



SAFE HAVENS, SAFE PASSAGES FOR VULNERABLE FISH AND WILDLIFE

CRITICAL LANDSCAPES IN THE SOUTHERN CANADIAN ROCKIES, BRITISH COLUMBIA AND MONTANA

John L. Weaver

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As exemplar of the Southern Canadian Rockies, a mountain landscape in Glacier
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SUMMARY

Some of the best-known and most-cherished mountains on Earth are set in the Canadian Rockies of British Columbia and Alberta. Indeed, the mention of Banff, Jasper, Kootenay or Yoho National Parks evokes images of snow-capped peaks, thundering falls and turquoise waters, numerous natural wonders and majestic wildlife. The adjoining Provincial Parks in British Columbia – Mount Robson, Mount Assiniboine, and Hamber – are just as spectacular, if not quite as renowned. Waterton Lakes National Park in Alberta and Glacier National Park in Montana – brought together in 1931 as an International Peace Park by the respective Rotary Clubs – exemplify international cooperation and wilderness and wildlife without borders. All 9 of these parks have been designated as *World Heritage Sites* in recognition of their outstanding natural importance to the common heritage of humanity.

In the midst of international acclaim over the past century for these spectacular Parks, however, the area *between* them has been overlooked by all but a few. Known as the Southern Canadian Rockies, much of this intervening landscape rivals the others in terms of sky-piercing mountains, broad river valleys, and verdant forests. It supports one of the most diverse communities of carnivores and ungulates anywhere in North America – including grizzly bears and wolverines, mountain goats and bighorn sheep. For many years, the Southern Canadian Rockies enjoyed ‘de-facto’ protection due to few roads, local economies, and modest levels of mining and logging. That situation, however, began changing in the 1950s as resource extraction for timber and coal expanded. The network of accompanying roads spread throughout the Southern Canadian Rockies, eventually penetrating all major valleys and into most tributary valleys.

Now, the melting glaciers of Glacier National Park signal changes in climate that may become even more pronounced in coming decades. Climate scientists project that there will be warmer winters and hotter summers, decreasing snow-pack and earlier melting in spring, declining stream flows and warmer streams, and longer wildfire season with more severe fires. In response, animals will need room to roam as they try to track the shifting location of their habitats. The problem for these vulnerable species, of course, is that the landscape has been fractured by roads and developments – leaving few safe havens and safe passages. The challenge now is to match the spectacular beauty and wildlife

treasures of the Southern Canadian Rockies with appropriate stewardship by charting new directions.

The purpose of this report is to inform discussions and decisions about land and resource management in the Southern Canadian Rockies of British Columbia and adjacent Montana. The goal is to assess the conservation value of 16, 978 km² (6632 mi²) of the Southern Canadian Rockies for a suite of vulnerable fish and wildlife species: bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi*), grizzly bear (*Ursus arctos horribilis*), wolverine (*Gulo gulo*), mountain goat (*Oreamnus americanus*), and Rocky Mountain bighorn sheep (*Ovis canadensis*). In this conservation assessment, I (1) identify and map current and future key areas for these species using empirical data and models, (2) assess options for connectivity across Highway 3 and Continental Divide, and (3) recommend conservation lands such as a regional Wildlife Management Area (WMA) in British Columbia.

Bull trout and westslope cutthroat trout exhibit high vulnerability. They are adapted for cold waters – especially for spawning and rearing. Bull trout populations are impacted by non-native lake trout and brook trout, whereas westslope cutthroat trout can be hybridized by non-native rainbow trout. Although adult bull trout can move long distances, human fragmentation of streams can have acute impacts on connectivity. Bull trout and westslope cutthroat trout are vulnerable to several detrimental effects associated with roads such as increased sedimentation to streams. Finally, climate change may warm lower-elevation waters past their tolerance. Protection of large patches of cold-water habitat and reduction of non-native trout comprise important elements in the conservation of these native trout.

Regional strongholds for populations of bull trout are found in the trans-border Flathead River, Wigwam River, and upper White River drainages. Populations of westslope cutthroat trout with intact genetic integrity occur throughout the Elk River, Bull River, and upper portion of the trans-border Flathead River drainages. These large watersheds represent rare bastions of viable populations.

Although resourceful in finding food and habitat, **grizzly bears** have high vulnerability due to low demographic or population resiliency. Bears have very low reproduction and cannot quickly compensate for excessive mortality. Young females do not disperse very far, which makes bear populations susceptible to landscape fragmentation. Roads with even modest traffic volume can displace bears from key habitats and expose them to greater risk of human-caused mortality. Protection of large areas of productive habitats with security from human disturbance and mortality are key conservation measures.

The trans-border Flathead River basin sustains the highest density of grizzly bears recorded thus far for non-coastal populations in North America. The area between the Elk River and the Bull River appears to have suitable habitat to sustain high densities of grizzly bears, too. About 38.3% of the area has very-high and high habitat value, and another 19.7% has attractive habitat but low security.

Wolverines have high vulnerability. Although they have a broad foraging niche, wolverines select areas characterized by persistent snow cover during spring for their reproductive habitat, summer habitat, and dispersal routes.

Wolverines have very low reproductive rates, too. Consequently, they cannot sustain high mortality rates, which can be exacerbated by trapping pressure. Wolverines appear sensitive to human disturbance near maternal sites. Due to their adaptation for snow environments, wolverines appear particularly susceptible to reductions in suitable habitat as a result of projected climate change.

About 56.7 % – 60.2% of the higher country of the Southern Canadian Rockies appears highly suitable habitat for the rare wolverine, with 28.9% - 33.2% suitable as maternal habitat. These snowy environments may provide suitable conditions for wolverines longer into the warming future.

Mountain goats have high vulnerability. They are constrained to live on or near cliffs that provide escape terrain from predators and more accessible forage in winter. Female goats have very low reproduction rates and cannot quickly compensate for excessive mortality (notably hunting). Goats (primarily males) do disperse modest distances, which may provide connectivity among some populations. Mountain goats are especially sensitive to motorized disturbance and access. Abundant populations of mountain goats are found in various mountain ranges, particularly north of Highway 3 in the rugged terrain north of Fernie all the way to Banff and Kootenay National Parks.

About 9.6% of the area appears suitable for critical winter habitat and 20.4% as summer habitat for mountain goats.

Bighorn sheep exhibit moderate vulnerability. They need cliffs for escape terrain but have a narrow feeding niche on grasses. Female sheep have low to moderate reproduction, but wild sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. Because Rocky Mountain bighorn sheep have strong fidelity to chosen sites, they do not disperse very readily and have a low capacity for re-colonizing vacant habitats. Bighorn sheep appear less sensitive to motorized disturbance than goats. Warming winter climate could enable elk to range higher and compete with bighorn sheep. The East Kootenays of British Columbia have long been known for outstanding populations of bighorn sheep. Several critical low-elevation winter ranges are located along the eastern side of the Rocky Mountain Trench, whereas numerous high-elevation winter ranges occur east of the upper Elk River on wind-blown ridges and ecologically-unique grasslands. These winter ranges only cover 2.4% of the area but are critical; summer habitat comprises 27.4% throughout the SCR.

Roads and settlements have fragmented habitats for all these vulnerable species across the Southern Canadian Rockies. Such fracturing can reduce population and genetic exchange, and impede movements of animals to track shifting climatic conditions. Consequently, many wildlife scientists recommend landscape linkages to facilitate current and future movements. Highway 3 (and associated railroad) is a major east↔west transportation route across the Southern Canadian Rockies, which fractures north↔south connectivity. Based upon wolverine habitat mapping and using least-cost distance and Circuitscape® modeling techniques, we mapped 8 suitable linkages where wolverines might cross Highway 3: between Elko and Morrissey (1), Morrissey and Fernie (3) Fernie and Hosmer (1) and Sparwood (2), and just west of Crowsnest Pass. Several of these same sites had been identified previously as linkage sites for grizzly bears and ungulates, too. Based upon data and local knowledge, we

identified 16 mountain passes that provide important connectivity for wildlife across the Continental Divide between Alberta and British Columbia. Some of the key passes include: Marvel, Palliser, Elk/Tobermory, Fording, Racehorse, Deadman, Ptolemy, North Kootenay, Middle Kootenay, Sage and South Kootenay.

Outstanding Provincial Parks such as Elk Lakes and Height of the Rockies comprise only 5.7% of the Southern Canadian Rockies of British Columbia, and they protect between 2.6 % and 16.9 % of key habitat for these vulnerable species. Hence, there is a mis-match between current protection of valuable fish and wildlife habitat and multiplying threats. The challenge, then, is to provide a higher level of committed stewardship commensurate with these remarkable treasures of native fish and wildlife.

Conservation groups have proposed a National Park in the Canadian Flathead adjoining Glacier National Park (U.S.) to the south and Waterton Lakes National Park in Alberta to the east. This area has high conservation value for vulnerable fish and wildlife species which move among these jurisdictions and would provide spatial congruence with the other parks. A wildland park (National or Provincial) would be commensurate with other laudable efforts to safeguard the remarkable biodiversity of the trans-border Flathead River basin.

Under section 4 of the BC *Wildlife Act*, a 'Wildlife Management Area' (WMA) can be designated for the benefit of regionally to internationally significant fish and wildlife species or their habitats, including key landscape linkages for migration or response to climate change. Conservation and management of fish, wildlife and their habitats is the priority in a WMA but other compatible land uses may be accommodated, too. Designation and management of WMAs is without prejudice to future land claim settlements by First Nations or exercise of their aboriginal rights.

Designation of a WMA seems like a promising path for matching conservation stewardship appropriate to the very high values of fish and wildlife in this region. Therefore, I strongly recommend designation of 719, 297 ha of Crown land as the 'Southern Canadian Rockies Wildlife Management Area'. This recommendation is based upon a bottom-up, scientific analysis of the important areas for vulnerable fish and wildlife – rather than an arbitrary number. The SCR Wildlife Management Area would include much of the Canadian Flathead River basin (outside the proposed Park), Wigwam River and Lizard Range, high country west of the Elk River from Fernie north to Elk Lakes Provincial Park and adjacent areas on the Bull River side, upper branches of the White River, and the headwaters of the Alberta and Cross Rivers. The WMA would comprise about 41.8% of the assessment area but include 66.7% of lands containing the top 50% of the composite scores. It would encompass the following proportions of the very-high conservation scores for bull trout 73.3 %, westslope cutthroat trout 71.2%, grizzly bear 72.2 %, wolverine 62.0%, mountain goat 63.7 %, and bighorn sheep 53.6%. Hence, the WMA would bring a high return-on-investment in terms of conservation gains for land area.

In September 1905, the naturalist William T. Hornaday hunted big game with local guides in the mountains west of Elkford in the upper Elk River valley. He wrote a book about their adventures entitled Campfires in the Canadian Rockies, wherein he extolled the beauty and wildlife of the area for which he

advocated protection. This area was protected as the Elk River Game Reserve from 1908-1963. But more and more logging roads have penetrated several of the tributary valleys on the west side of the Elk River. In recent years, local citizens and guides/outfitters have re-invigorated the campaign to provide more lasting protection for this remnant wildland in the Southern Canadian Rockies.

Based upon scientific assessment, I concluded that this area has high conservation value for vulnerable wildlife species. Sites having the top 50% of *composite* scores are common throughout the area and much of the area provides habitat for grizzly bears, wolverines, mountain goat, and bighorn sheep (61% - 94%, depending upon the species). Accordingly, I recommend approximately 64,048 ha be designated as the *Hornaday Wilderness* (or *Hornaday Conservancy*). It would extend from Crossing Creek on the north end (northwest of Elkford) south to Lladner and Sulphur Creeks (west of the town of Sparwood). The eastern border would run along the edge of Crown land flanking the west side of the Elk River valley, while the western boundary would parallel the east side of the upper Bull River.

During times of uncertainty, a common strategy among managers facing risk to valued resources is to minimize their exposure by placing them in 'safe havens' or refugia. Ecologists and land planners have been modeling climate refugia for vulnerable species to identify conservation areas in the Central Interior of British Columbia. As a catalyst to accelerate similar conversations and planning for adaptation, I identified 36 candidate sites for safe havens across the Southern Canadian Rockies of British Columbia. These included sites with high density of the top 50% of composite values and complex topography which will provide ecological options. Many of these safe havens were in the Canadian Flathead and upper Elk River watersheds. Safe havens could be part of the management plan for the WMA, but some areas would need better management of access to serve this role.

For the Montana side of the trans-border Flathead River basin and Whitefish range, I recommend 64,986 ha (160,515 ac) of remnant roadless areas be legislated as a national **Wilderness area**. An additional 41,887 ha (103,460 ac) with moderate-value fish and wildlife habitats could be designated for roadless backcountry conservation as part of revised Forest Plans. These additions would protect the highest-value habitats for these vulnerable fish and wildlife species, enhance connectivity with both Glacier National Park and the Canadian Flathead/Wigwam, and provide options for future responses to climate change. It would underscore a strong American commitment to protecting the ecological integrity of the trans-border Flathead River basin.

In conclusion, the spectacular landscapes of the Southern Canadian Rockies of British Columbia and Montana provide some of the best remaining strongholds for a suite of vulnerable fish and wildlife species. Designation of these conservation lands in British Columbia and Montana will help ensure that this rich diversity of fish and wildlife will be enjoyed by generations yet to follow. Success of flexible approaches like Wildlife Management Areas is predicated on strong commitment to truly conserve fish and wildlife values in an arena of competitive pressures for resource development. This will require proactive planning and rigorous environmental assessment of projects and cumulative effects.

RESUME

Beaucoup des montagnes les plus célèbres et aimées sur Terre se trouvent dans les Rocheuses Canadiennes de Colombie Britannique et d'Alberta. La simple mention des Parcs Nationaux de Banff, Jasper, Kootenay ou Yoho suffit à évoquer des images de sommets enneigés, de cascades tumultueuses et d'eaux turquoise, un grand nombre de merveilles naturelles et une faune majestueuse. Bien que moins connus, les Parcs Provinciaux contigus en Colombie Britannique – Mount Robson, Mount Assiboine et Hamber – sont tout aussi spectaculaires. Le Parc National de Waterton Lakes en Alberta et le Parc National des Glaciers dans le Montana – unis en 1931 sous la forme d'un Parc International pour la Paix par leurs Rotary Clubs respectifs – illustrent la coopération internationale et les étendues et la faune sauvages sans frontières. Ces 9 parcs ont été placés sur la Liste du Patrimoine Mondial en reconnaissance de leur contribution naturelle remarquable à l'héritage commun de l'humanité.

Cependant, les acclamations internationales reçues par ces parcs spectaculaires au cours du siècle précédent masquent le fait que les terres situées entres eux ont été négligées par presque tous. Connue sous le nom des Rocheuses Canadiennes du Sud, la majorité du paysage y rivalise celui de sites plus célèbres en terme de montagnes immenses, de larges vallées et de forêts verdoyantes. Elle supporte l'une des communautés de carnivores et d'ongulés les plus diverses d'Amérique du Nord – comprenant l'ours grizzly, le glouton, la chèvre des montagnes et le mouflon. Des années durant, les Rocheuses Canadiennes du Sud ont eu droit à une protection "de facto" due à la paucité des routes, à l'économie locale, et à de faibles niveaux d'extraction minière et de coupes forestières. Cette situation a cependant commencé à changer dans les années 50 suite à l'expansion des extractions forestières et minières. Le réseau routier s'est étendu au travers des Rocheuses Canadiennes du Sud, pour finalement pénétrer toutes les vallées majeures et la plupart des vallées tributaires.

Les glaciers fondants du Parc National des Glaciers sont de nos jours le signe d'un changement climatique qui risque de s'aggraver au cours des décennies à venir. Les climatologues prédisent des hivers plus doux et des étés plus chauds, une réduction du manteau neigeux et une fonte des neiges plus précoce, une réduction du flux des rivières et une augmentation de leur température, ainsi qu'une plus longue saison d'incendies accompagnée de feux de forêt plus

intenses. Pour répondre à ces changements, la grande faune aura besoin d'espace lui permettant de suivre la localisation changeante de son habitat. Parce qu'elle réduit la quantité de refuges et de passages protégés, la fracturation du paysage par les routes et autres développements humains pose problème à ces espèces vulnérables. Le challenge actuel consiste à égaler la beauté spectaculaire et les trésors faunistiques des Rocheuses Canadiennes du Sud, et un niveau de gestion proactive approprié, en proposant de nouvelles orientations.

Le but de ce rapport est d'informer les discussions et décisions concernant la gestion du territoire et des ressources naturelles dans les Rocheuses Canadiennes du Sud de la Colombie Britannique et du Montana adjacent. L'objectif est d'évaluer la valeur de conservation de 16,978 km² (6632 mi²) des Rocheuses Canadiennes du Sud pour un groupe d'espèces vulnérables : omble à tête plate (*Salvelinus confluentus*), truite fardée des versants de l'ouest (*Oncorhynchus clarki lewisi*), ours grizzly (*Ursus arctos horribilis*), glouton (*Gulo gulo*), chèvre des montagnes (*Oreamnus americanus*), et mouflon des Montagnes Rocheuses (*Ovis canadensis*). Dans cette évaluation de la conservation, j'ai : (1) identifié et cartographié les sites clés présents et futurs pour ces espèces à l'aide de données empiriques et de modèles, (2) évalué les options de connectivité pour traverser l'autoroute 3 et la Ligne de Partage des Eaux, et (3) recommandé des lieux de conservation tels qu'une Zone de Gestion de la Faune en Colombie Britannique.

L'omble à tête plate et la truite fardée présentent une vulnérabilité élevée. Elles sont adaptées à l'eau froide – particulièrement pour la ponte et l'élevage. Les populations d'omble à tête plate sont touchées par les truites exotiques telles que l'omble du Canada et la truite mouchetée, tandis que les populations de truite fardée peuvent s'hybrider avec la truite arc-en-ciel. Bien que les ombles adultes soient capables de se déplacer sur de longues distances, la fragmentation humaine des rivières peut avoir un effet grave sur la connectivité. Les ombles et truites fardées sont vulnérables à plusieurs effets préjudiciables liés au réseau routier, tels que l'augmentation de la sédimentation dans les rivières. Enfin, le réchauffement climatique pourrait causer une augmentation de la température des eaux des rivières de basse altitude en-dehors de leur tolérance.

Des bastions régionaux des populations d'omble à tête plate se situent dans la rivière transfrontalière Flathead et dans les bassins versants des rivières Wigwam et Upper White. Des populations de truite fardée à l'intégrité génétique intacte se trouvent dans les bassins versants des rivières Elk, Bull, et dans la partie supérieure de la rivière transfrontalière Flathead. Ces larges bassins versants représentent de rares bastions de populations viables.

Bien que doués pour dénicher nourriture et habitat, les ours grizzly ont une vulnérabilité élevée en raison d'une faible résilience démographique. Les ours ont un taux de reproduction faible et ne peuvent pas contrebalancer rapidement une mortalité excessive. Les jeunes femelles ne se dispersant pas loin, les populations d'ours sont sensibles à la fragmentation du paysage. Même avec un faible volume de circulation, les routes peuvent faire fuir les ours d'habitats-clés et les exposer à de plus grands risques de mortalité liée à l'homme. La protection de larges étendues d'habitats productifs, à l'abri des dérangements et des causes de mortalité humaines, est une mesure de conservation clé.

Le bassin versant transfrontalier de la rivière Flathead supporte la densité d'ours grizzly la plus élevée enregistrée jusqu'à présent pour les populations d'ours non côtières en Amérique du Nord. La zone entre les rivières Elk et Bull semble également à même de supporter une densité d'ours grizzly élevée. Environ 38.3% de la région est composée d'habitats de haute et très haute valeur, avec 19.7% supplémentaires présentant un habitat favorable mais à faible sécurité.

Les gloutons ont une vulnérabilité élevée. Bien qu'ayant un large créneau de recherche de nourriture, les gloutons sélectionnent comme sites de reproduction, d'estivage et de routes de dispersion des milieux caractérisés par un manteau neigeux permanent au printemps. Les gloutons ont aussi un taux de reproduction très bas. Ils ne peuvent par conséquent pas absorber des taux de mortalité élevés, lesquels peuvent être exacerbés par la pression de trappage. Les gloutons paraissent sensibles au dérangement humain des sites maternels. En raison de leur adaptation au milieu enneigé, les gloutons seraient particulièrement sensibles à une réduction de leur habitat résultant d'un réchauffement climatique.

Entre 56.7% et 60.2% des hautes terres des Rocheuses Canadiennes du Sud possèdent l'habitat requis par le rare glouton, dont 28.9% à 33.2% d'habitat maternel. Ces milieux enneigés pourraient fournir plus longtemps des conditions favorables aux gloutons dans le cas d'un futur se réchauffant.

Les chèvres des montagnes ont une vulnérabilité élevée. Elles sont contraintes de vivre sur ou à proximité des falaises qui leur permettent d'échapper aux prédateurs et leur fournissent un fourrage plus accessible en hiver. Les femelles ont un taux de reproduction très bas et ne peuvent pas contrebalancer rapidement un taux de mortalité élevé (en particulier lié à la pression de chasse). Les chèvres (surtout les males) se dispersent sur de modestes distances, ce qui peut être source de connectivité entre certaines populations. Les chèvres des montagnes sont particulièrement sensibles à l'accès et aux dérangements motorisés.

On trouve des populations abondantes de chèvres des montagnes dans diverses chaînes de montagnes, en particulier au nord de l'autoroute 3 dans le terrain accidenté au nord de Fernie et jusqu'aux Parcs Nationaux de Banff et Kootenay. L'aire d'hivernage critique couvre environ 9.6% de la région, l'aire d'estivage en couvrant 20.4%.

Le mouflon présente une vulnérabilité moyenne. Il a besoin de falaises pour échapper aux prédateurs et dispose d'une niche de nutrition étroite liée aux herbages. Les femelles ont un taux de reproduction bas à moyen, mais les mouflons sauvages sont hautement sensibles aux épidémies (certaines transmises par les chèvres domestiques) qui peuvent rapidement décimer un troupeau. Fortement attachés à leurs sites de vie, les mouflons des Montagnes Rocheuses ne se dispersent pas facilement et ont une faible capacité de recolonisation des habitats vacants. Les mouflons semblent moins sensibles que les chèvres au dérangement motorisé. Le réchauffement hivernal pourrait permettre aux cerfs d'hiverner en plus haute altitude et d'être en compétition avec les mouflons.

Les Kootenays de l'Est de la Colombie Britannique ont longtemps été renommés pour leurs populations exceptionnelles de mouflons. Plusieurs aires d'hivernage cruciales en basse altitude se situent le long du côté est de Rocky Mountain Trench tandis que nombre d'aires d'hivernage de haute altitude se trouvent à l'est de la rivière Elk supérieure, sur des crêtes battues par le vent et des prairies écologiquement uniques. Ces aires d'hivernage couvrent seulement 2.4% de la région mais sont cruciales ; l'aire d'estivage couvre 27.4% des Rocheuses Canadiennes du Sud.

Les routes et agglomérations ont fragmenté les habitats de toutes ces espèces vulnérables à travers les Rocheuses Canadiennes du Sud. Une telle fracture peut réduire les populations et les échanges génétiques, et gêner les mouvements d'animaux cherchant à répondre à des conditions climatiques changeantes. Par conséquent, de nombreux scientifiques étudiant la faune sauvage recommandent la mise en place de liens paysagers pouvant faciliter ses mouvements actuels et futurs.

L'autoroute 3 (et la voie ferrée associée) est un axe de transport majeur d'est en ouest à travers les Rocheuses Canadiennes du Sud de la Colombie Britannique, et constitue une sérieuse coupure de la connectivité entre le nord et le sud. En nous basant sur la cartographie de l'habitat du glouton et en utilisant les techniques de modélisation du trajet le moins coûteux et de Circuitscape®, nous avons cartographié 8 sites pouvant permettre aux gloutons de traverser l'autoroute 3 : Entre Elko et Morrissey (1), Morrissey et Fernie (3), Fernie et Hosmer (1) et Sparwood (2), et juste à l'ouest de Crownsnest Pass. Plusieurs de ces mêmes sites ont déjà été identifiés comme sites de liaison pour les ours grizzly et les ongulés. En nous basant sur des données et connaissances locales, nous avons identifié 16 cols de montagne fournissant à la faune une connectivité importante à travers la Ligne de Partage des Eaux entre l'Alberta et la Colombie Britannique. Ils comprennent Marvel, Palliser, Elk/Tobermory, Fording, Racehorse, Deadman, Ptolemy, North Kootenay, Middle Kootenay, Sage et South Kootenay.

Les Parcs Provinciaux exceptionnels tels que Elk Lakes et Height of the Rockies composent seulement 5.7% des Rocheuses Canadiennes du Sud de la Colombie Britannique, et protègent entre 2.6% et 16.9% des habitats clés des espèces vulnérables présentées. Il y a donc une déconnexion entre les niveaux actuels de protection des habitats importants aux mammifères et poissons, et les menaces qui s'y multiplient. Le challenge consiste en l'application d'un niveau supérieur de gestion engagée, commensuré avec ces trésors faunistiques remarquables.

Des groupes de conservation ont proposé la création d'un Parc National dans la région Flathead canadienne attenante au Parc National des Glaciers (Etats-Unis) au sud et au Parc National de Waterton Lakes en Alberta à l'est. Cette zone possède une haute valeur de conservation pour les espèces faunistiques se déplaçant entre ces juridictions et fournirait une congruence partielle avec les autres parcs. Un parc sauvage (National ou Provincial) serait à la hauteur d'autres efforts louables pour sauvegarder la biodiversité remarquable du bassin versant transfrontalier de la rivière Flathead.

D'après la section 4 du Wildlife Act de Colombie Britannique, une 'Zone de Gestion de la Faune' (Wildlife Management Area, WMA) peut être désignée pour le bénéfice d'espèces de mammifères et de poissons d'importance régionale ou internationale, ou de leurs habitats, y compris les zones de passage clés des migrations ou de l'adaptation au réchauffement climatique. La conservation et la gestion des poissons, mammifères, et de leurs habitats a priorité dans une WMA, mais d'autres utilisations du milieu y sont également possibles. La désignation et la gestion des WMAs ne portent pas préjudice à l'ensemble des revendications territoriales des Nations Premières ou à l'exercice de leurs droits autochtones.

La désignation d'une WMA semble être une voie prometteuse pour mettre la gestion conservatrice au niveau des valeurs élevées du milieu pour les espèces de mammifères et de poissons de la région. Par conséquent, je recommande fortement de désigner 719,297 ha des terres de la Couronne sous la forme de "Zone de Gestion de la Faune des Rocheuses Canadiennes du Sud". Plutôt qu'être un chiffre arbitraire, cette recommandation se base sur une analyse scientifique du bas-en-haut des sites importants pour les espèces de mammifères et de poissons et de leurs habitats. La zone de gestion comprendrait le bassin versant de la rivière Flathead canadienne (en dehors du parc proposé), la rivière Wigwam et la chaîne Lizard, les hautes terres à l'ouest de la rivière Elk de Fernie au nord au Parc Provincial d'Elk Lakes et les terrains adjacents du côté de la rivière Bull, les sections supérieures du bassin versant de la rivière White, et l'amont des rivières Alberta et Cross. La WMA inclurait environ 41.8% de la zone analysée mais 66.7% des terres comprenant les 50% supérieurs des scores composés. Elle inclurait les proportions suivantes des scores de très haute conservation : pour l'omble, 73.3% ; la truite fardée, 71.2% ; l'ours grizzly, 72.2% ; le glouton, 62.0% ; la chèvre des montagnes, 63.7% ; et le mouflon, 53.6%. De ce fait, le retour sur investissement serait élevé en terme de gain de conservation par unité de terrain.

