern Canadian Rocky Mountains. The most relevant field studies have been conducted in northwest Montana (Hornocker and Hash 1981), central Idaho (Copeland 1996), the north Columbia Mountains (Krebs and Lewis 2000) and central British Columbia (LoFroth 2001), along with landscape models for wolverines in the northwestern U.S. (Rowland et al. 2003). Other research efforts have been reviewed and summarized (Banci 1994). Across our regional study area, wolverines are expected to be distributed at low densities, but are more likely to be associated with cooler, montane to subalpine forested ecosystems. Wolverines are primarily scavengers of ungulates killed by other predators or by starvation, disease or accidents, but they are also opportunistic predators, and their summer diet includes prey such as marmots (*Marmota spp*), ground squirrels, and smaller species. The health and viability of wolverine populations may be directly linked to the abundance and diversity of ungulates in a region. Wolverines typically range at higher elevations in summer and females typically use higher average elevations than males. Old forests tend to be used more than younger age classes. Habitat use patterns may reflect the availability of carrion in ungulate wintering areas, fossorial rodents in alpine habitats during summer, energetic requirements, and/or human avoidance. Krebs and Lewis (2000) found that capture success and landscape use by study animals was at least partially related to remoteness from human disturbance and protection from trapping. Wolverine reproductive success may be related to the quality and availability of denning sites, and may be partially influenced by the constancy of deep snow throughout the winter denning period (Magoun and Copeland 1998). Natal and maternal dens are often at high elevations, in cirque basins, with woody debris and large talus. Wolverine home ranges are extensive, averaging 311 to 405 km^2 for females and 1,005 to 1,582 km^2 for males, and with subadults (particularly males) covering greater areas (Copeland 1996, Krebs and Lewis 2000, LoFroth 2001). Juvenile dispersals of 185 to 378 km have also been reported. Wolverines exhibit very low demographic potential (Weaver et al. 1996), with average kit production ranging from 0.5 to 0.7 per year and most females not breeding until at least their third year. Most wolverine mortality is attributed to human causes, primarily trapping, and trapped populations can be expected to decline in the absence of immigration from protected refugia (Krebs et al. 2004). Genetic analyses indicate that fragmentation of wolverine populations appears to increase progressively toward peripheries of their range (Kyle and Strobeck 2002). We consider the overall resilience of wolverines to be <u>low</u> in this region.

Methods

Model Development

Among our suite of focal species, empirical models predicting habitat value, as well as species occurrence, distribution and/or abundance have been developed at a variety of spatial scales in the Rocky Mountains for grizzly bears (Boulanger and Apps 2002, Theberge 2002, Apps et al. 2004), wolves (Callaghan 2002), lynx (Apps 2001), bobcats (Apps 1996), and badgers (Apps et al. 2002). These models were developed with the dual objective of understanding causal relationships and providing local predictions for management. Broader-scale models for a suite of carnivores were also applied across the greater Rocky Mountain biome (Carroll et al. 2001). It is for several reasons that we chose not to directly apply the above models directly across our study region. Since most were developed specific to a different ecological scale or range of conditions than characterized by our study region and objectives, we were concerned that predictions based on correlative relationships could break down upon extrapolation in space and/or spatial scale. This, in addition to differences in sampling and analytical methods and environmental data sources, would confound comparisons of model outputs among species and erode our confidence in their interpretation.

In light of the above concerns, we developed a knowledge-based modeling approach using a framework that (1) is consistent among focal species, (2) reflects our *a priori* understanding of how factors operate to define the likelihood of species occurrence and distribution throughout the study area, (3) integrates relationships across spatial scales, and (4) accounts for uncertainty in predictions. Our understanding of factors that control population distribution and abundance varies among species, as does our ability to spatially represent these factors. Resembling a Bayesian belief network (Lee 2000, Marcot et al. 2001), our approach accounts for inherent uncertainty in relationships and underlying data, while model structure and parameters are transparent and subject to debate, testing and refinement.

Across our regional study area, our intent was to predict the likelihood of species occurrence across spatial scales by way of an index of population distribution and abundance. From this, we expected that population core and peripheral areas and landscape linkages could be directly inferred. We expected model parameters to reflect the best extant knowledge of limiting factors and probable requirements for each species, given currently available biophysical and human use data.

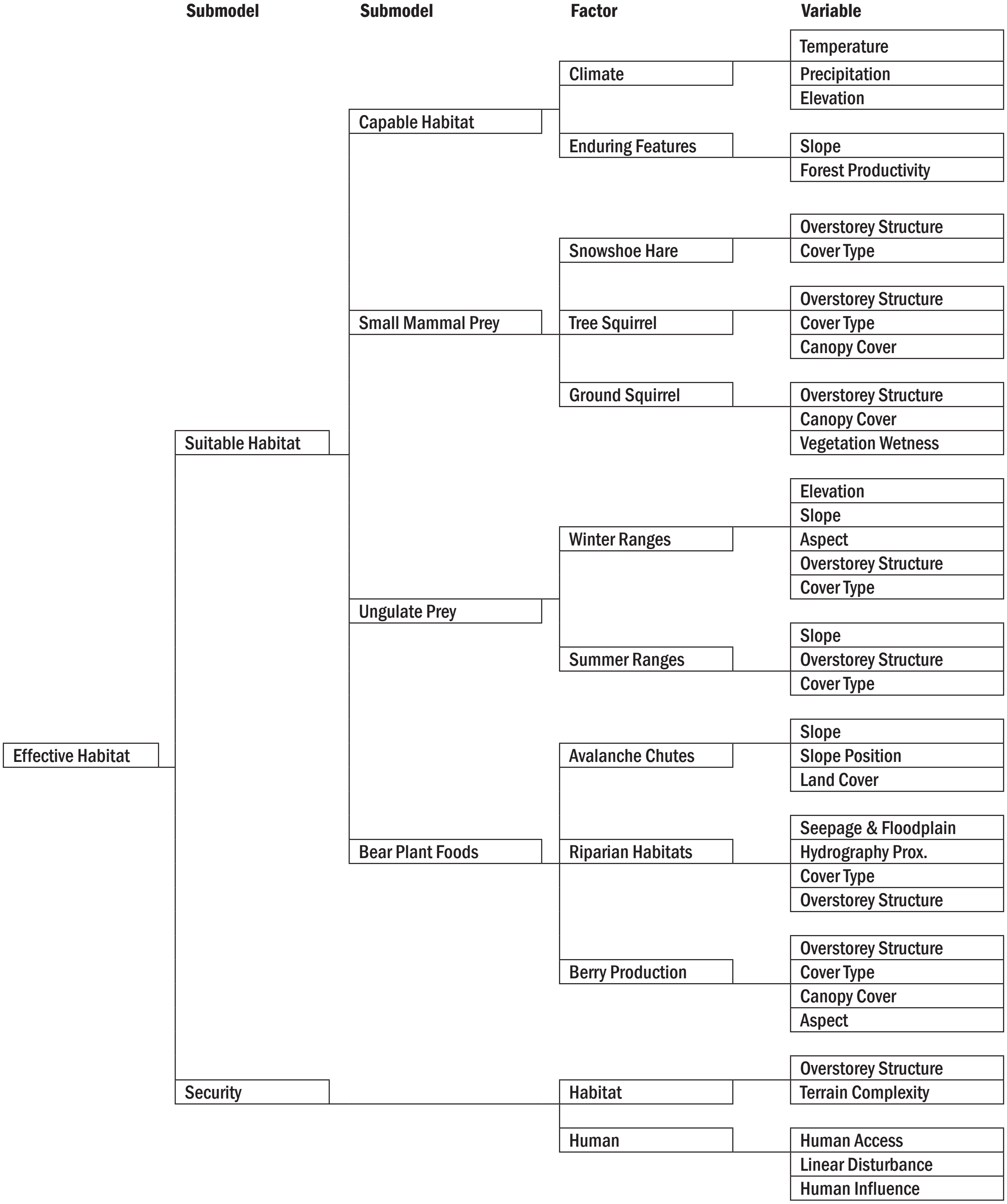
Model Structure

Framework and Elements

We developed a hierarchical, knowledge-based modeling framework to account for species life requisites and limiting factors (Figure 2)[5]. We defined landscape quality for each species in terms of habitat "capability", "suitability", "security" and "effectiveness". Habitat *capability* characterized the inherent potential to support a species under ideal conditions of vegetation composition and structure, while habitat *suitability* reflected the landscape's current capacity to support a species given existing vegetation and resulting prey conditions. *Security* referred to protection afforded by the landscape in the context of human disturbance and interspecific competition. Habitat *effectiveness* equated to the realized ability of a species to inhabit and persist within a landscape after accounting for human influence factors. We included mortality risk in our definition of habitat effectiveness. The magnitude of difference between suitability and effectiveness, we term *vulnerability*.

[5] Specific ratings were derived by Apps, Weaver and Paquet, with input from McLellan on grizzly bear ecological relationships.

Figure 2. Hierarchical structure for modeling landscape suitability and vulnerability for six wide-ranging carnivore species in the southern Canadian Rocky Mountains. Specific elements varied among species (see Appendix B for species-specific models).



[6] See Acknowledgements for those contributing to species-specific models in addition to the authors

At hierarchical levels (ascending), model elements consisted of submodels, factors and variables. Within variables, a rating system was used to score mutually exclusive classes relative to expected species response. At each hierarchical stage, model elements were weighted and combined to reflect the expected likelihood of species occurrence and distribution throughout the study area. This framework allowed us to account for known interactions and relationships among model elements.

We relied on knowledge from species experts[6] and relevant studies to define model structure and parameters. For each species, we assumed that climate (i.e., temperature and precipitation patterns) and enduring features (i.e., elevation, slope, and forest productivity which integrates soils and climate) exert a fundamental influence on habitat capability. We combined habitat capability with submodels of the principal food sources (small mammals, ungulates, and/or bear plant foods as relevant) to define habitat suitability. Factors within the small mammal prey submodel included snowshoe hares, tree squirrels, and ground squirrels, each of which was defined by combinations of forest structure, cover type, canopy cover, and/or vegetation wetness. The ungulate prey submodel was composed of winter range and summer range factors, each of which was a different combination of slope, aspect, forest structure, and cover type. For grizzly bears, the submodel of key plant foods was defined by habitat factors associated with avalanche chutes, riparian habitats, and berry production. Pertinent descriptors of avalanche chutes included slope, position on slope, and land cover. Proximity to sites influenced by water (streams, seeps, etc.), cover type, and forest structure defined riparian habitats. Variables of forest structure, cover type, canopy cover and aspect defined sites of berry productivity. For each species, we developed a habitat security submodel that was combined with habitat suitability to represent habitat effectiveness. Security was determined by habitat and human conditions represented by canopy cover, terrain complexity, human access, and human influence variables.

Scale-Dependency of Relationships

We derived model elements at each of three spatial scales using a GIS moving window routine (Bian 1997). Level 1 was defined as the broadest scale at which we expect landscape conditions to influence species occurrence. For this, we used a landscape radius of 9 km, resulting in a window size of 254 km^2, roughly approximating maximum home ranges sizes for female grizzly bears, lynx, bobcats, and badgers in our region. Level 3 was defined as the finest scale that most of our focal species respond to in making daily movements. For this, we used a landscape radius of 2.25 km, an area of 16 km^2, approximating the mean daily movements of grizzly bear and lynx in our region. At level 2, we used a landscape radius of 4.5 km, the mid-point between levels 1 and 3, defining an area we assume to roughly approximate core home ranges for most of our focal species.

Parameters

We constructed model elements by first assigning coefficients to mutually exclusive variable classes using a nine-point scale, reflecting the expected direction and degree of species association within the context of the evaluated factor and submodel (Figure 3). Variable classes were scored and scaled independently for each element to which they contributed. That is, known associations with other variables and known influence on other model elements were ignored. For example, the agricultural land class within the human influence variable was rated only specific to the influence of agricultural practices, without consideration to the typical habitat conditions, such as lack of overstorey cover; these other associations were accounted for by different variables. At each hierarchical level of model-building, we re-scaled (0→1) and weighted elements (variables, factors or submodels). We then combined elements in one of two ways depending on whether their influence was considered:

(a) compensatory = $(V_1\beta_1 + V_2\beta_2 + \ldots + V_p\beta_p)$, or
(b) limiting = $(V_1^{\beta 1} \times V_2^{\beta 2} \times \ldots \times V_p^{\beta p})^P$

where V = variable class, β = coefficient or weighting factor, and P = number of parameters. In determining model parameters for each species (Appendix B), we considered the best available knowledge of each species' ecology, habitat associations, and known or theoretical response to human activity. For each species, spatial model outputs are depicted as relative landscape-suitability, and also the relative conservation threat — a reduction of landscape quality due to species-specific human influence (*sensu* Root et al. 2003).

Figure 3. Scale used for scoring classes within model elements in the prediction of landscape quality and vulnerability for carnivore species in the southern Canadian Rocky Mountains.

0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Very High	High	Medium	Low	Neutral	Low	Medium	High	Very High
Negative Influence					**Positive Influence**			

Data Sources and Variables

Data

We obtained geographic data from several sources. Planimetric data of hydrography and point and linear human features were extracted from 1:20,000 Terrain Resource Information Management (TRIM) files (Surveys and Resource Mapping Branch 1992) for BC, and from AltaLIS (2001) for Alberta. Terrain coverages were derived from a 1:20,000 digital elevation model (DEM; Geographic Data BC 1996). A 1:20,000 coverage of forest inventory planning (FIP) data were acquired for the Cranbrook and Invermere Forest Districts in BC (Resources and Inventory Branch 1995). A compatible forest inventory was also acquired from Tembec Industries Ltd. for its privately held managed forest lands. The 1:20,000 Alberta Vegetation Inventory (AVI) was compiled for the Alberta portion of the study area, excluding Waterton Lakes National Park (Alberta Environmental Protection 1991). We derived vegetation indices from a Landsat 7 TM scene taken during August, 2000 and covering most of the regional study area. For lands beyond the extent of this image but within the study area, we used existing Landsat 5 TM data and adjusted reflectance values to best match the more recent data. Other habitat data included the 1:250,000 biogeoclimatic ecosystem classification (BEC; Meidinger and Pojar 1991) and baseline thematic mapping (BTM; Surveys and Resource Mapping Branch 1995). Regional land use plans were obtained in the form of Resource Management Zones for BC (RMZ; Land Use Coordination Office 1997) and the Integrated Resource Management Plan for Alberta (IRP; Alberta Environment 2000). From the FIP database, we obtained private land ownership data for BC at the "district lot" level. We obtained ownership data at the "subdivision" level for Alberta (AltaLIS 2001). Data were rasterized at 25 and 100 m for fine- and broad-scale applications respectively.

Variables

We derived 16 variables from the above data sources (Table 1). The FIP, AVI and Landsat data were combined to depict overstorey cover types and structural stage classes. The FIP data did not distinguish among non-forested habitats that were closed shrub, open shrub, or forb/grass dominated, but satellite imagery can identify vegetation succession (Green et al. 1993). Therefore, we trained the Landsat coverage on these classes using the AVI data, and we combined the FIP and Landsat data to differentiate the above classes in British Columbia (C. D. Apps, unpubl. report). Forest productivity classes were derived from the site index[7] (FIP), timber productivity rating (AVI), and Landsat data. Within this variable, potentially forested sites were split into four subjective classes ranging from "very low" to "high" site productivity corresponding to those used in the BC forest inventory. From the DEM, we defined nine elevation bands, five slope classes, an index of slope position (Pellegrini 1995), and two continuous variables depicting east→west and north→south aspects. We derived an index of terrain complexity by calculating, for each pixel, the diversity[8] of slope position classes within a 250 m radius. We developed an index of landscape accessibility, or remoteness, a function of motorized travel time from human population centers given existing road networks and types, and the size of those population centers. The algorithm includes decay exponents reflecting the decreased "willingness" of people to travel over increasing time, and the lower per capita influence on the regional landbase as population centers become more urbanized (C. D. Apps, unpubl. report). To linear human features, we applied a disturbance class weighting (Apps 1997; Table 2). We then calculated linear disturbance density, which we grouped into four classes of km/2.25 km^2 (mi/mi^2), consistent with previous cumulative effects modeling applications. A human influence variable was derived by assigning three zones of influence to "low- and high-use" features of human activity, "developed" areas, and agri-

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[7] Site index is a measure of expected forest stand productivity. It is determined using species growth curves and stand height and breast height age measures. It is expressed in metres. Index tables (Thrower et al. 1991) range from 5 to 40 m.

[8] Diversity Index H = -sum[p*ln(p)], where sum = all possible classes, p = proportion of each class in the kernel, and ln = natural logarithm (Turner 1989).

Table 1. Variables and classes applied in modeling landscape quality and vulnerability for wide-ranging carnivores in the southern Canadian Rocky Mountains.

Variable	Class
COVER TYPE	Spruce - fir
	Cedar - hemlock
	Douglas-fir
	Lodgepole pine
	Western larch
	Alpine larch
	Whitebark & limber pine
	Deciduous overstorey spp.
	Non-forested vegetated
	Non-forested unvegetated
	Alpine and Barren^b
OVERSTOREY STRUCTURE	Non-forested barren
	Non-forested grass/forb
	Non-forested open shrub
	Non-forested shrub
	Forested 10 - 20 yrs
	Forested 20 - 40 yrs
	Forested 40 - 60 yrs
	Forested 40 - 80 yrs
	Forested 80 - 120 yrs
	Forested >120 yrs
CANOPY COVER	0 – 5%
	6 – 30%
	31 – 50%
	51 – 70%
	71 - 100%
HYDROGRAPHY PROXIMITY	<50 m of feature
	50 - 100 m of feature
	100 - 300 m of feature
	300 - 500 m of feature
LINEAR DISTURBANCE DENSITY	0 km/2.25 km^2
	0 – 1.6 km/2.25 km^2
	1.6 – 3.2 km/2.25 km^2
	>3.2 km/2.25 km^2
FOREST PRODUCTIVITY	High (site index >20)
	Medium (site index 16-20)
	Low (site index 11-15)
	Very low (site index <11)
	Non-forest - vegetated
	Non-forest - unvegetated
	Non-forest - water
SLOPE	Flat <10%
	Gentle 10 - 30%
	Moderate 30 - 50%
	Steep 50 – 80%
	Very steep >80%
ASPECT	North→South
	East→West
SLOPE POSITION	Bottom
	Lower
	Mid
	Upper
	Top
TEMPERATURE	Warm
	Cool
PRECIPITATION	Dry
	Moist
TERRAIN COMPLEXITY	Very low (< 0.2)
	Low (0.2 - 0.39)
	Moderate (0.4 - 0.59)
	High (0.6 - 0.79)
	Very high (≥ 0.8)
ACCESS	Very low (< 0.2)
	Low (0.2 - 0.39)
	Moderate (0.4 - 0.59)
	High (0.6 - 0.79)
	Very high (≥ 0.8)
HUMAN INFLUENCE	200-500 m of "low use" features
	50-200 m of "low use" features
	<50 m of "low use" features
	200-500 m of "high use" features
	50-200 m of "high use" features
	<50 m of "high use" features
	Agricultural lands
WET VEGETATION INDEX	Very xeric (< -60)
	xeric (-60 to -35)
	subxeric (-35 to -20)
	mesic (-20 to 0)
	submsesic (0 to 10)
	hygric (10 to 15)
	subhygric (15 to 20)
	hydric (> 20)
SEEPAGE & FLOODPLAIN	< 50 m of seepage or floodplain
	> 50 m of seepage or floodplain
ELEVATION	< 1000 m
	1000 - 1200 m
	1200 - 1400 m
	1400 - 1600 m
	1600 - 1800 m
	1800 - 2000 m
	2000 - 2200 m
	2200 - 2400 m
	> 2400 m

Table 2. Linear disturbance feature types and relative weightings for density calculations (Apps 1997) in modeling landscape quality and vulnerability for wide-ranging carnivores in the southern Canadian Rocky Mountains.

Disturbance Class	Specific Feature Types	Weight
primary	all paved roads	2
secondary	all gravel and 2 lane loose roads all rail lines	1
tertiary	all rough, loose dry weather and 4-wheel drive roads	0.5
quaternary	"cart-tracks", seismic lines, and all above ground transmission and pipe lines	0.25

cultural lands. We split the Landsat-derived Wet Vegetation Index (Crist and Cicone 1984) into eight subjectively determined moisture regime classes ranging from very xeric to hydric. TRIM hydrographic features were rasterized to define sites > or < 50 m from a stream, lake, or swamp.

We derived macro-climatic variables of temperature and precipitation from biogeoclimatic ecosystem subzone labels in BC and Alberta natural regions. Ecosystems defined by "warm" biogeoclimatic subzones and variants have mean temperatures that range from 10.1 to >12.6°C and –1.9 to 1.4°C during summer and winter respectively. "Cool" ecosystems have mean temperatures that range from <7.0 to 10°C and <-4.1 to -2°C during summer and winter respectively. Ecosystems that occur within the "dry" climatic region receive summer precipitation of <200 to 300 mm and winter snow water equivalent of <200 to 800 mm. Ecosystems within the "moist" climatic region receive summer precipitation of 301 to 400 mm, and a winter snow water equivalent of 351 to 800 mm (Braumandl and Curran 1992).

For each species, model outputs represent an index of inherent landscape suitability as well as the relative reduction of landscape quality that can be attributed to species-specific human influence (i.e., landscape vulnerability). These models reflect the best available knowledge of each species' ecology, habitat associations, and known or theoretical response to human activity.

Results and Discussion

For each species, two model outputs are provided: (a) the inherent potential for landscape occupancy and population distribution, and (b) species vulnerability as a function of both inherent suitability and human influence. This latter output may be interpreted as the potential for a population "sink" (mortality exceeds local recruitment) or, alternatively, the potential conservation impact of restoration (*sensu* Root et al. 2003). For each of our focal species, regional model outputs can be interpreted to delineate core habitat areas, landscape linkages among them, as well as peripheral landscapes of marginal habitat quality. Collectively, these conditions define the likely extent of natural distribution for each species.

Grizzly Bear: For grizzly bears, an empirical evaluation of our expert-based model suggested that predictive confidence was not appropriate for conservation planning (see Chapter 3). We expect that this poor performance was mostly related to an inability of existing biophysical data, to directly account for plant and ungulate foods that are seasonally important to bears. Thus, we relied on a purely empirical modeling approach using DNA-based detection data independently sampled within the region at a scale appropriate for predicting population distribution and evaluating influential factors (*sensu* Apps et al. 2004). In addition to the variables we describe, this empirical approach also considered remotely-sensed vegetation indices (e.g., Stevens 2001). In this process, measures were taken to ensure that modeled grizzly bear–habitat relationships do not reflect variation (noise) unique to the underlying data (thus of little predictive value). However, the actual ecological meaning of some modeled relationships can be difficult to describe given that interdependence among model parameters can be expected. In the application of such data-based models, it is thus critical that predictive confidence be properly defined as a direct function of how representative the sample data are relative to variation in landscape conditions. Based on such an analysis, the derived empirical grizzly bear population occurrence and distribution model was applied only within a defined extrapolation area within which we judged the data to be representative (C. D. Apps, unpubl. Report, Figure 4A).

Our results projected rather high suitability for grizzly bears in the mountains and higher foothills throughout much of our study region, both south and north of the Crowsnest Highway (Figure 4A). Landscapes of high suitability included the following areas: (1) the lower Flathead basin (BC) and adjacent Castle drainage (AB), (2) east side of the Wigwam basin (BC), (3) the upper reaches of the Flathead basin (BC) and adjacent Carbondale area (AB), (4) Michel Creek (BC) and adjacent Lynx Creek area (AB), (5) Alexander drainage (BC) and adjacent Allison Creek basin (AB), (6) upper Elk River basin (BC) and adjacent upper Highwood River drainage (AB), (7) west side of the upper Elk River (BC), and (8) Lizard Range (BC), Our modeling[9] suggests that grizzly bear populations are of moderate to high vulnerability along the Crowsnest Highway (Hwy 3), Elkford Highway (Hwy 43), and the Corbin road in B.C., and the Forestry Trunk road (940) and Castle River road (774) in Alberta (Figure 4B). The following landscape linkages across the Crowsnest Highway could connect several core areas: (1) south of Fernie to connect the Lizard Range and the Morrissey and upper Flathead drainages, (2) north of Fernie to link Three Sisters/Hartley Pass/Lladner Creek and Fernie-Hosmer Ridge complex, and (3) west of Crowsnest Pass to connect Michel and Alexander Creek valleys. Many of the east↔west passes along the Continental Divide (both north and south of the Crowsnest Highway) appear important for maintaining continuity of highly suitable landscapes shared by Alberta and British Columbia.

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[9] The model of potential grizzly bear population distribution, as derived through the above process, was combined with the expert-based security submodel to provide a spatial estimate of population vulnerability, as done for other focal species.

Lynx: Our model of landscape suitability for lynx predicted a patchy distribution of highly suitable habitat along major ridge complexes and valleys at higher elevations (Figure 5A). Variations in predictions among landscapes and the resulting patchy distribution of the population have been verified by analysis against independent sampling of lynx occurrence (Chapter 3). This patchy distribution indicates that the stability of the regional lynx population likely is dependent on the productivity, security, and connectivity of several key landscapes. Important areas include: (1) south of the Crowsnest Highway — upper drainages east of Fernie and south of Sparwood and the upper Flathead River basin in British Columbia, Lynx Creek and upper Castle River in Alberta, and (2) north of the Crowsnest Highway – west of the Bull River, within and north of Top of the World Provincial Park, confluence of the upper branches of the White River, and especially the Upper Elk River area in BC, and a narrow band of habitat in Alberta just east of the Continental Divide extending from upper Racehorse Creek northward to upper Highwood River. In some areas, young conifer regeneration following natural fire or logging has provided suitable habitat at present for snowshoe hare and lynx. Habitats along the primary highways in the major valleys usually provide lower suitability. The most likely linkages for connecting core areas for lynx appear to include: (1) south of Sparwood to connect Fernie-Hosmer-Sparwood Ridge complex with Lladner Creek and Hartley Pass, and (2) between Sparwood and Crowsnest Pass to connect Michel Creek and Alexander Creek drainages. On the Alberta side, suitable habitat appears to be further away from the Crowsnest Highway, thus leaving a wider gap of open, unsuitable habitat for lynx to cross north↔south. In addition, human developments occur more continuously along this section of the highway. Candidate linkages for lynx to move east↔west across the Continental Divide include North Fork Pass, Andy Good Pass, and Sage Pass between the Flathead River (BC) and the Castle River drainage (AB).

Badger: Landscapes with potential to support badgers tend to coincide with low elevations and relatively dry and open conditions, and our results suggested that the most extensive landscapes with high suitability for badgers would occur primarily in the dry, open grasslands of the Rocky Mountain trench along Highway 93 in British Columbia and the Rocky Mountain foothills north and south of Lundbreck in Alberta (Figure 6A). Some localized habitat of moderate quality also occurs in the upper Elk Valley, north of Sparwood, and within the Flathead Valley. Our modeling suggests that badger populations are of moderate to high vulnerability in all these areas (Figure 6B) due to human settlements, agricultural lands, and major highways and other roads — which underscores the chronic vulnerability of this endangered species.

Bobcat: Given that bobcats in this region are very near a range limit, their habitats coincide with low elevation forested landscapes associated with relatively dry and mild winter climatic conditions (Figure 7A). As such, bobcat distribution tends to be somewhat peninsular in this region, occurring mostly along the flanks of the Rocky Mountain Trench parallel to Highway 93 in British Columbia as well as forested plains and foothills in Alberta. Our modeling suggests that bobcats are of moderate to high vulnerability in some of the major valleys and plains where Highway 93, the Crowsnest Highway, the Elkford Highway (Hwy 43), and Hwy 22 in Alberta coincide with the some of the limited habitat available to bobcats (Figure 7B).