En septembre 1905, le naturaliste William T. Hornaday chassa le gros gibier avec des guides locaux à l'ouest d'Elkford dans la vallée supérieure de la rivière Elk. Il écrivit un livre de leurs aventures, intitulé Feux de Camp dans les Rocheuses Canadiennes, dans lequel il exalte la beauté et la faune d'une région dont il plaida pour la protection. Cette région fut protégée en tant que Elk River Game Reserve de 1908 à 1963, mais un nombre croissant de routes de bucheronnage pénétrèrent ensuite plusieurs des vallées tributaires sur le versant ouest de la rivière Elk. Ces dernières années, les citoyens locaux et les guides ont revigoré la campagne visant à fournir une protection plus durable aux dernières terres sauvages intactes des Rocheuses Canadiennes du Sud.

En me basant sur une évaluation scientifique, j'ai conclu que cette région dispose d'une haute valeur de conservation pour la faune vulnérable. Les sites possédant les 50% supérieurs des scores composés sont fréquents à travers cette région dont une grande partie fournit l'habitat aux ours grizzlis, gloutons, chèvres des montagnes, et mouflons (61% - 94% selon l'espèce). En

conséquence, je recommande qu'environ 64,048 ha soient désignés comme la Wilderness Hornaday (ou Hornaday Conservancy). Elle s'étendrait de Crossing Creek au nord (nord-ouest d'Elkford), et au sud jusqu'à Lladner Creek et Sulphur Creek (à l'ouest de la ville de Sparwood). La frontière est serait parallèle au cote est de la rivière Bull.

En période d'incertitude, une stratégie commune aux gestionnaires de ressources menacées consiste à minimiser l'exposition de ces ressources au dérangement humain en les plaçant dans des 'bastions' ou refuges. Des écologues et gestionnaires du territoire ont modélisé les refuges climatiques d'espèces vulnérables dans l'Intérieur Central de la Colombie Britannique afin d'identifier des zones de conservation. Comme catalyseur pour accélérer des mesures de conservation similaires et pour préparer l'adaptation des espèces au changement climatique, j'ai identifié 36 sites candidats comme bastions à travers les Rocheuses Canadiennes du Sud de la Colombie Britannique. Ils comprennent des sites à forte densité des 50% supérieurs des valeurs composées, et une topographie complexe qui fournira des options écologiques. Beaucoup d'entre eux se trouvent dans les bassins versants de la rivière Flathead canadienne et de la rivière Elk. Ces bastions pourraient faire partie du plan de gestion de la WMA, mais certaines zones devraient recevoir une meilleure gestion de leur accès pour jouer ce rôle.

Cote Montana, pour le bassin versant transfrontalier de la rivière Flathead et pour la chaîne de montagnes Whitefish, je recommande que 64,986 ha (160,515 acres) des zones encore sans routes soient légiférées sous la forme d'une zone Wilderness nationale. 41,887 ha (103,460 acres) supplémentaires comprenant des habitats de moyenne valeur pourraient aussi être désignés comme arrière-pays sans routes, dans le cadre de Plans Forestiers révisés. Ces additions protégeraient les habitats à la valeur la plus élevée, amélioreraient la connectivité avec le Parc National des Glaciers et la Flathead/Wigwam canadienne, et fourniraient des options de réponses futures au réchauffement climatique. Cela soulignerait un fort engagement américain pour la protection de l'intégrité écologique du bassin versant transfrontalier de la rivière Flathead.

En conclusion, les paysages spectaculaires des Rocheuses Canadiennes du Sud de la Colombie Britannique et du Montana fournissent parmi les meilleurs bastions restants pour une suite de mammifères et de poissons vulnérables. Une protection officielle de ces régions de conservation en Colombie Britannique et au Montana permettra aux générations futures de jouir de cette riche diversité d'espèces. Le succès d'approches flexibles telles que les Zones de Gestion de la Faune repose sur un engagement fort visant à réellement protéger les valeurs de la faune dans une arène de pressions compétitives pour le développement des ressources naturelles. Cela exigera une gestion proactive et une évaluation environnementale rigoureuse des projets et des effets cumulés.

1. SOUTHERN CANADIAN ROCKIES OF BRITISH COLUMBIA AND MONTANA

A Spectacular Landscape, Rich in Wildlife

Some of the best-known and most-cherished mountains on Earth are set in the Canadian Rockies of British Columbia and Alberta. Indeed, the mention of Banff, Jasper, Kootenay or Yoho National Parks evokes images of snow-capped peaks, thundering falls and turquoise waters, numerous natural wonders and majestic wildlife. The adjoining Provincial Parks in British Columbia – Mount Robson, Mount Assiniboine, and Hamber – are just as spectacular, if not quite as renowned. More than nine million people annually visit the seven preserves along the Alberta-British Columbia border.

About 200 km (125 mi) further south along the Continental Divide are set other jewels of the Crown of the Continent Ecosystem: Waterton Lakes National Park in Alberta and Glacier National Park in Montana. More inspiring beauty splashed from prairie to peak, accompanied by tremendous diversity of plants and animals. Brought together in 1931 as the Waterton – Glacier International Peace Park as petitioned by the Rotary Clubs of Montana and Alberta, they exemplify international cooperation and wilderness and wildlife without borders. And all 9 of these parks have been designated as *World Heritage Sites* in recognition of their outstanding natural importance to the common heritage of humanity.

In the midst of international acclaim over the past century for these spectacular Parks, however, the area *between* them has been overlooked by all but a few. Known as the Southern Canadian Rockies, much of this intervening landscape rivals the others in terms of sky-piercing mountains, broad river valleys, and verdant forests (Figures 1 and 2). The most diverse assemblage of carnivore species anywhere in North America inhabits the region. Of course, the indigenous Ktunaxa/Kootenai people have long hunted, fished, and gathered foods and medicinal plants throughout this, their traditional territory. Pioneering naturalists like William Hornaday and Andy Russell hunted here and wrote

glowingly of the wildlands and wildlife such as mountain goats, bighorn sheep, and grizzly bears. Small-scale mining and logging did not seem to have much impact.

Through many years, the Southern Canadian Rockies enjoyed ‘de-facto’ protection due to the few roads, local economies, and modest levels of mining and logging. That situation, however, began changing in the 1950s as resource extraction for timber and coal expanded. The network of accompanying roads spread throughout the Southern Canadian Rockies, eventually penetrating all major valleys and into most tributary valleys. More recently, prosperous regional (globalized) economies have led to burgeoning outdoor recreation, facilitated by advances in 4-WD and ATVs. The result has been more and more human activity penetrating deeper into the backcountry. Now, a warming climate will bring additional changes to the environment of the Southern Canadian Rockies, pushing fish and wildlife to roam as they try to track the shifting location of their habitats. The problem for these vulnerable fish and wildlife, of course, is that the landscape has been fractured by roads and developments – leaving few safe havens and safe passages.

The challenge now is to match the spectacular beauty and wildlife treasures of the Southern Canadian Rockies with stronger stewardship by charting new directions for land and resource management.

Threats to Fish and Wildlife Values

Overarching Threat of Climate Change

One challenge facing conservation of wildlife and wildlands over the past century has been the ever-expanding footprint of humans – urban and rural sprawl, superhighways and forest roads, dams and diversions. But scientists are alerting us to a new challenge for the next century: climate change. What changes in climate can we anticipate over the next 50-100 years? What will be the ecological consequences? What might comprise thoughtful responses to this new challenge?

Over the past 100 years, a new array of instruments has enabled climate scientists to measure trends and variability in temperature, precipitation, snow-pack and other climate variables with greater accuracy and better geographic representation. This has provided a strong empirical record for many areas, including the Crown of the Continent Ecosystem.

Attempting to predict *future* climate conditions, though, is a daunting but important endeavor. Projecting climate change depends, of course, upon the (1) assumed scenario of greenhouse gas (GHG) emissions and (2) variables and relationships used to build any specific climate model. The empirical record of past climate change helps scientists better understand the performance of a model. In an attempt to develop robust projections, researchers increasingly are using ensembles of different climate models to examine implications of different GHG scenarios.

In this report, I examined patterns and trends reported by a diverse set of investigators in several recent climate assessments encompassing the Crown of the Continent Ecosystem. The key references (in alphabetical order) include: Graumlich and Francis (2010), Hamann and Wang (2006), Hebda (2010),

Figure 1. Location of the trans-border Crown of the Continent Ecosystem in Alberta, British Columbia, and Montana. The boundary of the Southern Canadian Rockies for this conservation assessment is delineated in the bolder purple. It covers a total of 16,978 km² (6632 mi²), with 77% (13,123 km² or 5126 mi²) in British Columbia and 23% (3,855 km² or 1506 mi²) in Montana. Map courtesy of the Misstakis Institute.

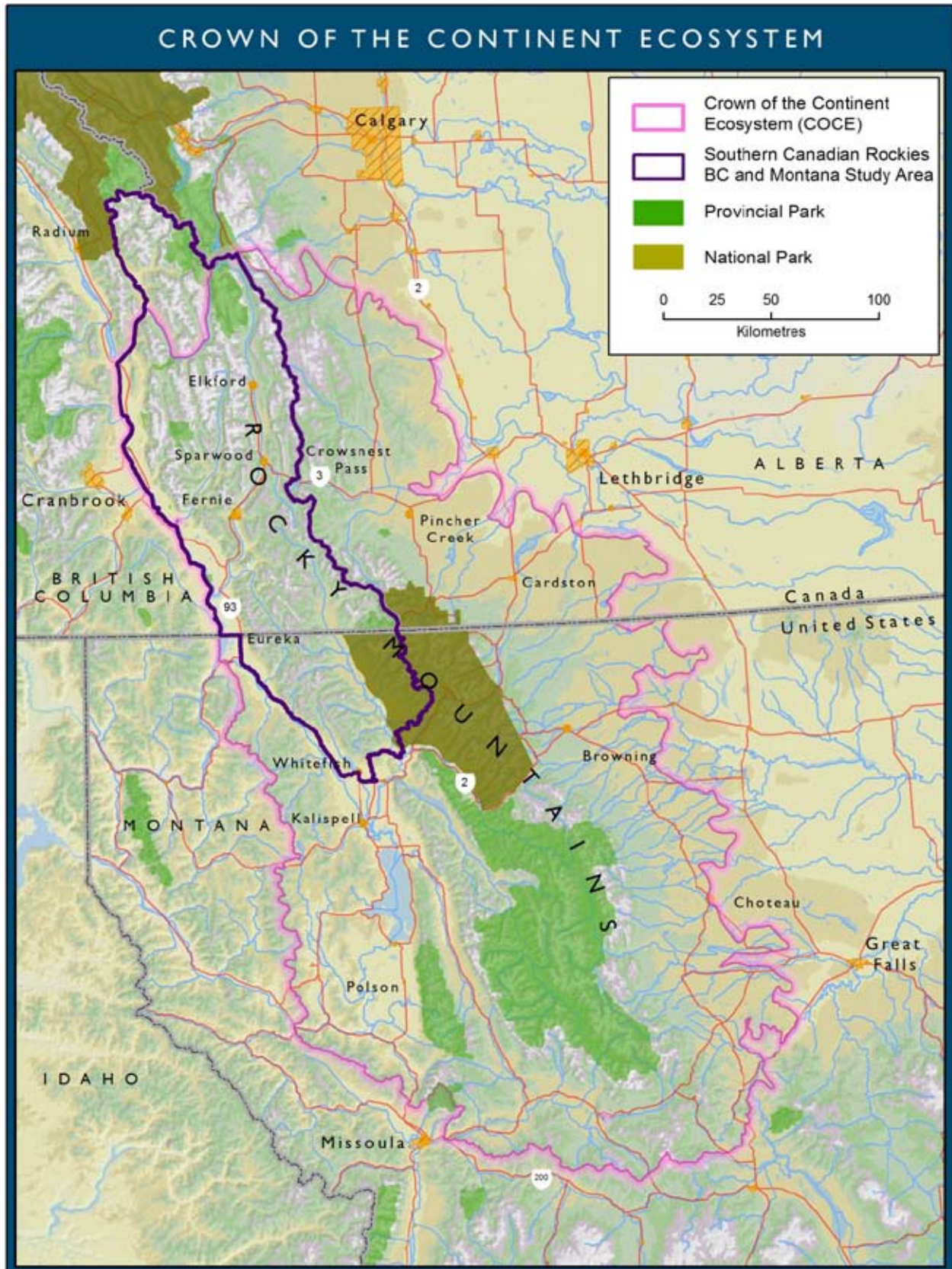
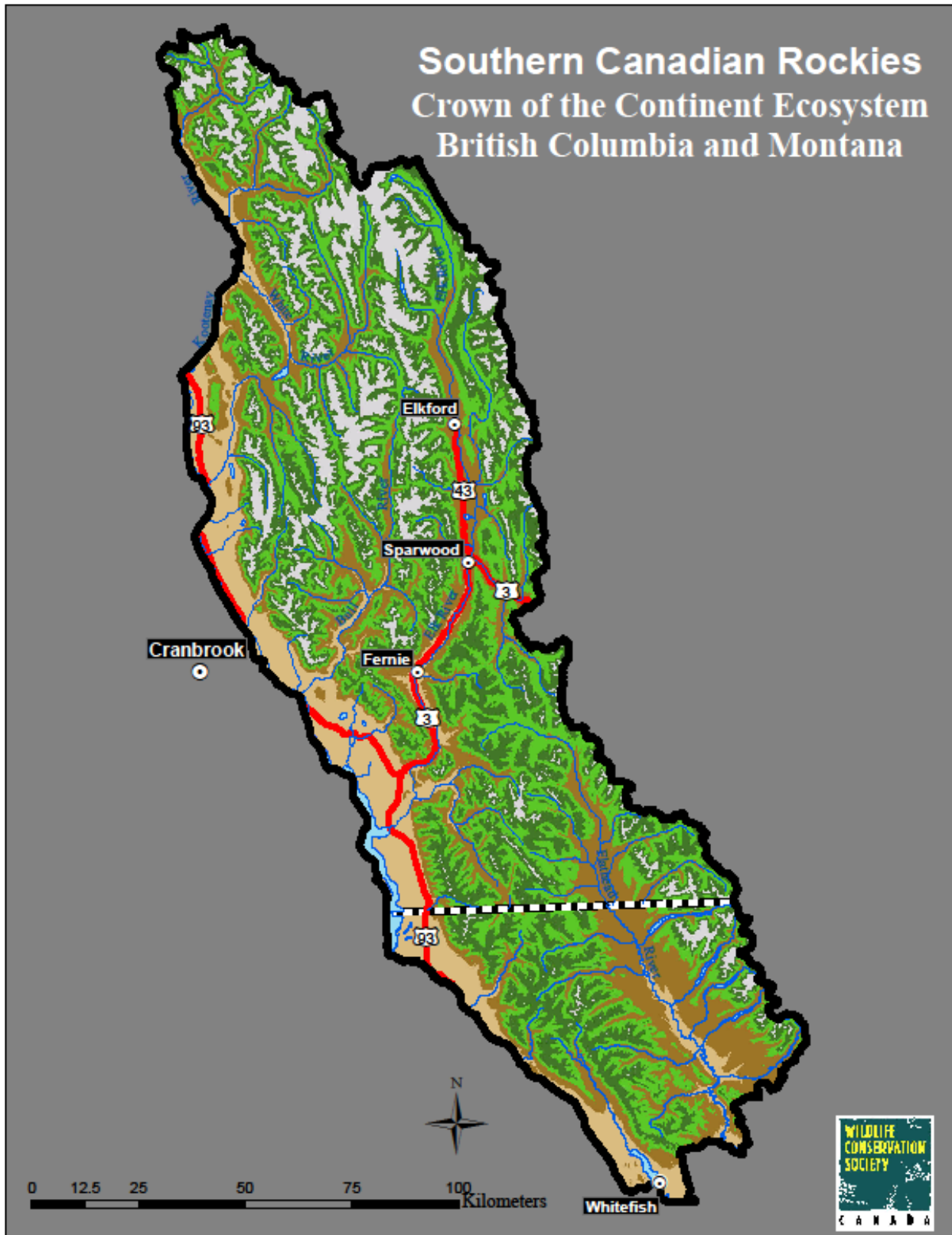


Figure 2. Topography, towns, and major highways of the Southern Canadian Rockies, British Columbia and Montana. See Figure 5 for map of extensive network of other roads.



Mbogga et al. (2009), McWethy et al. (2010), Murdock and Werner (2011), Pederson et al. (2010), Wang et al. (2012), and Running and Oyler (*In Prep*). The authors represent several university/agency climate research groups (University of Alberta, University of British Columbia, University of Victoria, University of Montana, Montana State University, USGS, and NPS). These studies used empirical weather-station data for the past 100 years and multi-model ensembles with regional downscaling to develop future projections. Taken together, these represent some of the best available analyses and projections of future climate conditions for the Crown of the Continent. There is strong agreement among the assessments, too. Although there is still considerable uncertainty in climate projections (especially for complex environments like mountains), climatologists expect that patterns and trends in climate over the past 50-100 years will continue and perhaps accelerate under even moderate GHG scenarios.

Here, I synthesize the major findings from recent research to describe climate patterns over the past 100 years as well as projected changes over the next 40 years (2011-2050). This lays the foundation for anticipating changes in future environmental conditions that vulnerable fish and wildlife may encounter.

△ **Disappearing glaciers**

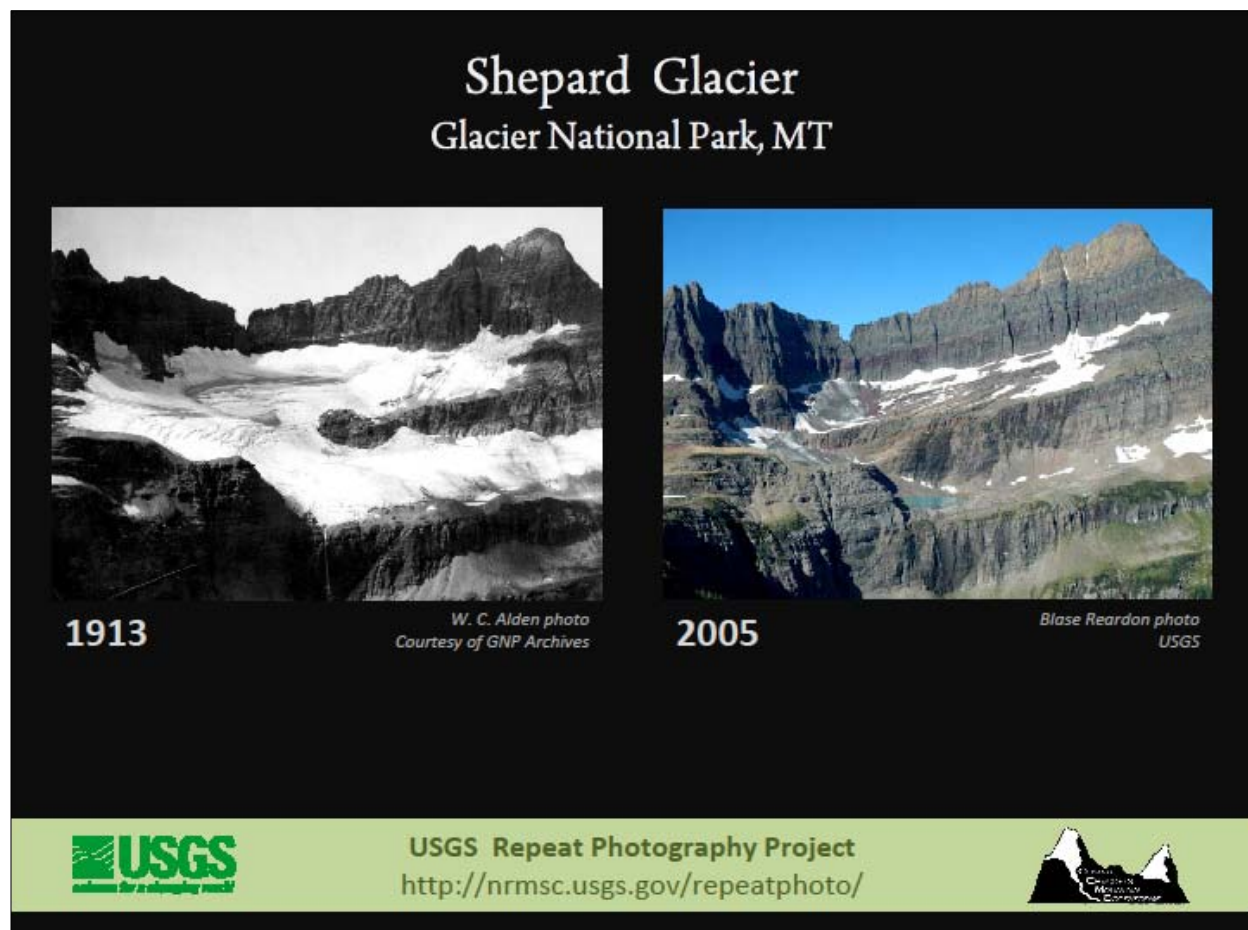
Perhaps the most iconic impact of climate change in western Montana has been the disappearance of glaciers from Glacier National Park (Figure 3). Of 150 glaciers in the Park in 1850 (covering 99 km² total), only 25 (<16 km² total) remain today. Increasing temperature during the critical spring and summer melting season has accelerated the retreat of glaciers. If trends continue, scientists expect glaciers will disappear from Glacier Park by 2030 (Hall and Fagre 2003, McWethy et al. 2010).

△ **Warmer winters and hotter summers**

Over the past 100 years, mean annual temperature (MAT) in western Montana has increased 1.3° C (2.3° F), nearly twice the rise in global temperature (Pederson et al. 2010). In the Columbia River basin of southeast British Columbia, MAT has increased by 0.7°-1.7° C over past 100 years (Murdock and Werner 2011). The largest increase has taken place in winter, when minimum temperatures rose +2.4° C and maximum temperatures +1.8° C (similar in B.C. Kootenays: Murdock and Werner 2011). The average number of days below-freezing in winter has dropped from 186 days to 170 days, due mostly to warmer days in early spring (Westerling et al. 2007). Temperatures have warmed dramatically since the early 1980s and hot temperatures have occurred longer through the summer (Bonfils et al. 2008, McWethy et al. 2010, Pederson et al. 2010). This increase in summer temperature has been 3x greater at higher elevations. Such accelerated warming at high elevations has been reported from many areas across the globe (Pepin and Lundquist 2008).

Climatologists project that by 2050, annual temperatures will be 1.4° – 3.1° C (2.5° – 5.5° F) warmer than now (Barnett et al. 2005, McWethy et al. 2010, Mbogga et al. 2009, Pederson et al. 2010, Murdock and Werner 2011) (Figure 4). Both winters and summers will become warmer, with intense heat waves in

Figure 3. Melting of glaciers in Glacier National Park signals an era of changing climate.



summer becoming more common and longer in duration. There will be fewer, shorter, and less intense episodes of really cold weather in winter. For example, in winter in the Montana portion of the Crown of the Continent, major river valleys will have average daily maximum temperature above 0° C (32° F) by 2020s, tributary valleys by 2040s, and many mid to high-elevation sites by 2080s (S. Running and J. Oyler, University of Montana, *in prep.*). There still could be large variability (1.0° – 1.8° C) in temperatures between years and decades due to ENSO and PDO events (Murdoch and Werner 2011).

△ **Variable precipitation patterns**

During the 20th century, there have been periods of drought and periods of greater precipitation in western Montana. Indeed, the high variability in seasonal, annual, and decadal patterns of precipitation overrides any strong century-long trends (Selkowitz et al. 2002). Precipitation patterns are more difficult to predict than temperature, especially in complex terrain of mountains. Summers are likely to become even hotter and drier, which could increase evapotranspiration. Various models suggest a slight increase or decrease (-10% → +10%) in annual precipitation in the Crown region, characterized by perhaps slight increases in winter (0% → +10%) and slight decrease in summer (0% → -10%) (Mbogga et al. 2009, Murdoch and Werner 2011).

△ Decreasing snowpack and earlier melting in spring

Annual snowpack level (indexed by April 1 Snow Water Equivalent, SWE) has declined by 15 to 30 percent throughout the Rocky Mountains during the second half of the 20th century (Hamlet et al. 2005, Mote et al. 2005, Pierce et al. 2008) and by approximately 20% in the Crown (Pederson et al. 2011). More of the winter precipitation in the western United States has been falling as rain rather than snow – especially at lower elevations – due to significant increases in number of days when temperatures are above freezing

(Knowles et al. 2006, McWethy et al. 2010). Rain-on-snow events have become more frequent at low to mid-elevations, increasing the prospects for winter flooding (Hamlet and Lettenmaier 2007). Over the past 50 years, warmer temperatures have led to earlier runoff in the spring (by 1-4 weeks) and reduced base-flow of streams in the summer and autumn across western United States (Stewart et al. 2005, Hildago et al. 2009). In the Crown of the Continent Ecosystem, for example, average snowmelt advanced about 8 days earlier in the spring between 1969 and 2006 (Pederson et al. 2011).

For the future, climatologists project that, due to warmer temperatures during winter, there will be more rain and less snow falling at low and mid elevations (Knowles et al. 2006). This will result in less snowpack, shorter snow season, and earlier melt in spring (Mote et al. 2005, Pederson et al. 2011). Most areas in the Montana section of the Crown will experienced 10-40% decrease in April 1 SWE by 2050s (S. Running and J. Oyler, University of Montana, *in prep*) and 0-15% near Elkford, B.C. This may result in more floods out of the mountains (Hamlet and Lettenmaier 2007).

△ Declining stream flows and warmer streams, particularly by late summer

Approximately 60-80% of surface water flow in the interior Mountain West is governed by the amount of snowpack (Barnett et al. 2005). Over the past 50 years, there has been a general decline in stream flows associated with reduced snowpack (Barnett et al. 2008). In the Northern Rockies, for example, water flow in August decreased by an average of 31% (range 21-48%) during 1950-2008 (Leppi et al. 2010). In the Flathead River, summer base flows decreased about 11% between 1978 and 2007 (C. Muhlfield, USGS, *unpublished data*). The decline in snowpack has reduced recharge of aquifers, which makes less water available for groundwater flow into streams and also decreases the base flow during the key summer period (Rood et al. 2008). In the Crown of the Continent Ecosystem, increased precipitation during spring may have buffered the annual streamflow from more severe declines due to decreased snowpack alone (Pederson et al. 2011). With warmer air temperatures, loss of shading cover along streams due to wildfire, and lower stream flows by August, stream temperatures have also increased (Isaak et al. 2010, Arismendi et al. 2012). Moreover, both the year-to-year variability in stream flow (Pagano and Garen 2005) and multi-year duration of drought conditions are increasing (McCabe et al. 2004). Researchers project that these trends in stream flows will continue in the future, with negative consequences for coldwater native trout and other biota (Jones et al. 2013) (Figure 4).

△ **Longer season of wildfire, with severe fires across more of the landscape**

Wildfires, of course, have long been a feature of landscapes and driver of ecological processes across western North America. Beginning in the mid-1980s, large forest fires have become more frequent and much more severe than in previous decades (Running 2006). Compared to the 1970-1985 period, for example, there has been a 6-fold increase in number of acres burned each year and the fire season is about 78 days longer (Westerling et al. 2006). Notably, much of the increased fire activity has occurred in forests at higher elevations (5500 to 8500 feet), where snowpack levels normally keep wildfire activity low. More intense fires have swept across streams, and the loss of critical shading has exacerbated warming of streams (McKenzie et al. 2004, Dunham et al. 2007, Pettit and Naiman 2007). As temperatures continue to climb in the future accompanied by earlier snowmelt and hotter, drier summers, there will likely be a longer fire season with severe fires across more of the landscape (Spracklen et al. 2009, McWethy et al. 2010, van der Kamp and Bürger 2011).