Wolf: The potential distribution of wolves largely coincides with major valley networks throughout the region — specifically the grasslands and foothills flanking the east side of the Canadian Rockies in Alberta and the larger montane valleys in British Columbia such as the Elk, Flathead, Kootenay, and Columbia River valleys (Figure 8A). However, the actual distribution of this species has undoubtedly been influenced by low levels of habitat security (Figure 8B). Our results indicate that wolf populations are of moderate-high vulnerability along Highway 93 and the Elkford Highway (Hwy 43) in British Columbia, and open landscapes along the Crowsnest Highway and Highway 22 in Alberta. Currently, the regional wolf population likely is dependent on the productivity and somewhat higher security of landscapes such as the Flathead drainage and the upper Elk Valley. Wolf research within the region supports the conclusion that major valleys parallel to the Continental Divide from Glacier National Park up to Banff National Park and associated passes along the Continental Divide are conduits for wolf movements. In particular, the Flathead River upper Carbondale-Castle River, and upper Elk River valleys appear to be important areas in the region.

Wolverine: Among our focal species, we know least about landscape attributes influencing wolverine distribution throughout the region. We do know that wolverines are potentially associated with a variety of landscape conditions, particularly as they pertain to the availability of ungulates and carrion. Our model of landscape suitability for wolverines predicted rather high suitability in the mountains and higher foothills throughout much of the regional study area (Figure 9A). Many of the areas of high suitability for grizzly bear also appear good for wolverines. As with our other species, the actual distribution of wolverines in the southern Canadian Rocky Mountains is expected to be constrained by human activity and its influence on wolverine mortality risk, displacement and food availability. Our results suggest moderate to high wolverine vulnerability along the Crowsnest Highway, Elkford Highway (Hwy 43), Kananaskis-Highwood Highway (Hwy 40) and associated towns and high recreation zones (Figure 9B). Potential linkages connecting core areas closest to the Crowsnest Highway occur near Morrissey, south and west of Sparwood, and Michel-Alexander Creek in British Columbia. Many of the east↔west passes along the Continental Divide (both north and south of the Crowsnest Highway) appear important for maintaining continuity of highly suitable habitat shared by Alberta and British Columbia.

Figure 4. Predicted GRIZZLY BEAR distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta. This empirically-derived model is extrapolated only to landscapes within which sampling data are considered representative.

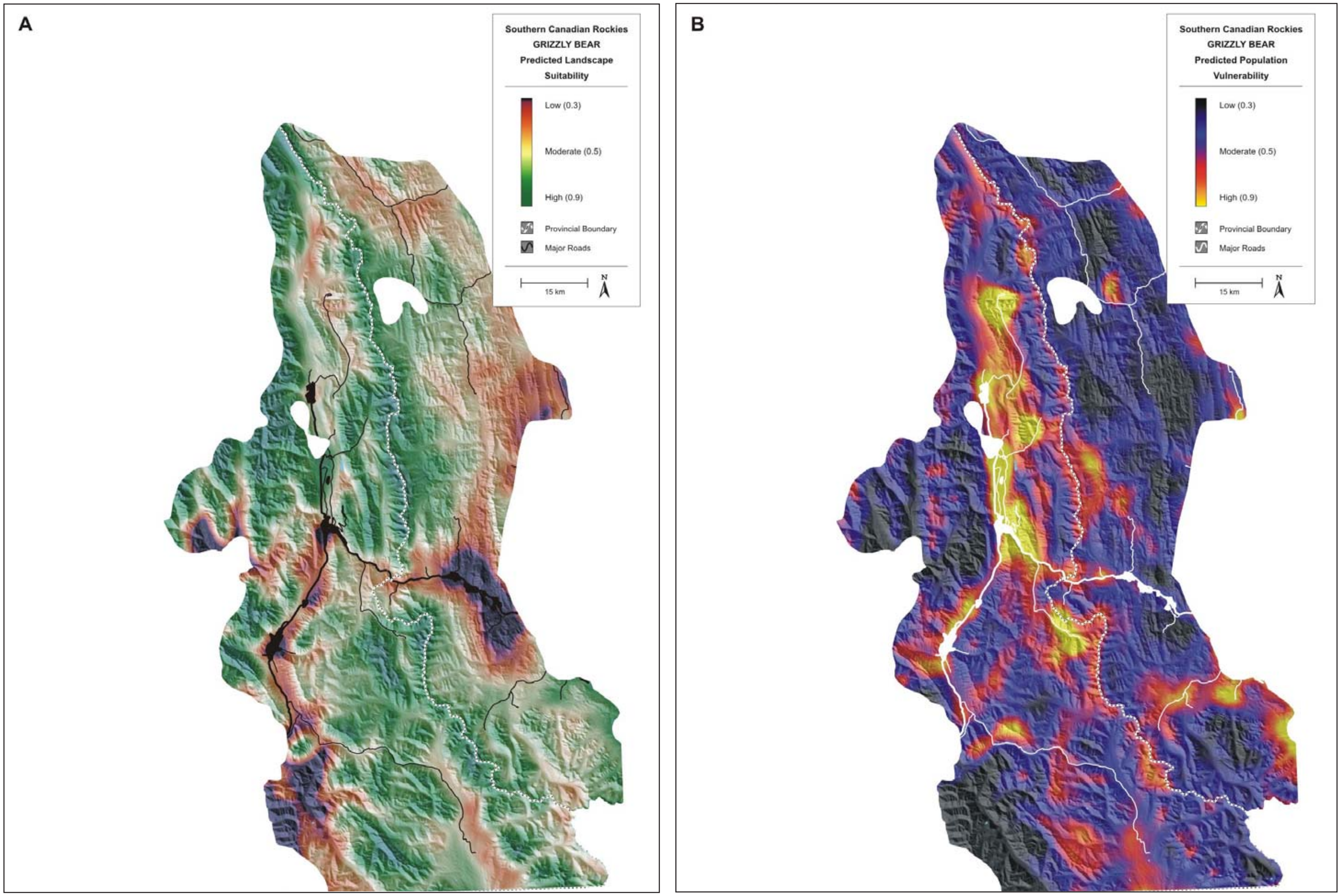


Figure 5. Predicted LYNX distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta.

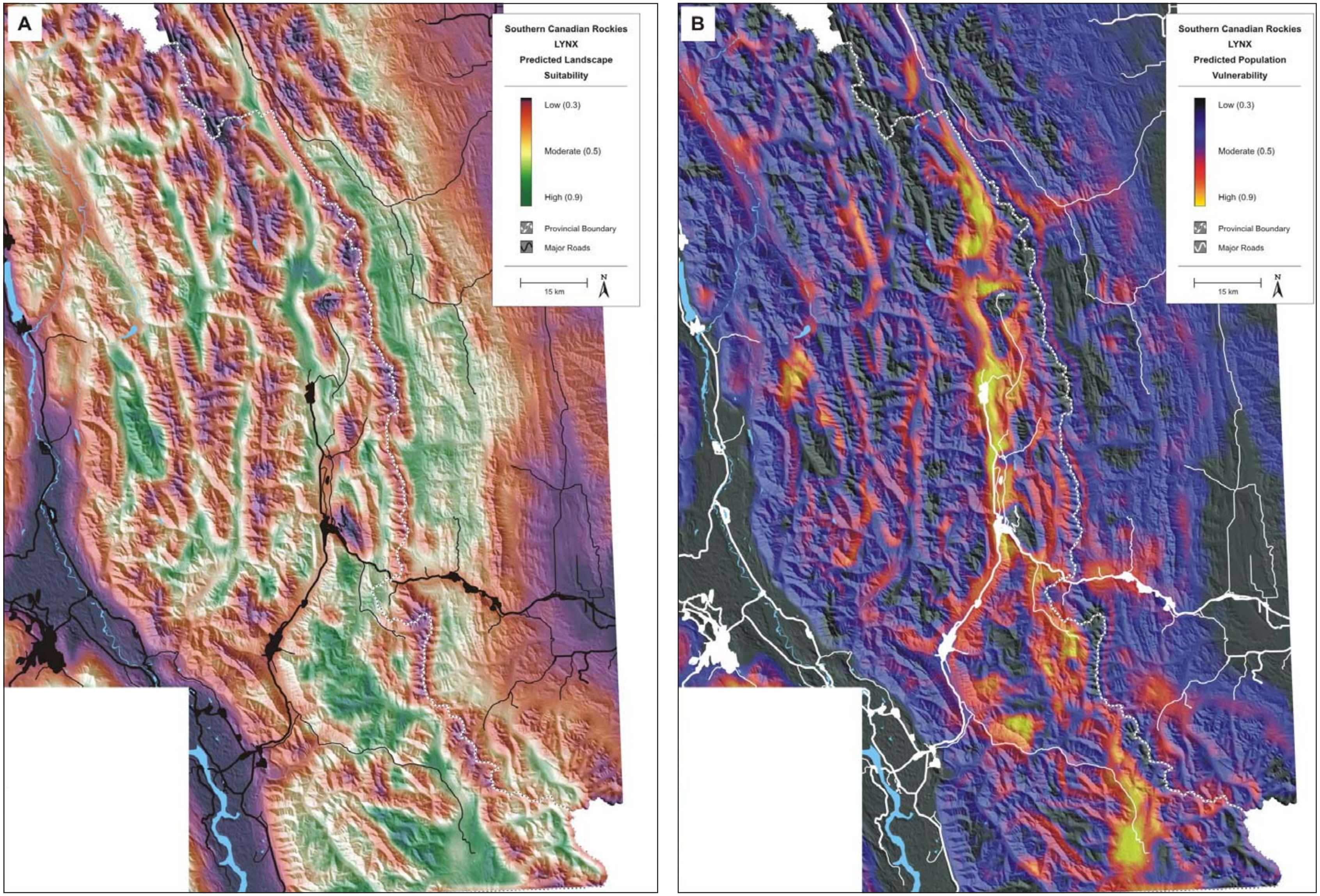


Figure 6. Predicted BADGER distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta.

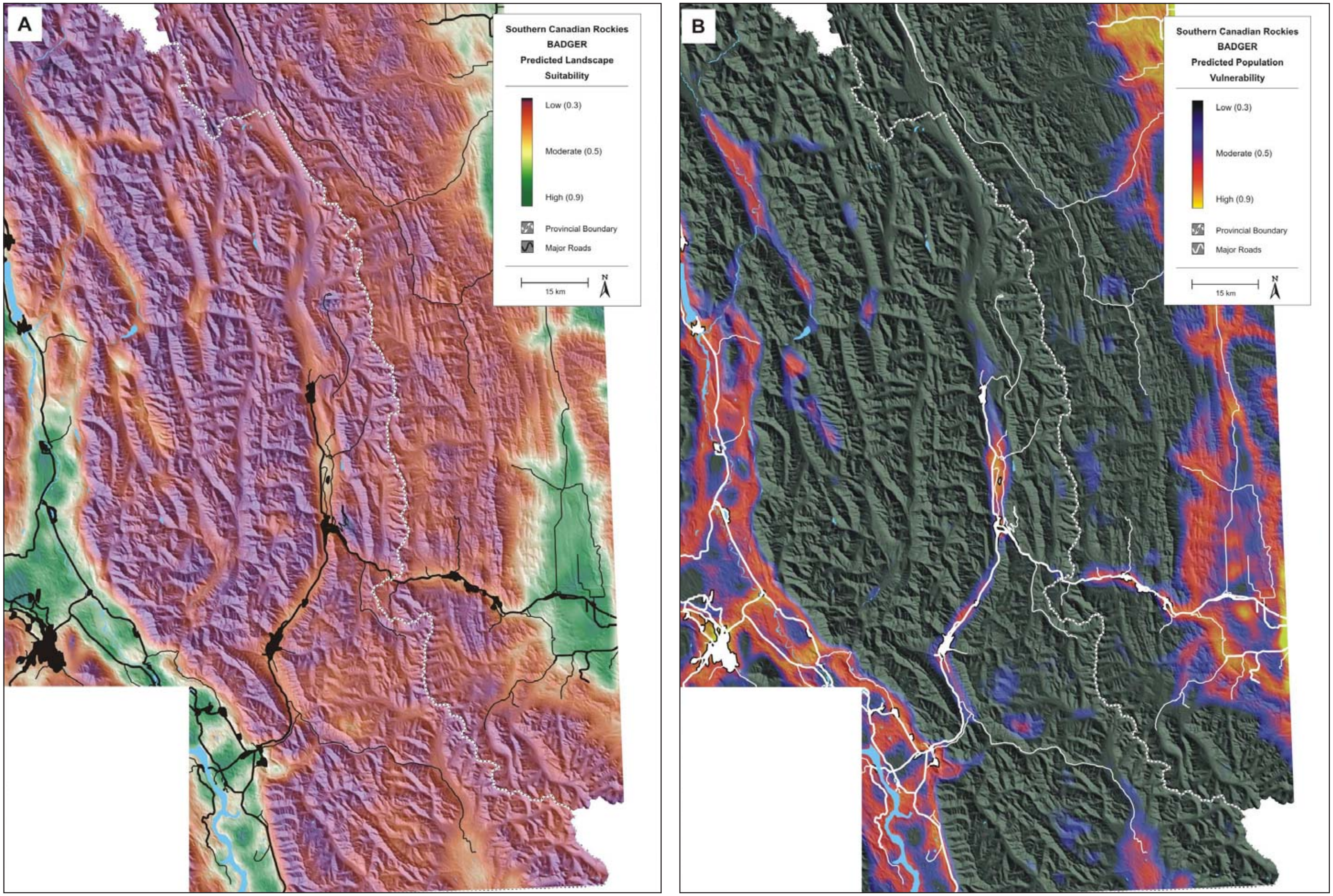


Figure 7. Predicted BOBCAT distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta.

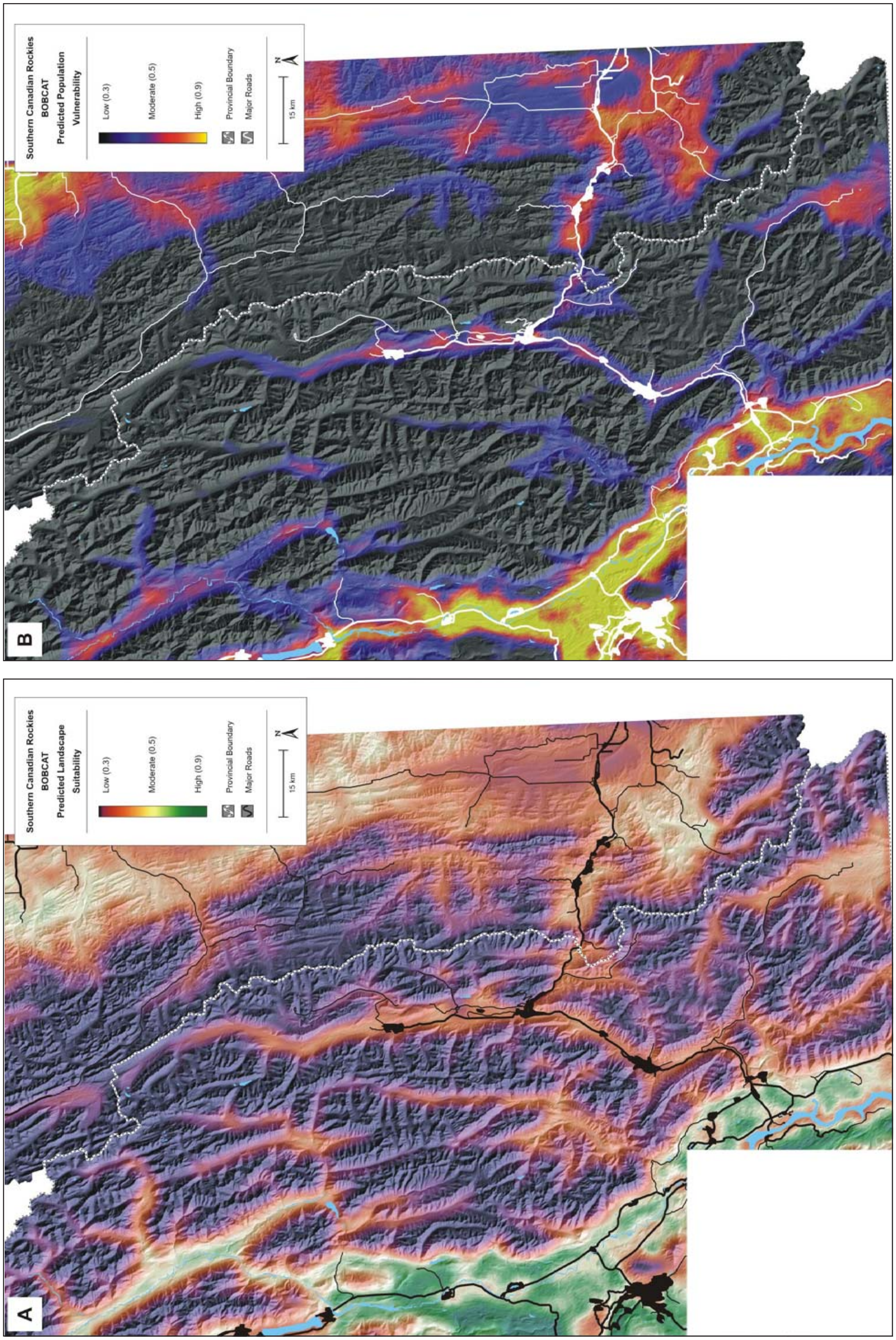
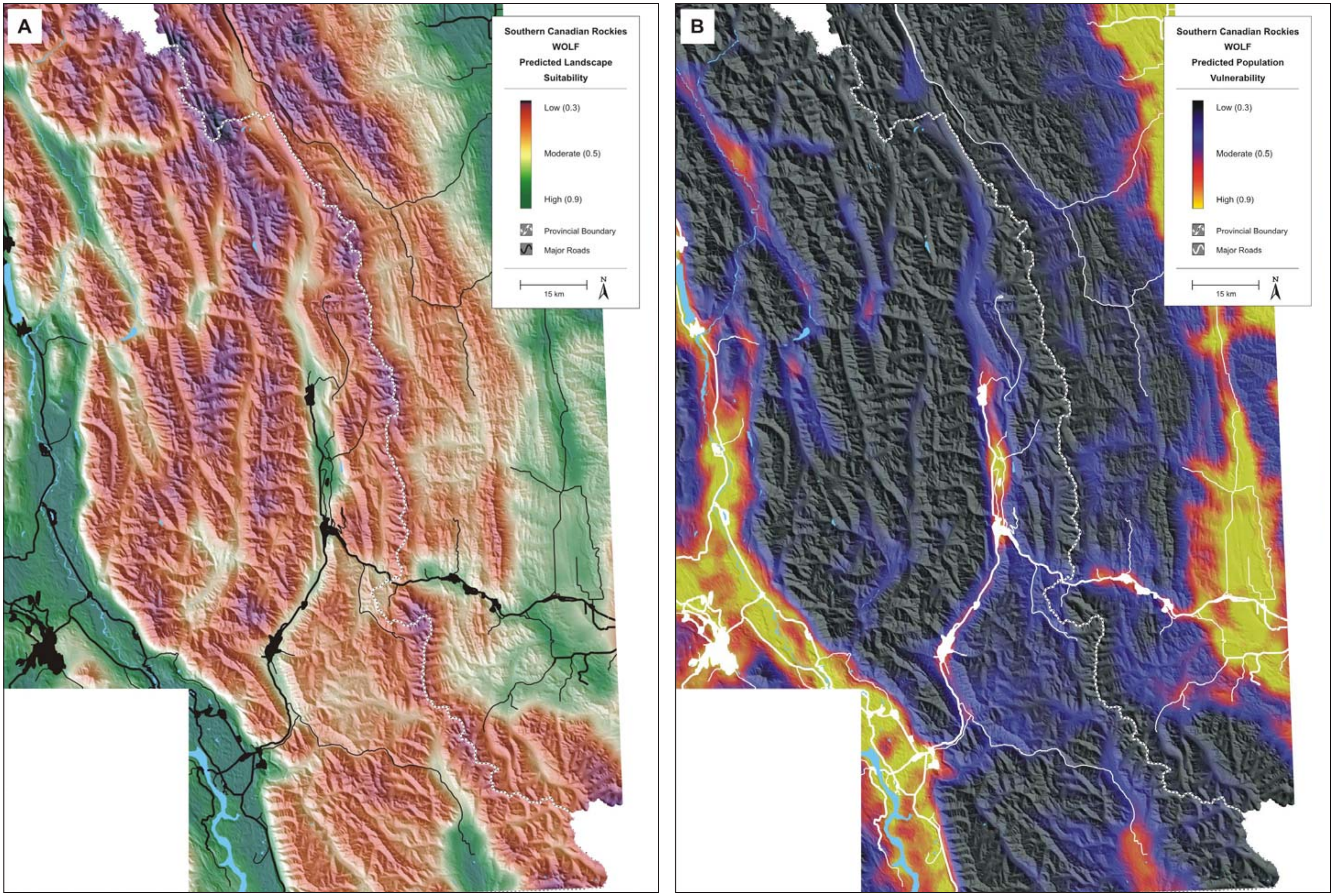


Figure 8. Predicted WOLF distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta.



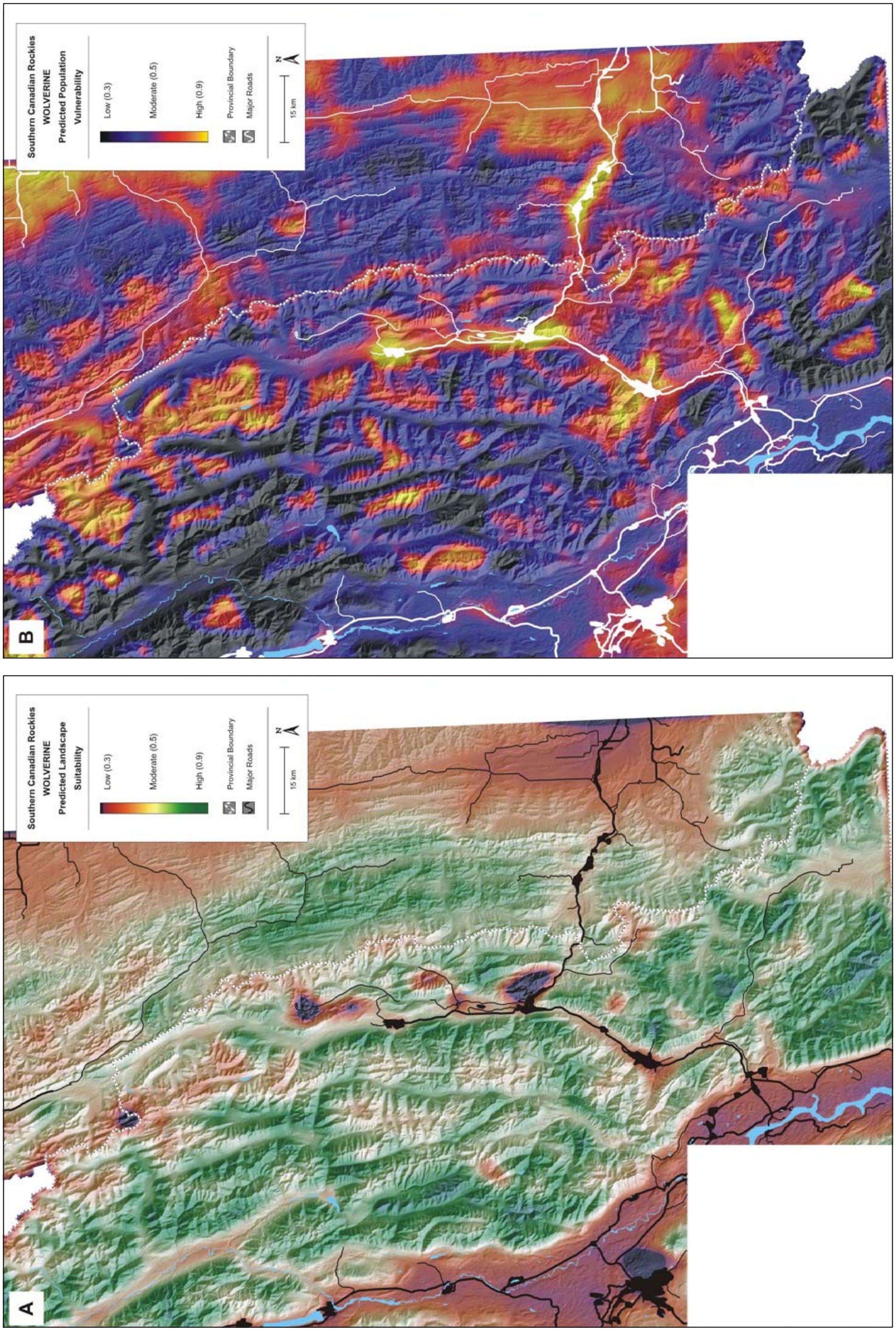


Figure 9. Predicted WOLVERINE distribution – a reflection of landscape suitability (A) and population vulnerability (B) across the southern Canadian Rocky Mountains, British Columbia and Alberta.

3. DISTRIBUTION OF GRIZZLY BEARS AND LYNX NEAR THE CROWSNEST HIGHWAY

Introduction

In stage 1 (Chapter 2), we developed models that predicted both the likely distribution and vulnerability of populations for each of six species of wide-ranging carnivores. These models predicted that landscapes supporting badger, bobcat, and wolf were mostly associated with the broad valleys and foothills or plains that flank the west and east sides of the study region. However, for three of the less resilient species — grizzly bear, lynx, and wolverine, the models predicted a population distribution associated with the mountains and valleys along the main axis of the southern Canadian Rockies. Map outputs (Figures 4, 5, & 9) clearly indicated that the Crowsnest Highway and associated developments bisect the primary distribution of these species, potentially limiting north↔south population connectivity. The rugged Continental Divide also appeared likely to restrict east↔west movements between Alberta and British Columbia. Thus, in the next stage of our research, we narrowed our focus to the distribution and movements of two species — grizzly bear and lynx — in an area that paralleled and included the Crowsnest Highway where it passed through the southern Canadian Rockies. We conducted field surveys to: (1) determine relative abundance, distribution and population connectivity of these species proximal to the Crowsnest Highway, and (2) compare their actual occurrence to their predicted distribution.

Methods

Field Surveys

In the late 1990's, wildlife researchers and geneticists pioneered new techniques for surveying carnivores using scented stations to collect hair for DNA analysis (bears: Woods et al. 1999; lynx and other cats: Weaver 2002, Weaver et al. 2005). Such data can provide information on the species, gender, and identity of individuals, as well as the genetic diversity and connectivity of populations. We followed their basic protocols to survey carnivore occurrence and distribution in landscapes surrounding the Crowsnest Highway.

We established hair-snag stations systematically across grids that straddled the Crowsnest Highway (Figure 10). Each grid cell was 5 km x 5 km in size (25 km^2), presumably small enough for these carnivores to encounter a station during a 10 to 20 day sampling period. In 2002, we surveyed a 36-cell grid across a 900-km^2 area centered on the Continental Divide at Crowsnest Pass where the highway runs east↔west ('Crowsnest Pass' grid). On this grid, 22 cells were located north and 14 cells south of the Crowsnest Highway. In 2003, we surveyed a 40-cell grid across a 1,000-km^2 area in the lower Elk Valley between Sparwood and Elko where the highway runs more north↔south ('lower Elk Valley' grid). On this grid, 22 cells were located west and 18 cells east of the Crowsnest Highway. Altogether, we surveyed 44 grid cells on one side (north and west) of the highway and 32 grid cells on the other side (south and east).

In the grizzly bear survey, we placed a single sampling station within each grid cell. We selected sites we expected to have the best likelihood of detecting a grizzly bear based upon habitat conditions and likely travel routes. We piled logs, brush, and moss and poured three liters of rotted cattle blood and one liter of rotted fish oil over the mound (Figure 11). We enclosed the site by running a single strand of barbed wire around several trees about 5 m out from the mound and uniformly about 50 cm above the ground (see Fig. 1 in Woods et al. 1999). We established sites in early June using a helicopter, then checked and re-scented them every 10 days thereafter on the ground. We completed four 10-day sampling sessions each year.

Many (but not all) species of the cat family naturally rub their cheeks on objects with certain scents (Mellen 1993). To survey lynx, we used a technique that capitalizes on this natural cheek-rubbing behavior (Weaver 2002). Using the same 25-km^2 grid cells as for the bear survey, we placed four rub-pad stations in each cell at sites that we judged most likely to intercept movements by lynx (e.g., intersection of wildlife trails near foraging habitat). At each site, we established a station by posting both a visual attractant and a hair-snare pad on a tree adjacent to the trail (Figure 12). For a visual attractant, we tied half of an aluminum pie plate to a 10-cm leader of monofilament with a swivel at the loose end and clipped it onto the bottom loop of 19-gauge wire twisted around a branch. The pie plate hung about 1 m above the ground and fluttered in the breeze. We then nailed a rub-pad to the tree at approximately 40 cm from the ground. Each rub-pad consisted of a 10 x 10 cm piece of short-napped carpet through which barbed roofing nails were punched from the back. We scented the pads with 10 ml of Weaver's Cat Call™ and dried catnip, which elicits a strong cheek-rubbing response from lynx, bobcats, and other felids (Weaver 2002, Weaver et al. 2005). Flexing of the nails within the pad ensured no harm to a rubbing animal while obtaining a hair sample. We conducted two sampling sessions of approximately 20 days each during August through early October of 2002 and 2003. At the end of the first session, we collected and replaced pads that had been rubbed, moved some stations, and re-scented all stations.

Figure 10. Location of carnivore DNA hair-snaring grids proximal to the Crowsnest Highway (bold line) in the southern Canadian Rocky Mountains. Shown are the Crowsnest Pass grid (purple) and the lower Elk Valley grid (blue), with cells of 25 km^2. The regional study area is represented by the white outline.

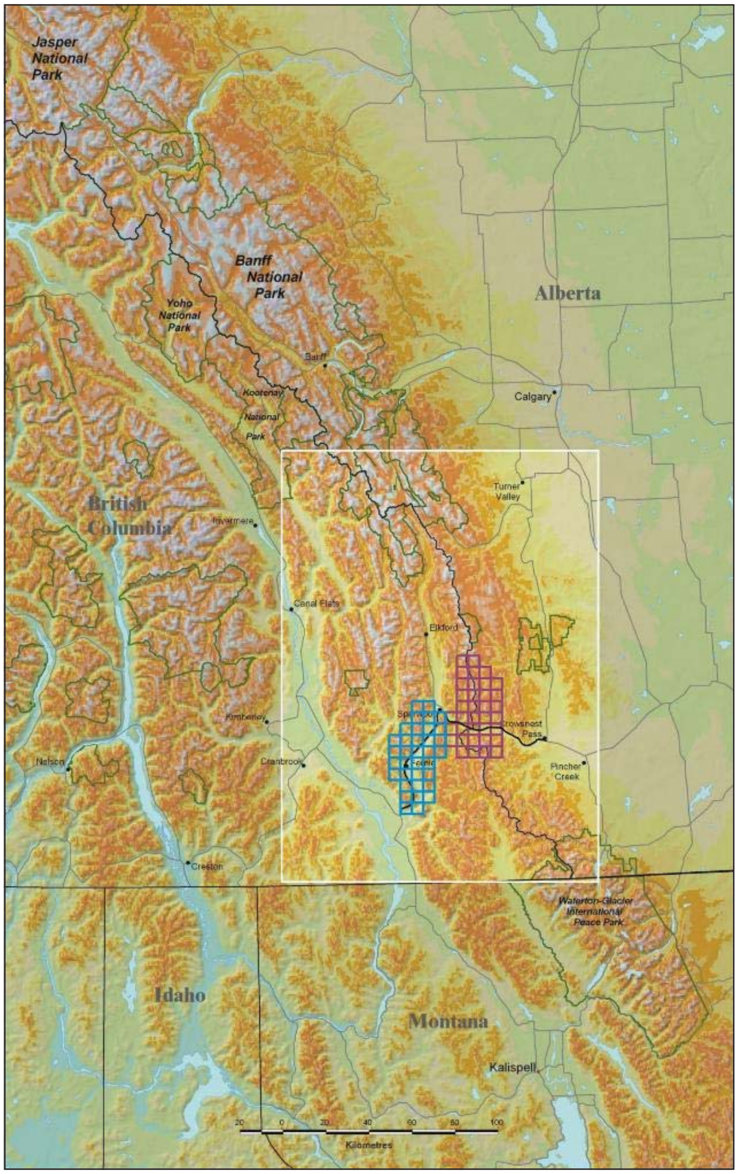


Figure 11. Typical survey station for detecting bears, showing (A) barbed-wire corral and scented brush pile, and (B) a clump of bear hair for DNA analysis.

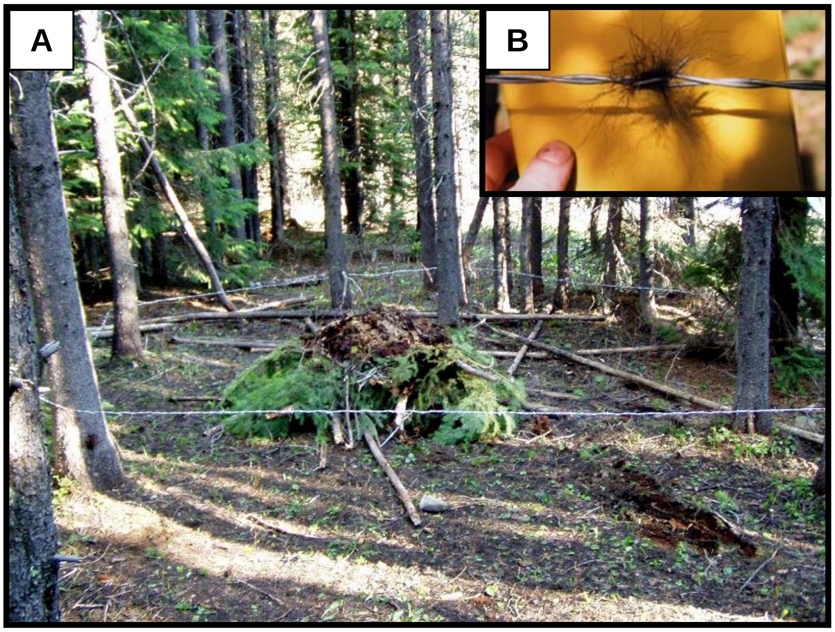
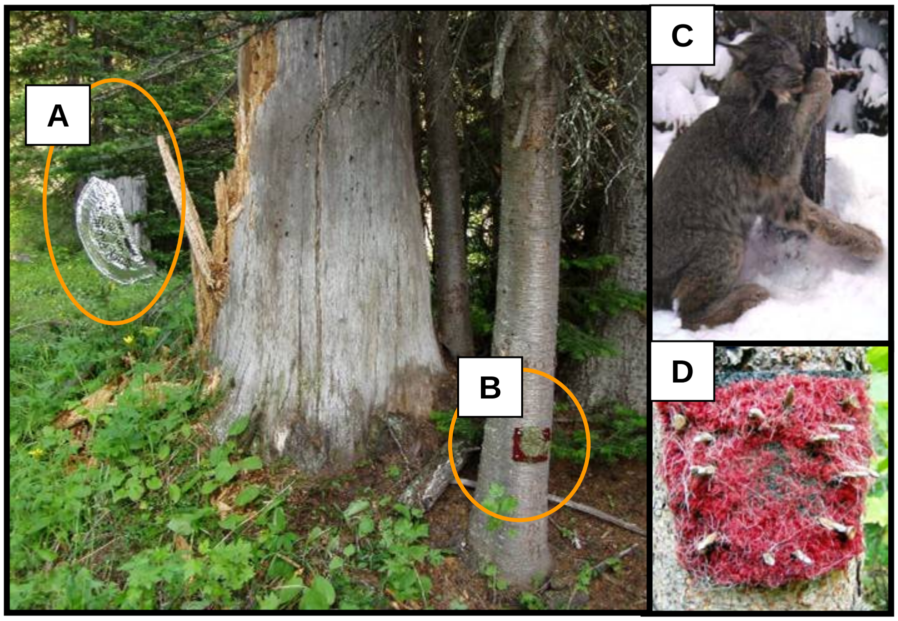


Figure 12. Typical survey station for detecting lynx, showing (A) aluminum pie plate as visual attractant, (B) scented carpet for eliciting a rubbing response and hair sample, (C) lynx cheek-rubbing on pad, and (D) a rubbed pad with lynx hair ensnared on the nail tips and the carpet fibre.



DNA Analyses

The Wildlife Genetics International (WGI) lab (http://www.wildlifegenetics.ca) in Nelson, BC, under the direction of Dr. David Paetkau, conducted the DNA analyses for all samples. To ensure rigorous and reliable identification of individuals, the WGI lab selected a specific set of variable genetic markers, culled marginal samples at an early stage in the process, scrutinized similar pairs of genotypes, and adhered to high laboratory standards for quality control (Paetkau 2003, Waits and Paetkau 2005).

WGI extracted DNA using QIAGEN's DNeasy kits (QIAGEN Inc., Mississauga, Ontario, Canada). To guard against possible contamination, WGI kept DNA that had been amplified using polymerase chain reaction (PCR) in an isolated facility apart from hair samples and genomic DNA extracts. They monitored for contamination by running blank samples (no hair added) with each set of samples that was extracted or amplified.

WGI used the microsatellite marker G10J to distinguish grizzly bears (even-numbered alleles) from black bears (odd-numbered alleles). From an extensive regional database on the grizzly bear genome, WGI selected a six-locus marker system (G10J plus G1D, G10B, G10H, G10M, and MU50) with high variability to identify individual bears. They excluded samples that produced strong signals at fewer than five loci (other than G10J) because such samples are prone to amplification errors (Taberlet et al. 1996) or the 'shadow effect' (described by Mills et al. 2000). They scored samples using GENOTYPER software (Applied Biosystems, Foster City, California, USA). A second, highly experienced person confirmed scoring of all complete genotypes that comprised the final data set. For each individual grizzly bear thus identified, WGI selected one extraction to determine gender based on a size polymorphism in the amelogenin gene (Ennis and Gallagher 1994).

For the lynx survey, a representative sample of hair was taken from the rub pad. To determine species, WGI compared a sequence of the 16S rRNA mitochondrial gene (Johnson and O'Brien 1997) to a genetic 'reference library' of 80 species (Wildlife Genetics International, unpublished report). To identify individual felids, WGI selected five markers that exhibited considerable variability and produced clear, strong alleles: Fca45, Fca90, Fca559, Lc106, and Lc109. WGI personnel followed similar, rigorous protocols for scrutinizing and recording these results as they did for grizzly bear samples. WGI determined gender of the lynx samples based on presence or absence of the SRY gene (Y-chromosome), along with co-amplification of the ZFX/ZFY gene (both X- and Y-chromosomes) as an internal control. They followed the approach outlined in Aasen and Medrano (1990) but modified primers and reaction conditions to produce strong amplifications in felids.

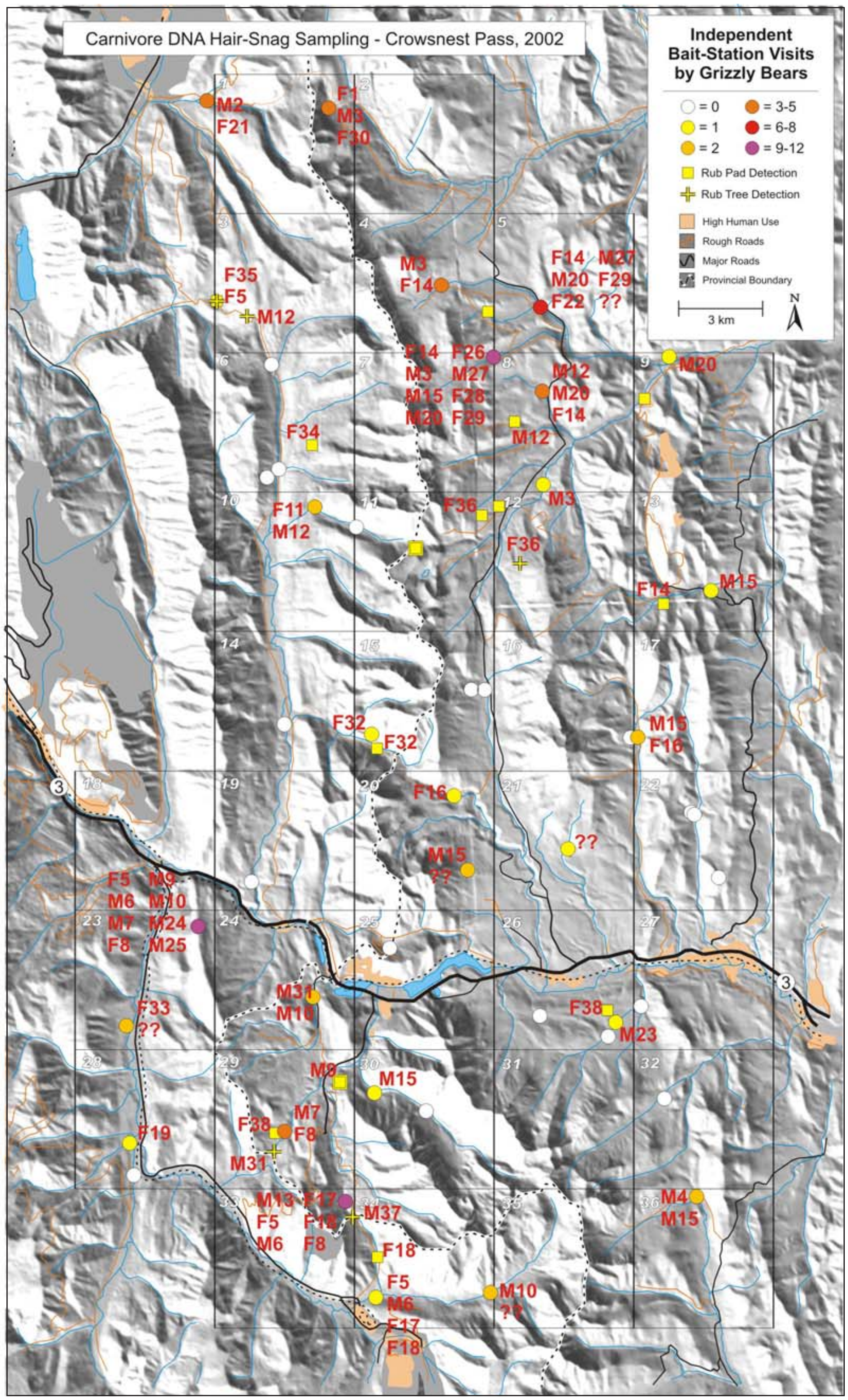
Evaluation of Regional Occurrence and Distribution Models

Within the survey areas (combined for 2002-2003), we evaluated the predictive veracity of regional occurrence and distribution models for grizzly bears and lynx using two tests. First, we compared the average scores of relative species-occurrence scores using Mann-Whitney U tests ($\alpha = 0.05$). We also derived the area under the relative operating characteristic (ROC) curve (Pearce et al.

Table 4. Detection of grizzly bears (gender/individual or G for grizzly) at barbed-wire corral sets (sessions I – IV) and rub pads (sessions V and VI) in and around the Crowsnest Pass, Alberta and British Columbia, 2002. Location of grid cell noted as north (N) or south (S) of Crowsnest Highway.

		Session					
Cell	Hwy	I 12 June –22 June	II 23 June – 5 July	III 6 July – 16 July	IV 17 July – 27 July	V 12 Aug – 14 Sep	VI 9 Sep – 3 Oct
1	N	M2	F21	F21			
2	N	F1		F1, M3	F30		
3	N					F35	
4	N			M3, F14	F14		
5	N		F14, M20, F22	F14, G	M27, F29		
6	N					F34	
7	N	F14	M3, M15	F14, M20	F26, M27, F28, F29		M12
8	N		M12, M20		F14, M20		
9	N				M20		G
10	N	F11, M12					
11	N					F36, G	
12	N	M3					G
13	N			M15			F14
14	N				F32		
15	N			F16			F32
16	N	M15, F16					
17	N						
18	S	F5, M6, M7, F8, M9, M10		M10, M24, M25			
19	N						
20	N		M15	G			
21	N	G					
22	N						
23	S				F33, G		
24	S				M10, M31		
25	N						
26	S					F38	
27	S						
28	S	F19					
29	S	M7, F8		F8			F38
30	S			M15		G	M9
31	S			M23			
32	S						
33	S	M13	F5, M6, F17, F18	F5, M13, F18	F5, F8, M13		
34	S	F5, M6, F17, F18	F17	F18			F18
35	S	M10		G			
36	S	M4			M15		

Figure 13. Visits of individual grizzly bears to scented stations and rub pads in grid cells surrounding the Crowsnest Highway near Crowsnest Pass, Alberta and BC, June – September 2002.



2002) or *c* statistic, which is the proportion of paired cases between detections and non-detections in which a higher relative occurrence score is assigned to cases where the species has been detected. We used the software SPSS 12.0 (SPSS Inc. 2003) for all analyses.

Results

Here, we present the results of our field surveys for grizzly bears and lynx and discuss their occurrence and movements relative to the Crowsnest Highway and the Continental Divide.

Grizzly Bear Occurrence and Movements

Crowsnest Pass Grid

On the Crowsnest Pass grid during June and July 2002, we detected 33 grizzly bears (16 males and 17 females) a total of 82 times (Table 4, Figure 13). In addition, nine individual grizzly bears (2M, 7F) rubbed on the scented carpet pads during the August-September surveys for lynx. Four of these bears, all females (F34, F35, F36, F38), were 'new' bears that visited sites in cells where we had not detected any grizzly bears during the earlier sessions (cells 6, 3, 11, and 26, respectively). We also identified five individual grizzlies (3M, 2F) from hair we collected off natural rub trees. This included M37 who was a new bear (cell 33).

During both survey efforts, we detected 38 grizzly bears in 29 (81%) of the 36 cells in the Crowsnest Pass grid. Three of the seven stations without a grizzly bear detection were located within 3 km of the Crowsnest Highway (Figure 13). One female (F5) and one male (M15) occurred on both sides of the highway. Grizzly bears were common both north and south of the highway in terms of occupancy, occurrence, and relative density (Table 5). Interestingly, male bears predominated south of the highway (12M, 7F) compared to the north side (6M, 15F) and were unlikely to come from areas with the same sex ratio (G=4.73, 1 df, P=0.030).

We found grizzly bears concentrated in several areas during summer. One area occurred south of the Crowsnest Highway near Crowsnest Pass itself and along both sides of the Continental Divide. Another concentration occurred north of the Crowsnest Highway and along either side of the Continental Divide in the upper reaches of Alexander Creek and the Oldman River. Some of these denser occurrences may have included family groups.

We detected several individuals on both sides of the Crowsnest Highway and others on both sides of the Continental Divide. Here, we provide a detailed account of sequential locations for each bear (Table 4, Figure 14).

Figure 14. Generalized movements of grizzly bears inferred from multiple detections of individuals surrounding the Crowsnest Highway near Crowsnest Pass, Alberta and BC, June – September 2002.

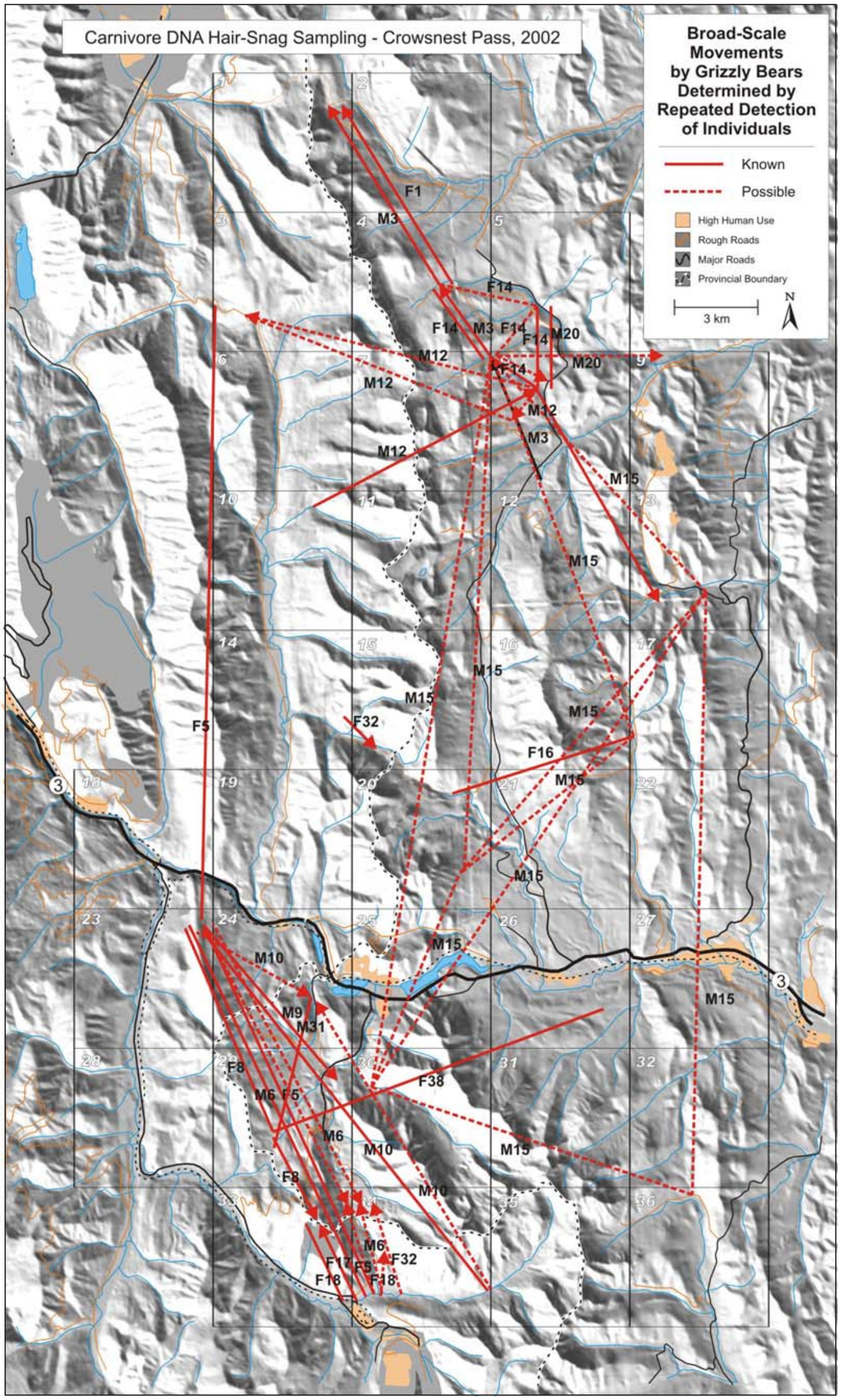


Table 5. Occupancy, occurrence, and relative density of grizzly bears north and south of the Crowsnest Highway (Hwy 3) in the vicinity of Crowsnest Pass, Alberta and British Columbia, June-July 2002.

Location	Cells	Occupancy (% cells w/bears)	Occurrence (detections/cell)	Relative Density (individuals/cell)
North of Hwy	22	82	1.82	0.95
South of Hwy	14	79	2.13	1.36

F5 – During the bear survey on the Crowsnest Pass grid in summer 2002, we collected hair from F5 several times at stations south of the Crowsnest Highway. During session 1 in mid-June, she visited a station just east of Michel Creek about 2 km south of the highway, and another station further up Michel Creek about 10 km south of the highway. These detections occurred just west of the Continental Divide in British Columbia. During the next three sessions (late June–July), she repeatedly visited a station within Ptolemy Pass on the Continental Divide about 7 km south of the highway. However, we also collected hair of F5 off a natural rub tree near the headwaters of Alexander Creek about 20 km north of the Crowsnest Highway. Given the possible unique occurrence of a female grizzly bear on both sides of the Crowsnest Highway, we requested that the WGI lab conduct an extended analysis (using 11 microsatellite markers) of F5 hair samples from the three most distant locations, and all samples matched. It was not possible to determine the date when she rubbed on the tree north of the highway, but we did not detect her at any of the active stations on the north side. She did, however, make five visits to active stations south of the highway, including sites on both sides of the Continental Divide. From our subsequent radio-telemetry work, we know her home range to straddle the Continental Divide and the British Columbia / Alberta border in the vicinity of Ptolemy and Tent Mountain Passes, south of the highway. We infer that this female moved (possibly dispersed) from north to south of the Crowsnest Highway where she has her present home range. Her probable movement corresponds to the Michel-Alexander linkage zone previously identified by Apps (1997). We captured and radio-collared F5 in May, 2003, and will present additional details on her movements in a subsequent report.

M6, M7, F8, M9, M10, F17, F18 – Within the Crowsnest Pass grid, we detected seven other bears at several stations on both sides of the Continental Divide *south* of the Crowsnest Highway at Crowsnest Pass. In their movements between Michel Creek in British Columbia and Ptolemy Creek in Alberta, these bears likely used Tent Mountain Pass and Ptolemy Pass, as well as an un-named pass immediately south of the highway. However, none of these bears were detected east of the Ptolemy massif, which we expect is a barrier to grizzly bear movement further into Alberta.

M12 – During the bear survey on the Crowsnest Pass grid in summer 2002, bear M12 visited several stations on both sides of the Continental Divide *north* of the Crowsnest Highway. We collected his hair at a station and a rub tree in the upper Alexander Creek Valley in British Columbia in early June. We then detected him at a station in Racehorse Creek on the Alberta side in late June/ early July, and on a rub pad in the same area later in September. It is likely that this bear used Racehorse Pass (or passes immediately north) to traverse the Continental Divide.

M15 – During the bear survey on the Crowsnest Pass grid during summer 2002, we collected hair from M15 at six different stations both north and south of the Crowsnest Highway in Alberta. During session I, he visited a station in the McGillivray drainage about 8 km north of the highway. During session II, he visited a station in the North Racehorse drainage and another one near Mt. Tecumseh, 22 km and 3 km, respectively, north of the highway. Then, during Session III, we recorded him at a station about 13 km north of the highway and another one about 3 km south of the highway in the Ptolemy drainage. Thus, he crossed the highway sometime during early to mid July. Finally, during Session IV, M15 moved eastward and visited a station near Lynx Creek about 9 km south of the Crowsnest Highway. The minimum distance between the most northerly and southerly locations for M15 was about 30 km.

M31 – In 2002, we collected hair from M31 at a natural rub tree in Tent Mountain Pass on the Continental Divide about 6 km south of Crowsnest Pass. During session IV of the Crowsnest Pass bear survey that year, M31 visited a station (cell 24) 1 km south of the Crowsnest Highway at Crowsnest Pass. The following year, we gleaned hair of this individual from a fence adjacent to the north side of the highway and directly west of the Continental Divide. These localized movements demonstrate that M31 crossed the Crowsnest Highway, though the date and direction of the passage are unknown.