△ **Spread of insects, invasive weeds, and non-native fish**

In the wake of milder winter temperatures, populations of mountain pine beetle have exploded in recent years across western North America (Logan et al. 2003, Nordhaus 2009). More than 5 million acres of Montana's forests have been affected by the current infestation. In addition, warmer summers with longer droughts have stressed many coniferous tree species, enabling bark beetles to expand to higher elevations and new host species – such as the white-bark pine (Logan et al. 2003). The willow stem borer has spread throughout southern British Columbia and attacked up to 75 percent of willows, a keystone shrub with many ecosystem benefits (Jim Pojar, *personal communication*). Along with warmer temperatures and prolonged droughts, wildfire and land alterations have promoted spread of invasive plant species such as cheatgrass and spotted knapweed (Bradley 2009) and non-native rainbow and brook trout to the detriment of native, cold-water trout (Dunham et al. 2003, Rahel and Olden 2008). Climate change may alter the transport and establishment of new invasive species, distribution and impact of existing species, and effectiveness of control strategies (Hellmann et al. 2008).

△ **Shifting distribution of plants and animals**

As conditions become warmer and more arid in the future, different plant species will become stressed and will need to shift in response to changes in temperature and soil moisture (Rehfeldt et al. 2006). At lower elevations, forests will decline in density and extent, and some may transition to shrub-dominated sites and grasslands (Fagre 2007). In the middle sections of mountain slopes, the structure and composition of forest communities will change as different species shift mainly upward or to different aspects. In the Columbia River basin, some models project that the Interior Cedar Hemlock (ICH) will replace Montane Spruce (MS) in the river valleys by 2025; but this has not happened yet as forecasted (Hamann and Wang 2006). Their model projects that the ICH and Englemann Spruce-Subalpine Fir (ESSF) will shift upwards by 150-200 m by 2050, which is similar to empirical data from Jasper National Park

for 9,000 yrs B.P. (Pielou 1991). With warming and longer growing seasons at higher elevations, trees could colonize alpine meadows and fill-in more over time (Klasner and Fagre 2002).

During warming episodes in past millennia, distribution of animals in North America generally shifted north in latitude and upward in elevation, too (Pielou 1991). In the mountains, various mammals shifted distribution upward in elevation or perhaps to a different aspect and consequently did not have to shift as far north as those in flatter areas (Guralnick 2007, Lyons et al. 2010). (Of course, there were no roads and other human infrastructure back then that posed barriers to shifts by species in response to climate change.) In recent years, researchers have documented similar shifts northward and upward (Parmesan 2006, Moritz et al. 2008). But, there may be niche or physiological constraints to such adaptive movements. As alpine animals like pikas shift upward, they may find temperatures too warm even on mountaintops; 4 of 10 local pika extirpations in the Great Basin happened after 1999 (Beever et al. 2011).

Implications of Climate Change for Conservation in the Southern Canadian Rockies

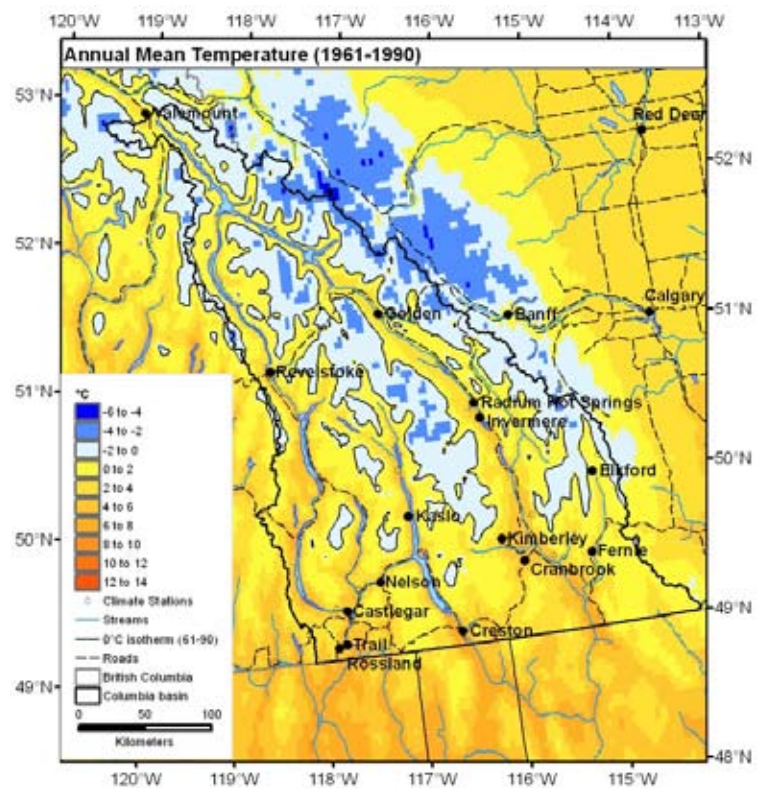
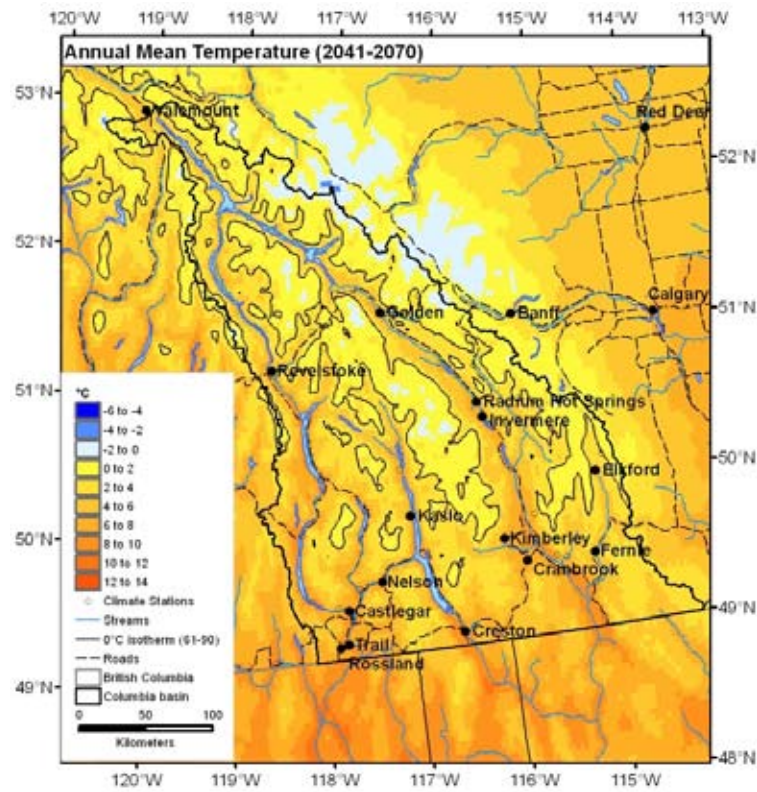
From this litany of past and projected changes in climate, there appears to be strong consensus that the Crown of the Continent Ecosystem will continue to get warmer. It's sobering to see how relatively small changes in average temperature (1°- 2° C) and snow-rain thresholds already have resulted in large ramifications for water resources such as snowpack and summer stream flow.

Projected changes in climate will set many ecological changes cascading into motion, putting increasing pressure upon plants and animals to adapt their niche or move to track preferred environmental conditions. Although species' responses to environmental change differ, their primary response to large climatic changes during the Quaternary period was to shift their geographical distributions, albeit at much slower pace than will be required under most climate change scenarios (Huntley 2005). Scientists are already documenting changes in species distribution over recent decades (e.g., Parmesan 2006). Furthermore, because species respond individualistically, composition and structure of ecosystems will change in the future as novel assemblages come together (Williams and Jackson 2007). Complex ecological interactions may affect species beyond simply changes in their climatic 'envelope'.

More people may move into the Southern Canadian Rockies as a response to more intense climate change (heat, drought, sea rise) elsewhere (e.g., Strauss et al. 2012). Resource development pressures may intensify and expand as humans scramble for dwindling fossil-fuel and water resources (Turner et al. 2010). Ever-increasing numbers of people across the landscape would only exacerbate current challenges of habitat fragmentation and mortality risk. What does all of this imply for conservation strategies to maintain species, ecosystems, and the critical services they provide society?

One key conservation concept involves *resilience* thinking (Walker and Salt 2006). 'Resilience' can be defined as the capacity of species or system to withstand disturbance and still persist (sensu Holling 1973, Folke et al. 2004). Plants and animals evolved in ecosystems where natural disturbances varied in frequency, intensity, duration, and extent – thereby resulting in different

Figure 4. Projected change in mean annual temperature during 2041-2070 (top) compared to mean annual temperature during 1961-1990 for Southern Canadian Rockies and Columbia River basin, British Columbia and Montana. Source: Climate WNA from Murdock and Werner (2011).



spatial and temporal patterns of change (Pickett et al. 1989). Over millennia, animals developed important behaviors and ecological traits that imbued them with resilience to certain kinds and levels of disturbance (Weaver et al. 1996, Lavergne et al. 2010). But as human activities accelerate rates of disturbance across a greater extent of the landscape, the combination of rapid change and simplification can undermine the evolved resiliency of species and render their populations more fragile.

Importantly, the resilience framework does not require an ability to precisely predict the future, but only a qualitative capacity to devise systems that can withstand disturbance and accommodate future events in whatever surprising form they may take (Berkes and Folke 1998). *One of the key messages of resilience thinking is to keep future options open through an emphasis on ecological variability across space and time*, rather than a focus on maximizing production over a short time (Walker and Salt 2006).

This kind of resilience thinking is reflected in several ‘climate-smart’ strategies identified by scientists and managers from around the world (Hannah and Hansen 2005, Heller and Zavaleta 2009, Mawdsley et al. 2009, Graumlich and Francis 2010, Hansen et al. 2010, Davison et al. 2012). A broad consensus has emerged on the following actions to enhance resiliency in the face of climate change:

- ✓ Protect large landscapes with high topographic and ecological diversity
- ✓ Enhance connectivity among such key landscapes
- ✓ Reduce other pressures on species and ecosystems

In an ever-changing world where impacts of habitat loss and fragmentation, invasive species, and climate warming are accelerating, vulnerable species will persist longer with well-designed networks of core refugia and connectivity that offer ecological options (Carroll et al. 2009, Hodgson et al. 2009).

Multiple Effects of Roads and Human Access on Fish and Wildlife

One challenge facing conservation of wildlife and wildlands over the past century has been the ever-expanding footprint of humans – urban and rural sprawl, superhighways and forest roads, dams and diversions. Roads, vehicle traffic, and associated human activity can have a variety of substantial effects upon species and ecosystems (see reviews of research findings by Olliff et al. 1999, Trombulak and Frissell 2000, Gucinski et al. 2001, Forman et al. 2003, Coffin 2007, Fahrig and Rytwinski 2009, Beckman et al. 2010 and *hundreds* of references therein). These authors concluded that roads and associated human activities can have a negative effect on behavior and abundance of animals and ecological processes. High-speed highways and backcountry (‘forest’) roads have different characteristics, problems, and solutions. Here are some of the principal effects that roads, vehicle traffic, and human activity can have on ecosystems and fish and wildlife. Subsequent chapters will provide more detail on (1) effects of forest roads on conservation of the 6 vulnerable fish and wildlife species, and (2) management of backcountry roads for wildlife security and for landscape connectivity across Highway 3.

- ★ ***Road construction kills sessile or slow-moving organisms and high-speed roads increase collisions and mortality.*** Road construction destroys soil biota, plants and slow-moving organisms within the road alignment. Given the 13 million km of roads in the United States (in 1996), this is not a trivial matter. Collisions with vehicles along roads kill many animals every year – including large and small mammals, birds, amphibians and reptiles, and countless insects. Vehicle mortality is a serious concern for amphibians, which are declining due to multiple factors. Mortality from vehicles may be nonselective in terms of age, sex, or condition of the animal. In general, mortality increases with traffic volume and speed. Wide clearing of vegetation along roads can either increase or decrease likelihood of collisions. Recent modifications such as wildlife underpasses and overpasses have reduced mortality and facilitated passage (see Safe Passages: Highways, Wildlife, and Habitat Connectivity by Beckman et al. 2010 for recent examples and innovations).
- ★ ***Road placement can have long-term and long-distance impact on the structure and function of aquatic ecosystems.*** Placement of roads and crossings can re-route surface water or shallow groundwater – thereby changing the flow of water, sediments, and nutrients. These changes can undermine stability of adjacent slopes and trigger mass slumping, downcutting of new gullies, and erosion. Such effects may not show up until years later and/or miles downstream when an infrequent but intense rainstorm occurs. In particular, roads in the floodplain of a river or stream can interfere substantially with the natural dynamics that promote the diversity of these habitats. During the road construction phase, fine sediments may be deposited in adjacent waters, which can kill aquatic organisms and impair aquatic productivity. Road crossings commonly act as barriers to passage by fish and other aquatic organisms. Bull trout and westslope cutthroat trout are especially vulnerable to these barriers. Some of these impacts can be mitigated effectively by proper design and construction of roads, culverts, and bridges.
- ★ ***Road maintenance and vehicles introduce chemical contaminants that degrade air and water.*** Many chemicals are introduced into the local environment due to road maintenance and vehicles. For example, a variety of heavy metals are deposited from gasoline additives and de-icing salts. These contaminants can pollute nearby soils, plants, and waterways. Ungulates such as mountain goats and bighorn sheep are attracted to salt applied to highways and are killed in vehicular collisions. On some gravel roads, dust mobilized by vehicles can impact nearby vegetation.
- ★ ***Roads facilitate spread of invasive plants (weeds) and introduction of non-native fish.*** Road construction inevitably disturbs soils, which can stress or eliminate native plants and favor establishment of nonnative ‘weeds’. Nonnative plants, spores of exotic diseases, and mollusks can ‘hitchhike’ on vehicles and spread to new sites. All-terrain vehicles (ATVs) can be the extending vector spreading weeds when the people drive them off roads or

penetrate deeper into the backcountry on 4-WD roads. Indeed, such unwitting spread of nonnative species is one of the biggest problems in contemporary conservation. Roads into remote areas also facilitate unsanctioned introduction of nonnative fish into lakes and streams, leading to profound effects on native fish such as bull trout and westslope cutthroat trout and aquatic ecosystems.

- ★ ***Roads reduce available habitat due to direct removal or displacement.*** Roads are typically built for extraction of commodity resources such as oil and gas development or logging, which often removes or alters habitats for variable periods of time. The loss of habitat depends upon the type and extent of the development. Some wildlife species avoid roads and associated human activity during both the extraction phase and subsequent use of open roads by people. Depending upon the type, volume of traffic, and duration of traffic, animals can be displaced from 100 m to 2 km from a road or facility. This displacement results in the loss of available habitat, which can result in less productivity in some cases. Some animals can habituate to road traffic that is predictable in space and time. Even when animals are not displaced from roadside habitats, human activity/vehicles on roads can elevate their metabolic rate and costly expenditure of energy.
- ★ ***Roads reduce security for wildlife and increase risk of human-caused mortality.*** New roads open up access into remote areas, which can lead to increased mortality from poaching, incidental killing, and excessive harvest. Grizzly bears, wolverines, mountain goats, and bighorn sheep are especially vulnerable to the effects of new access and inadequate regulations. If excess harvest of fish remains chronic, this can give rise to public demand for artificial stocking to compensate for unsustainable harvest ... at the further expense of native trout populations and ecosystem integrity.
- ★ ***Snowmobiling activity along roads can affect behavior, habitat use, health and inter-specific relationships among wildlife.*** The noisy activity of snowmobiles or helicopters can displace animals from their selected habitats in winter, which can negatively affect their energy balance – especially if it occurs in late winter which is a critical time period for ungulates like bighorn sheep and mountain goats. This is also the denning period for wolverines (Feb-April) which have their dens in snowy terrain at high elevations. Trails packed by snowmobiles may facilitate new access into areas of deep snow usually avoided by predators like wolves and coyotes.
- ★ ***Road access leads to un-natural wildlife behavior, with more habituation and greater likelihood of getting accustomed to food/garbage left by people.*** Habituation along roadways can result in loss of wariness for species like grizzly bears, or the animals become conditioned to receiving rewards of available food or garbage at campgrounds. This prompts managers to capture and relocate them to more remote areas (but the bears often return to the original site) or kill the animal after repeat episodes.

- ★ *Roads fracture connectivity for population and genetic exchange.* Roads may pose an impermeable barrier to some small organisms, and a partial barrier to larger species. Depending upon density of roads and traffic volume, this can impact an animal's movements on a daily or seasonal basis in response to severe weather events or a shortfall in key foods. Fragmentation of the larger landscape fractures natural connections, resulting in less opportunity for animals from 1 area to move into another area and boost the recipient population. This can result in smaller populations and greater isolation, which increases the risk of local extirpation. Finally, landscape fragmentation reduces the genetic exchange between populations, which can adversely affect longer-term viability. Species like grizzly bears with limited population resiliency and dispersal are particularly vulnerable to landscape fragmentation. Roads fracture landscapes into smaller patches at an exponential rate rather than a linear rate; hence, even a single major road can have substantial fragmentation effect. Loss of habitat and landscape fragmentation is another one of the major and ever-expanding issues in contemporary conservation of biodiversity.

- ★ *Roads can restrict freedom for animals to move in response to climate change.* As climate changes in the future, fish and wildlife will need to move to find new sites for sustaining their ecological needs. Because the exact location of new habitats will be difficult to predict, animals will need room to roam in their search. Providing for such connectivity is one of the smartest strategies for promoting resiliency of many species in the face of climate change.

- ★ *At the larger scale of landscapes, increasing road density can lead to cumulative effects of multiple human activities.* A single road arguably may have little detrimental effect upon fish and wildlife populations. But a spidery, expansive network of many roads can result in substantial and cascading cumulative effects upon animal populations and ecological processes. This has been called the 'tyranny of small decisions' whereby the total impact of seemingly insignificant, single decisions combine to cause substantial cumulative effects.

The expansive literature on roads leads to several key conclusions:

- ★ The physical imprint of a road itself can have impacts, particularly on fish and aquatic ecosystems due to sedimentation and barriers to passage – *regardless of the level of traffic or human behavior.*
- ★ Risk of mortality from direct shooting (legal hunting or poaching) and spread of invasive species increases as access expands – *regardless of traffic volume.*
- ★ Increasing levels of traffic volume on backcountry roads and secondary highways reduces amount of useable habitat via displacement (or shifts to nighttime use) and reduces permeability of roads to wildlife crossing.

Some of the detrimental effects of roads can be mitigated with proper design and management (such as permanent or seasonal closure), and some effects (such as mortality of food-conditioned bears) can happen at backcountry sites, too. Yet – in the big picture – vulnerable populations of fish and wildlife will have a better chance to prosper and persist in large, secure roadless areas. Hence, as a greater proportion of the natural landscape continues to be modified by human infrastructure and activities, protected wildlands become even more critical and valuable.

In the Southern Canadian Rockies of British Columbia and Montana, roads proliferated dramatically starting in the 1950s. The initial purpose of these new roads was to enable extraction of timber and energy resources such as coal and oil and gas. Over time, however, they became accustomed access for other uses such as summer and/or winter recreation. With recent improvements in the capability of ATV vehicles and snow machines to access more difficult terrain and recent prosperity in the regional economy, recreational access into the backcountry has exploded across the Southern Canadian Rockies.

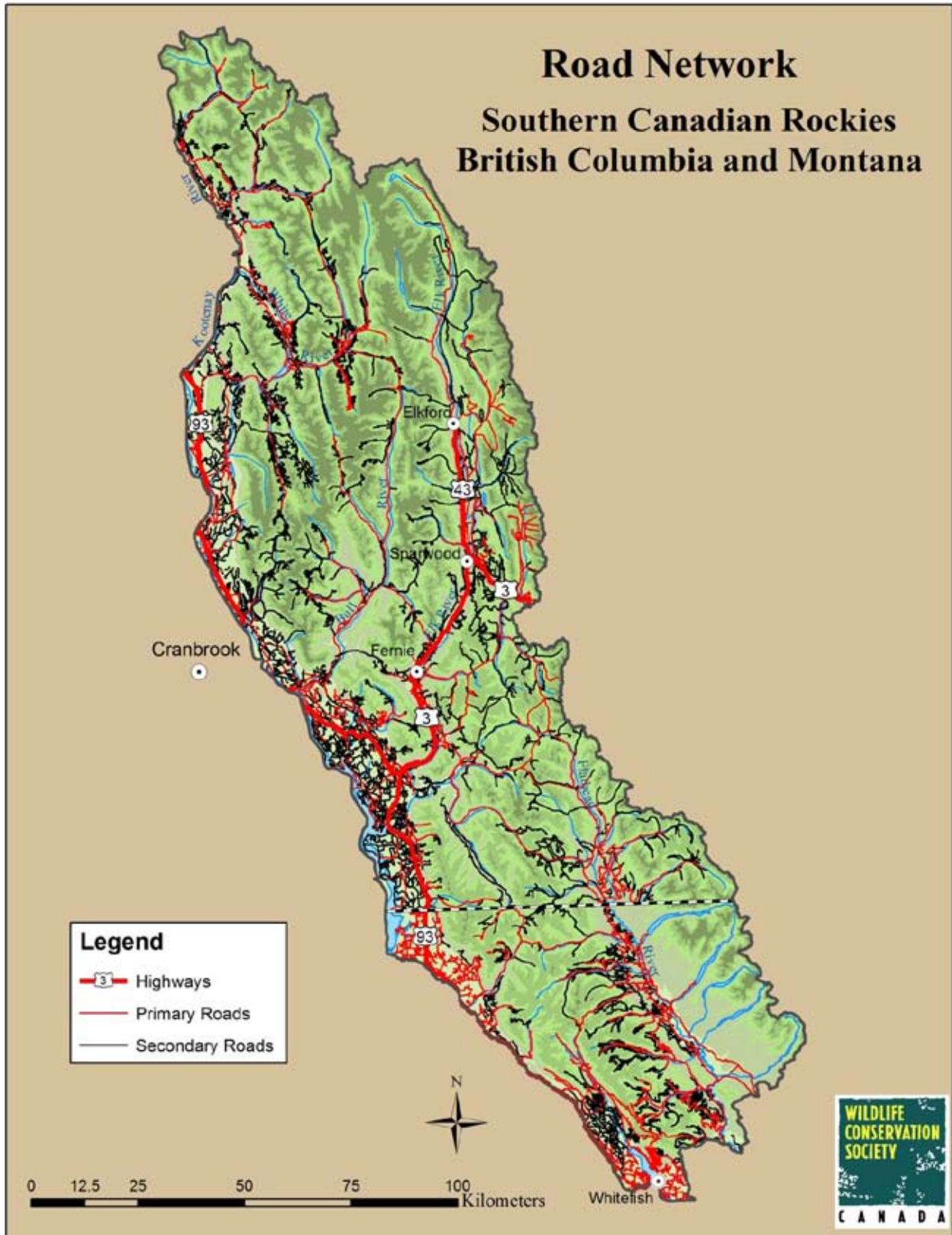
Today, there are approximately 4582 km of primary forest roads and 7450 km of secondary forest roads across the region (Figure 5). Every major river valley and nearly every tributary valley throughout the Southern Canadian Rockies of British Columbia and Montana has a road in it. Although there were early and continuing efforts to manage this road network in light of better information on their effects on fish and wildlife, many wildlife professionals and conservationists believe that past decisions and practices have fallen far short of a balanced plan. As human populations and affluence increase in the region, the importance of managing proliferating roads and human access will become ever more critical.

Purpose, Goal and Objectives, and Organization of the Report

The purpose of this report is to inform discussions and decisions about land and resource management in the Southern Canadian Rockies of British Columbia and adjacent Montana. The goal is to assess the conservation value of 16, 978 km² (6632 mi²) of the Southern Canadian Rockies for a suite of vulnerable fish and wildlife species. Specific objectives are to: (1) compile and critically examine the latest scientific information about conservation needs of these species and contemporary threats of climate change and road access, (2) identify current and future key areas for these species using empirical data and models, (3) assess options for connectivity across Highway 3 and Continental Divide, and (4) make recommendations for various levels of conservation such as a regional Wildlife Management Area (WMA). The approach involves synthesis of available spatial data into maps of conservation value for vulnerable species and a geographical narrative to draw attention to key areas.

The Wildlife Conservation Society has woven together several lines of contemporary thinking about planning for wildlife conservation into a concept called ‘landscape species’ (Sanderson et al. 2002). It is based on the notion that species which use large, ecologically diverse areas can serve as useful ‘umbrellas’ or surrogates for conservation of other species. Importantly, a suite of species is chosen considering area requirements, heterogeneity of habitats, ecological

Figure 5. Location of the road network across the Southern Canadian Rockies, British Columbia and Montana.



functionality, and socioeconomic significance. For assessing the conservation value of the Southern Canadian Rockies, I selected the following suite of fish and wildlife species: bull trout (*Salvelinus confluentus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi*), grizzly bear (*Ursus arctos horribilis*), wolverine (*Gulo gulo*), mountain goat (*Oreamnus americanus*), and Rocky Mountain bighorn sheep (*Ovis canadensis*). These are the same species I used in a previous conservation assessment in the Montana portion of the Crown (Weaver 2011).

In Chapter 2, I introduce a framework for assessing the *vulnerability* (or lack of resiliency) of a species using 5 factors (following Weaver et al. 1996). For each focal species, I provide a vulnerability profile based upon its ecology, demography, and behavior. Next, I describe my method for scoring conservation importance (current and future) of lands or waters for the species. Based upon results of that mapping, I identify and discuss key conservation areas for each species by watershed. Finally, I combine maps of important areas for individual species into a composite or overall map of conservation values. Considerable spatial information about these species and key areas is captured in the series of maps.

In Chapter 3, I present current information and mapping of key corridors across and along Highway 3 (Crowsnest Hwy) to ensure connectivity across the larger landscape of the Southern Canadian Rockies. I add our new modeling of such connectivity for wolverines, a wide-ranging but demographically vulnerable species. Lastly, I identify and map key mountain passes through the Continental Divide between British Columbia and Alberta, which are also quite important for regional connectivity.

In the closing Chapter 4, I sum up the critical importance of the Southern Canadian Rockies of British Columbia and Montana for long-term conservation of these vulnerable fish and wildlife species. I endorse a wildland Park (National or Provincial) for the Canadian Flathead and recommend a Wildlife Management Area (WMA) designation for a portion of the Southern Canadian Rockies in British Columbia that would include a network of ‘safe havens’. I recommend Wilderness and Backcountry Conservation designations for some of the remaining roadless areas in the Flathead River basin and Whitefish Range of Montana.

2. SENTINELS OF THE SOUTHERN CANADIAN ROCKIES: VULNERABLE FISH AND WILDLIFE SPECIES

Introduction

For each of the 6 focal species of fish and wildlife, I provide a profile of its vulnerability based upon its ecology and behavior. Next, I describe the methods for scoring areas of conservation value for that particular species. Lastly, I provide GIS-based maps of the distribution of key conservation areas for the species, as well as a table summarizing the amount of area (ha) in each conservation value for the 5 major watersheds. In a geographical narrative by watershed, I identify key areas of conservation value.

Framework for vulnerability profiles

Vulnerability refers to the susceptibility of species to disturbances of various kinds. Over millennia, species have persisted by a variety of mechanisms that buffered environmental disturbance at various spatial and temporal scales. Yet some species seem more vulnerable than others. What factors contribute to their vulnerability?