Lower Elk Valley Grid

On the lower Elk Valley grid during June and July 2003, we detected 45 grizzly bears (22 males and 23 females) a total of 71 times (Table 6, Figure 15). This included one bear (M24) that we had detected on the Crowsnest Pass grid the previous year. In addition, ten individual grizzly bears (4M, 6F) rubbed on scent pads at ten sites during the August-September lynx surveys. Seven of these bears (3 males and 4 females; F84, M85, M86, M87, F88, F89, F90) were 'new' bears that had not been detected in the barbed-wire corral sets during the earlier sessions. Three of the rub-pad visits occurred in cells (21, 25, and 31) where we had not previously detected grizzly bears. We also identified two individuals (1M, 1F) from hair we collected from natural rub trees, both were bears we had detected previously at barbed wire stations in the same or adjacent cell.

During both survey efforts, we detected 52 grizzly bears in 29 (73%) of the 40 cells in the lower Elk Valley grid. Seven of the 11 stations without a grizzly bear detection were located within 3 km of the Crowsnest Highway. Grizzly bears were more common west of the Crowsnest Highway in terms of occupancy, occurrence, and relative density (Table 7).

We found grizzly bears to be concentrated in several areas in the lower Elk Valley grid during summer (Table 5, Figure 14). We detected numerous individuals in the ranges west of the Crowsnest Highway, including the Lizard Range between Elko and Fernie, the Island Lake and Iron Creek drainages west of Fernie, and the environs of Hartley Pass to the northeast. Although grizzly bear density within our grid appears to be lower east of the Crowsnest Highway, we did detect several individuals within the Coal Creek and Morrissey Creek drainages east of Fernie.

Table 6. Detection of grizzly bears (gender/individual or G for grizzly) at barbed-wire corral sets (sessions I – IV) and rub pads (sessions V and VI) in and around the lower Elk Valley, British Columbia, 2002. Location of grid cell noted as west (W) or east (E) of Crowsnest Highway.

		Session					
		I	II	III	IV	V	VI
Cell	Hwy	6/12 – 6/22	6/23 – 7/5	7/6 – 7/16	7/17 – 7/27	8/11 - 9/20	9/1 - 10/10
1	W		M39				M39
2	W		M56, F57				
3	W				F79, F80, G		
4	W	M24			M81		
5	E	M39			G	M86	
6	W					F40	
7	W						
8	W						
9	E						
10	W	F40, F41	G	F41, F67, M68			
11	W			F67	G	F88	
12	W			M69	M68		
13	E						
14	E			F70			
15	W			F43, M59	G		
16	W	M42, F43					
17	W	F44			G		
18	W		F58				
19	E	M45			M49		
20	W	F43, M46, F47	M42, F43, M46, M59, F60, M61	M46, M71, M72			
21	W						F84, M85
22	W	M42, M48, M49, F50					
23	E						
24	E						
25	W						F53
26	W						
27	E		G				
28	E		F55	M49			F89
29	W			M73, F74, M75, F76	F82		F90
30	W						
31	E					M87	
32	E	M51, F52					
33	W	F53	M54, F62	M77, F78	M54		
34	E						
35	E		F63, F64, M65				
36	W	M54, G	M66				
37	E	F55					
38	E						
39	E	F55					
40	E						

Figure 15. Visits of individual grizzly bears to scented stations and rub pads in grid cells surrounding the Crowsnest Highway within lower Elk Valley, BC, June – September 2003.

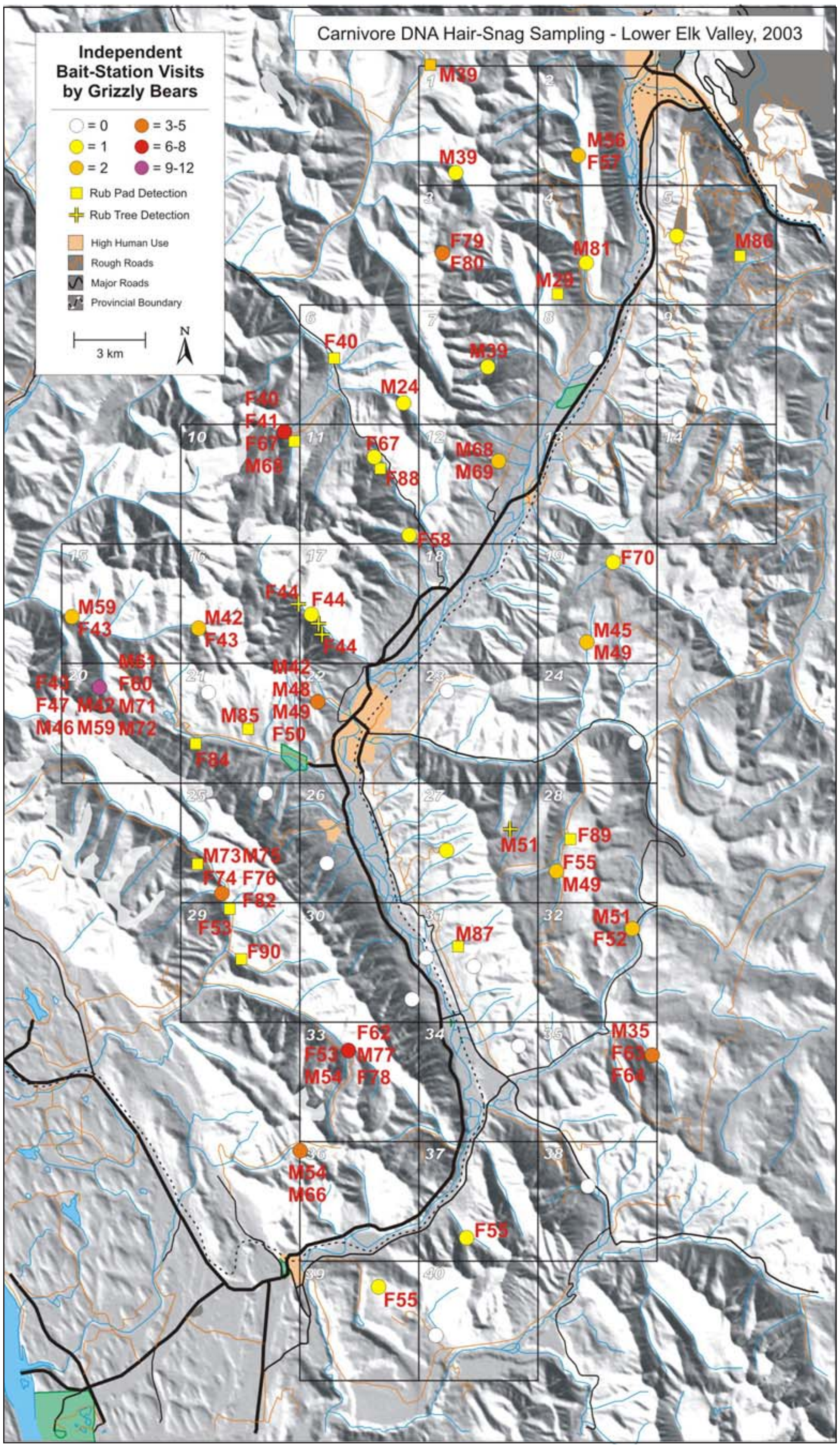


Table 7. Occupancy, occurrence, and relative density of grizzly bears east and west of the Crowsnest Highway (Hwy 3) in the vicinity of the lower Elk Valley, British Columbia, June-July 2003.

Location	Cells	Occupancy (% cells w/bears)	Occurrence (detections/cell)	Relative Density (individuals/cell)
West of Hwy	23	83	2.26	1.43
East of Hwy	17	79	0.94	0.71

Of the grizzly bears we detected in the lower Elk Valley grid, many individuals were identified multiple times at different sampling stations. Here, we infer significant movements from the sequential detections of these bears (Table 7, Figure 16).

M24 – During the bear survey on the Crowsnest Pass grid in 2002, M24 visited a station just east of Michel Creek and about 2 km south of the highway. During early June the following year, he visited a station about 21 km to the west near Hartley Pass, north of the Crowsnest Highway (Figs. 13 & 15). Later in September, we obtained his hair from a rub pad station within the Lladner Valley north of the highway and west of Sparwood.

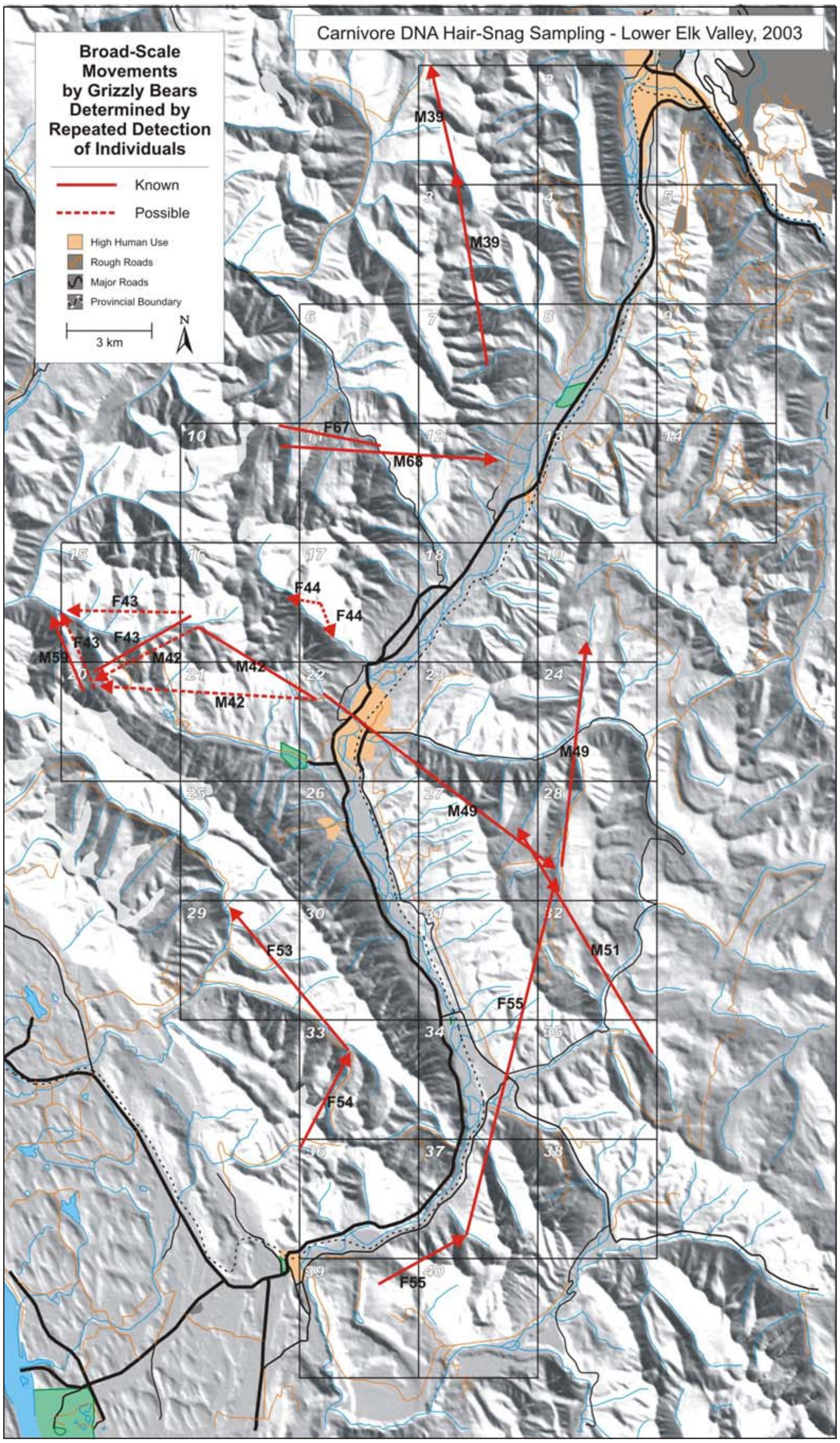
M49 – During the bear survey on the lower Elk Valley grid in 2003, M49 visited stations on both sides of the Crowsnest Highway. During session I in early June, we detected M49 at a station about 1 km west of Fernie and the Crowsnest Highway. During session III, he visited a station southeast of Fernie, approximately 7.5 km east of the highway. Later, during session IV, he moved north across Coal Creek about 10 km to visit another station 7 km east of the highway.

F55 – From the Mount Broadwood area in the Elk Valley, this bear moved north 15 km across the Lodgepole and Morrissey Valleys east of the Crowsnest Highway, almost to Coal Creek.

F67, M68 – The locations at which we detected F67 and M68 within the Elk Valley grid suggest that Hartley Pass is a likely conduit between the Elk Valley and areas to the northwest.

Summary for Grizzly Bears – To summarize, during both years and with both techniques, we detected 90 (42M, 48F) different grizzly bears over the combined 1,900 km^2 sampling area. This equates to a minimum density of 4.73 bears per 100 km^2 of survey area. We documented five grizzly bears (4M, 1F) that moved across the Crowsnest Highway. The female moved a distance of 20 km, which matched the longest dispersal by a young female in the Flathead area (McLellan and Hovey 2001b). Subsequent radio-tracking of this female suggests that she had dispersed to establish a home range south of the highway. The distances moved by the male bears are within the typical span of home ranges, particularly during the breeding period in early summer. We also recorded several bears moving between BC and Alberta through passes along the Continental Divide both north and south of the Highway.

Figure 16. Generalized movements of grizzly bears inferred from multiple detections of individuals at hair-snag stations surrounding the Crowsnest Highway, lower Elk Valley, BC, June – Sept. 2003.



Lynx Occurrence and Movements

Crowsnest Pass Grid

On the Crowsnest Pass grid during August and September 2002, we detected a minimum of seven lynx (6 males and 1 female) at 17 sites in 13 cells (Table 8, Figure 17). Individual identity could be resolved by WGI for 10 (53%) of the 19 samples[10]. North of the Crowsnest Highway, lynx detections clustered in upper Alexander Creek. South of the Highway, lynx were detected primarily west of Michel Creek. Although we did not detect any lynx individual on both sides of the highway, the Alexander-Michel Creek linkage appears to be a likely north↔south connector. For lynx, west↔east linkages across the Continental Divide are likely to include Racehorse Pass north of Crowsnest Highway and Tent Mountain and Ptolemy Passes south of the highway.

Table 8. Detections and known identities of lynx (gender/individual) within sampling grid cells of the Crowsnest Pass and environs, Alberta and British Columbia, August-September, 2002. 'L' refers to a lynx of unknown individual identity.

Session I		Session II	
Cell	**Lynx**	**Cell**	**Lynx**
6	M1	3	M1
10	M1, M2	10	L
12	L	12	M6
		14	L
18	M?	18	F5, F5
23	M4	32	L
29	L		
33	M3	33	M7
35	L	34	L
		36	L

Lower Elk Valley Grid

On the lower Elk Valley grid during August and September 2003, we detected seven lynx (4 males and 3 females) at 22 sites in nine cells (Table 9, Figure 18). Individual identity could be resolved by WGI for 18 (64%) of the 28 samples. *All* of the lynx detected in this grid occurred in the upper drainages east of the Crowsnest Highway primarily between Sparwood and Fernie. This clumped distribution was consistent with predictions of our regional population distribution model. Typically, we detected both a male and female lynx associated with the upper basins of several drainages. A reliable sighting of a lynx crossing the Crowsnest Highway near Morrissey junction in August, 2003 was also reported to us (S. Gniadek, *pers. comm.*).

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[10] Although the sample in cell 34 produced complete alleles at only three of five loci, those three markers were different than any other sample and may have represented another individual.

Figure 17. Visits of individual lynx to rub-pad DNA sampling sites in the Crowsnest Pass and environs, Alberta and BC, August – September 2002.

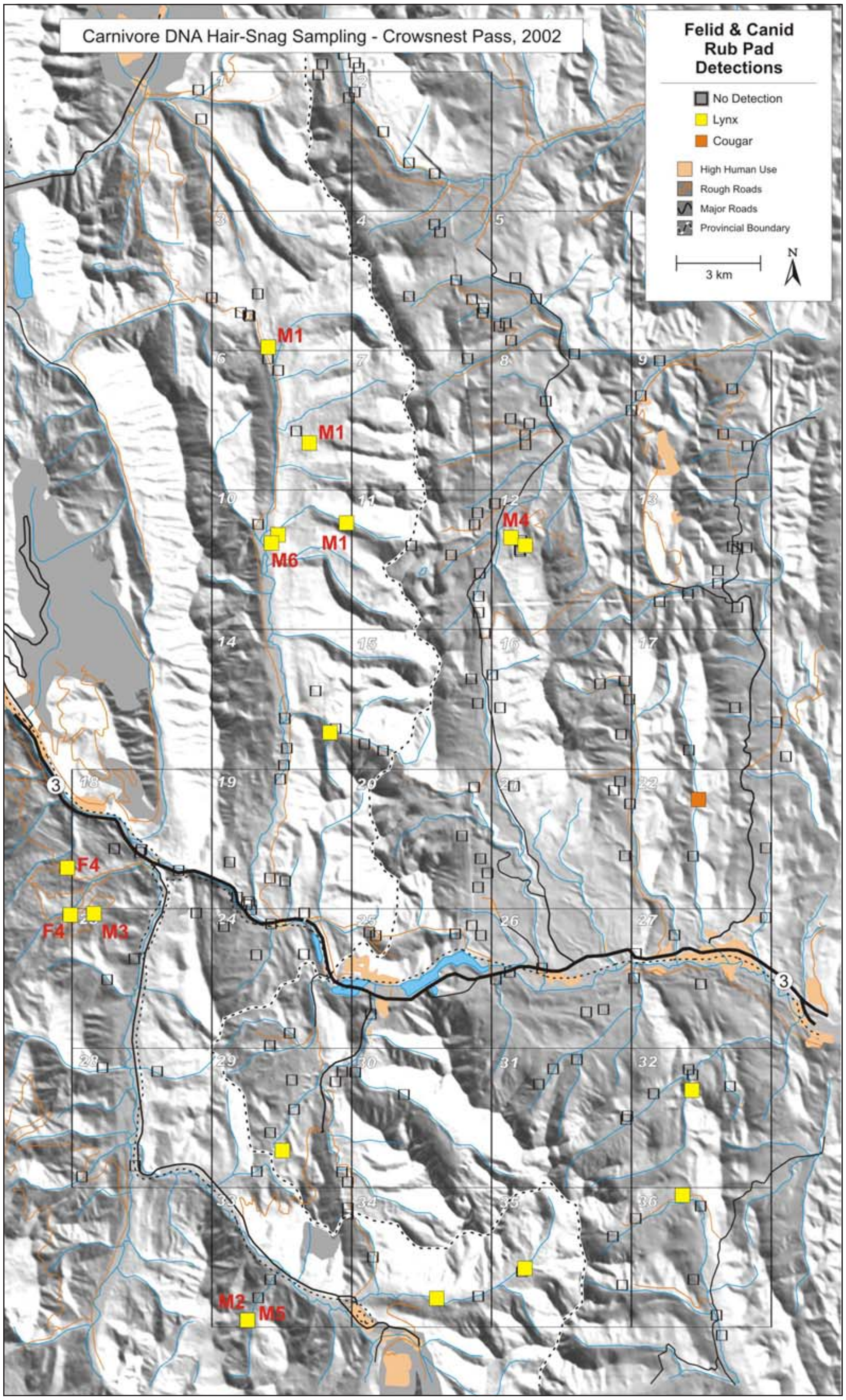

Table 9. Detections and known identities of lynx (gender/individual) detected within sampling grid cells of the lower Elk Valley and environs, British Columbia, August-September, 2003. 'L' refers to a lynx of unknown individual identity.

Session I	
Cell	**Lynx**
5	F8, L
9	F8
13	M13
14	M9, M9
19	M10, M13, M13
24	F14
27	M11, F12
28	M10, L

Session II	
Cell	**Lynx**
5	F8, L
9	M9
14	L, L
19	F14, F14, L
24	F14, L
27	L, F12
28	L
38	L

Summary for Lynx – To summarize, we detected at least 14 individual lynx (10 males and 4 females) for a minimum density of 0.74 lynx per 100 km^2 of survey area. However, because individual identity could not be determined in 19 (40%) of 47 hair samples, it is likely that the actual number of lynx detected was higher. We expect that the predominance of male lynx in our small sample is not due to differences in rubbing behavior between genders[11] but likely due to wider ranging by males (Apps 2007). In terms of lynx distribution, we detected lynx in only 29% (22 cells) of 76 cells surveyed across the two grids. Thus, we found lynx clumped in disjunct landscapes across the survey areas. Although we detected no individual lynx on both sides of the Crowsnest Highway, optimal habitat did not occur directly adjacent to the highway, and major features such as highways often represent home range boundaries for lynx (Apps 2000).

Evaluation of Regional Occurrence and Distribution Models

Our regional model of lynx occurrence and distribution performed well in testing against field detections of lynx. The model discriminated between lynx detections and non-detections significantly better than random expectation ($U = 6625.0$, $P < 0.001$; Figure 19). The area under the receiver operating characteristic (AUC) curve indicated that lynx detections were assigned a higher predicted occurrence value in 77.0% of possible combinations with non-detections, which is significantly better than a random model ($P < 0.001$).

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[11] 34 captive lynx showed no gender-related differences in rubbing on scent pads (J.L. Weaver, unpubl. data).

Figure 18. Visits of individual lynx to rub-pad DNA sampling sites in the lower Elk Valley and environs, British Columbia, August – September 2002.

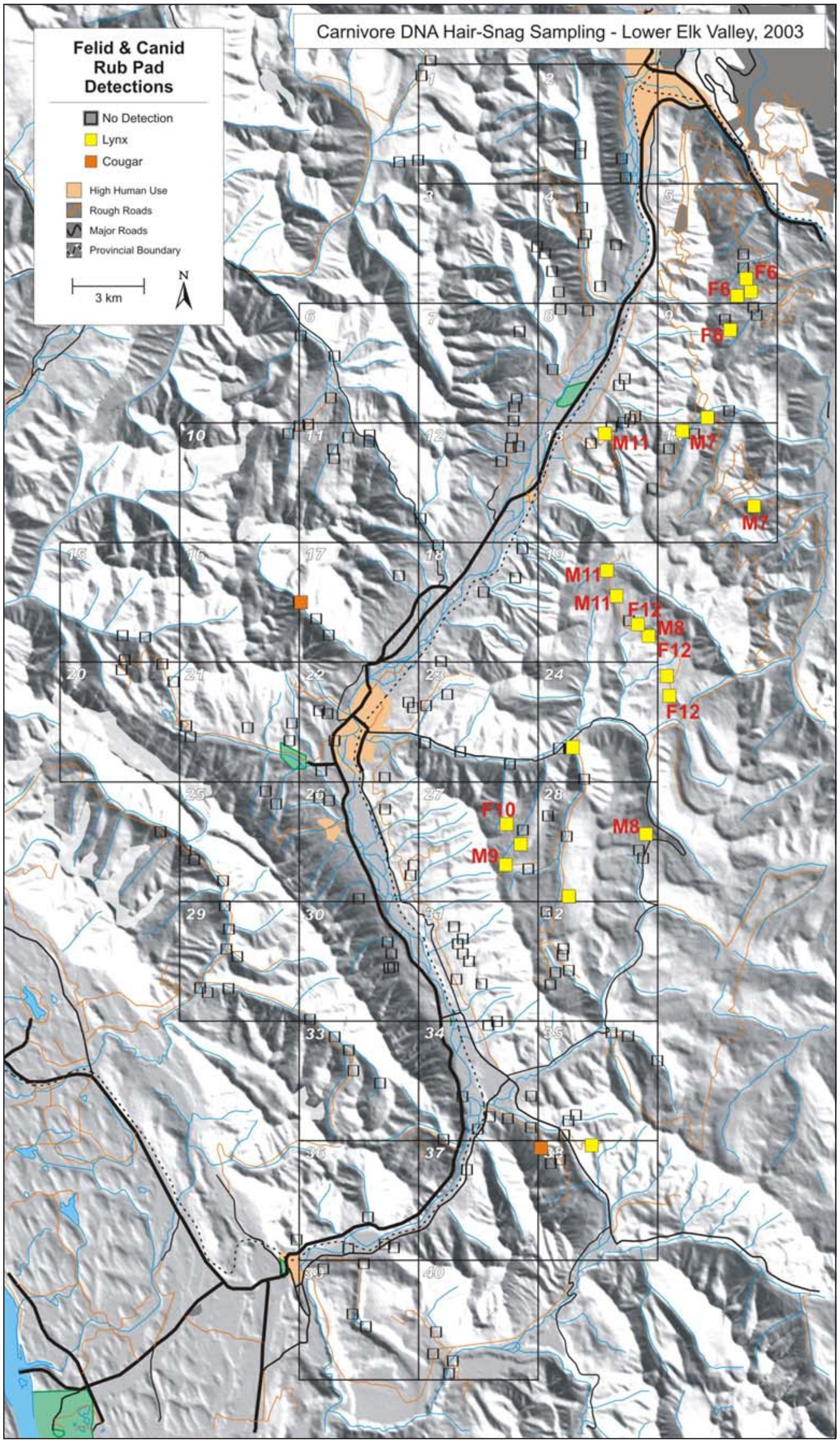
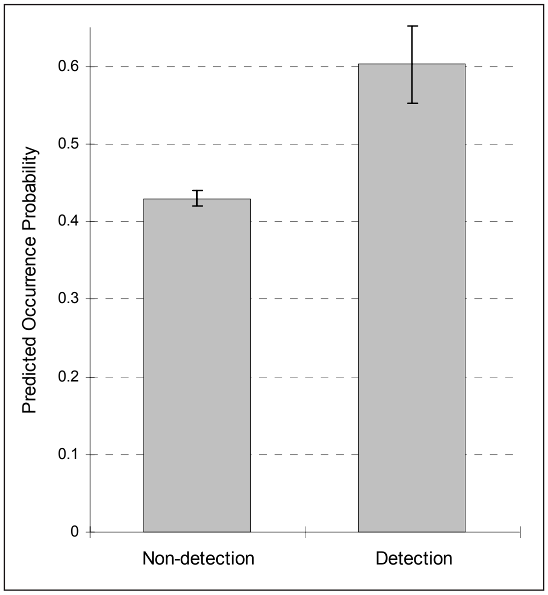


Figure 19. Difference in mean predictions (±SE) of a knowledge-based lynx occurrence model as compared between actual lynx detections and non-detections. Data are from rub-pad surveys surrounding the Crowsnest Highway, Alberta and British Columbia, August – September, 2002-2003.



Our preliminary model of grizzly bear occurrence (knowledge-based) did not discriminate satisfactorily between grizzly bear detections and non-detections (U = 9041.0, P < 0.69; AUC = 52%) and did not predict better than random expectation (Figure 20). We believe that the available biophysical inventory data, and resulting surrogate variables did not permit adequate modeling of grizzly bear plant and ungulate food distribution. In such circumstances, we believe that empirical modeling may be more appropriate (Apps et al. 2004). Our revised model developed for the region (Boulanger and Apps 2003) did perform well, discriminating between grizzly bear detections and non-detections significantly better than random expectation (U = 6129.5, P < 0.001; AUC = 67.6%; Figure 21). We used this revised model to predict grizzly bear distribution across a portion of the study region for which survey data were considered representative (see Figure 4 in Chapter 2).

Figure 20. Difference in mean predictions (±SE) of a knowledge-based model of grizzly bear occurrence as compared to actual grizzly bear detections and non-detections. Data are from barbed-wire corral and rub-pad stations surrounding the Crowsnest Highway, Alberta and British Columbia, June – September, 2002-2003.