The concept of *resilience* can guide our thinking about vulnerability. Resilience can be defined as the capacity of species to withstand disturbance and still persist (*sensu* Holling 1973, Folke et al. 2004). Species can be considered as nested hierarchies of individuals, populations, and meta-populations in which the higher levels provide context for mechanisms at lower levels. Persistence may be accomplished by ‘spreading the risk’ (e.g., separate small herds of big-horn sheep will be less vulnerable than a single large herd to spread of a virulent disease). Because disturbances occur at different spatial and temporal scales, no

single level of organization can respond adequately to all disturbances. Hence, the nested structure increases resilience by linking the system across hierarchical levels (Pickett et al. 1989).

Following Weaver et al. (1996), I postulate a basic mechanism of resistance or resiliency at each of three hierarchical levels: individual, population, and metapopulation. At the individual level, an animal can exhibit physiological tolerance to an environmental condition or behavioral flexibility in food acquisition and selection of habitat. For example, in the face of environmental change, an individual may substitute one resource for another in its diet, thereby ameliorating flux in food availability.

At the population level, native fish may have little resistance to invasion by non-native fish and are vulnerable to hybridization and/or competition. Some mammals compensate for excessive mortality with increased reproduction and/or survivorship, thereby mitigating demographic fluctuations. High survivorship and longevity of reproducing adult females typically is critical to the continued well-being of many mammal populations.

At the metapopulation level, dispersal enables animals to augment an existing population or re-colonize an area where a population has been extirpated. Dispersal usually refers to movements by juvenile animals when leaving their natal range after reaching the age of independence (adults occasionally disperse, too). Dispersal is successful only if the individual survives, establishes a home range, finds a mate and reproduces. In landscapes fragmented by human disturbance, successful dispersal is the mechanism by which declining populations are supplemented, genes are shared across the landscape, and functional connectivity of meta-populations is established (Gilpin and Hanski 1991).

In reference to human disturbance, niche flexibility addresses the problem of loss or change in habitat conditions. Capacity for greater productivity enables populations to compensate for overexploitation or to come through a genetic 'bottleneck' more quickly. Dispersal addresses the problem of habitat fragmentation at a landscape scale. Resiliency, however, have definite limits. As human activities accelerate rates of disturbance across a greater extent of the landscape, the combination of rapid change and simplification can undermine the evolved resiliency and render their populations more fragile. Cumulative effects can accrue that threaten their persistence. One of the key messages of resilience thinking is to *keep future options open through an emphasis on ecological variability across space and time*, rather than a focus on maximizing production over a short time (Walker and Salt 2006).

In this section, I use this framework of resilience to assess vulnerability for 6 species of native fish and wildlife. Each profile addresses the following factors: (1) niche flexibility, (2) resistance to hybridization (fish) or reproductive capacity and mortality risk (mammals), (3) dispersal and connectivity, (4) sensitivity to human disturbance, and (5) response to climate change.

Methods for Scoring Conservation Importance

To assess the relative importance of areas across the Southern Canadian Rockies of British Columbia and Montana, I developed a scoring system to quantify the conservation values for vulnerable fish and wildlife species. The scoring system comprised 3 relative ranks: *Moderate* Importance = score of 1; *High* Importance = score of 2; and *Very High* Importance = score of 3. The scoring system started with moderate importance (rather than low importance) for two reasons: (1) the Crown of the Continent Ecosystem is one of the most ecologically intact and important areas for native fish and wildlife and will likely serve as a large refugia as climate changes, and (2) each of the vulnerable species has national and/or Provincial/State importance due to federal listing in the U.S. (e.g., bull trout, grizzly bear, wolverine) and/or iconic prominence (mountain goat, big-horn sheep).

I customized the scoring criteria for each vulnerable species to reflect attributes that are important to the long-term persistence of that species. In several cases, a higher score incorporates either direct assessment or consideration of future habitats under warming climate – with the intent of providing some future options for that species. For example, in the case of wolverines, places where snow cover persists during a critical spring period are a critical element of their distribution and population ecology. I assigned a high score (2) to areas where such snow cover is likely to remain until the year 2050 under different climate-change scenarios. Details of the scoring system are provided under each species.

Description of Key Conservation Areas of Conservation Value

I used the scored maps to identify key conservation areas for each species. In addition, I summarized the scores in 2 complementary ways. First, I added scores across all species to derive a *composite* score for each 1-km² grid cell across the study area (max potential score = 18, 6 species x highest score of 3). I also mapped *species importance* whereby a grid cell with a score of 3 or 2 for any species was highlighted.

Although synthesis of existing information was central to this assessment, I believe strongly in the value of field reconnaissance. Therefore, I spent 89 days during 2011-2012 exploring the Southern Canadian Rockies of B.C. and Montana. I hiked and rode horseback many miles on and off trails. I also conducted field studies here during an earlier project 2002-2003 (Apps et al. 2007).

Bull Trout

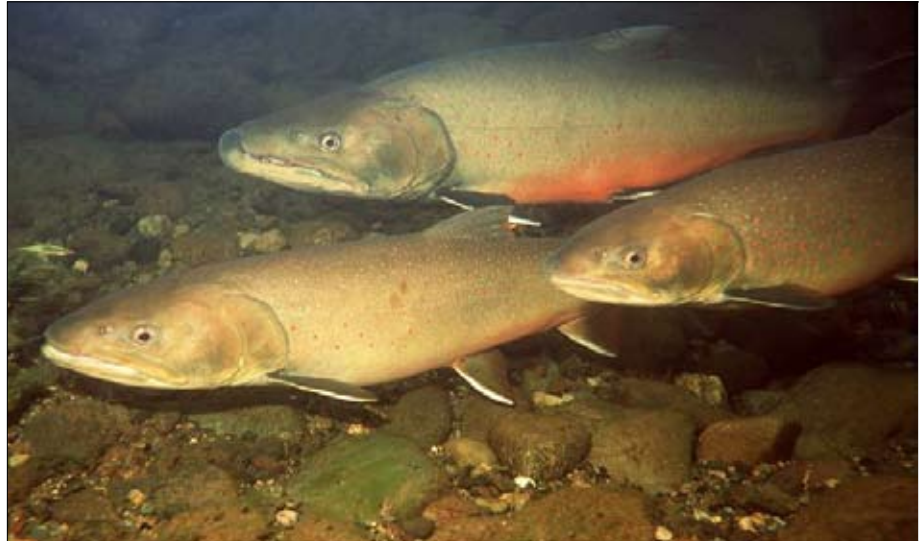


Photo: US Fish and Wildlife Service

Vulnerability Profile

Populations of bull trout have declined throughout much of their native range in the United States (Rieman et al. 1997, USFWS 2002). Declines have been attributed to habitat degradation and fragmentation (Fraley and Shepard 1989, Rieman et al. 1997, Baxter et al. 1999) and interactions with non-native charr/salmonids (Kitano et al. 1994, Martinez et al. 2009). Bull trout in Montana are federally listed as ‘threatened’ under the Endangered Species Act and critical habitat has been designated (USFWS 2010). In British Columbia, bull trout are blue-listed as ‘species of special concern’. Pacific populations of bull trout have been assessed as “Not at Risk” by COSEWIC (Committee on the Status of Endangered Wildlife In Canada) (http://www.cosewic.gc.ca/eng/sct1/SearchResult_e.cfm?commonName=bull+trout&scienceName=&Submit=Submit).

Niche Flexibility: Bull trout are one of the most thermally sensitive cold-water species in western North America. Warm but sub-lethal temperatures can alter metabolism, growth, and competitive interactions for cold-water trout, whereas high water temperature can cause direct mortality. Laboratory studies suggest that peak growth in bull trout occurs between 10°-15° C (52°- 60° F), whereas the upper lethal temperature is about 21° C (70° F) (Selong et al. 2001). Across the range of bull trout in northwestern United States, spawning and rearing occurs mostly in streams where the maximum daily temperature during August – September is <12° C (<54° F) (Dunham et al. 2003). In the Flathead River system in Montana, a new spatial model estimated August stream temperatures of spawning and rearing habitat for bull trout at <13° C (<55° F) and foraging, migrating, and overwintering habitat at <14° C (<57° F) (Jones et al. 2013). Bull trout select stream reaches for spawning where upwelling of ground water provides cooler and well-oxygenated conditions (Baxter and Hauer 2000, USFWS 2010). In winter, warm groundwater and beaver ponds inhibit formation of anchor ice, which otherwise would cause high mortality as young trout emerge (Jakober et al. 1998).

Resistance to Hybridization: Because fish have external fertilization, hybridization is more common in fishes than in any other vertebrate taxa (Leary et al. 1995). In undisturbed ecosystems, reproductive isolation is maintained by spatial and temporal isolation during the spawning period. Barriers to interbreeding may be lost, however, due to introduction of non-native species and exacerbated by habitat alterations. Non-native fish can also displace native fish through predation and competition.

Brook trout can reproduce with bull trout, thereby producing mostly sterile hybrids which reduce reproductive potential in populations (Leary et al. 1993, Kitano et al. 1994). In addition, they can depress foraging by bull trout (Nakano et al. 1998) or out-compete them for scarce resources (Gunckel et al. 2002). Brook trout can displace or push bull trout from lower elevations, with greater displacement in streams with smaller patches initially or with lower stream gradients (Rieman et al. 2006). Conversely, they may invade from higher elevation if introduced to a headwater lake (Adams et al. 2001). Brook trout are moving into higher gradient/higher elevation streams that once were considered refugia for bull trout (McMahon et al. 2007).

Competition with non-native lake trout (*Salvelinus namaycush*) in lakes is considered the most significant threat to recovery and conservation of bull trout in several areas (Martinez et al. 2009). Lake trout prey on young bull trout and can completely displace bull trout in mountain lakes due to substantial overlap in their niches (Donald and Alger 1993, Fredenberg 2000). For bull trout that spawn in the North Fork Flathead River and migrate downstream to winter in Flathead Lake (Fraley and Shepard 1989), lake trout represent a significant threat to their recovery (USFWS 2002).

Dispersal and Connectivity: Connectivity throughout a watershed is critical for bull trout for in terms of migration strategies, population persistence and genetic diversity. Bull trout express a variety of life history strategies, depending upon where they migrate after 1-3 years as juveniles in natal streams. Some bull trout remain in their natal streams (*resident*), some migrate into larger tributaries (*fluvial*), and others migrate into lakes (*adfluvials*). In the Flathead River system, bull trout migrate up to 250 km upriver from Flathead Lake to spawn in their natal tributaries in British Columbia (Fraley and Shepard 1989). Most bull trout populations are small in size (even smaller in terms of genetically effective size) and are connected to a larger metapopulation via low rates of dispersal among populations (Dunham and Rieman 1999, Rieman and Allendorf 2001). Bull trout exhibit high fidelity to selected spawning sites, which can be located at specific patches. Much of the genetic variation in bull trout occurs at very fine geographic scales (Spruell et al. 1999, Warnock et al. 2010, Ardren et al. 2011), especially below and above barriers (Costello et al. 2003). For example, bull trout in the Elk River above the Elko dam (built upon a natural barrier) might be genetically differentiated (allele frequency) from those in the Wigwam River. In the Flathead River drainage, researchers found that adjacent populations were highly isolated in terms of reproduction (Kanda and Allendorf 2001, Meeuwig et al. 2010). Hence, it's vital to maintain local populations to safeguard genetic diversity and to promote long-term persistence (Spruell et al. 2003).

Ensuring connectivity in the dendritic or branching structure of stream networks, however, can be challenging for several reasons (Fagan 2002, Meeuwig et al. 2010). First, the linear distance between 2 patches at the head of 2 long streams may be short ‘as the crow flies’ but very far ‘as the fish swims’. Secondly, isolated but nearby patches may suffer the same correlated risk to landscape disturbances such as wildfire. Conversely, in a linear feature like streams, all patches may be at risk regardless of distance when a toxic pollutant enters at the headwaters and flows downstream. Lastly, the effect of fragmentation in a dendritic stream network depends upon the position of the fracture. If it occurs at the trunk, it can affect a much more extensive network than if it happens at a higher branch. Thus, bull trout may appear especially vulnerable to increasing fragmentation of dendritic stream networks.

Sensitivity to Human Disturbance: Bull trout are vulnerable to a wide range of human disturbances (USFWS 2002). The combination of slow growth, late age at maturity, low fecundity, longevity, and high catchability render adfluvial bull trout particularly susceptible to overfishing, even with per-capita angler restrictions (Post et al. 2003). Some over-exploited populations have recovered in 10 years after zero-harvest regulations were implemented (Johnston et al. 2007). Roads increase ready access for angler mortality and poachers (Long 1997), particularly in small lakes and tributary streams where bull trout are especially vulnerable (Parker et al. 2007).

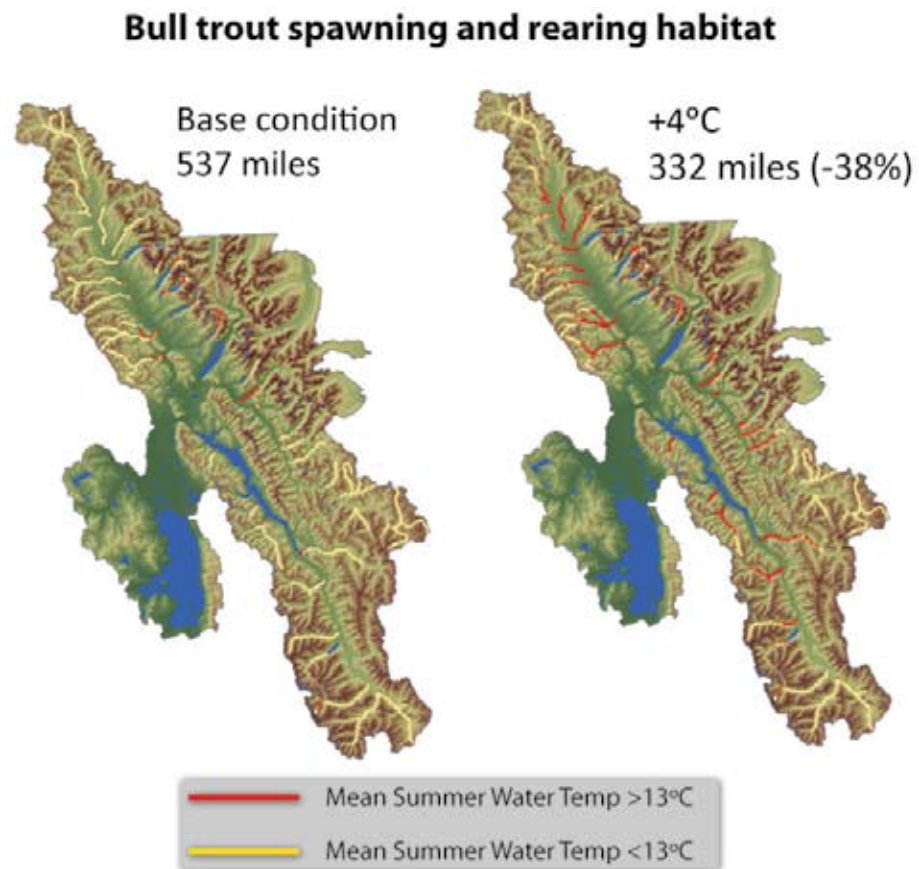
Dams can pose the biggest threat by blocking fish movements, resulting in genetic isolation and loss of migratory populations and altering natural flow regimes and river habitats (Hagen 2008, Muhlfeld et al. 2011). Such blockage can be detrimental to migratory populations that require diverse, connected habitats for different life stages (Muhlfeld and Marotz 2005). Conversely, a large reservoir may support abundant forage fish and support large, migratory populations if connected to high quality spawning and rearing habitat (e.g., Koocanusa reservoir and Wigwam River in B.C. [Cope 2007]). Improper timber harvesting practices and associated roads/culverts can increase sedimentation into spawning streams, block access for trout, remove riparian cover and increase stream temperatures (Baxter et al. 1999, Ripley et al. 2005). Mining and oil and gas activities can cause massive chemical pollution of streams and major mortality of fish (Moore et al. 1991), while associated roads can increase sedimentation and provide access (Ripley et al. 2005). Major highways and railroads can increase the potential for catastrophic spill of toxic substances, too. Agricultural practices can de-water streams, increase water temperature, degrade stream banks and increase sedimentation, and disrupt migrations. Finally, purposeful stocking in the past and continued illegal releases of non-native trout have resulted in the most challenging threat to native bull trout in the Flathead River basin (USFWS 2002).

Response to Climate Change: Bull trout will likely be vulnerable to several manifestations of climate change. Over the past several decades in western Montana, there has been decreased snowpack and more rain-on-snow events and flooding in winter, accelerated melting of snow and earlier runoff in spring, reduced recharge of groundwater and lower base flows, warmer stream temperatures and longer periods of drought in summer, and increased sedimentation due to more wildfires. The net result has been warmer water and lower base flows at low-mid elevations, particularly in late summer and fall when bull trout are migrating and spawning. These changes are projected to continue into the future (see Chapter 1 for fuller discussion of climate change and references).

Warmer temperatures and drought could render the lower elevation sections thermally unsuitable as FMO and SR habitat for these cold-adapted fish, thereby raising the lower-elevation limits and/or disconnecting the 2 habitats (Rieman et al. 2007, Jones et al. 2013). Some of the most dramatic increases in stream temperatures could occur in areas that are burned severely by wildfire and lose the shading cover of streamside trees and shrubs (Issak et al. 2010). In addition, warmer stream temperatures could enable non-native brook trout to invade higher reaches of streams, conceivably raising the prospects of competition and hybridization (McMahon et al. 2007). The net outcome would be continued shrinkage of the cold-water niche for bull trout, thereby reducing both the size and connectivity of remaining suitable patches and eventually resulting in fewer bull trout (Rieman et al. 2007, Haak et al. 2010, Isaak et al. 2010, Wenger et al. 2011). One might postulate that bull trout in the Southern Canadian Rockies of British Columbia and Montana would be at lower risk due to the more northerly location and higher elevation (Haak et al. 2010). A recent model using a conservation scenario of climate warming, however, estimated a potential loss of 58% FMO habitat in the main stems of the Flathead River and 36% loss of SR habitat in the lower-elevation tributaries by the year 2059 should air temperatures increase by 3.3° C (6° F) (Figure 6).

Conclusion: Bull trout exhibit **high vulnerability** due to low resistance to a variety of factors. They have a demanding cold-water niche – especially for spawning and rearing – and low resistance to warming water. Bull trout have low resistance to invasion by non-native trout, too. Although adult bull trout can move long distances, human fragmentation of hydroscaapes can have acute effects on dispersal and connectivity. Bull trout are vulnerable to several detrimental effects of human activities associated with roads. Finally, climate change may impact the stringent cold-water niche of bull trout and lead to smaller, more isolated populations that could be less viable and thus more vulnerable. Protection of clean, cold, structurally-complex and well-connected habitat from invasion by non-native fish remains a central element in the conservation of bull trout.

Figure 6. Predicted changes in critical bull trout habitats in trans-boundary Flathead River due to projected warming scenarios. Graphic adapted from Figure 5 in Jones et al. (2013).



Montana Department of Fish, Wildlife, and Parks.

Methods for Scoring Conservation Importance

Initially, locations of both historic and current records for bull trout were obtained from the B.C. Fishery Summary System (FISS) data set compiled prior to the year 2000 and geo-referenced to the 1:50,000 scale. Each fish point represents either a specific site where a fish species has been identified or the point (at the mouth) represents an entire stream in which the fish species is known to be present. More recent point records were obtained from the Land and Resource Data Warehouse. I incorporated information from studies on key streams such as the Wigwam River (Cope 2003) and upper White River (Baxter and Oliver 1997, Cope 2007). The recent status review of bull trout in British Columbia was also helpful (Hagen and Decker 2011). Lastly, we vetted this preliminary map with the regional fish habitat biologist in Cranbrook, B.C. for accuracy and updated information (H. Tepper, B.C. Ministry of Forests, Lands and Natural Resource Operations, *personal communication*). It should be noted that, in some cases, bull trout may occur higher up the mapped section of a tributary. For the trans-border Flathead River system, I used the most recent distribution map based upon research by aquatic biologists based in Glacier National Park (C. Muhlfield, USGS, *personal communication*).

The primary challenge in conservation of bull trout is to maintain viable populations with genetic integrity in suitable aquatic habitats that are cold, complex, and connected (USFWS 2002). Crucial habitats included lakes, main stems of rivers, and tributaries to capture all the various life history stages and full range of migration/resident strategies. As climate change unfolds, however, waters at lower elevations may become too warm for bull trout, especially for spawning and rearing (Rieman et al. 2007, Isaak et al. 2010). Tributaries may provide important future options (refugia) due to higher elevation and the input of cooler groundwater (Jones et al. 2013).

Accordingly, I assigned the following importance scores for bull trout:

- Very High (3) = spawning and rearing habitat in upper tributaries (SR)
- High (2) = rivers/streams for foraging, migration, overwintering (FMO)
- Moderate (1) = n.a.

Key Conservation Areas

Approximately 1015 km of streams with *very high* conservation value (spawning and rearing, SR) and 1209 km of *high* conservation value (foraging-migration-overwintering, FMO) occur in the Southern Canadian Rockies of British Columbia and Montana (Table 1, Figure 7). The key spawning and rearing areas are the (1) Wigwam River and tributaries, (2) trans-border Flathead River and tributaries, and (3) major tributaries to the White River (Cope 2007). Nearly half (46%) of the mapped SR habitat lies in the trans-border Flathead River watershed, with most of the remaining area in the Lower Elk, Upper Elk, and Palliser-White River watersheds. The amount of FMO habitat was more equitably distributed among watersheds, with the Flathead River (26.9%) again

having slightly more. The majority of bull trout over-winter in the Kootenay River, Koocanusa Reservoir, and Flathead Lake (Westover and Heidt 2004). Interestingly, only 1.7% of the SR habitat and 2.9% of the FMO habitat is within the B.C. Provincial Parks in the region. Much of the SR habitat (87.1%) and the WMO habitat (75.4%) in B.C. are within 500m of roads. Bull trout populations rebounded in both the Lower and Upper Elk River watersheds following more restrictive angling regulations implemented ca. 1995 (Hagen and Decker 2011).

Trans-border Flathead River Watershed: In Montana, the entire North Fork Flathead River and many of its tributaries have been designated as critical habitat for bull trout as part of the Flathead Lake Core Area (USFWS 2010). Designated spawning/rearing tributaries on the west side of the North Fork (Flathead National Forest) with their source in the roadless Whitefish Range include: Trail, Whale/Shorty/Inuya, Red Meadow, Coal/Cyclone, South Fork Coal / Mathias, and Big/Hallowat Creek. Bull trout also spawn and rear in Kishenena Creek and the major lakes on the west side of Glacier National Park. The main stem Flathead River and several other tributaries are used for foraging/ migration/over-winter: Moose, Hay, Moran, headwaters of Coal, and Skookoleel/ Werner/Kletomas (Big Creek). In Glacier National Park, these include Starvation and Akokala Creeks. Projected climate warming is predicted to negatively affect bull trout populations in the lower main stem Flathead River and adjacent tributaries by 2059 (Jones et al. 2013).

In the Upper Flathead Core Area in British Columbia (Hagen and Decker 2011), bull trout use the main stem in the headwaters for spawning and rearing as well as the following tributaries: Kishenena, Sage, Cauldrey, lower Cabin, Howell, ‘Squaw’ (as shown on map, unfortunately), McLatchie, and un-named creek opposite/north from Foisey and probably Harvey, Cate, lower Shepp, and Pincher. The main stem Flathead River and several other tributaries are used for foraging/migration/over-winter: Starvation, Leslie, Commerce, Middlepass/Haig Brook, St. Eloi Brook, Pollock, Foisey, and McEvoy. Abundance of bull trout in Flathead Lake has declined 10-30% due to non-native lake trout, while the proportion of the trans-border bull trout using the upper Flathead in B.C. has increased (USFWS 2005, Hagen and Decker 2011, C. Muhlfeld, *personal communication*). Recent actions by the Premier of British Columbia and Governor of Montana and Nature Conservancy Canada/The Nature Conservancy US have alleviated the threat of mining and oil and gas development in this critical trans-border watershed.

Lower Elk River/Koocanusa Reservoir Watershed: This includes the lower section of the Elk River below Fernie, B.C. and other streams that flow directly into Koocanusa Reservoir in British Columbia and Montana, a major over-wintering site for bull trout. It is the Koocanusa Core Area (Hagen and Decker 2011). The Wigwam River in B.C. provides crucial spawning and rearing area for perhaps the most prolific population of bull trout in the geographic range of the species, with counts of spawning sites (called ‘redds’) totaling 2200 in 2006 (Cope 2007). Key tributaries to the Wigwam used for SR include lower reaches

of Bighorn (Ram), Lodgepole, and Desolation Creeks. Little Sand Creek/ lower Sand Creek and Phillips Creek may also be used. The Elk River is used for foraging, migrating, and over-wintering. Lizard Creek and Morrissey Creek are used for spawning and rearing.

In the Grave Creek drainage in Montana, critical habitat for bull trout has been designated for the following streams: Grave Creek, Clarence Creek, lower section of Blue Sky Creek, above Frozen Lake, and upper Wigwam River (USFWS 2010). Bull trout also have been mapped as ‘abundant’ in Lewis Creek, Rich Creek, Stahl Creek, and Williams Creek where some rearing may take place.

Upper Elk River Watershed: This was designated by Hagen and Decker (2011) as the Elk Core Area (Hagen and Decker 2011). The main stem of the Elk River from Fernie all the way up to Elk Lakes Provincial Park serves as foraging, migration, and over-wintering habitat. Line Creek and South Line Creek are primary spawning tributaries (Allan 2001). Michel/Leach Creek also has considerable distance of suitable spawning and rearing habitat. Shorter reaches of the following streams may be used: Bean (near Hartley Creek), Lladner, Erickson, Cummings, Weigert, Grave, Bingay, Hornickel, Quarrie/ Forsyth, Aldridge, Bleasdel, Weary, Gardner, Cadorna, and outlets of Elk Lakes (Westover 1995, H. Tepper, *personal communication*).

Bull River Watershed: There are no bull trout above the Bull River dam, while the area below is used for foraging. Bull trout use the Wild Horse River (up to Trout Creek) for spawning and rearing, but perhaps less so than historically. Bull trout migrate up the Lussier River to about the canyon (below the hot springs) for spawning and rearing; resident populations occur in Fish Lake and for 5 km down the upper Lussier.

Palliser-White River Watershed: The upper White River is another regional stronghold for bull trout in the Southern Canadian Rockies (Cope 2007). According to Hagen and Decker (2011), there are “probably >1000 adult fish and at least 7 potentially interconnected fluvial populations.” The Middle White River and Blackfoot Creek have supported some of the higher number of redds (up to 200 and 100, respectively). Other important tributaries include Grave Creek, Thunder Creek, Elk Creek, East White River, and North White River (including Schofield Creek and short reaches of Akunam and Nilksuka Creek). The large and well-connected extent of the upper White River contributes towards viability of bull trout. Together with the Wild Horse and Lussier Rivers, it comprises the Upper Kootenay Core Area (Hagen and Decker 2011).