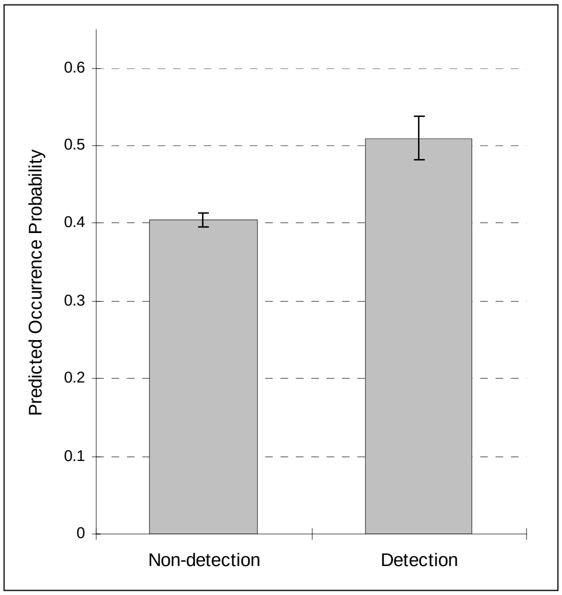
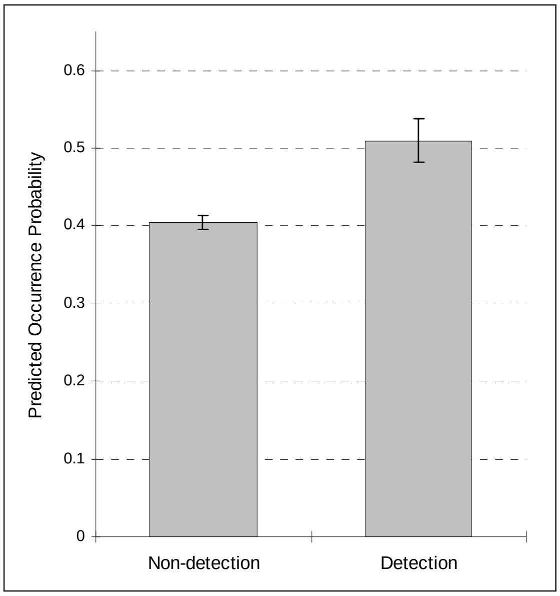


Figure 21. Difference in mean predictions (±SE) of an empirical model of grizzly bear occurrence as compared between actual grizzly bear detections and non-detections. Data are from barbed-wire corral and rub-pad stations surrounding the Crowsnest Highway, Alberta and British Columbia, June – September, 2002-2003.



Discussion

Density

Our minimum grizzly bear population count over the two-year sampling period results in an overall density estimate of 4.73 bears/100 km^2 for the combined sampling areas. This is rather high relative to other DNA hair-snag survey areas. For example, the average of grizzly bear densities reported from seven other sampling efforts in British Columbia (Boulanger et al. 2002) was 2.68 bears/100 km^2 (SD = 1.23, range = 1.03 – 4.25). It is, however, difficult to compare minimum counts between our sampling areas to infer differences in relative abundance because recapture rates were quite different. The relatively high (0.41) individual recapture rate in the Crowsnest Pass sampling area suggested that our grid encompassed at least some core habitat areas. The relatively low (0.10) recapture rate in the lower Elk Valley is not surprising since the Elk Valley grid was centered on the lower Elk Valley and Crowsnest Highway, which many if not most grizzly bear home ranges are unlikely to straddle. Because our primary goals pertained to relative abundance, distribution, and population connectivity across and surrounding the Crowsnest Highway, our sampling grids were not expected to meet the "closure" assumption for mark-recapture population estimation. This is especially true of the Elk Valley sampling grid that extended at least two cells (10 km) only from the highway corridor; hence, we were more likely to have detected grizzly bears at the periphery of their home ranges. The difference in recapture rates could also be at least partially due to differences in weather conditions between the two sampling years, and perhaps differences in the abundance of other species (such as black bears) visiting and disturbing sites and thereby reducing their scent, attractiveness and ability to detect grizzly bears.

Connectivity

At the population scale, fragmentation refers to the process whereby spatially continuous populations are divided into smaller, separate sub-populations (Young and Clarke 2000, Lindemayer and Fischer 2006). Fragmented sub-populations are potentially more vulnerable to extirpation due to smaller population size and less genetic diversity. Different species exhibit different vulnerability to fragmentation, depending upon their ecological and behavioural adaptation. An individual animal's response to human activities and dispersal pattern may also differ by gender. Among many mammals, males typically disperse more frequently and longer distances than females (Greenwood 1980). 'Genetic fragmentation' may result from interrupted movements of both genders, whereas 'demographic fragmentation' may result from hindered movements by one gender (either). Conservation biologists have considered demographic problems to be more ominous and urgent for populations than genetic issues (Lande 1988). The fragmentation problem may be especially acute for species such as grizzly bears that are sensitive to various human disturbances, occur at low density and do not disperse very far (especially females) (Weaver et al. 1996, Proctor et al. 2005).

Wildlife researchers have several ways of assessing the degree and kind of fragmentation impinging upon a wildlife population. They can use robust statistical analyses of genetic profiles to calculate the probability that an individual originated from a localized group. The individual (termed a 'putative migrant') is 'assigned' to the area with the highest probability of membership (Paetkau et al. 1995). More directly, a researcher can determine if an animal has moved across a highway or potential fracture zone from (a) detection of an individual on both sides using DNA sampling, or (b) tracking movements of animals, often using radio-telemetry.

Proctor (2003) examined the movements, dispersal, and population fragmentation of grizzly bears in southeastern British Columbia by obtaining DNA samples and genetic profiles of 470 bears. He found that human activity associated with the Crowsnest Highway has reduced grizzly bear population contiguity across their peninsular distribution in southwest Alberta and southeast British Columbia. Moreover, he did not detect any highway crossings by female grizzly bears. In our study region, Proctor et al. (2005) reported that none of 94 female grizzlies and only five (4.4%) of 112 males had moved across the highway. Two of the male grizzlies had been detected on each side of the highway, and the other three had been 'assigned' to the side opposite from their detection. In contrast, both male and female grizzly bears mixed freely across the nearby Flathead Valley associated with comparatively little human disturbance (Proctor et al. 2005).

In our study, we conducted a more intensive and systematic survey of grizzly bears around the Crowsnest Highway. Of those bears with multiple detections, we detected only one female (7.1% of 14 females) and four males (26.7% of 15 males) on both sides of the highway. When considered relative to a nearby and comparable, low elevation valley with relatively little human use (Flathead; Proctor et al. 2005), our results confirm that the cumulative influence of traffic volume, human settlement and activity associated with the Crowsnest Highway is contributing to the demographic fragmentation of grizzly bears in the southern Canadian Rocky Mountains.

Lynx have the potential to disperse much greater distance than grizzly bears. Researchers in northern Canada have documented 47 cases of adult lynx of both sex dispersing >100 km, with movements >500 km in 15 cases (Mowat et al. 2000). Analyses of lynx DNA samples from Montana to Alaska have failed to show any strong genetic differentiation among areas, which indicates that populations have been well-connected at a broad geographic scale (Schwartz et al. 2002, Schwartz et al. 2003, Campbell and Strobeck 2006). These analyses, however, are limited in their ability to detect recent population fragmentation. We did not detect any individual lynx on both sides of the Crowsnest Highway. Because resident lynx are found in certain habitats at higher elevations, home ranges do not straddle primary highways located in major valleys (Apps 2007). The Crowsnest Highway is likely to be crossed only by dispersing lynx or by males during the late-winter breeding period.

Several studies have used either snow-tracking or radio-tracking of collared animals to examine finer-scale effects of major highways and railroads on carnivore movements and population connectivity in the Canadian Rockies. Here, we present a synopsis of the pertinent findings for each major highway.

Highway 1 – Known as the Trans-Canada highway (TCH), Highway 1 bisects Banff National Park in Alberta, adjacent Yoho National Park in British Columbia, and provincial land in both Alberta and British Columbia. During the 1990s, much of the highway section in Banff was expanded to four lanes, with 'ungulate-proof' fencing erected along the right-of-way. Several types of underpasses and two overpasses have been constructed as mitigative measures. During summer 1998, an average of 21,500 vehicles passed along this highway each day (Parks Canada Highway Service Centre *unpubl.* data). The TCH is paralleled by a major railroad and intersected by several two-lane highways. Highways 93N and 93S bisect Kootenay and Banff National Parks, Highway 40 bisects Kananaskis Country in Alberta, and Highway 95 runs the length of the Rocky Mountain Trench along the western flank of the Rocky Mountains. Traffic volume on these highways ranged between 2000 and 3000 vehicles/day in 1998. We consider traffic volume to be 'high' on the TCH, 'moderate' on Highways 93 and 95, and 'low' on Highways 40 and 1A.

Chruszcz et al. (2003) tracked the movements of 74 grizzly bears fitted with conventional VHF radio-collars in this area during 1988-2001. Crossings of the high-volume TCH were made by 11 grizzly bears (4M: 7F) at least 209 times, whereas 18 individuals (6M, 12F) crossed low-volume highways at least 580 times. Researchers reported that crossings were 80% *less likely* to occur on high- versus low-volume highways. Notably, female grizzly bears were twice as likely to cross low-volume versus high-volume roads. Bears favored crossing sites with dense vegetation adjacent to the road. Bears also selected crossing sites in relatively subdued terrain and where habitat quality was high. The researchers found that bears used high-quality habitat adjacent to low-volume roads, but were less inclined to habituate to high-volume roads. They concluded that grizzly bears avoided crossing high-volume but not low-volume roads.

Chruszcz et al. (2003) reported more grizzly bears killed on the low-volume highways (six) than on the TCH (three) since 1981. The researchers attributed this to grizzlies likely making more *attempts* at crossings of low-volume highways where no mitigative structures have been constructed and collisions are more common (Benn 1998). We speculate that differential frequency of crossing attempts and mortalities among highways is also related to habitat quality within landscapes bisected by highways. In recent years, several female grizzly bears have used the underpasses beneath the high-volume TCH at four or five different locations (M. Gibeau, Banff National Park, *pers. comm.*). However, one of these females was killed on the railroad and two of her cubs were subsequently killed on the highway, demonstrating the high mortality risk for bears residing in proximity to major transportation routes.

The response of other carnivores to these same highways has also been studied. Serrouya (1999) reported that highways influenced black bear movements similarly to that described above for grizzly bears. Percy (2003) found that traffic volume was negatively correlated with the frequency of road crossings by wolves, grizzly bears, and black bears. Alexander et al. (2005) recorded the occurrence of snow-tracks for six carnivore species (cougar, coyote, marten, lynx, wolf, and wolverine) during three winters. Highways of low and moderate traffic volumes were more likely to be crossed by these species than highways of high to very high traffic volumes. The authors suggested that a volume of 300 to 500 vehicles per day during winter negatively influences carnivore movement. They also noted that the very high traffic volume on the TCH decreased permeability significantly for carnivores and recommended that highways with ≥5,000 vehicles per day have mitigative structures (e.g., open-span bridges) to facilitate crossings.

Inference of species response to highways from the aforementioned studies should be considered in light of two research design limitations. First, most studies to date have not considered the influence of underlying habitat quality on an animal's movements in response to highways. Highways are clearly built in association with certain landscape conditions, and they influence adjacent vegetation composition and structure in various ways. Second, most wide-ranging species respond to habitat and geographic features at broader landscape scales as well as finer-scales of daily to hourly movements, and broader-scale responses can confound finer-scale results. Studies of snow-track detection adjacent to the highway to which response is being measured cannot account for responses at the landscape scale at which wide-ranging carnivores may select movement routes.

Attempting to address these study design limitations, Apps (2007) evaluated spatial and movement response of lynx to the TCH, Highways 93N and 93S, and Highway 1A. He used an unbiased radio-telemetry sample of individual movements within respective home ranges and across seasons to examine space use by lynx at two scales as well as the frequency of highway crossing. The analysis controlled for the influence of underlying habitat quality reflected by an empirical habitat model derived from the same data. In four of ten lynx, a displacement effect only from the TCH could be measured. However, among animals, the likelihood of an actual highway crossing was reduced by a factor of 13.0 for the TCH and 2.2 to 3.1 for the moderate to low volume Highways 93 and 1A.

Only one study has evaluated the broad-scale influence of a major highway and associated human influence on grizzly bears. Apps et al. (2004) evaluated habitat and human factors influencing grizzly bear population distribution across an extensive study area centered on the TCH and including Yoho and Glacier National Parks, British Columbia. At broad scales of population distribution, human settlements, access and road density were correlated with landscapes bisected by the TCH. This collective human influence was an important negative factor explaining grizzly bear distribution and abundance. This influence was, however, reduced within the national parks, presumably due to protection from harvest and controls to human disturbance and behaviour that further minimize grizzly bear displacement and mortality risk.

Highway 2 – Along Highway 2 that separates Glacier National Park from the Bob Marshall Wilderness in Montana, Waller and Servheen (2005) tracked the movements of 28 grizzly bears during 1998-2001. During summer, an average of 1936 vehicles/day (range 17-4289) passed along this two-lane highway. Traffic volume peaked at about 100 vehicles per hour during afternoon (1300-1900 hr) but declined to nearly zero during pre-dawn hours (0100-0500 hr). By contrast, freight train traffic on a railroad that paralleled close by to Highway 2 peaked at 1.5 trains per hour during pre-dawn period.

Researchers documented that 15 (53%) of 28 grizzly bears crossed the highways, including the two-lane Highway 49 that passes through the foothills on the east side of the study area. Interestingly, fewer adult males (2 of 7) traversed the highway as compared to adult females (6 of 10), sub-adult males (4 of 5), or sub-adult females (3 of 6). Adult females with cubs-of-year appeared especially sensitive and did not cross the highway. Four of the 28 collared grizzlies accounted for the majority (56%) of the 181 crossings recorded. Along Highway 2 only, two sub-adult grizzlies made most (64%) of the 50 crossings. All six of the bears there crossed less frequently than random expectation. Bears made most (85%) crossings in late evening to early morning (2300-0700 hr) when corresponding highway traffic was lowest, averaging 11 vehicles /hr (range 0-67). The number of crossings declined exponentially with increasing traffic volume, with only four crossings (12%) occurring after traffic volume reached 60 vehicles/hr. Waller and Servheen (2005) also reported that bears appeared to select sites for crossing that were flatter and closer to hiding cover.

Many more grizzly bears were killed on the railroad (23) than on Highway 2 (2) during 1980-2002 (Waller and Servheen 2005). Much of this mortality was due to grain spillage or derailments along the tracks and inadequate clean-up, which attracted many bears to the spill sites. Although some remedial actions have reduced the occurrence of grain spills, grizzly bears continue to be killed on the railroad. During their study, Waller and Servheen (2005) recorded two mortalities of radio-collared grizzlies on the railroad and none on the highway.

Summary – Several lines of scientific evidence indicate that major highways of high traffic volume restrict carnivore movements, and have the potential to fragment populations. Grizzly bears are particularly vulnerable to these effects, with reproductive females being especially susceptible. Trains have been a major source of mortality. However, perhaps the greatest impact of highways is the cumulative human activity and spin-off development that they have facilitated over decades, and current settlement and development patterns continue in a pattern conforming to highways and associated access. These broader-scale impacts may well be the ultimate factor fracturing some carnivore populations. With intensive, systematic sampling focused on the Crowsnest Highway, we confirmed that the highway and associated development has reduced crossings by grizzly bears and perhaps lynx relative to what we expect to find in similar but relatively undeveloped landscapes.

4. CONSERVATION OF CARNIVORES: CORE AREAS AND CONNECTIVITY

Two principles in conservation science are fundamental to a successful conservation strategy for carnivores (Weaver et al. 1996, Weaver 2001):

- ➢ safeguard against excessive mortality via a network of core areas of security, and
- ➢ maintain connectivity across the region with landscape linkages that connect core areas.

In this concluding chapter, we integrate information from our regional models of carnivore occurrence (Chapter 2), field surveys surrounding the Crowsnest Highway (Chapter 3), and other pertinent studies to identify: (1) core areas that provide options for security, and (2) landscape linkages that facilitate population connectivity.

Core Areas: Options for Security

Several of the larger carnivore species (e.g., grizzly bear) have low resiliency to human disturbance and mortality and thus are vulnerable in human-dominated landscapes (Weaver et al. 1996). Accordingly, several experienced and highly-respected biologists have recognized the necessity of providing secure areas for grizzly bears in multiple-use landscapes to ensure their long-term persistence (Mace et al. 1996, Mattson et al. 1996, McLellan 1998, Gibeau et al. 2001). In a review of grizzly bear management in British Columbia, an independent scientific panel recognized the role of refugia in grizzly bear conservation and recommended that resource managers address and restrict (if necessary) motorized access in key areas (Peek et al. 2003).

Here, we identify 15 core areas in the southern Canadian Rockies based upon landscape suitability, vulnerability and movements of grizzly bears, lynx, and wolverines, and we rate them in terms of conservation significance and current level of relative security (Table 10). The accompanying map (Figure 22) shows the location of the individual core areas and how they knit together

Table 10. Conservation significance and current level of security of core areas for carnivores in the southern Canadian Rockies, Alberta and British Columbia.

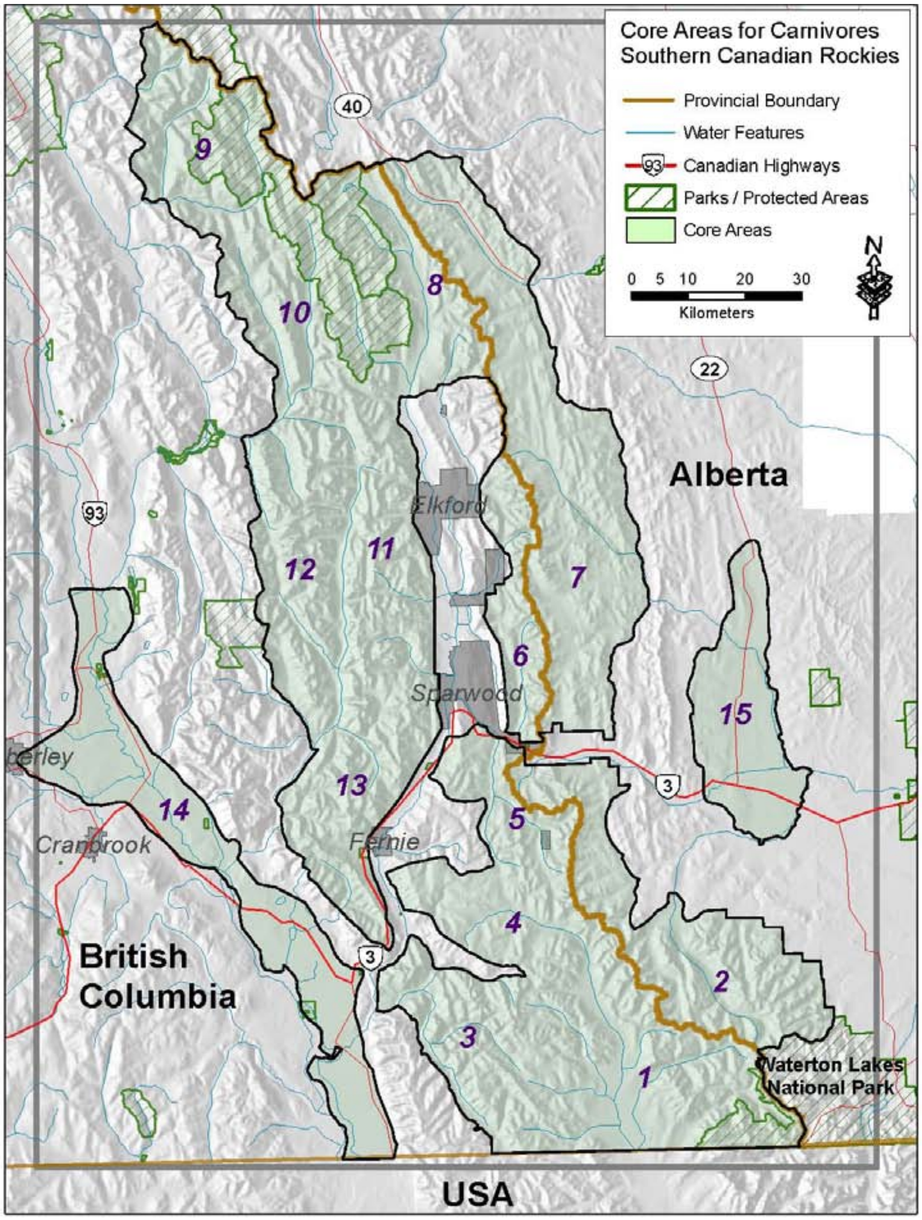
Core Area #	Core Area	Conservation Significance	Current Level of Security
1	Lower Flathead (BC)	Very High	Moderate
2	Upper Castle and Carbondale (AB)	High	Low
3	Wigwam (BC)	Moderate	High
4	Upper Flathead (BC)	High	Moderate
5	Michel (BC) – Ptolemy (AB)	Very High	Low
6	Alexander (BC)	High	Moderate
7	Upper Oldman (AB)	High	Low
8	Upper Elk (BC) – Upper Highwood (AB)	Very High	Moderate
9	Palliser – Albert (BC)	High	Moderate
10	Upper White (BC)	High	Low
11	West Elk – Upper Bull (BC)	High	High
12	Quinn (BC)	Moderate	High
13	Lizard Range – Hartley Pass (BC)	Very High	Low
14	Rocky Mountain Trench (BC)[a]	High	Low
15	Lower Oldman (AB) [a]	High	Low

[a] Specifically for badgers

across the region to form connected blocks both north and south of the Crowsnest Highway. It also provides context on the more important locations for landscape linkages across the Crowsnest Highway. It should be noted that Highway 93 and associated factors pose similar issues for badgers and perhaps bobcats.

(1) **Lower Flathead** (BC): The lower Flathead River basin, from the north boundary of Glacier National Park at the international border north to Harvey Creek, provides crucial habitat for a grizzly bear population that is of highest density recorded to date in the interior of North America. The models predict moderate to high landscape suitability for lynx, wolf, and wolverine. Studies indicate that some individuals of these carnivores and ungulates (moose, elk, and deer) range widely between the Montana and British Columbia sides of the Flathead River basin as well as the upper Castle River basin in Alberta Our models indicate that population vulnerability is potentially high due to the network of open roads in the valley bottom, though moderated by the relatively low traffic volume due to considerable travel time from human settlements and recent access management plans. While past human use has fluctuated in intensity, higher levels of use may return as the regional population increases. We rate the conservation significance of this core area as very high and the current level of security as moderate.

Figure 22. Location of core security areas for carnivores across the southern Canadian Rockies, British Columbia and Alberta. See text for description of numbered areas.



(2) **Upper Castle and Carbondale (AB):** The upper Castle and Carbondale drainages lie across the Continental Divide from the Flathead Basin, and north of Waterton Lakes National Park. This area provides moderate to high landscape suitability for grizzly bears and wolverines, and localized areas of high suitability for lynx. Although the models suggest that population vulnerability is low here, access by ATVs is widespread. Although animals can cross the Continental Divide in most locations, several low passes (Sage Pass, South and Middle Kootenay Passes) facilitate wildlife movements. North of the Castle, the Carbondale River drainage flanks the upper Flathead on the east side of the Continental Divide in Alberta. It also has high suitability for grizzly bears, wolverines, and lynx. Mountain passes at the head of Gardiner Creek and Carbondale River likely provide important connection to the upper Flathead. Security appears high near the Continental Divide but diminishes to the east. We rate the conservation significance of the upper Castle and Carbondale drainage as high and the current level of security as low.

(3) **Wigwam (BC):** The models predicted that the eastern side of this basin provides higher landscape suitability for grizzly bears, lynx, wolves, and wolverines than the west side. Security is generally high in this drainage, except for the lower section near Elko. Wigwam Flats is an important wintering area for ungulate prey. We rate the conservation significance of this core area as moderate and the current level of security as high.

(4) **Upper Flathead (BC):** This includes the upper Flathead River basin from Harvey Creek north to the headwaters and west to the Crowsnest Highway between Morrissey and Fernie. This area provides high habitat value for grizzly bears, wolverines, and lynx. Landscape suitability does diminish, however, going west from the ridges down slope to the lower Elk Valley and the highway. Nonetheless, the section near Morrissey offers an important option for connection to the Lizard Range. The headwaters of the Flathead River and the high ridges have high levels of security, whereas areas nearer to Highway 3 have lower security. We rate the conservation significance of this core area as high and the current level of security as moderate.

(5) **Michel (BC) – Ptolemy (AB):** The Michel Creek landscape south of the Crowsnest Highway has moderate to high suitability for grizzly bears, lynx, and wolverines. However, our models project high vulnerability due to the Corbin road and mine. On the Alberta side, landscapes are highly suitable for grizzly bears south of Crowsnest Pass and closer to the Continental Divide (Ptolemy Creek), but security is compromised by some of the roads and mines there. Grizzly bears and likely other carnivores regularly use the Tent Mountain and Ptolemy passes for east↔west movements across the Continental Divide, which links these two basins as an integrated unit. The northwest section of this core area (Hosmer and Sparwood Ridges) likely provides an important option for connectivity across the Crowsnest Highway between Hosmer and Sparwood to the west side of the Elk River. Another section between Crowsnest Pass and

where Michel Creek meets Hwy 3 provides a very important connection to the Alexander Valley north of the highway. We rate the conservation significance of this core area as high and the current level of security as low.

(6) **Alexander (BC):** Alexander Creek lies north of the Crowsnest Highway and west of the Continental Divide at Crowsnest Pass. It provides highly suitable habitat for grizzly bears, lynx, and wolverines. Several passes — particularly Deadman, Racehorse, North Fork, and Tornado — facilitate west↔east movements between Alexander Creek and adjacent drainages in Alberta (see below). At present, access management appears fairly good in the lower section of Alexander. Human access on ATVs, however, appears greater in upper Alexander, which results in lower security. We rate the conservation significance of this core area as high and the current level of security as moderate.

(7) **Upper Oldman (AB):** East of the Continental Divide in Alberta, the area from upper Allison Creek north to tributaries of the upper Oldman River has landscapes highly suitable for grizzly bears and moderately suitable for lynx and wolverines. Human activity (especially ATV use), however, is high in this area. We rate the conservation significance of this core area as high and the current level of security as low.

(8) **Upper Elk (BC) – Upper Highwood (AB):** The upper Elk River basin from north of Elkford to Elk Lakes has some of the most productive habitat conditions for lynx in the region. It also provides highly suitable habitat for grizzly bears and wolverines; the seasonal abundance of elk provides prey for wolves. Hair-snagging DNA surveys have confirmed concentrated occurrence of grizzly bears in the upper Elk River basin (Boulanger 2001). Recent analyses, however, have documented a regional concentration of human-caused mortality of 18 female grizzly bears from 1978 to 2002 (Herrero et al. 2005) Security in the upper Elk River basin appears moderate during summer, but snowmachine access in the winter may compromise security for lynx and wolverine. Across the Continental Divide in Alberta, our models indicate that landscape suitability in the upper Highwood River drainage is high for grizzly bears and moderately high for lynx and wolverines. Recent surveys for grizzly bears confirm their concentration between Forestry Trunk Road 940/Hwy 40 and the Divide (G. Stenhouse *pers. comm.*). Data from radio-collared grizzly bears document that home ranges of both female and male grizzly bears straddle the Continental Divide in this area (Carr 1989, Stevens and Gibeau 2005). Hence, the upper reaches of both basins function as an integrated unit for bears. Elk Pass undoubtedly serves as a connector from the upper Elk River drainage north to landscapes in Peter Lougheed Provincial Park in Alberta, and the pass connecting Aldridge Creek (BC) and Baril Creek (AB) may also provide connectivity. We rate the conservation significance of this core area as very high and the current level of security as moderate.