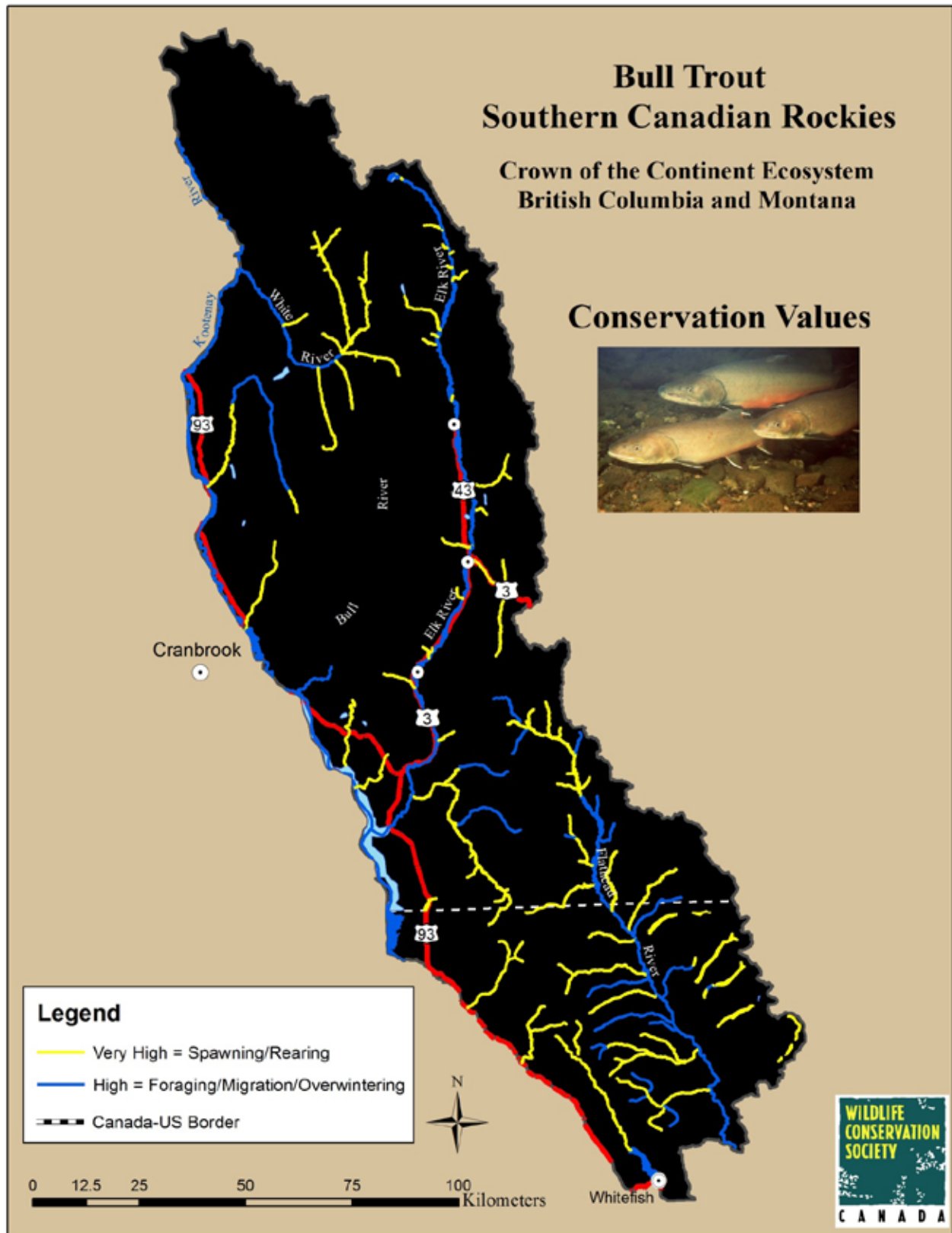
Nearly all these streams occur within ‘core areas’ for bull trout. The U.S. Fish and Wildlife Service identified ‘bull trout core areas’ which represent meta-populations (and their critical habitats) with demographic and genetic connections that function rather independently of other core populations (USFWS 2005). Using a standard methodology, USFWS identified 118 ‘bull

trout core areas’ across the western states for their conservation – including the North Fork Flathead and Graves Creek noted above (USFWS 2010). Following similar protocols, Hagen and Decker (2011) identified 115 core areas in British Columbia – including 4 in the Southern Canadian Rockies of British Columbia: (1) upper Flathead, (2) Koocanusa, (3) Elk, and (4) Upper Kootenay River containing streams noted above. Clearly, the Southern Canadian Rockies of British Columbia and Montana serve as a stronghold for the bull trout.

Table 1. Length (km) of streams and percentage of bull trout conservation values in watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Area	Very High CV (3)			High CV (2)		
		Length	% Area	% CV	Length	% Area	% CV
British Columbia	1,312,318	667	5.1	65.7	1022	7.8	84.5
Montana	385,479	348	9.0	34.3	187	4.8	15.5
TOTAL	1,697,797	1015	6.0	100.0	1209	7.1	100.0
Flathead	470,223	468	10.0	46.1	325	6.9	26.9
Lower Elk	289,938	190	6.6	18.7	172	5.9	14.2
Upper Elk	308,689	125	4.0	12.3	303	9.8	25.1
Bull	317,750	65	2.0	6.4	280	8.8	23.1
Palliser White	311,197	167	5.4	16.5	129	4.1	10.7
TOTAL	1,697,797	1015	6.0	100.0	1209	7.1	100.0

Figure 7. Location of key conservation values for bull trout in the Flathead, Wigwam, Elk, and White Rivers, Southern Canadian Rockies, British Columbia and Montana.



Westslope Cutthroat Trout



Photo: Michael Ready

Vulnerability Profile

Westslope cutthroat trout (WCT) is one of 15 recognized subspecies of native cutthroat trout in western North America (Behnke 2002). At present, genetically pure populations of westslope cutthroat trout occupy only about 10% of their historic range in the western United States (Shepard et al. 2005). This decline has been associated with introductions of non-native fish, habitat changes, and over-exploitation. In 1972, Montana Department of Fish, Wildlife and Parks (FWP) listed the westslope cutthroat trout as a State ‘species of special concern’, followed by a statewide Memorandum of Understanding and WCT Conservation Agreement in 1999. In British Columbia, westslope cutthroat trout were assessed as ‘species of special concern’ by COSEWIC in 2006 (http://www.cosewic.gc.ca/eng/sct1/SearchResult_e.cfm?commonName=cutthroat+trout&scienceName=&Submit=Submit).

Niche Flexibility: Like bull trout, westslope cutthroat trout also have stringent requirements for cold water. Laboratory studies suggest that optimum temperature for growth and long-term persistence in westslope cutthroat trout is about 13-15° C (55-59° F), whereas the upper lethal temperature is about 20° C (68° F) (Bear et al. 2007). Rainbow trout (RBT), a nonnative competitor and source of genetic introgression, have a greater capacity for growth at warmer temperatures and a higher upper limit of lethal temperature at 24° C (76° F) in the laboratory. In the North Fork Flathead River in Montana, non-hybridized westslope cutthroats were found in stream reaches where average summer temperatures ranged from 6.6°-11° C (44°-53° F) (Muhlfeld et al. 2009b). Brook trout, another non-native competitor, have similar optimum temperatures as westslope cutthroat trout but can tolerate a wider range of temperatures (Shepard 2010). WCT may grow faster than brook trout at their thermal optima, which would offer some resiliency to invasion within narrow thermal conditions (B. Shepard, WCS, *personal communication*).

Resistance to Hybridization: Westslope cutthroat trout have low resistance to hybridization and genetic introgression by non-native trout. Indeed, interbreeding between westslope cutthroat trout and rainbow trout and the resulting loss of genomic integrity is widely considered the greatest threat to the persistence of pure westslope cutthroat trout throughout their range (Shepard et al. 2005). Rainbow trout produce fertile offspring when crossed with cutthroat trout, resulting in genetic introgression. In early stages, populations may be comprised of admixtures of both hybrids and non-hybridized westslope cutthroats. But, in the absence of barriers, introgression often spreads until a hybrid swarm develops, and the native cutthroat genomes become extinct (Leary et al. 1995).

In the Flathead River drainage in northwest Montana, genetic introgression of native westslope cutthroat trout by rainbow trout spread rapidly between 1984 and 2004 (Hitt et al. 2003, Boyer et al. 2008). The source of rainbow trout appears to have been a singular source in the lower part of the drainage (Abbott Creek), with hybridization spreading upstream (Boyer et al. 2008). The spawning periods of both rainbow trout and especially hybrids overlap with those of native westslope cutthroats (Muhlfeld et al. 2009a). Westslope cutthroat trout migrated greater distances and spawned in headwater streams, whereas rainbow trout and hybrids spawned lower in the drainage. Hybridization was more likely to occur and spread in streams with warmer temperatures at lower elevations, increased number of roads crossing streams, and closer proximity to the main source of hybridization (Muhlfeld et al. 2009b). Although the amount of introgression decreases with greater distance from the source (isolation by distance), the spread of hybridization has been facilitated both by stepping-stone invasion and by long-distance dispersal and straying of hybrids and rainbow trout. Importantly, researchers have documented that as little as 20% hybridization can result in a 50% decline in reproductive success (Muhlfeld et al. 2009c). The conservation implication is that even low levels of genetic introgression may facilitate continued expansion of hybridization and place native cutthroat trout at risk, unless source populations of non-native trout are suppressed or eliminated.

In the upper Kootenay River area of southeast British Columbia, westslope cutthroat trout were isolated from rainbow trout in the lower Kootenay River for thousands of years by a large bedrock chute near Libby, Montana (Behnke 1992). The Libby Dam was constructed on that site in 1972, which created Koocanusa Reservoir. An average of 45,000 RBT was stocked per year in the reservoir between 1986 and 1998 (MDFWP 2001, MWLAP 2006 cited in Bennett and Kershner 2009). Although this stocking program ceased (or was replaced with WCT or triploid RBT) in 1999, a broad swarm of WCT-RBT hybrids has developed (Rubidge et al. 2001). Hybrids have dominated low-elevation sites and expanded into mid-elevation sites up to 80 km from Koocanusa Reservoir. Where natural barriers (with dams at site) have constrained the expansion of RBT and hybrids, the westslope cutthroat trout in the Elk River and Bull River have retained their genetic integrity (Rubidge and Taylor 2005, Bennett 2007, Bennett and Kershner 2009).

An interesting case of recovery-by-dilution has been documented. Summit Lake at Crowsnest Pass was stocked with 3,000-50,000 RBT per years for 20 years between 1939 and 1995 (MWLAP 2006). During years of high runoff, rainbow trout swept downstream into a tributary (Michel Creek) of the Elk River which resulted in some introgression of westslope cutthroat trout (6% hybrids: Rubidge et al. 2001). Recent monitoring, however, has indicated that this effect has been diluted over time (Bennett and Kershner 2009). Nonetheless, this case illustrates that RBT stocking of high-elevation lakes is a misguided practice that can facilitate the spread of hybridization downstream through much of the stream network (Adams et al. 2001). Bennett (2007) recommended a ban on stocking of any fertile rainbow trout. This is particularly critical to maintaining high genetic integrity of westslope cutthroat trout in the Elk River and Bull River drainages, which are the strongholds of native cutthroats in the Southern Canadian Rockies of B.C due to their natural (now dams) barriers.

In addition, brook trout are another widespread non-native species in the western United States (Dunham et al. 2002). They have a similar niche with cutthroat trout and can displace the natives in warmer waters at most elevations (Shepard 2010). Growth and reproductive success of the native cutthroats may decline, however, if confined to small, very cold headwater reaches (Coleman and Fausch 2007) and jeopardize their long-term viability (Fausch et al. 2009). Hence, barriers to prevent invasion by brook trout has become an important conservation strategy for preserving viable populations of westslope cutthroat trout (Shepard 2010), along with removal of non-native fish (Quist et al. 2004).

Dispersal and Connectivity: Various genetic studies have detected substantial genetic differentiation in westslope cutthroat trout among drainages; hence, it may be necessary to manage them separately to maintain genetic diversity across a region (beta-diversity) and its evolutionary legacy (Taylor et al. 2003, Drinan et al. 2011). Hence, translocation of WCT from 1 drainage to augment a population in another drainage could be detrimental to maintaining genetic diversity across the region.

The vulnerability of westslope cutthroat trout to genetic hybridization accentuates the trade-off dilemma between connectivity and isolation (Fausch et al. 2009). Theoretically, small and isolated populations have a greater likelihood of extirpation than those that are large and well-connected due both to systematic and random pressures (Gilpin and Hanski 1991). Consequently, a common conservation strategy is to promote connectivity between populations to facilitate both demographic and genetic exchange. In the case of stream fish, however, such connectivity also enables competition and genetic introgression by non-native species ... hence, the dilemma. Fausch et al. (2009) proposed a framework to explicitly examine the trade-offs in specific situations. Where non-native trout do not occur, fish biologists recommend maintaining large areas of interconnected habitats within drainages to furnish options for movements by juvenile fish, provide diverse habitats, and support migratory and resident life histories (Shepard 2010, Muhlfeld et al. 2012).

Sensitivity to Human Disturbance: The biggest human threat to native westslope cutthroat trout has been purposeful stocking of rainbow trout in the past (and continued illegal releases), resulting in loss of genetic integrity (Shepard et al. 2005). Westslope cutthroat are considered highly vulnerable to excessive take by angling (MacPhee 1966) but respond well to catch-and-release and closure regulations (Bjornn and Johnson 1978). Timber harvesting and associated roads and culverts can increase sedimentation into spawning streams, block access for trout, remove riparian cover and increase stream temperatures. Moreover, roads increase ready access for fish mortality by anglers. Agricultural practices can de-water streams, increase water temperature, degrade stream banks and increase sedimentation, and disrupt migrations. Mining and oil and gas activities can cause massive chemical pollution of streams and major mortality of fish.

Response to Climate Change: Like bull trout, westslope cutthroat trout appear quite vulnerable to myriad effects of climate change (Williams et al. 2009, Haak et al. 2010). Climate change is projected to have major effects on the hydrologic regime, including: decreased snowpack and more rain-on-snow events, accelerated melting of snow and earlier runoff in spring, increased flooding, and reduced recharge of groundwater and lower base flows. Increased warming and evapotranspiration will result in warmer stream temperatures in summer, longer periods of drought, as well as loss of shading cover along streams and increased sedimentation due to more wildfires. The net result of such changes will be warmer water and lower stream levels at low-mid elevations, particularly in late summer.

At the more northerly and higher elevation limits of cutthroat trout distribution, a warming climate may gradually improve habitat suitability and promote greater growth and recruitment (Sloat et al. 2005). However, warmer stream temperatures likely will enable rainbow trout to invade even further upstream, where they will compete and hybridize with westslope cutthroat trout (Dunham et al. 2003, Rahel and Olden 2008, Muhlfeld et al. 2009b). These warmer temperatures may also elevate the lower limits of suitable stream habitat for coldwater trout, thereby squeezing them between lower reaches that are too hot and upper reaches that are too small (Williams et al. 2009, Isaak et al. 2010). The net result would be continued shrinkage in habitat and population numbers, rendering them less resilient (Hilderbrand and Kershner 2000). Intense and widespread wildfires could have greater proportional impacts on these residual habitats and populations (Brown et al. 2001, Dunham et al. 2003, Haak et al. 2010).

Compared to other subspecies of cutthroat trout further south, westslope cutthroat trout populations in the Crown of the Continent region appear to be at less risk from climate change (but this varies). Haak et al. (2010) examined risk of 4 factors: increasing summer temperature, drought, wildfire, and flooding. Based upon their assessment, populations of westslope cutthroat trout at low to mid-elevations could become more vulnerable – especially if warmer and drier scenarios develop (e.g., North Fork Flathead River: Jones et al. 2013). Stress from climate change is likely to compound existing problems with genetic introgression of non-native trout.

Conclusion: Westslope cutthroat trout exhibit **high vulnerability** due to low resistance and resiliency to human impacts. They have a cold-water niche – especially for spawning and rearing – and low resistance to warming water. Moreover, westslope cutthroat have especially low resistance to invasion by non-native trout. Due to the wide-spread introduction of rainbow trout, many of the genetically-pure populations are now confined to headwater streams – where they have low growth and productivity. Westslope cutthroat trout are vulnerable to several detrimental effects of human activities associated with roads. Finally, climate change may counteract the thermal advantage niche of westslope cutthroat trout and lead to further isolation of smaller populations in headwaters. Two strategies appear useful: (1) safeguarding large, well-connected networks that retain genetically-pure populations of westslope cutthroat trout, and (2) stocking streams with natural barriers with genetically-pure specimens and/or installing barriers to protect selected cutthroat populations (Rahel et al. 2008).

Methods for Scoring Conservation Importance

Initially, locations of both historic and current records for westslope cutthroat trout (WCT) were obtained from the B.C. Fishery Summary System (FISS) data set compiled prior to the year 2000 and mapped at the 1:50,000 scale. Each fish point represents either a specific site where a fish species has been identified or the point (at the mouth) an entire stream in which the fish species is known to be present. In addition, we incorporated information from recent studies on genetic status of WCT in the Upper Kootenay River watershed (Rubidge 2003, Bennett and Kershner 2009). Next, we vetted this preliminary map with the regional fish habitat biologist in Cranbrook, B.C. for accuracy and updated information (H. Tepper, B.C. Ministry of Forests, Lands and Natural Resource Operations, *personal communication*). It should be noted that, in some cases, westslope cutthroat trout may occur higher up the tributary than mapped. For the trans-border Flathead River system, we mapped the most recent distribution based upon on-going research by Glacier National Park aquatic biologists and others (Muhlfeld et al. 2009a; C. Muhlfeld, USGS, *personal communication*).

Maintaining genetic integrity of westslope cutthroat trout in suitable cold-water habitat is widely considered to be a primary challenge in their conservation. The status assessment of westslope cutthroat trout designated populations with $\leq 10\%$ genetic introgression as ‘conservation populations’ (Shepard et al. 2005). Although including hybridized populations is subject to debate, some fish managers argue that elimination of any genetically-contaminated population might result in loss of unique phenotypic, genotypic, and behavioral variations (Dowling and Childs 1992). Others have recommended that only genetically pure populations of westslope cutthroat trout should be protected because this would best safeguard their evolutionary legacy, protect local adaptations presumed important for long-term persistence, and minimize opportunity for spread of introgression (Allendorf et al. 2004). Moreover, the best prospects for conservation of pure westslope cutthroat trout involve spacious watersheds (or upper portions) where large WCT populations can reside in genetic security (Hilderbrand and Kershner 2000).

Accordingly, I assigned the following importance scores for westslope cutthroat trout:

Very High (3) = populations of ≥ 99 % genetic purity at *watershed* scale

High (2) = populations of ≥ 99 % genetic integrity at stream scale

Moderate (1) = populations of ≥ 90 % but < 99 % genetic integrity

Key Conservation Areas

Approximately 2079 km of streams with *very high* conservation value and 447 km of *high* conservation value occur in the Southern Canadian Rockies of British Columbia and Montana (Table 2, Figure 8). The most important drainages for westslope cutthroat trout in the Southern Canadian Rockies are the (1) upper Flathead River (42.2%), (2) upper Elk River (36.9%), (3) Bull River (12.7%). These contain genetically-pure populations of WCT across large networks of interconnected streams secure from genetic invasion by rainbow trout. These represent the strongholds for this species in the region.

Trans-border Flathead River Watershed: In Montana, westslope cutthroat trout occur throughout the North Fork Flathead River watershed – albeit with a wide spectrum of genetic integrity (Figure 7). Most of the genetic introgression by non-native rainbow trout has occurred in the lower-elevation, warmer streams in the lower section of the drainage, which are closer to the main source of hybridization (Boyer et al. 2008, Muhlfeld et al. 2009b). Nonetheless, numerous streams in the upper section of the North Fork Flathead River in Montana still have pure strains of westslope cutthroat trout. Those streams with either headwaters and/or occupied reaches in roadless areas include: Trail Creek and several tributaries, Whale Creek and several tributaries, and Moose Creek. Red Meadow Creek has had genetically-pure WCT, but Red Meadow Lake may become a source of introgression (Muhlfeld et al. 2009a, Muhlfeld et al. 2009b). In the upper Flathead River in British Columbia, essentially all of the streams still harbour genetically-pure populations of westslope cutthroat trout. The trans-border Flathead River Watershed is considered a regional stronghold for westslope cutthroat trout.

Lower Elk River/Koocanusa Reservoir Watershed: Several streams in these watersheds have genetically-pure populations of westslope cutthroat trout but are accorded lower conservation value because they are open to invasion from rainbow trout/hybrids found in lower sections. In the Grave Creek drainage of the Kootenai River basin in Montana, WCT occur in the following streams: Williams Creek, upper section of Blue Sky Creek, upper Stahl Creek, Foundation Creek, above Frozen Lake, and Rich Creek (M. Hensler, Montana FWP, *personal communication*). In British Columbia, a similar situation exists in the lower Elk River, Lodgepole Creek, and Sand Creek.

Upper Elk River Watershed: In the upper Elk River in British Columbia, nearly all of the streams above Fernie still harbour genetically-pure populations of westslope cutthroat trout. Although WCT populations in Alexander Creek and Michel Creek were introgressed by RBT from Summit Lake, repeated sampling from 2000 to 2006 indicated that the level of introgression had decreased or stabilized with no or very few RBT or F₁ hybrids detected (Bennett and Kershner 2009). Upper Elk lake is a critical over-wintering location for westslope cutthroat trout. All of the Elk River above the dam is considered a regional stronghold for the species.

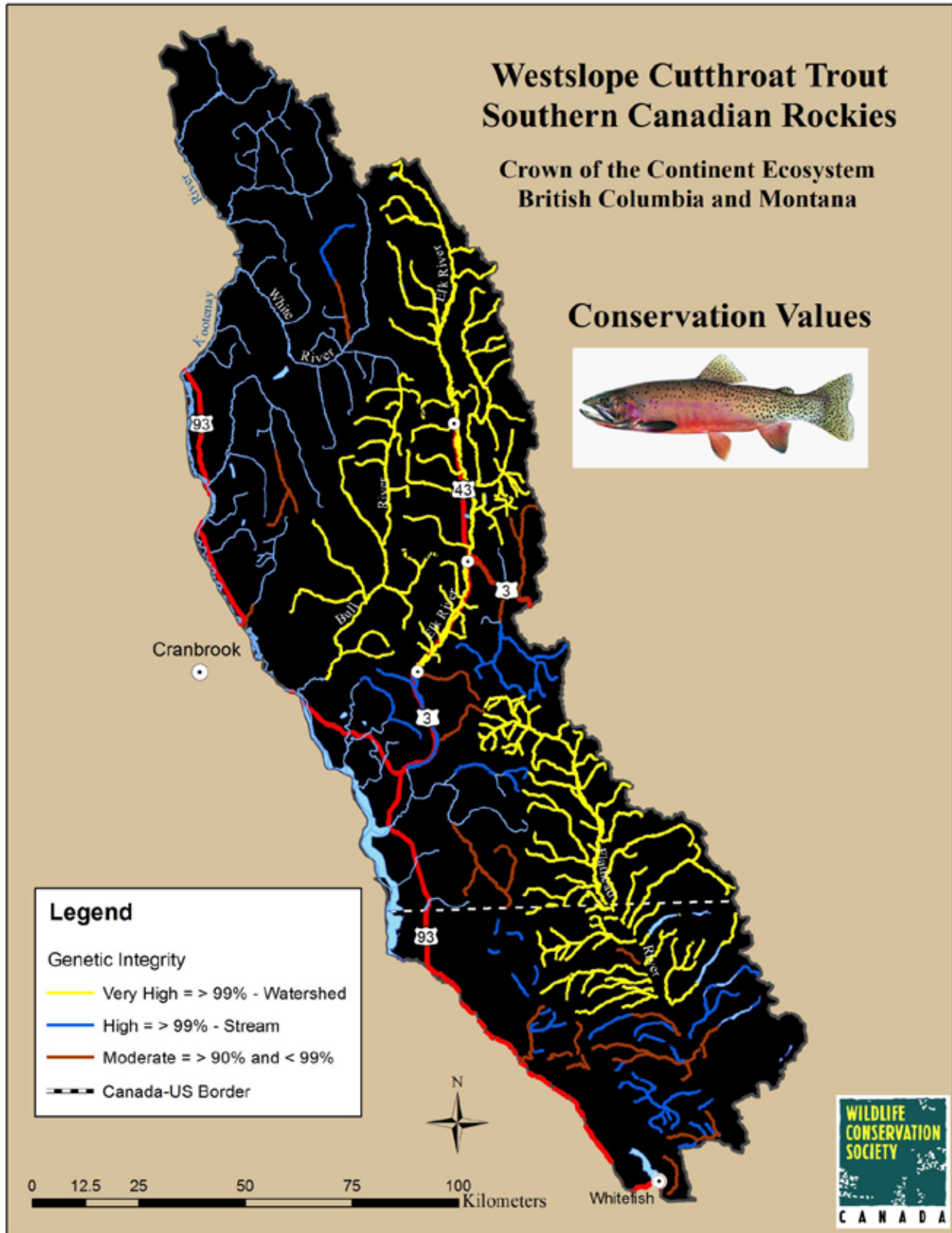
Bull River Watershed: All of the Bull River in British Columbia above the dam still harbours genetically-pure populations of westslope cutthroat trout (Baxter 2006, Bennett and Kershner 2009). All of the Bull River above the dam is considered a regional stronghold for the species.

Palliser-White River Watershed: Few streams in these watersheds have escaped invasion by rainbow trout. The upper reaches of North White River (above barrier) have an isolated population of genetically-pure westslope cutthroat trout.

Table 2. Length (km) of streams and percentage of westslope cutthroat trout conservation values in watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Area	Very High CV (3)		High CV (2)		Moderate CV (1)	
		Length	% CV	Length	% CV	Length	% CV
British Columbia	1,312,318	1776	85.4	237	53.0	247	60.1
Montana	385,479	303	14.6	210	47.0	164	39.9
TOTAL	1,697,797	2079	100.0	447	100.0	411	100.0
Flathead	470,223	898	42.4	186	41.6	164	39.8
Lower Elk	289,938	45	2.1	141	31.5	112	27.2
Upper Elk	308,689	851	40.2	96	21.5	73	17.7
Bull	317,750	325	15.3	0	0.0	40	9.7
Palliser White	311,197	0	0.0	24	5.4	23	5.6
TOTAL	1,697,797	2119	100.0	447	100.0	411	100.0

Figure 8. Location of key conservation values for westslope cutthroat trout in the trans-border Flathead, Elk, and Bull River watersheds, Southern Canadian Rockies, British Columbia and Montana.



Grizzly Bear



Photo: Milo Burcham

Vulnerability Profile

In the U.S., the grizzly bear is federally listed as a threatened species under the Endangered Species Act. In Canada, the western population of the grizzly bear (including British Columbia) was assessed as species of Special Concern by COSEWIC in both 2002 and 2012 but has not been listed under SARA (http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1195).

Niche Flexibility: Grizzly bears exhibit considerable flexibility in their foraging and habitat use over space and time (Schwartz et al. 2003a). Although grizzly bears in the Southern Canadian Rockies use a wide variety of foods, four main groups compose most of their diet: grasses and sedges, forbs and forb roots, berries, and mammals (including ungulates and rodents) (Craighead et al. 1982, Mace and Jonkel 1983, Hammer and Herrero 1987b, Aune and Kasworm 1989, McLellan and Hovey 1995, Nielsen et al. 2010). Here, grizzly bears fed on: (1) ungulates (usually carrion of winter-killed elk and moose or new-born calves), grasses and sedges, and glacier lily (*Erythronium grandiflorum*) bulbs and hedsarum (*Hedysarum* spp.) roots in spring; (2) grasses, horsetails (*Equisetum arvense*), forbs like cow parsnip (*Heracleum lanatum*) and angelica (*Angelica arguta*), and insects (ants, cutworm moth larvae) in summer; (3) huckleberries (*Vaccinium* spp.) and russet Huckleberries buffaloberries (*Shepherdia canadensis*) in late summer; and (4) berries, ungulates (gut-piles, weakened animals), and roots in fall.