(9) Palliser – Albert (BC): According to the British Columbia Ministry of Environment, Lands, and Parks, the relative abundance of grizzly bears is high in the valleys and basins of the Palliser and Albert Rivers. Our models project high landscape suitability for wolverines throughout much of the area and, for lynx, in the lower Palliser drainage. Recent analyses have documented a regional concentration of human-caused mortality of 11 female grizzly bears from 1978 to 2002 (Herrero et al. 2005), Security appears high in summer but low during winter. Several passes along the Continental Divide appear quite important to link: (1) upper Albert and Cross River with upper Spray River in Banff National Park, (2) upper Palliser with upper Kananaskis in Peter Lougheed Provincial Park, and (3) Palliser with North Fork White River. We rate the conservation significance of this core area as high and the current level of security as moderate.

(10) Upper White (BC): According to the British Columbia Ministry of Environment, Lands, and Parks, the relative abundance of grizzly bears is high in the valleys and basins of the North, Middle, and East Forks of the upper White River. Our models project high landscape suitability for wolverines and lynx there, too. Recent analyses have documented a regional concentration of human-caused mortality of nine female grizzly bears from 1978 to 2002 (Herrero et al. 2005). At present, security appears low in the North Fork of the White River. Two passes appear important to link: (1) Maiyuk Creek in the middle White River to Forsyth Creek in the upper Elk River, and (2) east fork of White River to upper Bull River. We rate the conservation significance of this core area as high and the current level of security as low.

(11) West Elk – Upper Bull (BC): Our models project high landscape suitability for grizzly bears and wolverines along the western side of the upper Elk River and moderate suitability on adjacent slopes of the upper Bull River. Security for carnivores appears fairly high there at present. The following passes appear likely for facilitating carnivore movements: (1) Hornaday Pass, and (2) the pass linking Crossing Creek in the upper Elk Valley to the area around the headwaters of the Bull River and the East Fork of the White River. We rate the conservation significance of this core area as high and the current level of security as high.

(12) Quinn (BC): According to the British Columbia Ministry of Environment, Lands, and Parks, the relative abundance of grizzly bears is high in the valleys and basins of Quinn Creek west of the Bull River. Our models suggest moderate suitability for wolverines. The pass linking upper Quinn Creek with Blackfoot Creek likely facilitates carnivore movements. The area has relatively high security, and we rate its conservation significance as moderate.

(13) Lizard Range-Hartley Pass (BC): This area lies west of the Crowsnest Highway in the lower Elk Valley and over to the Bull River. It provides very high habitat suitability for grizzly bears, moderate suitability for wolverines, and smaller patches for lynx. Habitat security is compromised around the Fernie Ski Hill but remains fairly high elsewhere in this area. Two passes appear key for linking landscapes in the Elk and Bull River drainages: (1) Hartley Pass, and (2) Iron Creek and Lizard Passes north of Island Lake. Within this unit, Thunder Meadows Pass through the Lizard Range is of extreme importance in linking high-quality seasonal habitat for grizzly bears. We rate the conservation significance of this core area as high and the current level of security as moderate.

(14) Rocky Mountain Trench (BC) and (15) Lower Oldman (AB): The dry, open grasslands of the Rocky Mountain Trench along Highway 93 in British Columbia and along Highway 22 north and south of Lundbreck in Alberta offer high suitability for badgers. In these areas, however, badgers are highly vulnerable due to human settlements, agricultural lands, and major highways and other roads. Specifically for badgers, we rate the conservation significance of these two core areas as high and the current level of security as low.

Landscape Linkages: Options for Population Connectivity

Here, we identify options available to carnivores in moving through and around largely human-dominated landscapes associated with the Crowsnest Highway (Table 11). We distinguish between *landscape linkages* as broader zones that should provide for residency, at least seasonally, for larger animals, and *corridors* as more narrow connectors that provide for quick passage. We identified these connections based upon the modeling of key habitats for the focal species, empirical data from the hair-snagging surveys (grizzly bear and lynx), preliminary radio-tracking data (grizzly bear), and current mapping of existing human developments and activities. Linkage zones across the Crowsnest Highway are generally consistent with those identified by Apps (1997). In areas between viable linkages across the Crowsnest Highway, linkages *parallel* to the highway can facilitate movement up and down the lower Elk Valley. A corollary to the provision of linkages is the importance of minimizing mortality risk along the railroad (which closely parallels Highway 3). To place specific linkages and corridors in conservation context, we numbered their locations on maps of potential restriction or blockage of passage (Figure 23)[12] and land ownership and zoning (Figure 24). We also depicted the most likely movement routes with arrows on photos of key landscapes. We suggest that readers refer to these maps and photos as they read each of the narrative descriptions.

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[12] This model of multi-species movement options integrates terrain, human development, and security cover under specific assumptions (C. Apps, unpubl. report).

Figure 23. Location of important linkage landscapes and corridors for wide-ranging carnivores across and along the Crowsnest Highway and the Continental Divide, southern Canadian Rockies, Alberta and British Columbia. Map numbers are keyed to photos and ratings shown in Table 10. See accompanying text and photos for detailed characterization.

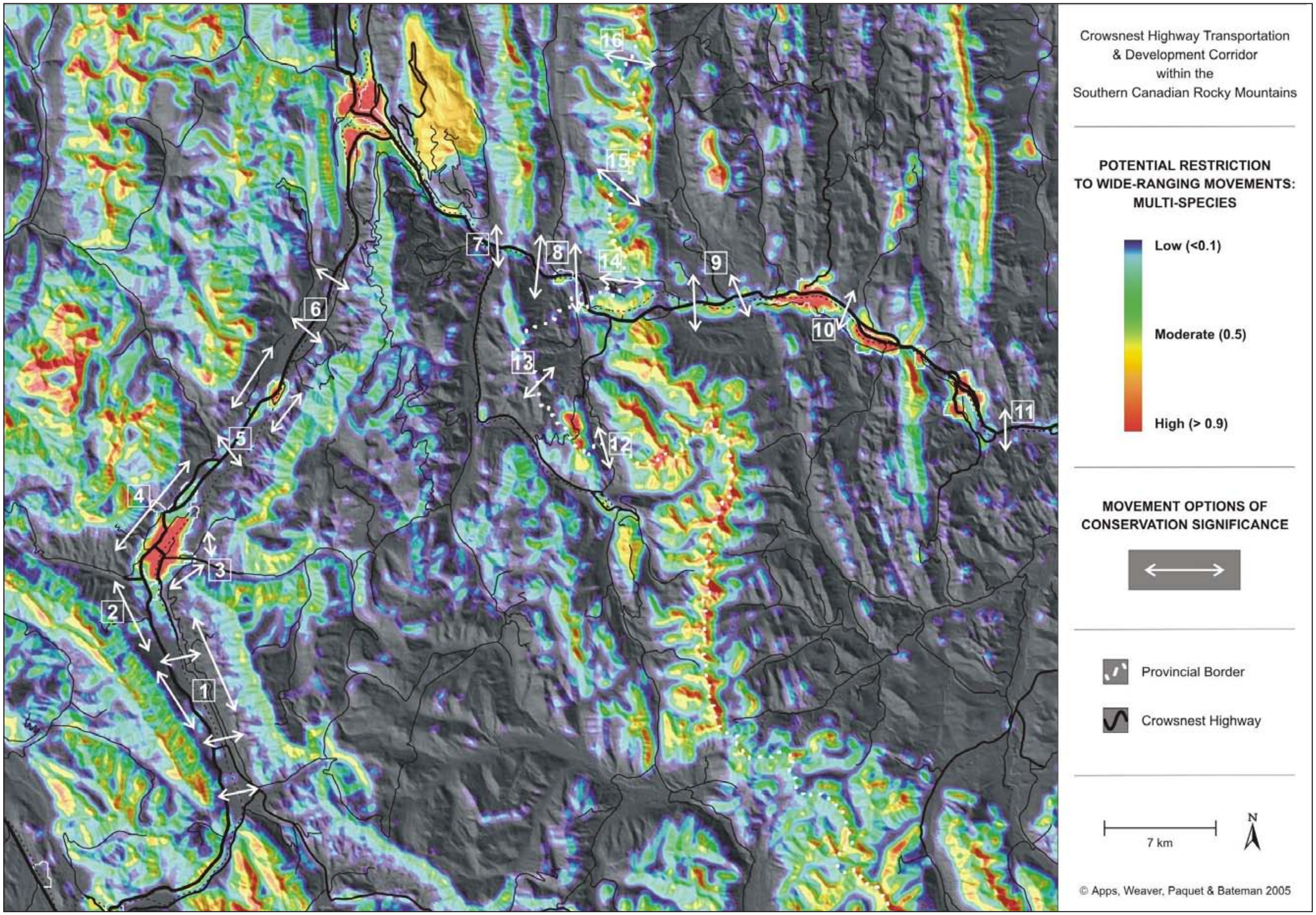


Figure 24. Location of important landscape linkages and corridors for wide-ranging carnivores relative to land ownership and zoning, southern Canadian Rockies and Crowsnest Highway, Alberta and British Columbia. Map numbers are keyed to photos and ratings shown in Table 10. See accompanying text and photos for detailed characterization.

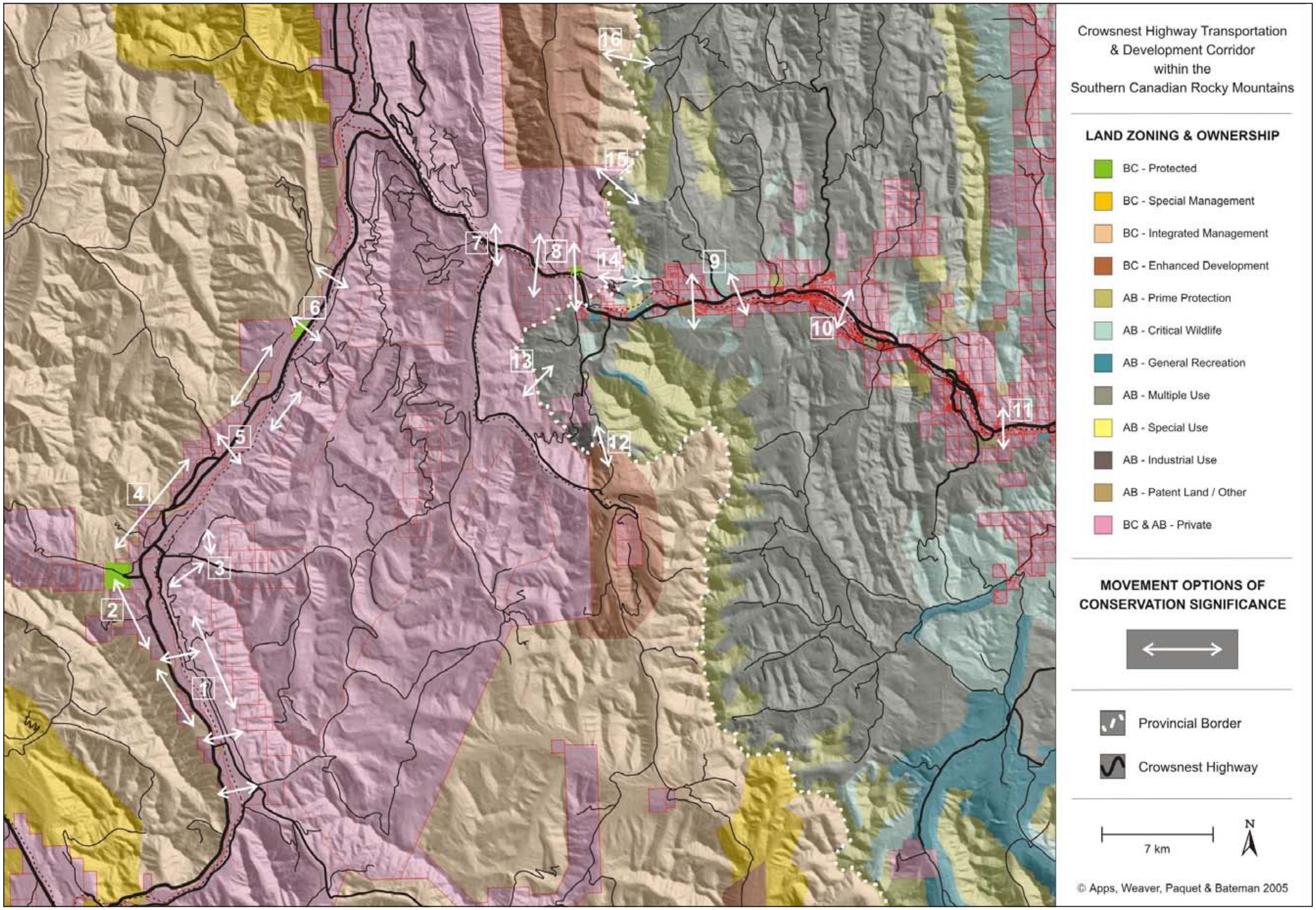
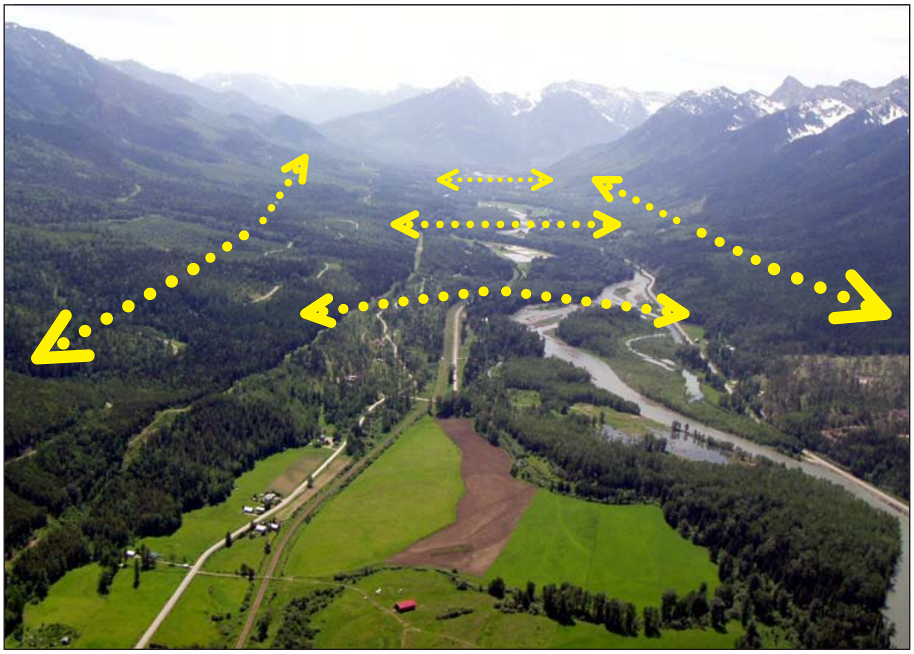


Table 11. Linkage landscapes and corridors for carnivores across and along the Crowsnest Highway and the Continental Divide within the southern Canadian Rockies, British Columbia and Alberta. Connectors are rated in terms of conservation significance, limitation to movement, and vulnerability to human developments or activities.

Map #	Photo #	Linkages and Corridors	Conservation Significance	Movement Limitation	Vulnerability
1	1	Fernie to Morrissey	Very High	Low	Moderate
2	2	Lizard Basin to Elk Valley	Very High	Moderate	High
3	3	Coal Creek to Elk Valley	Very High	High	Very High
4	4, 5, 6	Mount Fernie slopes	Very High	High	High
5	6, 7	Hartley across Elk Valley	High	Very High	Very High
6	6, 8	Hosmer to Sparwood	Very High	Low	Moderate
7		Michel Ck to Erickson Ck	Low	Moderate	Low
8	10, 11, 12	Michel Ck to Alexander Ck	Very High	Moderate	High
9	13	Crowsnest Municipality West	High	High	Very High
10	14	Crowsnest Municipality Centre	Low	Very High	Very High
11		Crowsnest Municipality East	Moderate	High	High
12	10	Ptolemy Pass	Very High	Moderate	Moderate
13	10	Tent Mountain Pass	Very High	Low	Moderate
14	13	Phillips Pass	Moderate	High	Moderate
15	13	Deadman Pass	Very High	Moderate	High
16		Racehorse Pass	High	Moderate	Low

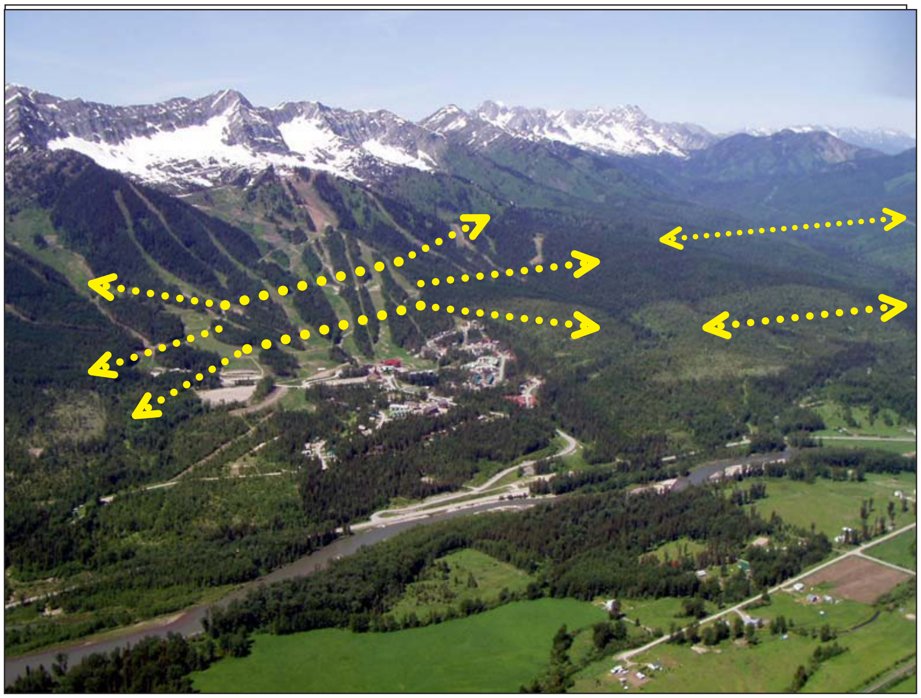
*(1) **Fernie to Morrissey Linkage*** (Photo 1) – This linkage zone provides connectivity for grizzly bears and other wildlife across the Crowsnest Highway between the valleys of Morrissey Creek and the east slopes of the Lizard Range. Although some human developments occur within the valley bottom, we have documented crossings by radio-collared female grizzly bears. We also received a credible report of a lynx crossing here. Currently, options for animals to move parallel to the Elk River on the east side of the valley appear relatively secure for the short term. Most of the land is owned by Tembec Industries and managed under a conservation agreement signed in 2003 that placed a 10-year moratorium on land sales and development. Lands west of the river directly upslope of the highway, however, are controlled by multiple private land owners with varying conservation values, and the effectiveness of this important movement conduit is problematic. Although several land owners recognize and appreciate the importance of their land in facilitating wildlife movement, individual actions such as the erection of 'elk-proof' fencing fracture what otherwise would be the most viable movement route across and parallel to the highway. We rate the 'Fernie↔Morrissey Linkage' as having *very high conservation significance, low limitation to passage, and moderate vulnerability.*

Photo 1. Movement option #1 (Fernie to Morrissey Linkage Zone) spanning the Elk Valley and Crowsnest Highway. View is from N to S.



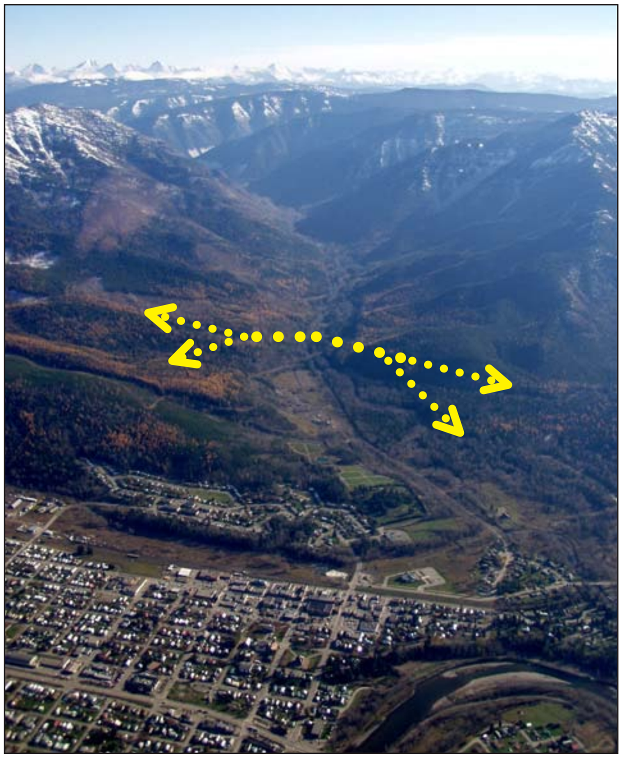
(2) ***Lizard Basin to South Elk Valley Linkage*** (Photo 2) – The Lizard Basin contains highly productive habitat for grizzly bears, and some bear-human conflicts have occurred here in the past. This critical connection passes directly through the Fernie Snow Valley Ski Resort and adjacent private land. Resort managers recognize the value of the landscape to bears and seek to minimize potential for conflict with humans. People from the community of Fernie and the ski area disperse widely elsewhere within the Lizard Basin for recreation, and the area receives considerable human use during summer. From a larger perspective, Lizard Creek basin connects to East Iron Creek and the Bull River drainage. We rate the 'Lizard Basin↔Elk Valley South' linkage as having *very high conservation significance, moderate limitation to passage, and high vulnerability.*

Photo 2. Critical pinch point of movement option #2 (Lizard Basin to Elk Valley South) connecting the Lizard Basin to the Fernie to Morrissey Linkage Zone. View is from E to W over the Elk River to the Fernie Alpine Resort, with the Lizard Basin in the background.



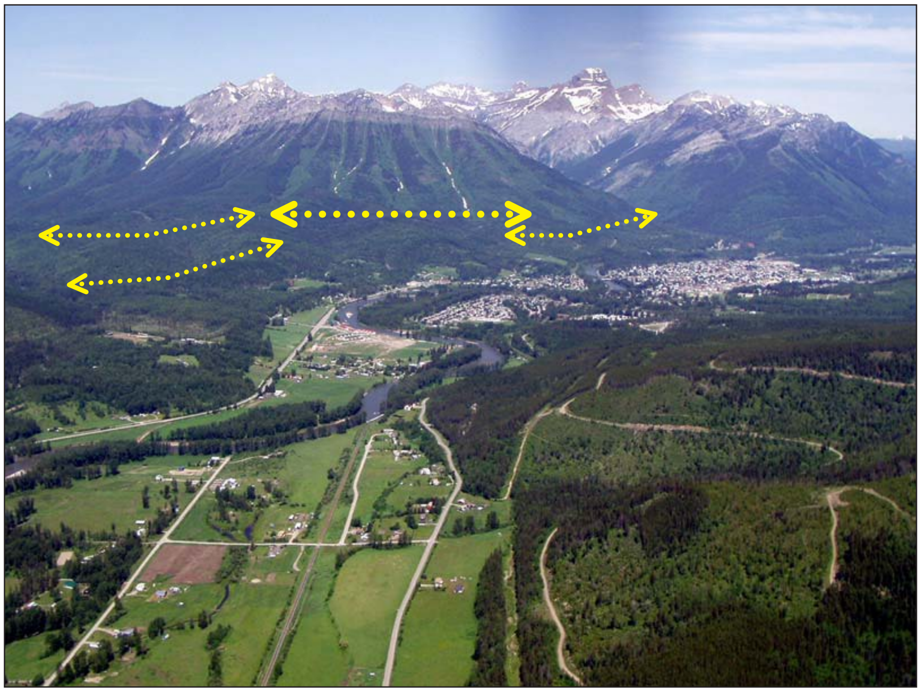
(3) Coal Creek to Elk Valley Linkage (Photo 3) – This linkage provides key connections from the Elk Valley to the Coal Creek drainage east of Fernie. However, the connection has become increasingly restricted due to the expansion of Fernie within the town limits. The Blackstone golf resort and housing development will likely impose further restrictions to animal passage. We rate the 'Coal Creek↔Elk Valley' linkage as having *high conservation significance, high limitation for passage, and very high vulnerability.*

Photo 3. Coal Creek drainage east of Fernie and part of movement option #3 (Coal Creek to Elk Valley). View is from W to E.



(4) ***Mount Fernie Slopes Linkage*** (Photo 4) – The lower slopes of Mount Fernie provide a very important connection for animals moving from the Lizard Basin north along the Elk Valley to the Hartley Pass area. Due to the difficult terrain between Mount Fernie and the Bull River, there are few other realistic options for movement by large mammals. We have documented radio-collared grizzly bears moving through this area, usually upslope of the power line. Below the power line, developments expanding out from Fernie are likely to compromise options for connectivity. We rate the 'Mount Fernie Slopes' linkage as having *very high conservation significance, high limitation to passage, and high vulnerability.*

Photo 4. View S to N over Fernie with Mount Fernie and movement option #4 (Mount Fernie Slopes) in the background. Movement fracture south of Fernie is apparent in the foreground.



(5) ***Hartley Creek - Elk Valley Linkage*** (Photos 5 & 6) – Hartley Creek is a natural funnel for carnivores moving into or out of the Elk Valley. Despite moderate levels of settlement and human activity along the bottom of the Elk Valley between the communities of Fernie and Hosmer, Hartley Creek remains an important connection across the Elk Valley for bears (and likely other species). At least one grizzly bear has been killed on the highway here in recent years (F. DeBoone, *pers. comm.*). Actions to reduce various attractants to grizzly bears on lands northwest of the highway and posting lower speed limits on the highway itself would enhance the effectiveness of this connection. In the future, Hartley Creek would be an obvious location for a highway overpass to facilitate safe passage across the valley. We rate the 'Hartley Creek↔Elk Valley' linkage as having *high conservation significance, high limitation to passage, and very high vulnerability.*

Photo 5. Movement option #5 (Hartley Drainage across Elk Valley), spanning the Crowsnest Highway and development corridor. View is from SE to NW across the Elk Valley, with the Hartley drainage in the background. Also shown are connections with movement options #4 to the south and # 6 to the north.