There are several key habitats that provide 1 or more of these seasonally important foods. Avalanche chutes on steep mountain slopes produce a diversity of foods, including grasses, horsetail, glacier lily and cow-parsnip, and berry-producing shrubs such as serviceberry (*Amelanchier alnifolia*) in the lower and middle sections of the chute and huckleberry in the adjacent string-

ers of open conifer trees (Mace and Bissell 1985, McLellan and Hovey 2001a, Waller and Mace 1997, Ramcharita 2000). Various sections of the chute produce foods from early spring through summer and even autumn. Bears of each gender select for these avalanche chutes (Zager et al. 1983, Waller and Mace 1997, Apps et al. 2004, Apps et al. 2008, Serrouya et al. 2011), and they may be especially important to females with cubs-of-the-year who choose to reside in high, secluded basins in rugged terrain (McLellan and Hovey 2001, Theberge 2002).

Riparian areas adjacent to streams, lakes, and wetlands represent another critical habitat for grizzly bears, particularly during spring and again in fall. Key foods include grasses and sedges, horsetails, hedysarum, cow parsnip, buffaloberry, and occasional moose (Mace and Bissell 1985, McLellan and Hovey 2001).

Although bears consume a diverse array of foods during spring and early summer, they focus upon berries in late summer and fall for weight gain and fat deposition necessary for successful hibernation and reproduction (Rogers 1987). Two of the most important in the Rocky Mountains are huckleberry and buffaloberry (especially east of the Continental Divide) which, interestingly, provide high energy value but low protein leading to small but fat female bears (Welch et al. 1997, McLellan 2011). Both of these flourish on relatively open sites burned by wildfire between 20 and 80 years ago, depending upon fire intensity and site conditions (Martin 1983, Zager et al. 1983, Hamer and Herrero 1987a, Walkup 1991, Hamer 1996, Waller and Mace 1997, Simonin 2000, McLellan and Hovey 2001). However, berry production in both species varies greatly among years (Martinka and Kendall 1986, Hobby and Keefer 2010, B.N. McLellan and F.W. Hovey unpublished data, S.E. Nielsen unpublished data) which appears influenced by variable weather patterns (Holden et al. 2012). In the trans-border Flathead River basin, both huckleberry and buffaloberry occur which researchers believed may ameliorate shortfalls in berry production by either species (McLellan and Hovey 1995).

In the face of a shortfall in nutritious food, bears move widely in search of food – which may increase encounters with humans (Mattson et al. 1992). This substantially increases the risk of immediate human-caused mortality, management capture and translocation with problematic success, and food-conditioning or habituation which may lead to future problems (T. Manley and J. Jonkel, Montana FWP, *personal communication*). Diversity of foods enables switching by bears, which may contribute toward sustaining a relatively stable and high density grizzly bear population (McLellan and Hovey 1995).

Reproductive Capacity and Mortality Risk: Grizzly bears exhibit very low reproductive potential and cannot readily compensate for high mortality rates (Schwartz et al. 2003a). Females produce their first litters at approximately 4-8 years of age and are most productive between 8-25 years of age (Schwartz et al. 2003b). They average 2 cubs per litter, with an average interval between litters of 3 years, for an annual production of only 0.5 – 0.8 cubs per year. It's estimated that the average female grizzly bear may produce only 3-4 surviving daughters during a full lifetime. There is no conclusive evidence of a sharp reproductive response or increased survival of young that would compensate for increased mortality (McLellan 1994, Craighead et al. 1995).

Consequently, grizzly bear populations cannot absorb high mortality levels. Survival – particularly of adult females – is the most important factor influencing population growth and long-term viability of grizzly bear populations (Boyce et al. 2001). Specifically, annual survivorship of female grizzly bears should be $\geq 92\%$ to maintain stable populations (Eberhardt 1990, Garshelis et al. 2005), but this is a difficult and expensive metric to measure. Known mortality rates from human causes should not exceed 4%, with deaths of females not to exceed 30% of that level (US Fish & Wildlife Service 1993).

Most mortality of grizzly bears is human-caused, either from direct shooting or removal by agency personnel if bears become habituated (loss of wariness) or conditioned to human food and garbage (Mattson et al. 1996, McLellan et al. 1999, Gibeau et al. 2002, Benn et al. 2005). Across 13 study areas in the interior mountains of western North America, people killed 75% of 77 grizzly bears that died while radio-collared between 1975 and 1997 (McLellan et al. 1999). It was estimated that approximately half of the deaths would not have been detected without the aid of radio-collars.

This human-caused mortality of grizzly bears often occurs around human settlements and/or within 1 km of roads – especially where open roads are proximal to streams or avalanche chutes in spring and berry patches at lower elevations during late summer-fall (McLellan and Shackleton 1988, Mace et al. 1996, Nielsen et al. 2004, Herrero et al. 2005). As resource extraction (e.g., oil and gas exploration and development, logging, mining) and motorized recreation expands into hitherto remote areas, road construction provides entry for hunters, poachers, and new sources of food and garbage which elevates mortality risk. Of special concern is human access into areas of naturally rich habitat that attract bears into situations having high risk of mortality ('attractive sinks': Delibes et al. 2001, Nielsen et al. 2006, Ciarniello et al. 2007). 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 (Weaver et al. 1996, Gibeau et al. 2001, Herrero et al. 2005, Nielsen et al. 2006, Ciarniello et al. 2007, Nielsen et al. 2010).

Dispersal and Connectivity: Relatively little is known about dispersal in grizzly bears. Dispersal by young bears appears to be a gradual process over months or even years (McLellan and Hovey 2001b). Compared to many other carnivores, young grizzlies do not seem to disperse very far from their natal range. In the trans-boundary Flathead area, the average dispersal distance was 10 km for females (longest = 20 km) and 30 km for males (longest = 67 km) (McLellan and Hovey 2001b). Sub-adult females often establish home ranges that overlap their mother's. The implication is that female grizzly bears are unlikely to colonize disjunct areas even at modest distances.

In the Canada-US border region, Proctor et al. (2012) reported extensive genetic and demographic fragmentation that corresponded to settled mountain valleys and major east west highways. Both female and male bears reduced their movement rates with increasing settlement and traffic volume but at different thresholds. When human settlement increased to $>20\%$ along a fracture zone (e.g., river valley), female grizzlies reduced their movement rates sharply. Males

continued to cross these zones but at lower rates than less settled areas. In areas with >50% settlement, both females and males exhibited much reduced movements in response to traffic, settlement, and mortality. Only 1 female grizzly bear has been detected as a migrant across Highway 3 in the Southern Canadian Rockies of B.C. (Apps et al. 2007).

In contrast, researchers have documented 5 female and 7 male grizzlies crossing the Continental Divide between Alberta and British Columbia between Highway 3 and the US border. Enough movements by male bears may mediate gene flow for now, but the low rate of female grizzly bear movements appears insufficient to augment a declining population or colonize one that has been extirpated. Hence, fragmentation of south north connectivity is a real conservation concern. Proctor et al. (2012) recommended (1) securing key linkage habitats across fracture zones that would enable connectivity for female bears, and (2) maintaining large core populations as sources of dispersers.

Sensitivity to Human Disturbance: Grizzly bears are vulnerable to human disturbance at different spatial and temporal scales. Earlier studies indicated that grizzly bears avoid roads 100-900 m away and human settlements even further (Mattson 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Apps et al. 2004). The *type* of human activity on a road may affect grizzly bear use. In the trans-border Selkirk Mountains, most of the radio-collared females and males selected against roads open to the general public (Wielgus et al. 2002). Most female bears also selected against roads closed to the public, perhaps because they were in the general vicinity of open roads. But neither female nor male bears selected against restricted roads open to forestry-use only where people were working at a focal site.

In terms of displacement, the *volume of vehicle* traffic may be as important as the road itself. In western Montana, Mace et al. (1996) reported that all collared bears avoided areas within 500 m of roads having >60 vehicles per day. For roads having 11-60 vehicles per day, the majority of sample bears avoided areas within 500 m during spring (7/11), summer (6/10), and fall (8/9). For roads with 10 or fewer vehicles per day, some bears avoided while others did not. In southwest Alberta, Northrup et al. (2012) reported similar findings for bear use within 500 m of roads: (1) for roads with *low* traffic volume (<20 vehicles per 24 hr), bears used areas at night (even crossing roads); but (2) bears avoided or strongly avoided roads with moderate (20-100 vehicles per 24 hr) and high (>100 vehicles per day), respectively. Gated roads had the lowest traffic volumes of any roads. Female brown bears have used steeper slopes and/or nighttime activity in response to human activities (Martin et al. 2010).

At a larger spatial scale of composite home ranges (CHR), road density was lower (0.6 km/km²) within the CHR of adult female bears than outside (1.1 km/km²) in the Swan Mountains of western Montana (Mace et al. 1996). Approximately 50% of their CHR was un-roaded and >80% of their telemetry locations occurred in blocks of undisturbed habitat > 9 km². Many land and resource agencies have embraced the conservation target: core habitat should have road densities below 0.6 km/km². Northrup et al. (2012) suggested that this should be amended as follows: to mandate that the majority of these roads should have low volume (<20 vehicles per 24 hr period).

Grizzly bear populations can live in large areas that contain some roads and certain kinds of human activities (e.g., McLellan and Shackleton 1988, Mace et al. 1996). Yet, some bears will be displaced from some key habitats and incur direct mortality and/or non-lethal conflicts with humans that result in their eventual removal from the population (Mattson et al. 1996, Herrero et al. 2005). Overall, both the history of grizzly bears in the lower 48 states where grizzly bears have lost 99% of their historical range (Mattson and Merrill 2002) and contemporary studies (Mace et al. 1996, Theberge 2002, Apps et al. 2004) indicate that grizzly bear populations persist longer in areas secure from human settlement and *motorized* access and associated mortality (Gibeau et al. 2001, Nielsen et al. 2006).

Response to Climate Change: With their general resourcefulness and wide-ranging ability, grizzly bears would seem capable of adapting to direct effects of climate change (Servheen and Cross 2010). The most likely ecological effects of warming climate in the Southern Canadian Rockies may be greater plant productivity in currently cold sites and greater extent of berry-producing shrubs due to greater frequency of forest fires (depending upon intensity). On the other hand, less snow could mean decreased avalanche activity. Perhaps the largest implication of climate change, though, is the extent to which humans will (1) migrate into the Southern Canadian Rockies as a response to more intense climate change (heat, drought, sea rise) elsewhere, and (2) expand development in a scramble for dwindling fossil-fuel and water resources. Ever-increasing numbers of people across the landscape would only exacerbate current challenges of habitat fragmentation and mortality risk.

Conclusion: Despite their resourcefulness, grizzly bears exhibit **high vulnerability** due to low population resiliency. They require secure access to quality forage in spring and late summer – fall, but roads with moderate traffic volume can displace bears from key habitats. Young females do not disperse very far and adult females do not readily cross major highways, which makes bear populations susceptible to landscape fragmentation. Most importantly, bears have very low reproduction and cannot quickly compensate for excessive mortality. Numerous studies have demonstrated that road access into high-quality habitats can increase encounter rates with people and lead to displacement, habituation, or mortality. Altogether, this does not provide much resiliency in human-dominated landscapes.

Methods for Scoring Conservation Importance

The key to successful grizzly bear conservation is to manage both from the bottom-up for secure access to important food resources and from the top-down for lower risk of human-caused mortality (Weaver et al. 1986, Nielsen et al. 2010). I combined data and maps of (1) high-quality habitat components as well as (2) zones of mortality risk around roads and settlements. To map habitat for grizzly bears, I devised a model that incorporates key habitat components where grizzly bears direct their foraging at various seasons. Key habitat components included riparian zones, avalanche chutes, patches of huckleberry resulting largely from fires, and subalpine basins (see synopsis under *Niche Flexibility*). Although I

initially modeled and mapped buffaloberry (or soapberry), it did not appear to contribute much explanatory power west of the Continental Divide and was deleted from this model.

To delineate riparian habitats, I mapped rivers and tributary streams having the following attributes: low stream gradient (0-3%), moderate-high stream sinuosity, multiple channels, and/or abandoned oxbows/meanders. I placed a grid of 1-km² cells across the assessment area (total = 16,797 grid cells) and inspected each cell using on-line Bing aerial photographs at scales down to 1:5,000. I buffered the edge of the stream on each side by 200m to capture the associated wetlands and riparian forests.

Using the same approach and on-line aerial photography, I inspected each 1-km² cell for presence (rather than the total number) of avalanche chutes with a clear path of green vegetation between stringers of trees. In the few areas where an aerial image was partially obscured, I inspected topographic maps down to 1:5,000 scale for steep, open areas with the shape of avalanche chutes. I did not map chutes that appeared to be primarily composed of rock rubble nor the 'head' of the chute if it appeared barren. I measured the width of the chute at the broadest point and tallied whether it was < or ≥ 100 m because there is some suggestion that bears select the wider chutes (Serrouya et al. 2011). I evaluated this mapping approach by comparing it to a surficial geology map of Glacier National Park (Carrara 1990) and found that I had identified all the avalanche chutes delineated on that map.

The most productive huckleberry sites typically are found on relatively open, mesic sites at mid-high elevations 20-80 years of age, often following a fire (Martin 1983, Simonin 2000). Huckleberries occur in avalanche chutes and/or the adjacent forest stringers, too. Logged sites can be productive for shorter duration if the ground has not been scarified and heavily planted (Zager et al. 1983). I developed a model of huckleberry distribution using the following variables and parameters gleaned from various studies (Pfister et al. 1977, Martin 1983, compilation in Simonin 2000, Hobby and Keefer 2010):

Table 3. Variables and parameters used for modeling occurrence of huckleberry (*Vaccinium membranaceum*/ *V. globulare*) in Southern Canadian Rockies, British Columbia and Montana.

Variable	Parameter
Elevation	1200 - 1999 m
Age of Forest Stand	20 - 80 years
Canopy Closure	6 - 30 %
Aspect	NW (315°) → SE (135°)

Remote, subalpine basins surrounded by rugged terrain can serve as landscape refugia where, in particular, adult females with young cubs may reside – perhaps to avoid male bears and/or humans (Theberge 2002, Apps et al. 2004, M. Gibeau personal communication). I mapped these basins using a DEM to identify pixels between 1600 – 2100 m in elevation with slope between 0-5 percent, sites which typically are surrounded by rugged terrain.

This simple habitat model performed well based upon the following evaluation:

1. 85.5% of 1041 locations of radio-collared grizzly bears in the upper Elk River watershed of B.C. (data from the Eastern Slopes Grizzly Bear Project kindly provided M. Gibeau), and
2. 94.8 % of 313 grizzly bear scent-station sites during various inventory surveys in 1997-2007 in the upper Elk River and North Fork Flathead River watersheds (Boulanger 2001, Apps et al. 2007, Grizzly Bear Inventory Team 2008, Kendall et al. 2009).

Finally, I created a security-zone map by buffering all highways, primary roads, and secondary roads by 500 m on each side (Mace et al. 1996, Northrup et al. 2012). Areas ≤ 500 m from such roads were defined as low security, whereas areas ≥ 500 m was deemed high security (Gibeau et al. 2001). I categorized riparian zones, avalanche chutes, and huckleberry patches as high habitat quality and the landscape refugia as moderate quality habitat.

With these GIS layers, I mapped and scored each 1-km² grid cell (following Nielsen et al. 2006):

1. primary habitats or 'safe harbours' (high-quality habitat and high security) = score of 3
2. secondary habitats (moderate-quality habitat and high security) = score of 2
3. 'attractive sinks' (high or moderate-quality habitats but low security) = score of 1.

Such an approach facilitates identification of conservation areas for grizzly bears (and non-critical areas) and enables managers to target *strategic* sites to improve security by modifying motorized access.

Key Conservation Areas

First, I describe key areas for each of the habitat components because grizzly bears use them at specific seasons (Figure 9). Areas with a notable extent of riparian habitat include (south→north): nearly all of the Flathead River (truly remarkable) and tributaries Kishinena Creek, Sage Creek, and Howell Creek; Wigwam Creek; nearly all of the Elk River (section north of Elkford less impacted) and Cadorna Creek; North Fork of the White River; Palliser River (middle sections); and Cross River.

Avalanche chutes are rather widely distributed throughout the rugged mountainous sections of the Southern Canadian Rockies. But some areas of concentration include (south→north): northwest and northeast portions of the upper Flathead River; Lizard Range west of Fernie; throughout the mountains west of the upper Elk River; west of the upper Bull River; west of the North Fork White River; and between the Palliser and Cross River.

The distribution of huckleberry patches closely tracks the history of fires in this part of the Southern Canadian Rockies, particularly those that burned 1933-1992 and even some in the 1919-1932 era (fire map courtesy of S. Nielsen, University of Alberta). The greatest extent of huckleberry appears concentrated in the Flathead River watershed including Glacier National Park, the Whitefish Range, and portions of the Canadian Flathead. Huckleberry patches also appear common in the mountains flanking either side of Hwy 3 between

Fernie and Sparwood. By comparison, huckleberry occurrence appears sparse through the Palliser, White, and Cross River watersheds as fires there have been limited and sporadic during the past century. Far fewer fires burned during the 1940s-1970s due to a combination of cool, wet climatic conditions and fire suppression policies.

Subalpine basins occur at higher elevations throughout the Southern Canadian Rockies but are most common in the Flathead River and Elk River watersheds and the area between the Bull River and the Lussier River.

Areas of high and moderate habitat value within zones of high security from human-caused displacement and mortality are the landscape foundations of grizzly bear viability. Areas having high habitat and high security value received the highest score of 3 and occurred on 411,025 ha or 24.2 % (Table 4) (Figure 10). Moderate habitat values within secure zones occurred on another 238, 871 ha or 14.1 % – these received a high score of 2 and often adjoined grid cells of higher value. Together, these vital areas covered 649, 896 ha or 38.3 % of the Southern Canadian Rockies of B.C. and Montana.

Areas assigned a moderate conservation score are also quite important as they represent potential *attractive sinks* (sensu Nielsen et al. 2006). These are sites having high or moderate habitat value but occur near roads, where the risk of human-caused mortality is considerably greater. Due to the wide-spread occurrence of roads in the Southern Canadian Rockies, there are 335, 329 ha or 19.7 % of the area with higher risk.

Table 4. Amount (ha) and percentages of grizzly bear conservation values (CV) by watershed in the Southern Canadian Rockies, British Columbia and Montana. CV3 = very high-high habitat values and high security, CV2 = moderate habitat values and high security, and CV1 = very high-high habitat values but low security.

Watershed	Area (ha)	Very High CV (3)		High CV (2)		Mod CV (1)		All CV
		Area	% Area	Area	% Area	Area	% Area	% CV
B.C.	1,312,318	294,236	22.4	195,635	14.9	268,094	20.4	76.9
Montana	385,479	116,789	30.3	43,236	11.2	67,235	17.4	23.1
TOTAL	1,697,797	411,025	24.2	238,871	14.1	335,329	19.7	100.0
S Hwy 3	748,955	226,269	30.6	97,461	13.0	169,353	22.6	50.0
N Hwy 3	948,842	184,756	19.5	141,410	14.9	165,976	17.5	50.0
TOTAL	1,697,797	411,025	24.2	238,871	14.1	335,329	19.7	100.0
Flathead	470,249	159,824	34.0	59,792	12.7	113,784	24.2	33.8
Lower Elk	289,938	62,330	21.5	36,215	12.5	41,961	14.5	14.3
Upper Elk	308,691	74,061	24.0	55,795	18.1	83,432	27.0	21.6
Bull	317,750	56,270	17.7	42,508	13.4	53,863	17.0	15.5
PalliserWhite	311,197	58,539	18.8	44,562	14.3	42,289	13.6	14.8
TOTAL	1,697,825	411,025	24.2	238,871	14.1	335,329	19.7	985,225

Figure 9. Location of key habitat components for grizzly bears, Southern Canadian Rockies, British Columbia and Montana.

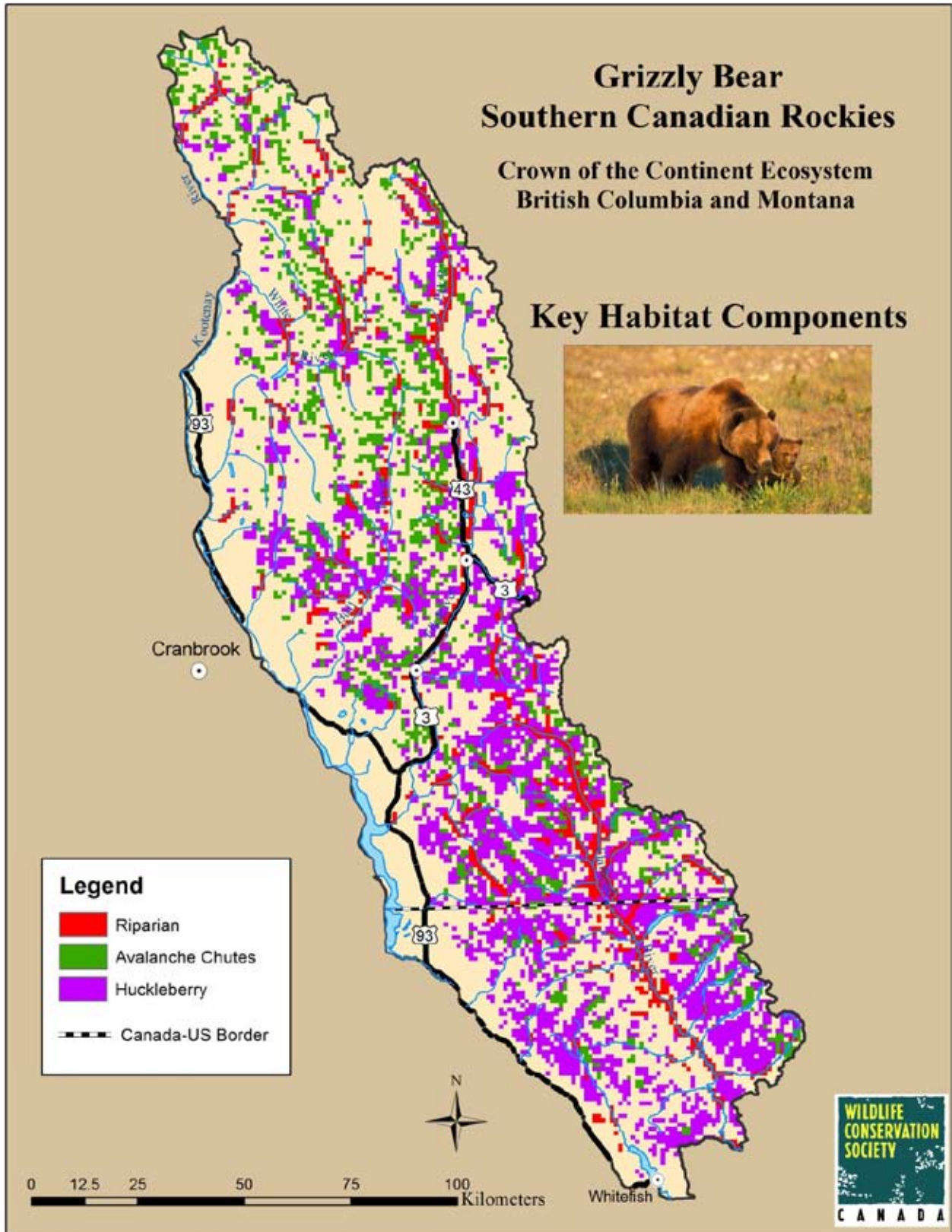
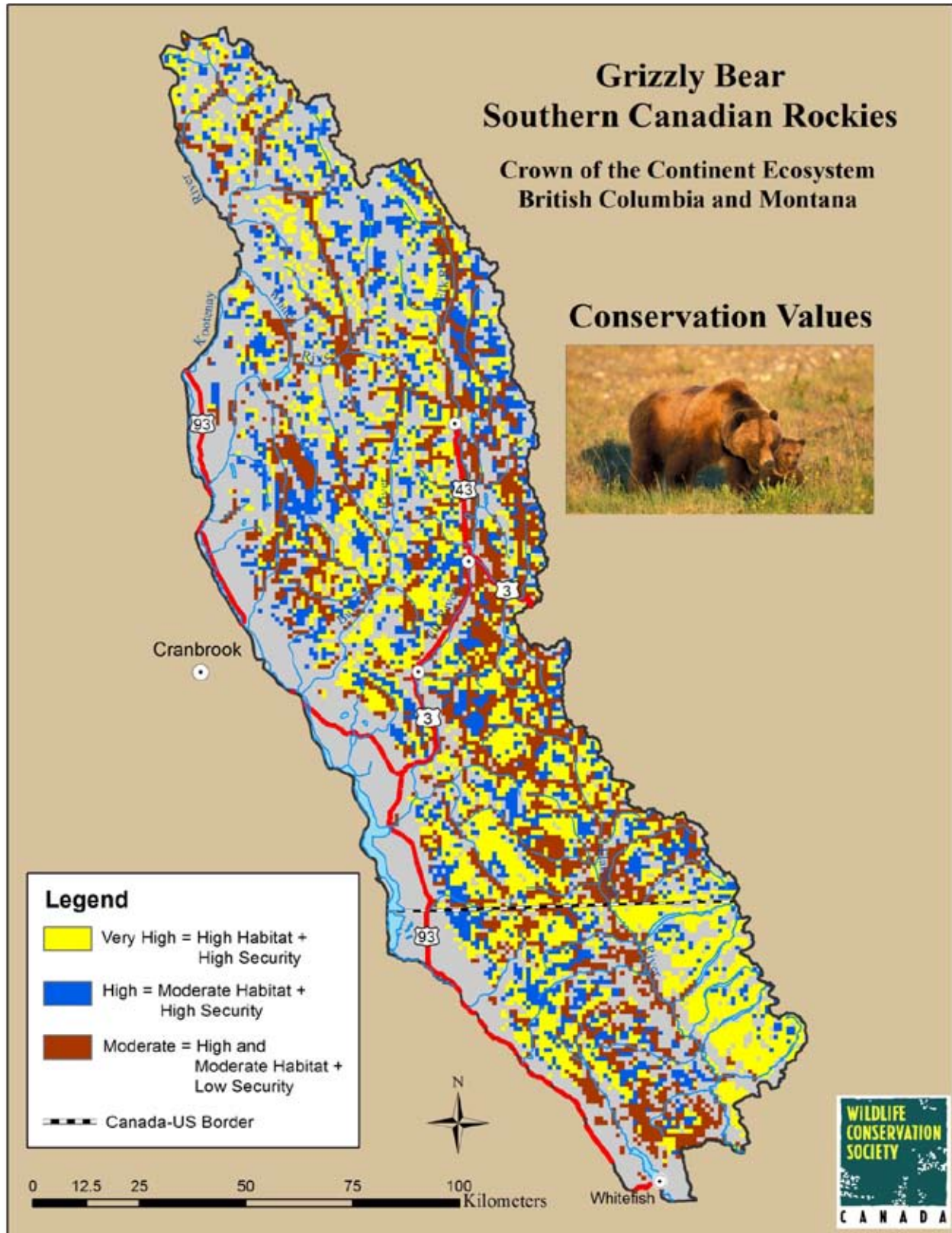


Figure 10. Location of key conservation values for grizzly bears, Southern Canadian Rockies, British Columbia and Montana.



It's possible that some of these roads may have very low traffic volume during some seasons – especially those further from the paved highways (Hwy 3, 43, and 93). For example, grizzly bears travel across the valley bottom of the B.C. Flathead River where there are many miles of logging roads but a 2-hour drive from Hwy 3 (B. McLellan, personal communication). Nonetheless, traffic volume increases during the hunting season on many of these roads, which adds risk of mortality. Numerous studies have called for greater precautionary management of human access into grizzly country (Weaver et al. 1996, Mace et al. 1996, Mattson et al. 1996, Gibeau et al. 2001, Herrero et al. 2005, Nielsen et al. 2010, Northrup et al. 2011). These attractive sinks represent opportunities for the astute land manager to raise the conservation score (from 1 to 2 or 3) by strategically closing selected roads and reducing risk.

Trans-border Flathead River Watershed: The highest densities of grizzly bears reported for interior North America occur here (Hovey and McLellan 1996, Kendall et al. 2009). This watershed has the greatest proportion (34%) of land in the *very high* conservation category. It also has substantial proportion (24.2%) in the *attractive sink* category. Conservation values for grizzly bear are high throughout much of the North Fork Flathead River basin, especially on the Canadian side – which is notable for its lack of human settlements. Larger patches of core area include:

- west side of Glacier National Park;
- roadless areas of the Whitefish Range in Montana including: Thoma-Mount Hefty, Tuchuck, Mount Thompson-Seton south to Lake Mountain, headwaters of Hay Creek and Coal Creek;
- much of the Flathead River watershed in British Columbia, including larger riparian zones along the Flathead River itself, upper Sage Creek, Middle Pass and Packsaddle Creeks, upper Cabin Creek, Howell and 29-mile Creeks, and the headwaters of the Flathead River.
- along the Continental Divide, the following mountain passes are used by grizzly bears moving between Alberta and British Columbia: Sage, South Kootenay, Middle Kootenay, and North Kootenay.

Lower Elk River/Koocanusa Reservoir Watershed: About 21% of its lands have *very high* conservation value; notable areas include:

- in Montana, roadless areas on the west side of the Whitefish Range and the Ten Lakes Scenic Area (also Stahl Peak and Wam Peak) on the Kootenai National Forest;
- in British Columbia, much of the east side of the Wigwam River basin adjoining the Flathead River basin and some of the Galton Range on the west side of the upper Wigwam River;
- Mount Broadwood, Kikomun Creek, Sand Creeks and the Lizard Range west of the Fernie ski hill.

Upper Elk River Watershed: This is the second-most important watershed for grizzly bears in the Southern Canadian Rockies. It has 24% of *very high* and another 18% of *high* conservation values. Although some of its substantial percentage (27%) of *attractive sink* habitat occurs along the highways, many of the tributary valleys to the upper Elk River have long roads. Much of the area is very rugged, with lots of avalanche chutes and remote subalpine basins. Key core areas include:

- East of Highway 3, upper Leach Creek and upper Michel Creek adjoining the upper Flathead;
- Nearly all of the high country flanking the west side of the Elk River from Fernie north all the way to Elk Lakes/Height of the Rockies Provincial Parks; more specifically Fairy Creek-Mount Proctor and Kuleski- Lladner Creek north of Fernie, Cummings Creek and Weigert Creek west of Sparwood, the 'Hornaday Wilderness' area from Brule Creek north to Crossing Creek, and Bingay Creek-Abbey Ridge-Quarry Creek.
- East of the upper Elk River - Alexander Creek, upper Fording Creek, and from Aldridge Creek north to Elk Pass;
- Along the Continental Divide, the following mountain passes are important conduits for grizzly bears moving between Alberta and British Columbia: Tent Mountain Pass and Ptolemy Pass, Racehorse Pass and Deadman Pass, Weary Gap and Fording Pass, and Elk Pass/ Tobermory Pass.

Bull River Watershed: Overall, this watershed has lower values for grizzly bears with about 18% in *very high* and 13% in *high* conservation value. Some important core areas include:

- along the east side - Iron Creek and Sulphur Creek and near the Bull River headwaters;
- on the west side of Bull River – area between Galbraith Creek and Quinn Creek, and smaller headwater tributaries up toward Munro Lake.

Palliser-White River Watershed: Similarly, this watershed has lower values for grizzly bears with about 19% in *very high* and 14% in *high* conservation value. Some important core areas include:

- in the White River watershed, area between Elk Creek and North White River and headwaters of Middle White River;
- Schofield Creek and upper Palliser River basin above Joffre Creek;
- Tangle Peak complex of high ridges and Mount Docking in the Cross River watershed;
- upper valleys and basins of Cross and Albert Rivers;
- along the Continental Divide, the following mountain passes are important routes for grizzly bears moving between British Columbia and Banff National Park and Provincial Parks: North Kananaskis Pass and South Kananaskis Pass, Palliser Pass, Leman Pass (Albert River), and Marvel Pass (east Assiniboine Creek).

Wolverine



Photo: Larry Master

Vulnerability Profile

The wolverine was proposed for federal listing as a ‘threatened’ species under the Endangered Species Act on February 4, 2013 (USFWS 2013). The western population of wolverine (including those in British Columbia), was assessed by COSEWIC as ‘species of special concern’ in 2003 but has not been listed under the Species At Risk Act (SARA).

Niche Flexibility: Wolverines are opportunistic, generalist feeders that exhibit broad regional and seasonal flexibility in their diet (Copeland and Whitman 2003). Comparatively little is known about their summer diet, but they likely use a variety of foods including ground squirrels and marmots, ungulate carrion, microtines, birds, and berries (Magoun 1987, Lofroth et al. 2007, Dalerum et al. 2009). With their traditional burrow sites and early emergence of young, marmots may comprise an important prey in late spring and summer for female wolverines raising young kits (Copeland and Yates 2006, Lofroth et al. 2007, Inman et al. 2012a). For the remainder of the year, wolverines subsist largely on carrion and occasional kills of ungulates (moose, caribou, mountain goats, elk, and deer) (Hornocker and Hash 1981, Magoun 1987, Banci 1987, Lofroth et al. 2007). Other carnivores such as wolves may be important provisioners of carrion (Banci 1987, Van Dijk et al. 2008), but there may be a tradeoff for wolverines between scavenging the food resource and avoiding competition and predation with larger predators (Inman et al. 2012b).

In the western U.S. and Canada, wolverines occur primarily at higher elevations in the subalpine and alpine life zones (Aubry et al. 2007, Copeland et al. 2007, Krebs et al. 2007, Inman 2013). Several researchers have pointed out the strong concordance of wolverine occurrence and persistence of snow cover during spring (mid-April thru mid-May), which covers the end of wolverine denning period (Aubry et al. 2007, Copeland et al. 2010). Female wolverines dig long tunnels in the snow (and under fallen trees/large boulders in the snowpack)

for birthing ('natal' dens) and early rearing of kits ('maternal' dens) and may re-use the same sites in subsequent years (Magoun and Copeland 1998, Copeland and Yates 2006). It's postulated that these snow dens provide thermal insulation and refuge from predators, which aids survival of the young. Later in summer, females 'park' their young at 'rendezvous sites' in talus fields composed of large boulders, often in subalpine cirque basins (Copeland and Yates 2006, Chadwick 2010). Based upon 3917 radio locations of wolverines recorded from 5 study areas in Montana, Idaho, and Wyoming, about 88% of summer locations and 84% of winter locations fell within areas covered by snow during the spring period (calculated from data in Copeland et al. 2010). Nonetheless, certain areas with persistent snow cover may not be occupied by wolverines. Additional factors such as latitude-adjusted elevation and terrain ruggedness also help explain habitat selection by wolverines (Inman 2013). Researchers have offered a 'refrigeration-zone' hypothesis which suggests that caching foods in cold micro-sites allows them to reduce competition from insects/bacteria/other scavengers and extend availability of scarce food resources (Inman et al. 2012a).

With their large plantigrade feet, compact body, and dense fur, wolverines are well adapted to travel and live in snowy environments, which may offer them a competitive advantage over other carnivores (Copeland and Whitman 2003, Inman et al. 2012a). In such low-productivity environments, though, wolverines must range widely in constant search for food (Chadwick 2010). Thus, their home ranges are large relative to their body size, with average annual home ranges (MCP and adaptive kernel methods) of 280 - 400 km² for adult females and 772 - 1,525 km² for adult males (Hornocker and Hash 1981, Copeland 1996, Krebs et al. 2007, Inman et al. 2012b).

Reproductive Capacity and Mortality Risk: Wolverines have a very low reproductive rate, which may reflect the tenuous nutritional regime for this scavenger. Based upon post-mortem analyses of trapped wolverines, an average of 63% of females (range of averages 50-85%) had fetuses at 2+ years of age (nearly 3-yr-old) (Rausch and Pearson 1972, Liskop et al. 1981, Magoun 1985, Banci and Harestad 1988, Anderson and Aune 2008). Based upon field monitoring of 56 adult female wolverines in Scandinavia during 141 reproductive seasons, Persson et al. (2006) reported an average age at first reproduction of 3.4 years. Percent of adult females (≥ 3 years) pregnant in any year in the lab studies varied from 73% to 92%, and average litter size *in utero* varied from 2.2 to 3.5 kits. In the Scandinavian study, an average of 53 % of adult females reproduced (yearly average was 58%), with average litter size of 1.88. Availability of food in the current winter (a variable commodity) influences reproduction by females and a poor winter can affect reproduction in the subsequent year, too (Persson 2005). The net result is low annual production, usually <1.0 offspring per adult female (Copeland and Whitman 2003, Persson et al. 2006). Few female wolverines in the wild are likely to reproduce past the age of 8 years (Rausch and Pearson 1972). Given average parameters and assuming annual survivorship of 0.50 for COYs/Sub-adults and 0.80 for adult females (Krebs et al. 2004, Squires et al. 2007), the average female wolverine may only produce one-two female offspring during her lifetime that survive to reproduce. This is very low, even compared to other large carnivores (Weaver et al. 1996).

maturity (Vangen et al. 2001, Dalerum et al. 2007, Inman et al. 2012b). If the territory of a resident adult female becomes vacant, often her daughter will take over that space (Vangen et al. 2001). Using both mitochondrial DNA (maternal-only) and nuclear microsatellite DNA, researchers reported that male gene flow predominated and female gene flow was restricted at the southern portion of their range (Cegelski et al. 2006).

The genetically-effective population size (the number of individuals actually involved in breeding, in contrast to the total number of animals) for wolverines in the northern U.S. Rocky Mountains has been estimated at only 35 individuals (range 28-52) (Schwartz et al. 2009). Due to such low effective population size and the patchy, 'island-like' distribution of suitable wolverine habitat in the Rocky Mountains, maintaining landscape connectivity that facilitates demographic and genetic interchange among sub-populations will be crucial to ensuring the viability of the larger meta-population (Schwartz et al. 2009, Inman 2013). Researchers have found that areas with persistent snow cover during late spring and sparse human footprint (housing density) characterize the least-cost pathways for successful gene flow among sub-populations of wolverines across the northern U.S. Rocky Mountains (Balkenhol et al. 2009, Schwartz et al. 2009, Rainey 2012, Inman 2013).

Sensitivity to Human Disturbance: Wolverines are vulnerable to human disturbance in several ways. Maternal female wolverines appear sensitive to human activity near maternal dens and rendezvous sites, which are used February through June (Magoun and Copeland 1998). With the advent of more powerful snow machines as well as heli-skiing, one concern is that such motorized access could disturb maternal females and young during the critical late winter and spring period. Major highways can have a significant impact on wolverine movements, too. In winter, wolverines avoided areas within 100 m of the Trans Canada Highway between Yoho and Banff National Parks and preferred areas >1100 m away from the highway (Austin 1998). Wolverines made repeated approaches and retreats and only crossed 3 of 6 times. Obviously, such major highways may fragment habitat and restrict movements and associated gene flow (Packila et al. 2007, Rainey 2012). In other areas, wolverines have crossed major highways – with upwards of 4,000 vehicles per day (Packila et al. 2007).

Response to Climate Change: Wolverines may be especially sensitive to climate change. As noted, the broad distribution of wolverines, their foraging and reproductive ecology, and travel routes associated with successful dispersal seem strongly linked to areas characterized by persistent snow cover during spring (Aubry et al. 2007, Schwartz et al. 2009, Copeland et al. 2010, McKelvey et al. 2011, Inman et al. 2012a). Moreover, 90% of 1474 wolverine locations during summer in the northern U.S. Rocky Mountains occurred in areas with average maximum temperatures during August <73° F (22.8° C) (calculated from data in Copeland et al. 2010). This is consistent with the hypothesis that wolverines select cooler habitats at higher elevations during hot summer months in the southern sector of their range. Warming climate could impact the ecology and populations of wolverines' alpine prey such as hoary

marmots (Lofroth et al. 2007) and reduce the abundance of ungulate carrion due to milder winter conditions (Wilmers and Post 2006). Some of the biggest changes wrought by global warming may be alterations to mountain snowpack. Recent warming has already led to substantial reductions in spring snow cover in the mountains of western North America (Mote et al. 2005, Pederson et al. 2010). Future projections under various scenarios through the year 2040 suggest this trend will continue, notably at low to mid-elevations (Pederson et al. 2011). Some researchers estimate that the extent of persistent snow cover in spring could decrease by 23% (McKelvey et al. 2011). Wolverines will be quite vulnerable to such changes, with likely reductions in the size of suitable habitat patches, loss of connectivity, and reduced effectiveness of its caching strategy to extend food availability.

Conclusion: Wolverines exhibit **high vulnerability** due to low resiliency. Although they have a broad foraging niche, their selection for reproductive habitat, summer habitat, and dispersal routes is closely linked to areas characterized by persistence of snow cover during spring. Wolverines have extremely low reproductive rates. Consequently, they cannot sustain high mortality rates, which can be exacerbated by trapping pressure – especially in areas of disjunct habitat patches. Trapping also may obviate the likelihood of successful dispersal by juvenile wolverines, which could be important to the viability of regional populations. Wolverines appear sensitive to human disturbance near natal den sites, and major highways may impede movements leading to fragmentation. Due to their multi-faceted adaptation to snow environments, wolverines appear particularly vulnerable to reductions in suitable habitat as a result of projected climate change.

Methods for Scoring Conservation Importance

I identified key conservation areas for wolverines by using 2 verified models that predict suitable habitat. The ‘Copeland’ model uses snow cover to predict geographic occurrence of wolverines across its circumboreal range (Copeland et al. 2010). These investigators developed a composite of MODIS satellite images (7 years from 2000-2006) that represented persistent snow cover throughout April 24 – May 15, which encompasses the end of the wolverine’s reproductive denning period. Approximately 89% of summer and 81% of winter telemetry locations from 8 study areas in western North America concurred with spring snow coverage. Moreover, about 90% of 62 known wolverine den sites in North America occurred within spring snow cover for 5-7 years (J. Copeland, *unpublished data*). Pathways of dispersal by wolverines also appear limited largely to areas of spring snow cover (Schwartz et al. 2009). Thus, many central features of wolverine ecology – historical occurrence, habitat use across gender/age/seasons, den sites and dispersals – correspond to this bioclimatic envelope of spring snow cover.

The ‘Inman’ model delineates suitable habitat for resident adult wolverines, reproductive females, and dispersers across the western United States (Inman 2013). This model addresses 6 key components of wolverine ecology: food, competition, escape cover for young wolverines, birth sites, dispersal, and human disturbance. To delineate primary habitat used by resident adults, the researchers used logistic regression to compare habitat characteristics associated

with 2,257 telemetry locations collected from 12 female and 6 male wolverines with those of random locations in the Greater Yellowstone Ecosystem. They also analyzed habitat characteristics for 31 natal den and rendezvous sites to identify maternal habitat. Their top model included 2 snow variables (April 1 snow depth, distance to snow on April 1), 3 topographic variables (latitude-adjusted elevation, terrain ruggedness index, distance to high-elevation talus), 1 vegetation variable (distance to treecover), and 2 human variables (human population density, road density). This model performed well against 3 independent data sets. Prediction of maternal wolverine habitat by the Inman model matched well with areas used by adult female wolverines in 4 independent study areas; prediction of primary habitat was congruent with historic records, too.

I tested the performance of each wolverine model in the Crown of the Continent Ecosystem with 2 independent data sets. The first set comprised 199 locations of adult wolverines during all seasons from the pioneering field study of wolverines conducted during the late 1970s in the South Fork of the Flathead River in western Montana (Hornocker and Hash 1981). About 74% and 78% of those locations fell within the areas predicted by the Copeland and Inman models, respectively (J. Weaver, unpublished data). Both models missed many of the same locations, which were at slightly lower elevation during winter than predicted by the model. I also obtained 36 observations of wolverines from knowledgeable guides/outfitters in the Southern Canadian Rockies of B.C. About 89% and 86% of those records fell within the areas predicted by the Copeland and Inman models, respectively; both models missed the same 4 locations which were wolverines trapped in winter at slightly lower elevations. Both models performed well and displayed strong congruence in mapping primary wolverine habitat (82.2%) and maternal habitat (75.5%) in the Southern Canadian Rockies of British Columbia and Montana, similar to their performance in a Yellowstone Park study (Murphy et al. 2011). The Copeland model provided slightly more conservative maps of primary habitat (3.6%), whereas the Inman model provided slightly more conservative maps of maternal habitat (4.3%).

Because wolverine appear to be an obligate to areas covered by snow during spring (Copeland et al. 2010, Inman 2013), climate change projections of lesser snowpack could impact wolverine habitat (Peacock 2011). Using an ensemble of climate-change models, McKelvey et al. (2011) estimated about a 12% loss of wolverine habitat in the Columbia River basin of British Columbia.. Because snow cover may be lost disproportionately at lower elevations of wolverine habitat, I approximated this loss by subtracting snow class 2 from the Copeland model, which yielded a 11% loss.

Accordingly, I assigned the following importance scores for wolverine:

- Very High (3) = Maternal Habitat
- High (2) = Future Primary Habitat
- Moderate (1) = Primary Habitat

Key Conservation Areas

Both the Copeland and Inman models mapped suitable primary and maternal habitat throughout much of the rugged, higher country in the Southern Canadian Rockies of British Columbia and Montana (Figure 11 and 12).

Between 961,777 ha (Inman model) and 1,021,122 ha (Copeland model) of primary habitat were identified, and between 490,240 ha (Copeland model) and 563,539 ha (Inman model) of maternal habitat (Tables 5-6). Both models yielded similar ranking for wolverine habitat (by % habitat) among watersheds: (1) trans-border Flathead > (2) Palliser-White > (3 or 4) Upper Elk and Bull > (5) Lower Elk. The exception was that the Inman model identified less maternal habitat in the trans-border Flathead, perhaps because there is more subdued topography in the Whitefish Range in Montana. Primary and maternal habitat occurs all along the Continental Divide border with Alberta, except around Crowsnest Pass.

Trans-Border Flathead: Suitable habitat for wolverine occurs throughout the higher country of the trans-border Flathead River basin. In Montana, large blocks of primary wolverine habitat are rather ubiquitous across all of the roadless sections on the west side of the river (Whitefish Range). Blocks of maternal habitat are large and well-connected in the northern roadless sector of the North Fork Flathead River basin but become progressively smaller and less connected south of Red Meadow Creek. The broad Flathead River valley on the Montana side does not appear to provide suitable habitat. Large, connected blocks of both primary and maternal habitat are well-distributed across the Canadian Flathead; again, the broad Flathead River valley does not map as primary habitat until about Commerce Creek.

Lower Elk River/Koocanusa Reservoir Watershed: Despite its lower ranking, there are some key areas of wolverine habitat in the Lower Elk River watershed. In Montana, blocks of both primary and maternal habitat east of Grave Creek are part of larger complexes that extend across the Whitefish Range into the North Fork Flathead River basin. These become smaller and less connected at the south end near Mount Marston. West of Grave Creek, there are large and well-connected blocks from the Mount Wam area south to Gibraltar Ridge and northwest up through the Ten Lakes Scenic Area. These blocks of suitable habitat continue north into B.C. along the high ridges on both sides of the Wigwam River. [Note: During 1985-1999, 25 (MT) and 10 (BC) wolverines were trapped in this trans-border Wigwam area, highlighting the need for inter-jurisdictional coordination.] The Mount Broadwood – Lizard Range areas may provide one of the few linkages across Highway 3 (see later chapter on connectivity).

Upper Elk River: Suitable primary and maternal habitat for wolverine occurs throughout the higher country of Upper Elk River basin. Again, lower-elevation lands along the Elk River and Fording River do not appear to provide suitable habitat. Primary habitat becomes knitted more closely from about Bingay Creek north along the upper Elk River.

Bull River: Suitable primary and maternal habitat for wolverine occurs throughout the higher country of Bull River basin, except for lower-elevation lands along the Bull River, east of the Kootenay River, Wild Horse River, and the Lussier River. ***Palliser-White Rivers:*** Suitable wolverine habitat for wolverine occurs throughout the higher terrain of the Palliser-White River basin, but little along the river valleys.

Table 5. Amount (ha) and percentages of wolverine habitats (Copeland model) in various watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Total Area	Maternal Habitat (3)			Primary Habitat (2)		
		Area	% Area	% MH	Area	% Area	% PH
B.C.	1,312,318	401,646	30.6	81.9	829,661	63.2	81.2
Montana	385,479	88,594	23.0	18.1	191,461	49.7	18.8
TOTAL	1,697,797	490,240	28.9	1.00	1,021,122	60.1	1.00
S Hwy 3	748,607	208,966	27.9	42.6	428,808	57.3	0.42
N Hwy 3	946,821	281,274	29.7	57.4	592,314	62.6	0.58
TOTAL	1,695,428	490,240	28.9	1.00	1,021,122	60.2	1.00
Flathead	470,138	147,828	31.4	30.1	291,301	62.0	28.5
Lower Elk	289,529	59,902	20.7	12.2	124,478	43.0	12.2
Upper Elk	308,498	78,947	25.6	16.1	200,937	65.1	19.7
Bull	317,247	87,058	27.4	17.8	183,415	57.8	18.0
Palliser-White	310,016	116,504	37.6	23.8	220,992	71.3	21.6
TOTAL	1,695,428	490,239	28.9	100.0	1,021,123	60.2	100.0

Table 6. Amount (ha) and percentages of wolverine habitats (Inman model) in various watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Total Area	Maternal Habitat (3)			Primary Habitat (2)		
		Area	%Area	% MH	Area	% Area	% PH
B.C.	1,312,318	489,524	37.3	86.9	782,216	59.6	81.3
Montana	385,479	74,015	19.2	13.1	179,561	46.6	18.7
TOTAL	1,697,797	563,539	33.2	1.00	961,777	56.6	1.00
S Hwy 3	748,607	143,374	19.2	0.25	356,174	47.6	0.29
N Hwy 3	946,821	420,165	44.4	0.75	605,603	64.0	0.71
TOTAL	1,695,428	563,539	33.2	1.00	961,777	56.7	1.00
Flathead	470,138	94,443	20.1	16.8	241,758	51.4	25.1
Lower Elk	289,529	45,277	15.6	8.0	112,690	38.9	11.7
Upper Elk	308,498	125,825	41.6	22.3	185,200	60.0	19.3
Bull	317,247	116,109	36.6	20.6	188,189	59.3	19.6
Palliser-White	310,016	181,885	60.9	32.3	233,939	75.5	24.3
TOTAL	1,695,428	563,539	33.2	100.0	961,776	56.7	100.0

Figure 11. Location of key conservation values for wolverines using Copeland model, Southern Canadian Rockies, British Columbia and Montana.

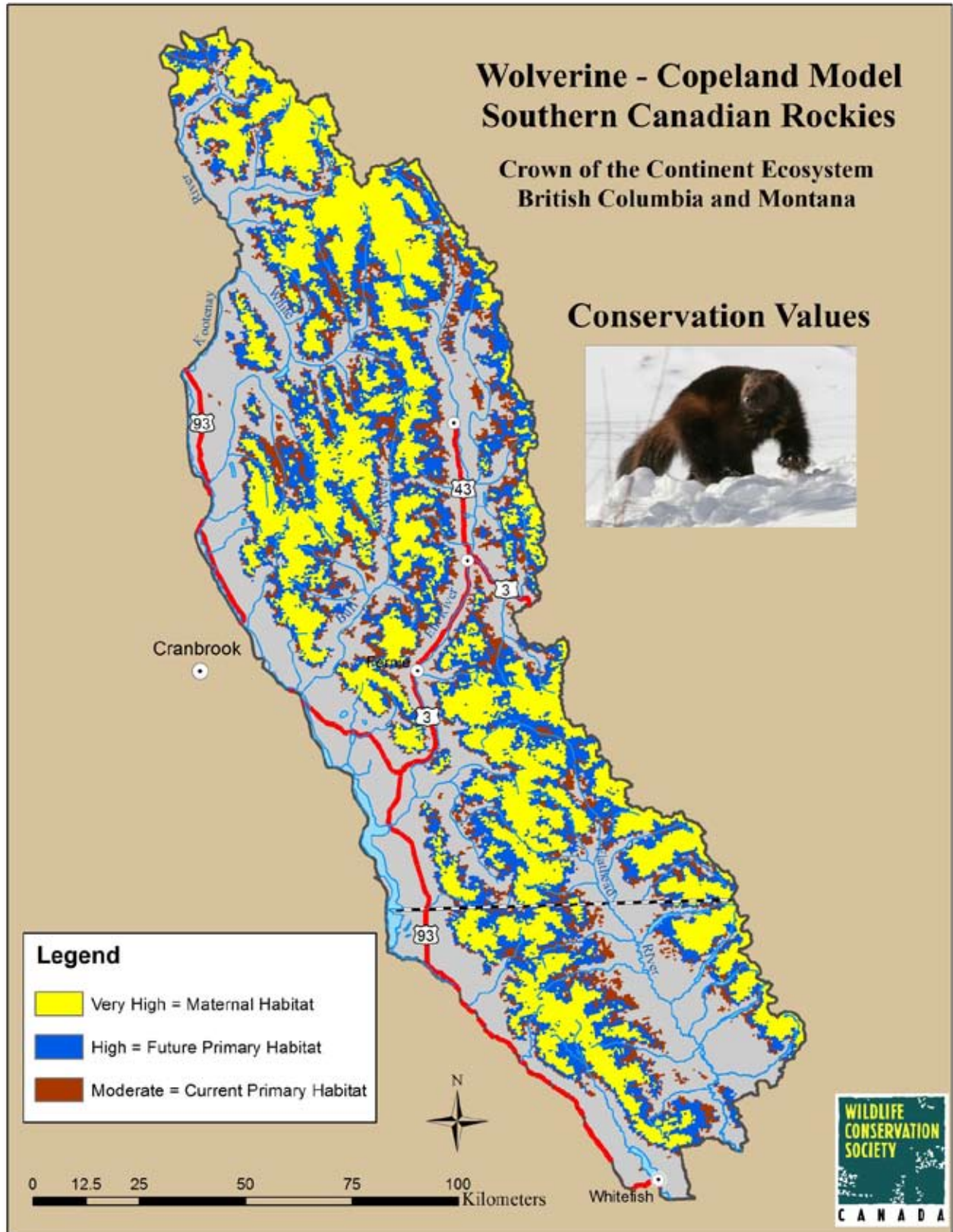
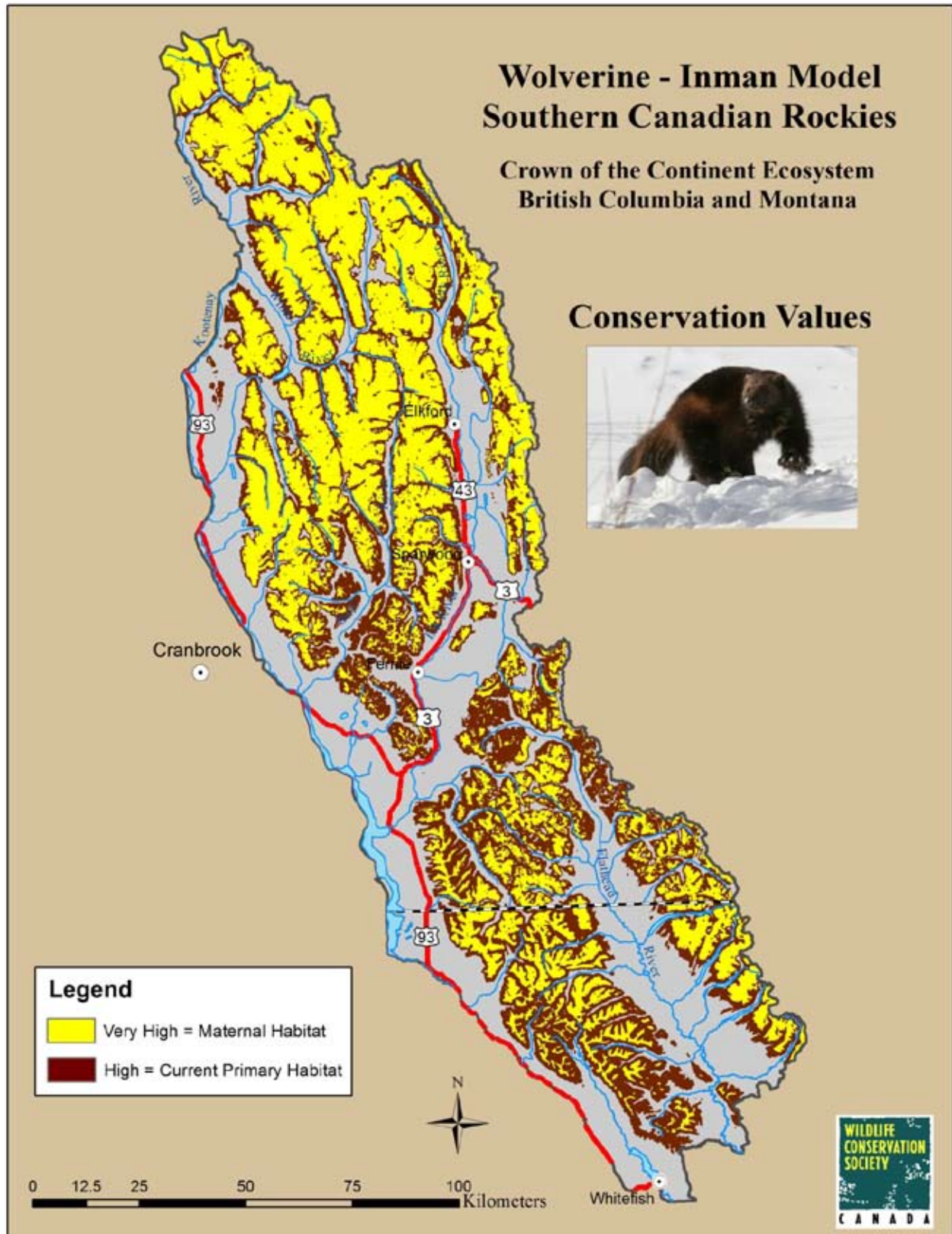


Figure 12. Location of key conservation values for wolverines using Inman model, Southern Canadian Rockies, British Columbia and Montana.