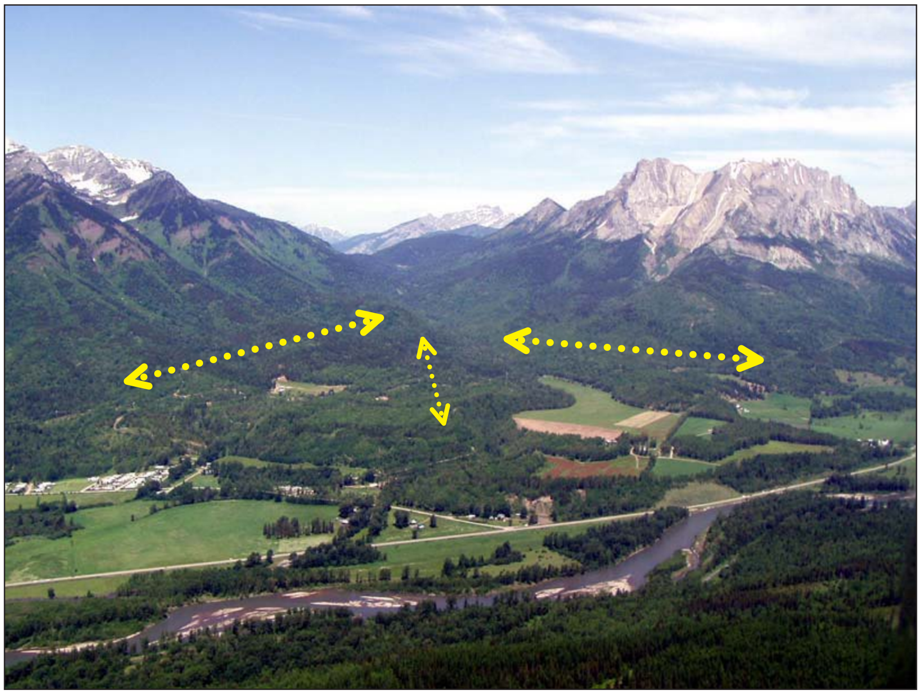
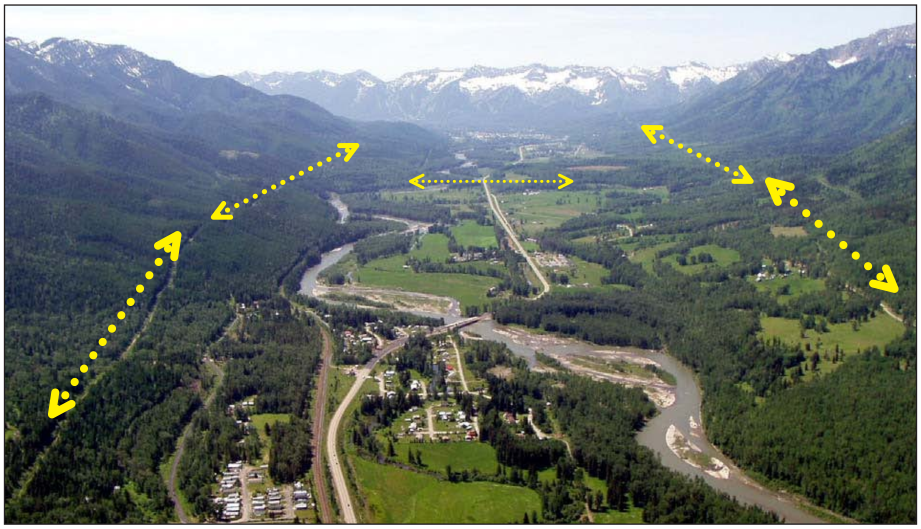
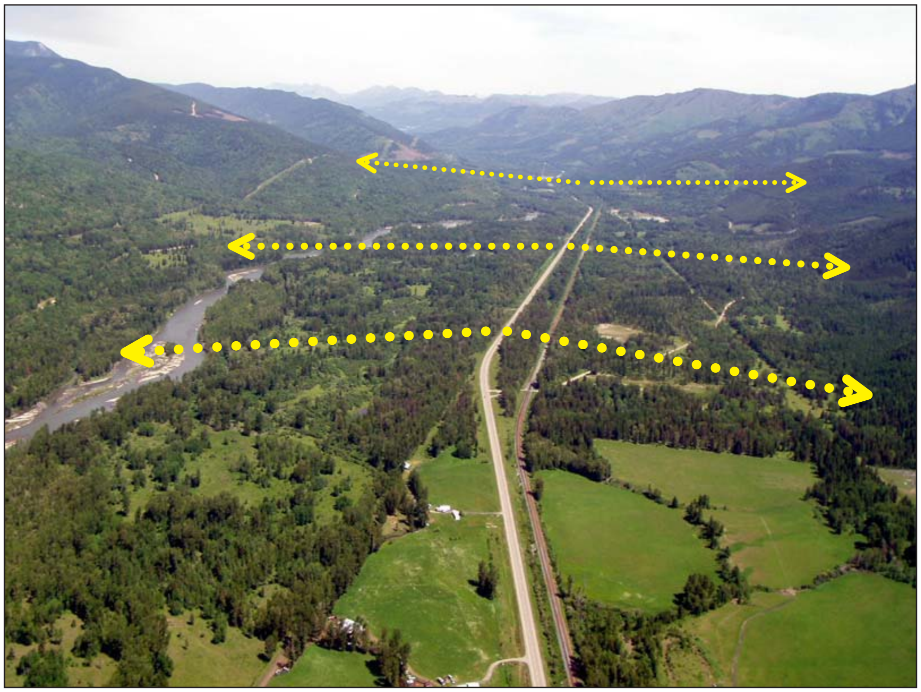


Photo 6. Movement option #5 (Hartley Drainage across Elk Valley), spanning the Crowsnest Highway and development corridor. View is from NE to SW down the Elk Valley, with the community of Hosmer in the foreground. Also shown are movement options up and down the Elk Valley parallel to the highway and river.



(6) ***Hosmer to Sparwood Linkage*** (Photo 7) – This landscape linkage provides crucial connectivity across the Crowsnest Highway. It links the complex of important ridges (Hosmer/Marten/Sparwood Ridges) southeast of the highway to several key areas (McCool and Lladner Creeks) on the other side. These connect further north to excellent grizzly bear habitat in landscapes associated with Sulphur Creek and Hornaday Pass. The slopes of Hosmer Mountain provide another vital connection to the Hartley Creek valley and through Hartley Pass, leading northward to the Bull River drainage. Logging has been relatively widespread within this linkage zone, but Tembec Industries is conducting continued forest harvest with measures to retain interim security values for carnivores (K. Stuart-Smith, *pers. comm.*). We rate the 'Hosmer↔Sparwood' linkage as having *very high conservation significance, low limitation to passage, and moderate vulnerability.*

Photo 7. Movement option #6 (Hosmer to Sparwood Linkage), spanning the Crowsnest Highway and Elk Valley. View is from SW to NE.



(7) ***Michel Creek to Erickson Creek Corridor*** (Fig. 23) – This minor or secondary connector was considered to have low conservation potential due to the rock dump from the Elkview coal mine that partially blocks the upper Erickson valley (Apps 1997). However, our radio-tracking of grizzly bears suggests that some bears are moving through the upper Erickson valley. Coal strip-mining operations have also impacted Harmer Creek, north of upper Erickson. Tembec Industries and the Elkview Coal Mine (Teck Cominco) own all the land in this corridor. We rate the 'Michel Creek↔Erickson Creek' corridor as having *relatively low conservation significance, moderate limitation to passage, and relatively low vulnerability* (due to access controlled by gate).

(8) ***Michel Creek to Alexander Creek Linkage*** (Photos 8, 9 & 10) – This primary landscape linkage connects the important Michel Creek valley south of the Crowsnest Highway to the Alexander Creek valley north of the highway. The southern portion of the linkage extends through a low pass into Island and Crowsnest Creeks in Alberta just south of Crowsnest Pass. The 'Michel Creek↔Alexander Creek' linkage undoubtedly represents one of the most intact and functional connections for wide-ranging carnivores across the Crowsnest Highway anywhere in southern British Columbia and Alberta. For example, in our field surveys in 2002, we gathered DNA evidence substantiating the only known movement of a female grizzly bear to date (F5) across the Crowsnest Highway (from Alexander Creek to Michel Creek). The next year, we attached a GPS radio-collar to this female and found that she resided within the linkage, directly south of the highway. We also captured and tracked another female grizzly that resided directly north of the highway. During the spring of 2003, we observed sign indicating that at least one male grizzly bear had moved through the linkage. Moreover, we detected several lynx in both Michel and Alexander Creek areas during our field surveys. Wolves have passed through these valleys, too. This north↔south connection also ties in with several east↔west passes across the Continental Divide (Tent Mountain pass and Ptolemy Pass south of the Crowsnest Highway; Deadhorse and Racehorse passes north of the highway).

Within this linkage, the displacement effects of a gas compressor station and a transport weigh-scale station along the highway appear to be localized. Tembec manages its lands on the BC side of Crowsnest Pass to limit motorized access. However, there is virtually no control over motorized access on the Alberta side of the Crowsnest Pass. Overall, we rate the 'Michel Creek↔Alexander Creek' linkage as having *very high conservation significance, moderate limitation to passage, and high vulnerability.*

Photo 8. Movement option #8 (Michel Creek to Alexander Creek Linkage). View is from N to S from Alexander Creek across the Crowsnest Highway across Michel Ridge to the Michel Valley (upper right of photo) and across the Continental Divide to Ptolemy Pass and Tent Mountain Pass (upper left of photo).

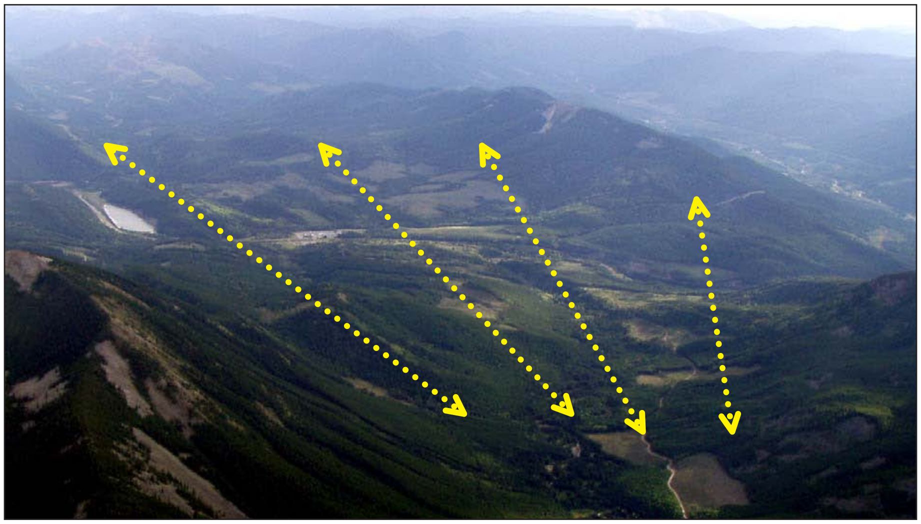


Photo 9. Critical area within movement option #8 (Michel Creek to Alexander Creek Linkage) bisected by the Crowsnest Highway. View is from W to E.

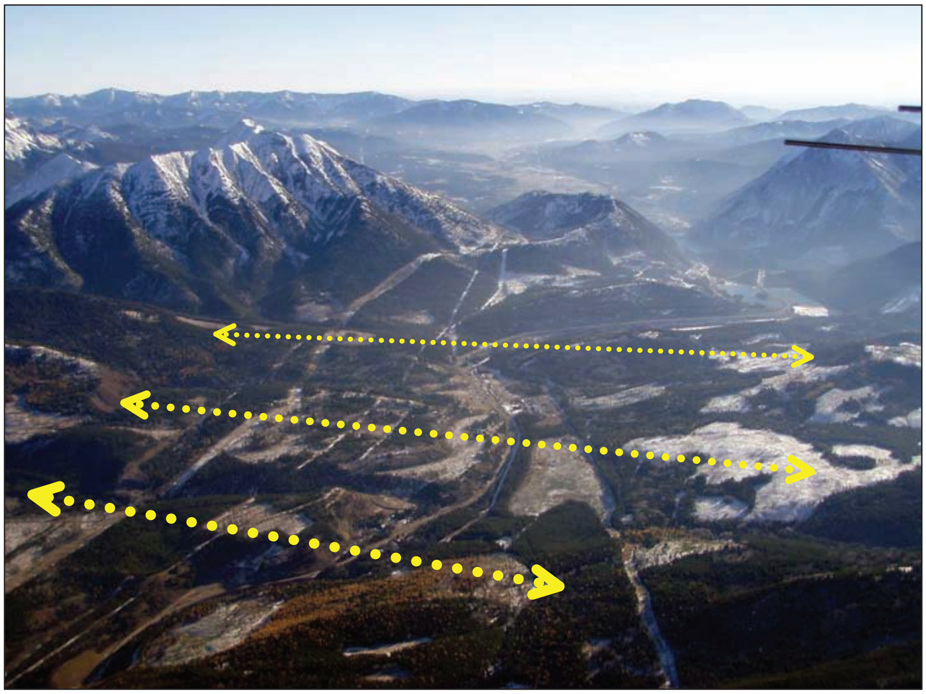
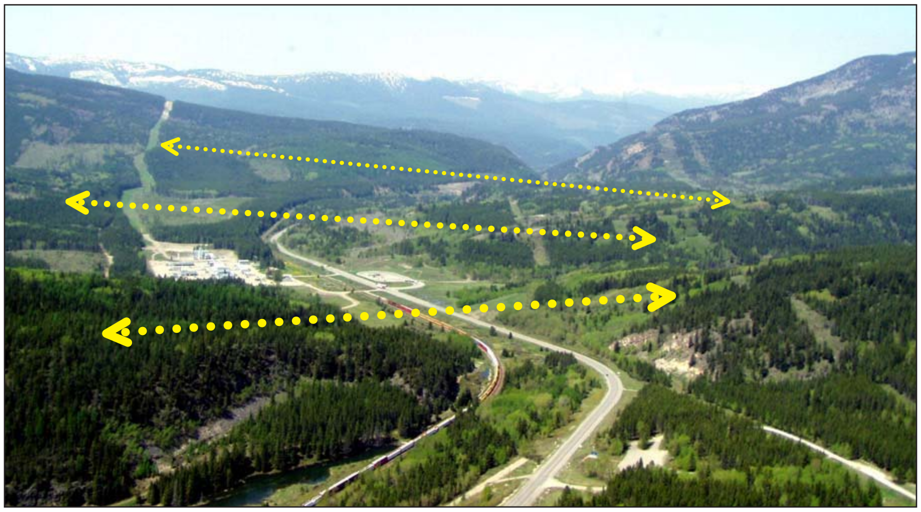
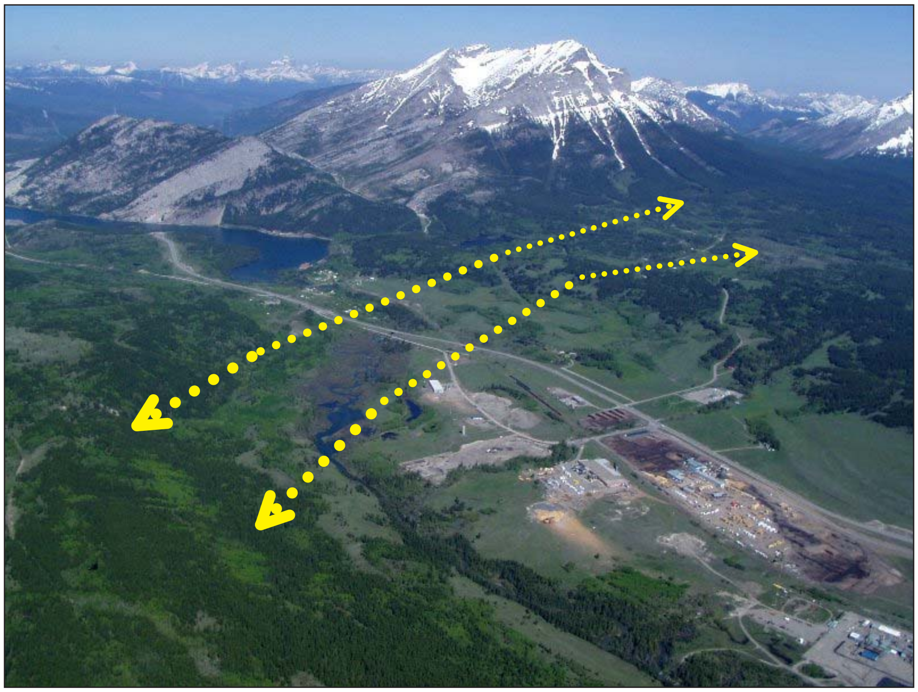


Photo 10. Critical area within movement option #8 (Michel Creek to Alexander Creek Linkage) bisected by the Crowsnest Highway. View is from E to W. Gas compressor station and highway weigh scale are visible.



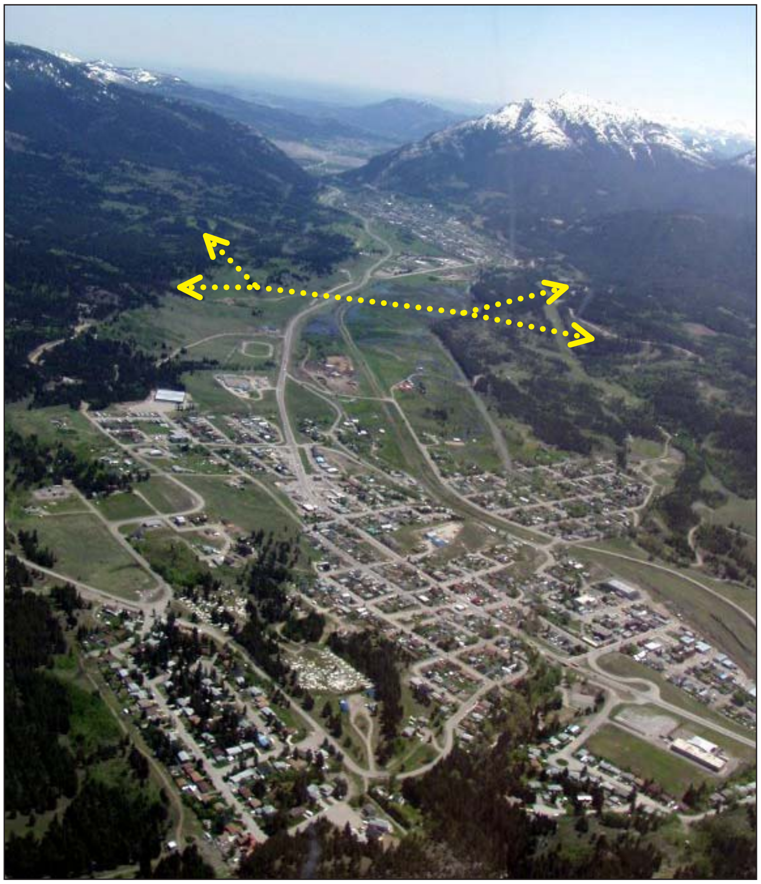
(9) Crowsnest Municipality West Corridor (Photo 11) – The Nature Conservancy of Canada (NCC) previously identified this corridor for passage across the Crowsnest Highway where wildlife could circumvent the western edge of the Crowsnest Pass Municipality (L. Simpson, *pers. comm.*). Our modeling of the regional landscape indicates that core habitat exists for grizzly bears, wolverines, and lynx both north and south of the highway. During the summer of 2002, a male grizzly bear (M15) visited scent stations on both sides of the highway and may have used this corridor. However, security cover is lacking along this entire section of the highway. We believe the most likely crossing occurs where the Crowsnest River passes underneath the highway bridge. It's also possible that wildlife might follow the narrow band of cover along Allison Creek north of the highway. Major residential developments in this area would likely hinder any remaining options for carnivore movements through this corridor, and would likely generate more human activity on Crown lands in the nearby core areas. Conservation covenants with varying stipulations apply to some private lands between Coleman and Crowsnest Pass; the NCC and the Rocky Mountain Elk Foundation (RMEF) have protected other parcels (299 ha) through outright purchase. We rate the 'Crowsnest Municipality West' corridor as having *high conservation significance, high limitation to passage, and very high vulnerability.*

Photo 11. Partial view of movement option #9 (Crowsnest Municipality West), spanning the Crowsnest Highway and development corridor. View is from SE to NW. The most likely movement route across the highway is along Crowsnest Creek that is spanned by the highway. Movement options #15 (Phillips Pass) and #16 (Deadman Pass) are partially visible in the background.



(10) ***Crowsnest Municipality Centre Corridor*** (Photo 12) –This highly tenuous corridor has less security cover, more human activity, and greater distance to core habitat than the previous one to the west. Therefore, we expect that it has much lower potential for providing population connectivity for the larger carnivores (particularly grizzly bears and wolves). NCC and the RMEF have purchased small parcels (78 ha) abutting the south side of the highway. Nonetheless, there is a greater proportion of unprotected, subdivided and developed land within this zone. Overall, we rate the 'Crowsnest Municipality Centre' corridor as having *low conservation significance, very high limitation to passage, and very high vulnerability.*

Photo 12. Movement option #10 (Crowsnest Municipality Centre), spanning the Crowsnest development corridor. View is from NW to SE over the communities of Coleman (foreground) and Blairmore (background) between which a tenuous connection is visible through the wetlands (Rocky Mountain Elk Foundation).



(11) Crowsnest Municipality East Corridor (no photo) – The Nature Conservancy of Canada identified a potential corridor across the eastern end of the Crowsnest Municipality between the communities of Bellevue/Hillcrest and Burmis. Although this connector is distant from core habitats for grizzly bears, we expect that it may facilitate movement of other carnivores (cougars, badgers, bobcats, and possibly wolves). This corridor appears to be more intact than the "centre" corridor across the Crowsnest municipality. NCC owns several parcels (318 ha) abutting and directly south of the highway, while conservation easements apply to some other lands. We rate the 'Crowsnest Municipality East' corridor as having *moderate conservation significance, high limitation to passage, and high vulnerability.*

(12-16) East↔West Connectors across Continental Divide (Fig.23) – In addition to such vital linkages for south↔north movements, there are several east↔ west passes across the Continental Divide that also provide crucial connectivity for wide-ranging carnivores. South of the Crowsnest Highway, these include Ptolemy Pass (12) and Tent Mountain Pass (13), which undoubtedly are critical to the functioning of the Alexander Creek to Michel Creek linkage zone (8). North of the highway, Deadman Pass (15) and Racehorse Pass (16) are key linkages. Even further to the north, the North Fork Pass provides another important east-west conduit.

Recommendations

The southern Canadian Rocky Mountains host the most diverse array of carnivores in North America. Due to its particular geographic position, the southern Canadian Rockies also represent one of the most strategically important sections in maintaining broad ecosystem connectivity from Yellowstone National Park to the Yukon and beyond. Yet, expanding human developments and activities — along the Crowsnest Highway but also throughout the region — pose an obvious threat to maintaining the integrity and connectivity of habitats and populations across this area.

The history of carnivore extirpations in the United States and parts of eastern Canada has demonstrated clearly that a policy of benign neglect will not suffice toward their conservation. Managers need to provide leadership in an arena of powerful economic interests, competing agendas, and multi-jurisdictional complexity.

<u>We urge land and resource managers, in concert with key stakeholders and the public, to implement the following recommendations toward conserving carnivores and other wildlife in the southern Canadian Rockies and ensuring connectivity of populations across the Crowsnest Highway.</u>

✓1. Continue to maintain a network of core areas with a high level of security through appropriate management practices. Important considerations include access management (fully implementing the Southern Rocky Mountain Access Management Plan), and avoiding excessive mortality through appropriate hunting and trapping regulations.

✓2. Develop a proactive conservation plan to maintain connectivity across and around the Crowsnest Highway. This plan should consider assessment and planning of possible highway expansion, incentives for land-use covenants, and other practices

In the context of expanding human population and developments and climate change, time is running out on these options. We look forward to assisting responsible stewardship.

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APPENDIX A. NOTES – DATA SOURCE COMBINATIONS FOR SOME MODEL VARIABLES

1. The FIP database does not consistently discriminate western larch (Lw) from alpine larch (La). On the advice of T. Braumandl (Research Ecologist, Ministry of Forests, Nelson, BC), we used an elevational cut of 1900 m to differentiate the 2 species.
2. Alpine/Barren (ALP-BARE):
   a. FIP "alpine" encompasses a lot of what is actually "rock/barren" in AVI. BTM splits rock, ice, and alpine better than FIP. Therefore this class is defined by "rock/barren"(37) from AVI and "alpine"(8) from BTM. "Rock" from FIP and "bare" from BTM, which is definitely pure rock faces, gets included in NF_UNVEG.
3. Non-forest vegetated (NF_VEG):
   a. FIP NPD = NPBR(11), NPBU(12), NP(13), M(62), OR(63)
   b. AVI NPD = 1-5, 11-16
   c. BTM = AGMX(15), AGR(16), AVA(7), RANG(14), SHRB(6)
4. Non-forest unvegetated (NF_UNVEG):
   a. FIP NPD = ICE(1), R(3), GR(6), SAND(7), CL(9), L(15), G(18), RIV(25), MUD(26), U(50)
   b. BTM = ICE (9), BARE(10)
   c. AVI NPD = 21-28, 31-36, 38
5. Agricultural lands (HI_AGR):
   a. AVI NPD = 11-13
   b. FIP NPD = P(60)
   c. BTM = AGMX(15), AGR(16)
6. Forest productivity (FP_*):
   a. Very low (FP_VLOW; 1): AVI TPR = U, FIP SIT = <10
   b. Low (FP_LOW; 2): AVI TPR = F, FIP SIT = 10-15
   c. Medium (FP_MED; 3): AVI TPR = M, FIP SIT = 15-20
   d. High (FP_HIGH; 4): AVI TPR = G, FIP SIT = >20
   e. FP_UVEG = all nonproductive lands (i.e., non of the above) that correspond to NF_UVEG and ALP-BARE.
   f. FP_VEG = all nonproductive lands (i.e., non of the above) that correspond to NF_VEG
   g. FP_Water: AVI does not differentiate "swamp" as does FIP or "wetland" as does BTM. Therefore we have this single class = FIP NPD = L (15), Riv(25), S(35); AVI NPD = 32-34

APPENDIX B. SPECIES-SPECIFIC MODEL PARAMETERS

		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
MODEL	Suitable Habitat		0.50		0.70		0.70		0.70		0.50		0.50
SUBMODEL	Capable Habitat		0.40		0.40		0.40		0.50		0.40		0.50
FACTOR	Climate		0.50		0.50		0.40		0.50		0.30		0.50
VARIABLE	Temperature		0.40		0.33		0.10		0.33		0.10		0.33
CLASS	Warm	1	0.70	1	0.20	1	0.90	1	0.90	1	0.50	1	0.40
	Cool	1	0.90	1	0.90	1	0.70	1	0.60	1	0.50	1	0.90
VARIABLE	Precipitation		0.40		0.33		0.10		0.33		0.20		0.33
CLASS	Low	1	0.80	2	0.60	2	0.90	2	0.90	2	0.70	2	0.80
	Medium	1	0.80	2	0.80	2	0.80	2	0.70	2	0.50	2	0.90
	High	1	0.90	2	0.90	2	0.70	2	0.50	2	0.30	2	0.90
VARIABLE	Elevation		0.20		0.33		0.80		0.33		0.70		0.33
CLASS	< 1000 m	3	0.80	3	0.10	3	0.90	3	0.90	3	0.90	3	0.70
	1000 - 1200 m	3	0.80	3	0.30	3	0.80	3	0.90	3	0.90	3	0.80
	1200 - 1400 m	3	0.90	3	0.70	3	0.70	3	0.70	3	0.90	3	0.90
	1400 - 1600 m	3	0.90	3	0.80	3	0.50	3	0.60	3	0.70	3	0.90
	1600 - 1800 m	3	0.90	3	0.90	3	0.50	3	0.30	3	0.50	3	0.90
	1800 - 2000 m	3	0.90	3	0.90	3	0.50	3	0.10	3	0.40	3	0.90
	2000 - 2200 m	3	0.90	3	0.90	3	0.50	3	0.10	3	0.30	3	0.90
	2200 - 2400 m	3	0.90	3	0.90	3	0.50	3	0.10	3	0.20	3	0.90
	> 2400 m	3	0.90	3	0.90	3	0.50	3	0.10	3	0.10	3	0.90
FACTOR	Enduring Features		0.50		0.50		0.60		0.50		0.70		0.50
VARIABLE	Slope		0.50		0.50		0.60		0.70		0.70		0.70
CLASS	Flat <10%	3	0.90	3	0.90	3	0.90	3	0.90	3	0.90	3	0.50
	Gentle 10 - 30%	3	0.90	3	0.90	3	0.90	3	0.90	3	0.60	3	0.60
	Moderate 30 - 50%	3	0.90	3	0.70	3	0.40	3	0.80	3	0.30	3	0.70
	Steep 50 - 80%	3	0.80	3	0.40	3	0.10	3	0.40	3	0.10	3	0.90
	Very steep >80%	3	0.60	3	0.10	3	0.10	3	0.10	3	0.10	3	0.70
VARIABLE	Forest Productivity		0.50		0.50		0.40		0.30		0.30		0.30
CLASS	High (site index >20)	3	0.90	3	0.90	3	0.70	3	0.90	3	0.90	3	0.90
	Medium (site index 15-20)	3	0.90	3	0.90	3	0.80	3	0.90	3	0.90	3	0.90
	Low (site index 10-15)	3	0.90	3	0.80	3	0.90	3	0.80	3	0.60	3	0.90
	Very low (site index <10)	3	0.90	3	0.70	3	0.90	3	0.70	3	0.40	3	0.90
	Non-forest - vegetated	3	0.90	3	0.50	3	0.90	3	0.50	3	0.80	3	0.90
	Non-forest - unvegetated	3	0.30	3	0.20	3	0.50	3	0.20	3	0.20	3	0.80
	Non-forest - water	3	0.10	3	0.10	3	0.10	3	0.10	3	0.50	3	0.30
SUBMODEL	Small Mammal Prey		--		0.60		0.60		0.50		--		--
FACTOR	Snowshoe Hare	--	--	3	0.80	--	--	3	0.50	--	--	--	--
VARIABLE	Structure		--		0.70		--		0.70		--		--
CLASS	Non-forested barren	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Non-forested grass/forb	--	--	0	0.20	--	--	0	0.20	--	--	--	--
	Non-forested open shrub	--	--	0	0.40	--	--	0	0.40	--	--	--	--
	Non-forested shrub	--	--	0	0.50	--	--	0	0.50	--	--	--	--
	forested 10 - 20 yrs	--	--	0	0.80	--	--	0	0.80	--	--	--	--
	forested 20 - 40 yrs	--	--	0	0.90	--	--	0	0.90	--	--	--	--
	forested 40 - 60 yrs	--	--	0	0.80	--	--	0	0.80	--	--	--	--
	forested 60 - 80 yrs	--	--	0	0.80	--	--	0	0.80	--	--	--	--
	forested 80 - 120 yrs	--	--	0	0.60	--	--	0	0.60	--	--	--	--
	forested >120 yrs	--	--	0	0.80	--	--	0	0.80	--	--	--	--

continued on next page

		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
VARIABLE	Cover Type		--		0.30		--		0.30		--		--
CLASS	Spruce - fir	--	--	0	0.90	--	--	0	0.70	--	--	--	--
	Cedar - hemlock	--	--	0	0.70	--	--	0	0.70	--	--	--	--
	Douglas-fir	--	--	0	0.60	--	--	0	0.70	--	--	--	--
	Lodgepole pine	--	--	0	0.90	--	--	0	0.90	--	--	--	--
	Western larch	--	--	0	0.50	--	--	0	0.40	--	--	--	--
	Alpine larch	--	--	0	0.10	--	--	0	0.40	--	--	--	--
	Whitebark & limber pine	--	--	0	0.20	--	--	0	0.70	--	--	--	--
	Deciduous overstory spp.	--	--	0	0.40	--	--	0	0.40	--	--	--	--
	Non-forested vegetated	--	--	0	0.50	--	--	0	0.50	--	--	--	--
	Non-forested unvegetated	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Alpine and Barren	--	--	0	0.10	--	--	0	0.10	--	--	--	--
FACTOR	Tree Squirrel	--	--	3	0.20	--	--	3	0.50	--	--	--	--
VARIABLE	Structure		--		0.40		--		0.40		--		--
CLASS	Non-forested barren	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Non-forested grass/forb	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Non-forested open shrub	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Non-forested shrub	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	forested 10 - 20 yrs	--	--	0	0.20	--	--	0	0.40	--	--	--	--
	forested 20 - 40 yrs	--	--	0	0.60	--	--	0	0.60	--	--	--	--
	forested 40 - 60 yrs	--	--	0	0.60	--	--	0	0.60	--	--	--	--
	forested 60 - 80 yrs	--	--	0	0.80	--	--	0	0.80	--	--	--	--
	forested 80 - 120 yrs	--	--	0	0.90	--	--	0	0.90	--	--	--	--
	forested >120 yrs	--	--	0	0.90	--	--	0	0.90	--	--	--	--
VARIABLE	Cover Type		--		0.20		--		0.20		--		--
CLASS	Spruce - fir	--	--	0	0.90	--	--	0	0.90	--	--	--	--
	Cedar - hemlock	--	--	0	0.70	--	--	0	0.80	--	--	--	--
	Douglas-fir	--	--	0	0.80	--	--	0	0.80	--	--	--	--
	Lodgepole pine	--	--	0	0.80	--	--	0	0.70	--	--	--	--
	Western larch	--	--	0	0.50	--	--	0	0.40	--	--	--	--
	Alpine larch	--	--	0	0.20	--	--	0	0.40	--	--	--	--
	Whitebark & limber pine	--	--	0	0.40	--	--	0	0.70	--	--	--	--
	Deciduous overstory spp.	--	--	0	0.20	--	--	0	0.20	--	--	--	--
	Non-forested vegetated	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Non-forested unvegetated	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	Alpine and Barren	--	--	0	0.10	--	--	0	0.10	--	--	--	--
VARIABLE	Canopy Cover		--		0.40		--		0.40		--		--
CLASS	0 - 5%	--	--	0	0.10	--	--	0	0.10	--	--	--	--
	6 - 30%	--	--	0	0.30	--	--	0	0.40	--	--	--	--
	31 - 50%	--	--	0	0.70	--	--	0	0.70	--	--	--	--
	51 - 70%	--	--	0	0.90	--	--	0	0.90	--	--	--	--
	70 - 100%	--	--	0	0.90	--	--	0	0.90	--	--	--	--
FACTOR	Ground Squirrel	--	--	--	--	3	1.00	--	--	--	--	--	--
VARIABLE	Structure		--		--		0.20		--		--		--
CLASS	Non-forested barren	--	--	0	--	0	0.10	0	--	--	--	--	--
	Non-forested grass/forb	--	--	0	--	0	0.90	0	--	--	--	--	--
	Non-forested open shrub	--	--	0	--	0	0.90	0	--	--	--	--	--
	Non-forested shrub	--	--	0	--	0	0.70	0	--	--	--	--	--
	forested 10 - 20 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--
	forested 20 - 40 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--
	forested 40 - 60 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--
	forested 60 - 80 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--
	forested 80 - 120 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--
	forested >120 yrs	--	--	0	--	0	0.50	0	--	--	--	--	--

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		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
VARIABLE	WVI		--		--		0.40		--		--		--
CLASS	very xeric (< -60)	--	--	0	--	0	0.90	0	--	--	--	--	--
	xeric (-60 to -35)	--	--	0	--	0	0.90	0	--	--	--	--	--
	subxeric (-35 to -20)	--	--	0	--	0	0.80	0	--	--	--	--	--
	mesic (-20 to 0)	--	--	0	--	0	0.60	0	--	--	--	--	--
	submsesic (0 to 10)	--	--	0	--	0	0.40	0	--	--	--	--	--
	hygric (10 to 15)	--	--	0	--	0	0.20	0	--	--	--	--	--
	subhygric (15 to 20)	--	--	0	--	0	0.10	0	--	--	--	--	--
	hydric (> 20)	--	--	0	--	0	0.10	0	--	--	--	--	--
VARIABLE	Canopy Cover		--		--		0.40		--		--		--
CLASS	0 - 5%	--	--	0	--	0	0.90	0	--	--	--	--	--
	6 - 30%	--	--	0	--	0	0.80	0	--	--	--	--	--
	31 - 50%	--	--	0	--	0	0.60	0	--	--	--	--	--
	51 - 70%	--	--	0	--	0	0.40	0	--	--	--	--	--
	70 - 100%	--	--	0	--	0	0.20	0	--	--	--	--	--
SUBMODEL	Ungulate Prey		0.05		--		--		--		0.60		0.50
FACTOR	Winter Ranges	--	--	--	--	--	--	--	--	--	0.60	--	0.50
VARIABLE	Elevation		--		--		--		--		0.10		0.20
CLASS	< 1000 m	0	--	0	--	0	--	0	--	0	0.90	0	0.60
	1000 - 1200 m	0	--	0	--	0	--	0	--	0	0.90	0	0.70
	1200 - 1400 m	0	--	0	--	0	--	0	--	0	0.80	0	0.80
	1400 - 1600 m	0	--	0	--	0	--	0	--	0	0.50	0	0.90
	1600 - 1800 m	0	--	0	--	0	--	0	--	0	0.30	0	0.90
	1800 - 2000 m	0	--	0	--	0	--	0	--	0	0.20	0	0.90
	2000 - 2200 m	0	--	0	--	0	--	0	--	0	0.10	0	0.90
	2200 - 2400 m	0	--	0	--	0	--	0	--	0	0.10	0	0.90
	> 2400 m	0	--	0	--	0	--	0	--	0	0.10	0	0.90
VARIABLE	Slope		--		--		--		--		0.10		0.20
CLASS	Flat <10%	0	--	0	--	0	--	0	--	0	0.90	0	0.90
	Gentle 10 - 30%	0	--	0	--	0	--	0	--	0	0.90	0	0.90
	Moderate 30 - 50%	0	--	0	--	0	--	0	--	0	0.50	0	0.70
	Steep 50 - 80%	0	--	0	--	0	--	0	--	0	0.30	0	0.50
	Very steep >80%	0	--	0	--	0	--	0	--	0	0.10	0	0.30
VARIABLE	Aspect		--		--		--		--		0.15		0.20
CLASS	South	0	--	0	--	0	--	0	--	0	0.90	0	0.90
	West	0	--	0	--	0	--	0	--	0	0.90	0	0.90
VARIABLE	Structure		--		--		--		--		0.15		0.20
CLASS	Non-forested barren	0	--	0	--	0	--	0	--	0	0.10	0	0.10
	Non-forested grass/forb	0	--	0	--	0	--	0	--	0	0.80	0	0.80
	Non-forested open shrub	0	--	0	--	0	--	0	--	0	0.60	0	0.60
	Non-forested shrub	0	--	0	--	0	--	0	--	0	0.60	0	0.60
	forested 10 - 20 yrs	0	--	0	--	0	--	0	--	0	0.20	0	0.20
	forested 20 - 40 yrs	0	--	0	--	0	--	0	--	0	0.20	0	0.20
	forested 40 - 60 yrs	0	--	0	--	0	--	0	--	0	0.40	0	0.40
	forested 60 - 80 yrs	0	--	0	--	0	--	0	--	0	0.50	0	0.50
	forested 80 - 120 yrs	0	--	0	--	0	--	0	--	0	0.70	0	0.70
	forested >120 yrs	0	--	0	--	0	--	0	--	0	0.90	0	0.90
VARIABLE	Canopy Cover		--		--		--		--		0.10		0.30
CLASS	0 - 5%	0	--	0	--	0	--	0	--	0	0.90	0	0.90
	6 - 30%	0	--	0	--	0	--	0	--	0	0.80	0	0.80
	31 - 50%	0	--	0	--	0	--	0	--	0	0.50	0	0.50
	51 - 70%	0	--	0	--	0	--	0	--	0	0.80	0	0.80
	70 - 100%	0	--	0	--	0	--	0	--	0	0.90	0	0.90

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		Grizzly Bear		**Lynx**		**Badger**		**Bobcat**		**Wolf**		**Wolverine**	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
VARIABLE	Cover Type		--		--		--		--		0.15		0.10
CLASS	Spruce - fir	0	--	0	--	0	--	0	--	0	0.70	0	0.70
	Cedar - hemlock	0	--	0	--	0	--	0	--	0	0.30	0	0.30
	Douglas-fir	0	--	0	--	0	--	0	--	0	0.90	0	0.90
	Lodgepole pine	0	--	0	--	0	--	0	--	0	0.50	0	0.50
	Western larch	0	--	0	--	0	--	0	--	0	0.20	0	0.20
	Alpine larch	0	--	0	--	0	--	0	--	0	0.10	0	0.10
	Whitebark & limber pine	0	--	0	--	0	--	0	--	0	0.10	0	0.10
	Deciduous overstory spp.	0	--	0	--	0	--	0	--	0	0.50	0	0.50
	Non-forested vegetated	0	--	0	--	0	--	0	--	0	0.70	0	0.70
	Non-forested unvegetated	0	--	0	--	0	--	0	--	0	0.10	0	0.10
	Alpine and Barren	0	--	0	--	0	--	0	--	0	0.10	0	0.10
FACTOR	Summer Ranges	2	1.00	--	--	--	--	--	--	--	0.40	--	0.50
VARIABLE	Slope		0.40		--		--		--		0.30		0.30
CLASS	Flat <10%	0	0.90	0	--	0	--	0	--	0	0.90	0	0.90
	Gentle 10 - 30%	0	0.90	0	--	0	--	0	--	0	0.90	0	0.90
	Moderate 30 - 50%	0	0.70	0	--	0	--	0	--	0	0.60	0	0.60
	Steep 50 - 80%	0	0.50	0	--	0	--	0	--	0	0.50	0	0.50
	Very steep >80%	0	0.10	0	--	0	--	0	--	0	0.10	0	0.10
VARIABLE	Structure		0.40		--		--		--		0.45		0.45
CLASS	Non-forested barren	0	0.20	0	--	0	--	0	--	0	0.10	0	0.10
	Non-forested grass/forb	0	0.90	0	--	0	--	0	--	0	0.90	0	0.90
	Non-forested open shrub	0	0.90	0	--	0	--	0	--	0	0.80	0	0.80
	Non-forested shrub	0	0.80	0	--	0	--	0	--	0	0.70	0	0.70
	forested 10 - 20 yrs	0	0.90	0	--	0	--	0	--	0	0.80	0	0.80
	forested 20 - 40 yrs	0	0.70	0	--	0	--	0	--	0	0.50	0	0.50
	forested 40 - 60 yrs	0	0.40	0	--	0	--	0	--	0	0.50	0	0.50
	forested 60 - 80 yrs	0	0.70	0	--	0	--	0	--	0	0.60	0	0.60
	forested 80 - 120 yrs	0	0.80	0	--	0	--	0	--	0	0.70	0	0.70
	forested >120 yrs	0	0.80	0	--	0	--	0	--	0	0.80	0	0.80
VARIABLE	Cover Type		0.20		--		--		--		0.25		0.25
CLASS	Spruce - fir	0	0.80	0	--	0	--	0	--	0	0.80	0	0.80
	Cedar - hemlock	0	0.50	0	--	0	--	0	--	0	0.40	0	0.40
	Douglas-fir	0	0.60	0	--	0	--	0	--	0	0.60	0	0.60
	Lodgepole pine	0	0.80	0	--	0	--	0	--	0	0.70	0	0.70
	Western larch	0	0.80	0	--	0	--	0	--	0	0.50	0	0.50
	Alpine larch	0	0.70	0	--	0	--	0	--	0	0.50	0	0.50
	Whitebark & limber pine	0	0.70	0	--	0	--	0	--	0	0.50	0	0.50
	Deciduous overstory spp.	0	0.90	0	--	0	--	0	--	0	0.60	0	0.60
	Non-forested vegetated	0	0.90	0	--	0	--	0	--	0	0.80	0	0.80
	Non-forested unvegetated	0	0.30	0	--	0	--	0	--	0	0.30	0	0.30
	Alpine and Barren	0	0.30	0	--	0	--	0	--	0	0.50	0	0.50
SUBMODEL	Bear Plant Foods		0.55		--		--		--		--		--
FACTOR	Avalanche Chutes	3	0.33	--	--	--	--	--	--	--	--	--	--
VARIABLE	Slope		0.33		--		--		--		--		--
CLASS	Flat <10%	0	0.10	0	--	0	--	0	--	0	--	0	--
	Gentle 10 - 30%	0	0.30	0	--	0	--	0	--	0	--	0	--
	Moderate 30 - 50%	0	0.60	0	--	0	--	0	--	0	--	0	--
	Steep 50 - 80%	0	0.90	0	--	0	--	0	--	0	--	0	--
	Very steep >80%	0	0.20	0	--	0	--	0	--	0	--	0	--

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		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
VARIABLE	Slope Position		0.33		--		--		--		--		--
CLASS	Bottom	0	0.50	0	--	0	--	0	--	0	--	0	--
	Lower	0	0.80	0	--	0	--	0	--	0	--	0	--
	Mid	0	0.90	0	--	0	--	0	--	0	--	0	--
	Upper	0	0.60	0	--	0	--	0	--	0	--	0	--
	Top	0	0.30	0	--	0	--	0	--	0	--	0	--
VARIABLE	Forest Productivity		0.33		--		--		--		--		--
CLASS	High (site index >20)	0	0.10	0	--	0	--	0	--	0	--	0	--
	Medium (site index 15-20)	0	0.10	0	--	0	--	0	--	0	--	0	--
	Low (site index 10-15)	0	0.10	0	--	0	--	0	--	0	--	0	--
	Very low (site index <10)	0	0.10	0	--	0	--	0	--	0	--	0	--
	Non-forest - vegetated	0	0.90	0	--	0	--	0	--	0	--	0	--
	Non-forest - unvegetated	0	0.30	0	--	0	--	0	--	0	--	0	--
	Non-forest - water	0	0.10	0	--	0	--	0	--	0	--	0	--
FACTOR	Riparian	3	0.33	--	--	--	--	--	--	--	--	--	--
VARIABLE	Seepage & Floodplain		0.25		--		--		--		--		--
CLASS	Seepage & Floodplain Terrain		0.90		--		--		--		--		--
VARIABLE	Hydrography Proximity		0.25		--		--		--		--		--
CLASS	<50 m of feature	0	0.90	0	--	0	--	0	--	0	--	0	--
	50 - 100 m of feature	0	0.70	0	--	0	--	0	--	0	--	0	--
	100 - 300 m of feature	0	0.50	0	--	0	--	0	--	0	--	0	--
	300 - 500 m of feature	0	0.30	0	--	0	--	0	--	0	--	0	--
VARIABLE	Cover Type		0.25		--		--		--		--		--
CLASS	Spruce - fir	0	0.80	0	--	0	--	0	--	0	--	0	--
	Cedar - hemlock	0	0.70	0	--	0	--	0	--	0	--	0	--
	Douglas-fir	0	0.20	0	--	0	--	0	--	0	--	0	--
	Lodgepole pine	0	0.40	0	--	0	--	0	--	0	--	0	--
	Western larch	0	0.20	0	--	0	--	0	--	0	--	0	--
	Alpine larch	0	0.20	0	--	0	--	0	--	0	--	0	--
	Whitebark & limber pine	0	0.10	0	--	0	--	0	--	0	--	0	--
	Deciduous overstory spp.	0	0.90	0	--	0	--	0	--	0	--	0	--
	Non-forested vegetated	0	0.80	0	--	0	--	0	--	0	--	0	--
	Non-forested unvegetated	0	0.30	0	--	0	--	0	--	0	--	0	--
	Alpine and Barren	0	0.10	0	--	0	--	0	--	0	--	0	--
VARIABLE	Structure		0.25		--		--		--		--		--
CLASS	Non-forested barren	0	0.10	0	--	0	--	0	--	0	--	0	--
	Non-forested grass/forb	0	0.90	0	--	0	--	0	--	0	--	0	--
	Non-forested open shrub	0	0.70	0	--	0	--	0	--	0	--	0	--
	Non-forested shrub	0	0.70	0	--	0	--	0	--	0	--	0	--
	forested 10 - 20 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
	forested 20 - 40 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
	forested 40 - 60 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
	forested 60 - 80 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
	forested 80 - 120 yrs	0	0.60	0	--	0	--	0	--	0	--	0	--
	forested >120 yrs	0	0.80	0	--	0	--	0	--	0	--	0	--

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		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
FACTOR	Berries	3	0.33	--	--	--	--	--	--	--	--	--	--
VARIABLE	Structure		0.30		--		--		--		--		--
CLASS	Non-forested barren	0	0.10	0	--	0	--	0	--	0	--	0	--
	Non-forested grass/forb	0	0.70	0	--	0	--	0	--	0	--	0	--
	Non-forested open shrub	0	0.90	0	--	0	--	0	--	0	--	0	--
	Non-forested shrub	0	0.80	0	--	0	--	0	--	0	--	0	--
	forested 10 - 20 yrs	0	0.80	0	--	0	--	0	--	0	--	0	--
	forested 20 - 40 yrs	0	0.80	0	--	0	--	0	--	0	--	0	--
	forested 40 - 60 yrs	0	0.60	0	--	0	--	0	--	0	--	0	--
	forested 60 - 80 yrs	0	0.60	0	--	0	--	0	--	0	--	0	--
	forested 80 - 120 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
	forested >120 yrs	0	0.50	0	--	0	--	0	--	0	--	0	--
VARIABLE	Cover Type		0.20		--		--		--		--		--
CLASS	Spruce - fir	0	0.70	0	--	0	--	0	--	0	--	0	--
	Cedar - hemlock	0	0.50	0	--	0	--	0	--	0	--	0	--
	Douglas-fir	0	0.50	0	--	0	--	0	--	0	--	0	--
	Lodgepole pine	0	0.90	0	--	0	--	0	--	0	--	0	--
	Western larch	0	0.50	0	--	0	--	0	--	0	--	0	--
	Alpine larch	0	0.40	0	--	0	--	0	--	0	--	0	--
	Whitebark & limber pine	0	0.50	0	--	0	--	0	--	0	--	0	--
	Deciduous overstory spp.	0	0.80	0	--	0	--	0	--	0	--	0	--
	Non-forested vegetated	0	0.80	0	--	0	--	0	--	0	--	0	--
	Non-forested unvegetated	0	0.30	0	--	0	--	0	--	0	--	0	--
	Alpine and Barren	0	0.20	0	--	0	--	0	--	0	--	0	--
VARIABLE	Canopy Cover		0.30		--		--		--		--		--
CLASS	0 - 5%	0	0.90	0	--	0	--	0	--	0	--	0	--
	6 - 30%	0	0.80	0	--	0	--	0	--	0	--	0	--
	31 - 50%	0	0.70	0	--	0	--	0	--	0	--	0	--
	51 - 70%	0	0.60	0	--	0	--	0	--	0	--	0	--
	70 - 100%	0	0.30	0	--	0	--	0	--	0	--	0	--
VARIABLE	Aspect		0.20		--		--		--		--		--
CLASS	South	0	0.90	0	--	0	--	0	--	0	--	0	--
	West	0	0.70	0	--	0	--	0	--	0	--	0	--
MODEL	Security		0.50		0.30		0.30		0.30		0.50		0.50
SUBMODEL	Security		--		--		--		--		--		--
FACTOR	Habitat	--	0.30	--	0.50	--	0.00	--	0.50	--	0.50	--	0.30
VARIABLE	Structure		0.70		0.70		0.50		0.50		0.60		0.60
CLASS	Non-forested barren	3	0.10	3	0.10	3	0.50	3	0.10	3	0.10	3	0.30
	Non-forested grass/forb	3	0.10	3	0.10	3	0.50	3	0.10	3	0.10	3	0.30
	Non-forested open shrub	3	0.20	3	0.20	3	0.50	3	0.60	3	0.20	3	0.50
	Non-forested shrub	3	0.30	3	0.30	3	0.50	3	0.70	3	0.30	3	0.50
	forested 10 - 20 yrs	3	0.50	3	0.60	3	0.50	3	0.70	3	0.50	3	0.60
	forested 20 - 40 yrs	3	0.70	3	0.90	3	0.50	3	0.90	3	0.80	3	0.80
	forested 40 - 60 yrs	3	0.80	3	0.80	3	0.50	3	0.80	3	0.80	3	0.80
	forested 60 - 80 yrs	3	0.80	3	0.70	3	0.50	3	0.70	3	0.80	3	0.80
	forested 80 - 120 yrs	3	0.90	3	0.80	3	0.50	3	0.80	3	0.90	3	0.90
	forested >120 yrs	3	0.90	3	0.90	3	0.50	3	0.90	3	0.90	3	0.90
VARIABLE	Terrain Complexity		0.30		0.30		0.50		0.50		0.40		0.40
CLASS	TC Very low (< 0.2)	3	0.10	3	0.20	3	0.50	3	0.20	3	0.40	3	0.40
	TC Low (0.2 - 0.4)	3	0.30	3	0.40	3	0.50	3	0.40	3	0.50	3	0.50
	TC Moderate (0.4 - 0.6)	3	0.60	3	0.70	3	0.50	3	0.70	3	0.80	3	0.80
	TC High (0.6 - 0.8)	3	0.80	3	0.90	3	0.50	3	0.90	3	0.90	3	0.90
	TC Very high (> 0.8)	3	0.90	3	0.90	3	0.50	3	0.90	3	0.90	3	0.90

continued on next page

		Grizzly Bear		Lynx		Badger		Bobcat		Wolf		Wolverine	
		Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff	Scale	Coeff
FACTOR	Human	--	0.70	--	0.50	--	1.00	--	0.50	--	0.50	--	0.70
VARIABLE	Access		0.20		0.33		0.00		0.33		0.40		0.40
CLASS	Access Very low (< 0.2)	2	0.90	2	0.90	2	0.90	2	0.90	1	0.90	1	0.90
	Access Low (0.2 - 0.4)	2	0.70	2	0.80	2	0.70	2	0.80	1	0.70	1	0.70
	Access Moderate (0.4 - 0.6)	2	0.50	2	0.60	2	0.50	2	0.60	1	0.50	1	0.50
	Access High (0.6 - 0.8)	2	0.30	2	0.30	2	0.30	2	0.30	1	0.30	1	0.30
	Access Very high (> 0.8)	2	0.10	2	0.10	2	0.10	2	0.10	1	0.10	1	0.10
VARIABLE	Linear Disturbance		0.40		0.33		0.30		0.33		0.30		0.30
CLASS	0 km/2.25 km2	2	0.90	2	0.90	2	0.90	2	0.90	2	0.90	2	0.90
	0 - 1.6 km/2.25 km2	2	0.60	2	0.70	2	0.70	2	0.70	2	0.70	2	0.70
	1.6 - 3.2 km/2.25 km2	2	0.30	2	0.50	2	0.40	2	0.50	2	0.30	2	0.30
	>3.2 km/2.25 km2	2	0.10	2	0.30	2	0.10	2	0.30	2	0.20	2	0.20
VARIABLE	Human Influence		0.40		0.33		0.70		0.33		0.30		0.30
CLASS	beyond any influence zone	3	0.90	2	0.90	3	0.90	2	0.90	3	0.90	3	0.90
	200 - 500 m of "low use" features	3	0.50	2	0.80	3	0.80	2	0.80	3	0.80	3	0.80
	50 - 200 m of "low use" features	3	0.40	2	0.70	3	0.70	2	0.60	3	0.70	3	0.70
	<50 m of "low use" features	3	0.20	2	0.50	3	0.50	2	0.20	3	0.50	3	0.50
	200 - 500 m of "high use" features	3	0.20	2	0.50	3	0.70	2	0.40	3	0.50	3	0.40
	50 - 200 m of "high use" features	3	0.10	2	0.30	3	0.50	2	0.20	3	0.30	3	0.20
	<50 m of "high use" features	3	0.10	2	0.20	3	0.20	2	0.10	3	0.10	3	0.10
	Agricultural lands	3	0.10	2	0.50	3	0.30	2	0.50	3	0.10	3	0.10

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