Mountain Goat



Photo: © Steven Gnam Photography

Vulnerability Profile

Mountain goats are managed as trophy big game species in Montana and British Columbia; their status in Canada has not been assessed by COSEWIC.

Niche Flexibility: Mountain goats have broad flexibility in their diet (Côté and Festa-Bianchet 2003, B.C. Mountain Goat Management Team [MGMT] 2010). They will feed on grasses, sedges, lichens, herbs, mountain shrubs, and conifer needles – sometimes, all on the same cliff. Indeed, they are masters of the opportunistic foraging microniche (Chadwick 1983). In contrast, mountain goats have very stringent habitat preferences based upon topography. Simply put, they select cliff faces usually $\geq 40^\circ$ – the steeper, the better because steep cliffs shed snow that buries the rest of the high country (Chadwick 1983, Gross et al. 2002, Poole et al. 2009). Most of the time, mountain goats are found on or within 250-400 m of cliffs that serve as escape terrain (Gross et al. 2002, Poole and Heard 2003), and females with kids often stay closer to cliffs to minimize risk of predation (Hamel and Côté 2007). Winter is a critical season for mountain goats due to the energetic costs of moving through deep snow (Côté and Festa-Bianchet 2003). Mountain goats adopt two winter-coping strategies: (1) remain on high-elevation windswept slopes with nearby escape terrain, or (2) in areas with deeper snow, move to bands of cliffs at lower elevations (Chadwick 1983, Rice 2008, Poole et al. 2009). In areas with dry, shallow snow conditions, mountain goats may winter on the same mountain top where they spent the summer, too. In areas where summer temperatures and solar radiation becomes intense, goats may select for cooler aspects or sites (B.C. MGMT 2010). Thus, the broad foraging niche of mountain goats may have evolved to compensate for their narrow habitat preference for safety among the cliffs (Geist 1971, B.C. MGMT 2010). Because their alpine plant foods contain low sodium and high potassium levels, mountain goats may travel considerable distance (up to 24 km) even through forests to obtain supplemental minerals

(sodium, magnesium, and carbonates) (Hebert and Cowan 1971, Ayotte et al. 2008, Poole et al. 2010).

Reproductive Capacity and Mortality Risk: Compared to other ungulates, native populations of mountain goats have very low reproductive potential (Côté and Festa-Bianchet 2003). Young goats grow more slowly than juvenile bighorn sheep, and female goats may delay age of first reproduction until 4 or 5 years, or even older (Festa-Bianchet and Côté 2008). Prime reproductive age for female mountain goats is from 6 to 12 years of age. A nanny typically carries only a single kid, but up to a 1/3 of adult females (>3 years old) may not produce offspring in a given year (Côté and Festa-Bianchet 2003). These parameters may improve *initially* for females in introduced populations (Swenson 1985), but others have urged caution in assuming compensatory reproduction in harvested populations (Cote et al. 2001). The longer a female goat lives, the more offspring she is likely to produce. Hence, longevity of female mountain goats is paramount to their lifetime reproductive success (Festa-Bianchet and Côté 2008). Native populations of mountain goats have extremely limited capacity to compensate for excessive mortality – especially of adult females.

The history of mountain goat populations harvested by hunters is strewn with case studies of excessive kill rates – particularly of adult females who can be difficult to distinguish (Côté et al. 2001, Hamel et al. 2006 and references therein). Excessive harvest is often facilitated by new road access (Chadwick 1983). Fortunately, many contemporary wildlife managers have embraced this realization and reduced harvest quotas for mountain goats. Some mountain goats, of course, also die from a variety of natural factors such as falls, avalanches, starvation, and predation (Côté and Festa-Bianchet 2003).

Dispersal and Connectivity: Young mountain goats appear to disperse more commonly and further distance than do bighorn sheep (Festa-Bianchet and Côté 2008). In the population of goats introduced to the Olympic National Park, young individuals of both genders (but mostly 2-3 year-old males) dispersed an average of 40 km (maximum >90 km) (Stevens 1983). Thus, goats appear to have moderate capacity for re-colonization through dispersal.

Sensitivity to Human Disturbance: Mountain goats appear particularly sensitive to disturbance from certain human activities (Joslin 1986, Côté and Festa-Bianchet 2003, B.C. MGMT 2010). Several studies have documented behavioral responses of goats to helicopters ranging from short movements (<100 m) and short bouts of nervous activity to panicked goats running at full speed over precipitous terrain resulting in at least 1 case of a broken leg (Côté 1996, Goldstein et al. 2005). The closer the helicopter, the stronger the behavioral reaction by goats. It does not appear that mountain goats habituate over time to helicopter activity. Goats likely would be vulnerable to disturbance to a variety of helicopter-supported activities: including backcountry skiing, fishing, biking and hiking, sightseeing, exploration for minerals/oil and gas, and wildlife research. Consequences of helicopter harassment could include abandonment of critical habitat, which could result in a decline in local goat populations (Festa-Bianchet and Côté 2008). Researchers have recommended no-fly buffer

zones ranging in size from 1.0 km (Goldstein et al. 2005) to 2.0 km (Foster and Rahe 1983, Côté 1996). Of course, mountain goats likely are susceptible to mechanized industrial activities in alpine areas or on winter range such as seismic exploration, mountain-top removal mining of coal, commercial logging (B.C. MGMT).

Response to Climate Change: Vulnerability of mountain goats to climate change is not well understood at present (Festa-Bianchet and Côté 2008). Projected warming of +2° C over the next 40-50 years could be even warmer in alpine. With such warming, subalpine forests could shift 300 m or higher in elevation resulting in 50% shrinkage of the alpine areas. Conceivably, warmer daytime temperatures and more intense solar radiation in the alpine during summer could force a reduction in foraging time for mountain goats, whose tolerance for heat does not seem high (documented for alpine ibex: Aublet et al. 2009). Adequate foraging in summer is important for female ungulates that must bear and nurse young and acquire good body condition to survive the following winter. On the other hand, warmer winters with less snow could result in milder conditions for goats during that season. In wintering sites where deep moist snow is more common, however, rain-on-snow events could create crusted snow conditions. This would be especially tough on young goats that have not reached full body size and cannot paw as well as adults (Chadwick 1983). For these mountain-top denizens, perhaps the best conservation strategy for now is to provide security from mechanized disturbance on a variety of cliff aspects and reduce other pressures such as liberal hunting quotas (B.C. MGMT 2010).

Conclusion: Mountain goats exhibit **high vulnerability**. They are constrained to live on or very near cliffs that provide escape terrain from predators and more accessible forage in winter. Female goats have very low reproduction and cannot quickly compensate for excessive mortality (notably hunting). Goats, particularly males, do disperse modest distances which may provide connectivity among some populations. Mountain goats are especially sensitive to motorized disturbance. In terms of climate-smart conservation strategies, maintaining secure access to a variety of aspects among cliffs and reducing other pressures could provide options.

Methods for Scoring Conservation Importance

For distribution of mountain goat summer ranges, we develop a step-wise model. First, we calculated terrain ruggedness following a method developed by Poole et al. (2009) to define escape terrain for mountain goats. We used the curvature function in ArcGIS to generate a curvature grid (at 30m resolution) and then did a moving window analysis for standard deviation within a 90m radius of each grid cell. This provided a measure of the variability of the rate of change in slope for each grid cell. Thus, a high ruggedness value would indicate a high degree of change in slope and cliff complexity. Escape terrain was defined as pixels from the ruggedness grid with a value ≥ 1.854 (the top 3 of 5 classes when displaying the grid using natural breaks). Next, we constrained the model to escape terrain between elevation contours of 1900 m and 2500 m. Finally,

we buffered those areas by 300 m as a conservative estimate of foraging distance away from escape terrain (Chadwick 1983, Hamel and Côté 2007, B.C. MGMT 2010). About 89.7% of 1190 summer locations fell within predicted summer habitat.

For distribution of mountain goat winter ranges (November-March), we used the same step-wise model but made two adjustments. We limited winter range to south-southwest aspects (157°-247°) and lowered elevation by 200m to the 1700 m contour (Chadwick 1983, Poole et al. 2009). Approximately 70.0% of 452 winter locations fell inside or within 90 m of predicted winter habitat. Expanding the criterion of suitable aspect to include aspects between 45° and 315° would capture an additional 18% of all winter locations – but at the cost of reduced specificity in the model.

Lastly, I examined location (to nearest km) of 4007 kill sites from 1975 to 2010 provided by Fish, Wildlife and Habitat Section of the B.C. Ministry of Forests, Lands and Natural Resource Operations. I excluded a few major mountain blocks of predicted occurrence where ≤ 1 hunter kill of mountain goats was recorded and 0-5 animals were inventoried through the years. These tended to be areas of patchy habitat and/or drier landscapes nearer to the Rocky Mountain Trench.

Accordingly, I assigned the following importance scores for mountain goats:

- Very High (3) = suitable winter habitat
- High (2) = suitable summer habitat
- Moderate (1) = n.a.

Key Conservation Areas

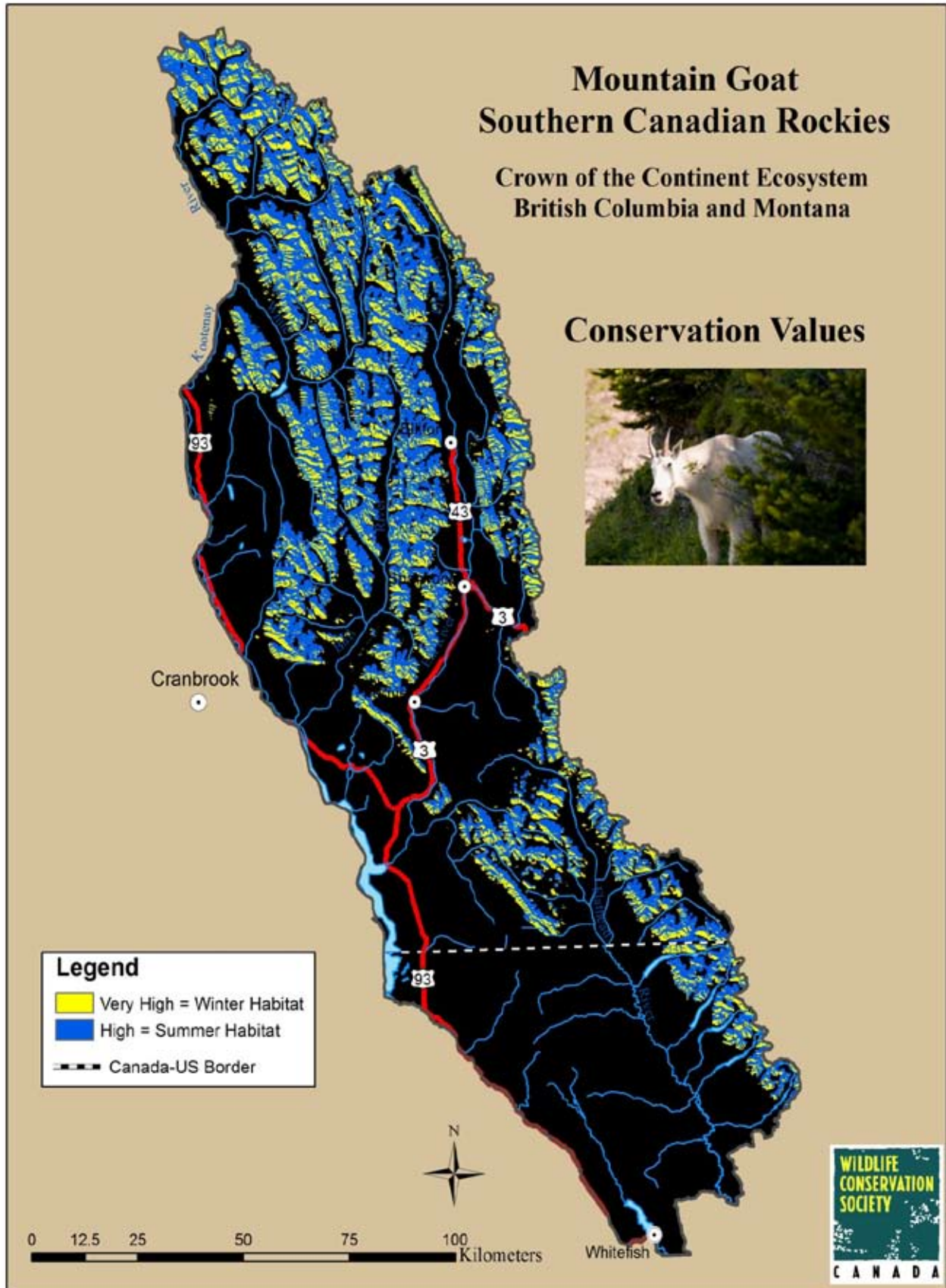
The Southern Canadian Rockies of British Columbia provide some of the most extensive habitat and goat populations anywhere in the Rocky Mountains. Based upon the habitat model, there is > 162,000 ha of winter range and >345,000 ha of summer range (Table 7). About 78-80% of winter and summer habitat for mountain goats is located north of Highway 3 in the Palliser-White River, upper Elk River, and Bull River watersheds (Figure 13). A higher amount of goat habitat (compared to other species) is provided within the B.C. Provincial Parks. In the narrative below about goat distribution by watershed, I note only certain peaks to orient the reader to the broad distribution of goats in this rugged landscape.

Trans-border Flathead River Watershed: According to Casebeer et al. (1950), upwards of 40-50 mountain goats occurred during the late 1940s in three areas on the west side of the North Fork Flathead River basin in Montana: (1) Mount Thompson Seton – Hornet Mountain – Cleft Rock Mountain north of Whale Creek (est. 15 goats), (2) Nasukoin – Mount Young – Lake Mountain north of Red Meadow Creek (est. 30 goats), and (3) Smoky Range between Big Creek and Canyon Creek (est. 5 goats). It is doubtful if any goats occur in any of these areas at this time (T. Thier, Montana FWP, *personal communication*). These patches of occupied habitat were smaller and more isolated from large patches than in areas where mountain goats have persisted. Mountain goats do occur along the Continental Divide in Glacier National Park (John Waller, Glacier National Park, *personal communication*).

Table 7. Amount (ha) and percentages of mountain goat habitats in various watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Total Area	Winter Habitat (3)			Summer Habitat (2)		
		Area	% Area	% WH	Area	% Area	% SH
B.C.	1,312,318	153,314	11.7	94.4	327,713	24.9	94.8
Montana	385,479	9,036	2.3	5.6	18,055	4.7	5.2
TOTAL	1,697,797	162,350	9.6	100.0	345,768	20.4	100.0
S Hwy 3	748,955	35,076	4.7	21.6	66,574	8.9	19.3
N Hwy 3	948,842	127,274	13.4	78.4	279,194	29.4	80.7
TOTAL	1,697,797	162,350	9.6	100.0	345,768	20.4	100.0
Flathead	470,223	27,095	5.8	16.7	52,893	11.2	15.3
Lower Elk	289,938	7,899	2.7	4.9	12,553	4.3	3.6
Upper Elk	308,689	39,161	12.7	24.1	88,809	28.8	25.7
Bull	317,750	31,037	9.8	19.1	65,333	20.6	18.9
PalliserWhite	311,197	57,159	18.4	35.2	126,179	40.5	36.5
TOTAL	1,697,797	162,350	9.6	100.0	345,768	20.4	100.0

Figure 13. Location of key winter and summer habitats for mountain goats, Southern Canadian Rockies, British Columbia and Montana.



On the B.C. side of the Flathead River basin, mountain goat distribution continues north through rugged sections of Akamina-Kishenena and Commerce Peak, then along the Continental Divide from Sunkist Ridge north to Mount Darrah. Some goats also inhabit areas west of the Flathead River along Inverted Ridge and Playsoo-Trachyte Ridge (D. Baranek, *personal communication*).

Lower Elk River/Kookanusa Reservoir Watershed: The few areas which appear to have suitable habitat for mountain goats include Inverted Ridge and Mount Doupe - Overfold Mountain. Goats are observed occasionally around Mount Broadwood and the south end of Lizard Range, which suggest possibility of some connectivity across this section of Highway 3.

Upper Elk River Watershed: Goats occur throughout the rugged terrain on the upper Elk River side of the watershed divide with the Bull River, including the proposed Hornaday Wilderness between upper Cummings Creek north to Crossing/Bingay Creek. This concentration continues north along the divide with White River all the way to Elk Lakes and Height of the Rockies Provincial Parks. On the east side of the Elk River, goats may be found along various sections of the Continental Divide including Allison Peak, Racehorse and Tornado Pass, Beehive Mountain, and Gill Peak.

Bull River Watershed: Goats occur throughout a narrow strip of rugged terrain on the Bull River side of the watershed divide with the upper Elk River, particularly from Mount Washburn north through the proposed Hornaday Wilderness. On the west side of the Bull River, goats occur at the head of Tanglefoot and Galbraith Creek, Top of the World Provincial Park, Goat Haven north, and the south end of Quinn Range up to Mount Folke and Harrison.

Palliser-White River Watershed: Goats occur throughout much of the White River watershed in the rugged ranges between Blackfoot Creek and Thunder Creek, Thunder Creek and East White River, Middle White River and Elk River, North White and Middle White, and Franklin Peaks-Mount Dornan. In the Palliser River watershed, goat habitat and locations include The Royal Group and peaks in upper Palliser, Tangle Peak and Mount Soderholm south of Cross River, and Mount Docking-Harkin and Mount Brussilof in the Mitchell Range.

Bighorn Sheep

Photo: John Weaver



Bighorn sheep are managed as trophy big game species in Montana and British Columbia; their status in Canada has not been assessed by COSEWIC.

Vulnerability Profile

Niche Flexibility: Rocky Mountain bighorn sheep have relatively low flexibility in their foraging and habitat niche (Geist 1971). Bighorn sheep feed primarily on grasses (especially bunchgrasses and fescues), though they occasionally consume palatable forbs and shrubs (Shackleton et al. 1999, Demarchi et al. 2000, Montana FWP 2009). During the short summer season, bighorn sheep often range in the alpine. Due to their strong affinity and perhaps physiological dependence on mineral licks during late spring-summer, sheep may travel several miles (even through forests) to visit such sites (Shackleton et al. 1999). Deep snow can hinder movements of bighorn sheep (especially ewes and lambs) and their access to grass forage, particularly if snowfall lasts for several days and/or becomes hard crusted. Thus, in winter, sheep usually select sites where deep snow does not accumulate due to low elevation, south exposure, and/or wind. Fire suppression can result in encroachment of open slopes by dense stands of conifers, which compromises the size and quality of these habitat patches (Schirokauer 1996). Moreover, bighorn sheep (particularly ewes with lambs) usually stay within 400-500 feet of rocky terrain and cliffs that provide escape habitat (defined as slopes $> 27^\circ$) from terrestrial predators ((Erickson 1972, Sweanor et al. 1996). Cliffs also provide available forage when snow events preclude use of other sites. This close interspersed of rocky terrain/cliffs with south-facing grassy slopes delimits suitable habitat during winter for Rocky Mountain bighorn sheep (Demarchi et al. 2000, Dicus 2002). Consequently, sheep also have low flexibility in their selection of habitat.

Reproductive Capacity and Mortality Risk: Rocky Mountain bighorn sheep have moderate reproductive potential (Demarchi et al. 2000). A ewe usually does not reproduce until 3 years of age and typically carries only a single lamb each year thereafter, but pregnancy rates can exceed 90% (Geist 1971, Jorgensen et al. 1993). Under high population density, though, age of first reproduction may be postponed and mature ewes may forego lamb production (Festa-Bianchet and Jorgensen 1998).

Adult survivorship is usually high between ages 2 and 8 years, but survival of lambs to 1 year can be low (10-60%) and varies substantially – depending upon maternal nutrition, spring weather, and the quality or vigor of the population (Shackleton et al. 1999, Demarchi et al. 2000). Adult bighorn sheep generally have an annual mortality rates of about 10% from natural causes, and lamb: ewe ratios of >30:100 (with all the precautionary caveats) may be 1 indicator of population trend (Demarchi et al. 2000). Bighorn sheep are notoriously susceptible to virulent outbreaks of pneumonia usually caused by *Pasturella* spp. bacteria transmitted by domestic sheep, which can decimate up to 95% of a herd rather quickly (Bunch et al. 1999, Demarchi et al. 2000, see Miller et al. 2012 for recent review). Bighorn sheep populations recover slowly from such reductions, depending upon the quality of the range. Hence, bighorn sheep exhibit low resistance to disease and possess low capacity to compensate rapidly for excessive mortality. Most contemporary management plans for bighorn sheep (e.g. Montana FWP 2009) have endorsed the conclusion that domestic sheep should be kept away from bighorn sheep range (Martin et al. 1996).

Dispersal and Connectivity: Bighorn sheep find their niche in patches of montane and alpine grassland that remain stable through time, and bighorn sheep exhibit high fidelity to these ranges. In undisturbed situations, most suitable patches are already occupied by sheep. Although sheep migrate between traditional seasonal ranges, dispersing into unknown areas where there is a low likelihood of finding suitable habitat would not be a good strategy. Instead, juveniles inherit home ranges from adults and pass them on as a living tradition to their offspring (Geist 1971). Male bighorns occasionally move upwards of 30-50 km between herds, which could maintain some genetic connectivity (Geist 1971, DeCesare and Pletscher 2006). Nonetheless, bighorn sheep have been perceived as poor dispersers with low potential for natural re-colonization of distant, vacant habitat (Shackleton et al. 1999).

Sensitivity to Human Disturbance: Bighorn sheep exhibit a variety of behavioral responses to human activities ranging from habituation to cardiac alarm and displacement (Geist 1971, Andryk 1983, Shackleton et al. 1999). For example, sheep tolerate industrial activities and readily use open-pit coal mines that have been re-claimed (McCallum and Geist 1992). Sheep also seem to habituate to predictable, repeated activities including highway traffic and even helicopter overflights beyond 0.25 miles (MacArthur et al. 1982, Stockwell et al. 1991). On the other hand, vehicle traffic and human activity impacted use of a nearby mineral lick by bighorn sheep (Keller and Bender 2007). Additionally, bighorn sheep do react negatively to approaching humans on foot, especially when accompanied by a dog (MacArthur et al. 1982). Chronic disturbances

at critical sites (i.e., mineral licks) and/or of sensitive groups (ewes and lambs) could compromise the health and productivity of bighorn sheep populations. Roads, ATV use, and helicopter-based activities have proliferated throughout the East Kootenays in British Columbia since the 1950s, impinging upon key winter ranges and altering hunting experiences (Demarchi et al. 2000). Demarchi and Demarchi (1994) made several recommendations regarding coordinated access management, but Demarchi et al. (2000) did not believe implementation had been adequate for bighorn sheep conservation. Motorized access by ATVs, snowmobiles, and helicopters continues to be a management issue.

Response to Climate Change: Potential effects of climate change on Rocky Mountain bighorn sheep appear variable with contrasting implications. The winter season is widely considered to be the most challenging for bighorn sheep survival (Shackleton et al. 1999, Montana FWP 2009). Warmer winters with less snow could result in milder conditions and more expansive range for bighorn sheep, particularly if frequency of fires increases and removes encroaching conifers from potential winter ranges. This scenario, however, could also enable elk populations to increase and range more widely during winter (Wang et al. 2002), which could result in direct competition with bighorn sheep for forage. Rain-on-snow events following periods of deep snowfall, however, could create a hard-crusting snow that would reduce sheep access to ground forage. Perhaps the best conservation strategy for now is to provide stress-free security along an elevation gradient of south-facing slopes interspersed with cliffs. This would allow bighorn sheep options for moving up or down in response to changing conditions.

Conclusion: Bighorn sheep exhibit **moderate to high vulnerability**. They have a narrow feeding niche on grasses and are constrained to live on or near cliffs for escape terrain. Female sheep have moderate reproduction, but bighorn sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. Because Rocky Mountain bighorn sheep have strong fidelity to chosen sites, they do not disperse very readily and have a low capacity for re-colonizing vacant habitats. Bighorn sheep appear less sensitive to motorized disturbance than goats. In terms of climate-change conservation strategies, maintaining secure access to cliffs and rocky terrain along an elevation gradient could provide options for bighorn sheep on montane and high-elevation winter ranges. Possible increase in elk-bighorn sheep competition should be monitored.

Methods for Scoring Conservation Importance

For location of winter ranges, I used the most recent map of winter ranges digitized by local ungulate biologists with many years of experience in the East Kootenays of British Columbia (kindly provided in January 2013 by P. Holmes/Habitat Biologist and I. Teske/Wildlife Biologist, B.C. Ministry of Forests, Lands and Natural Resource Operations). This mapping incorporated decades of locations from winter surveys and telemetry projects (e.g., compilations by Jalkotzy and Warkentin 2002, Kinley and others 2007, K. Poole, *unpublished data*).

For distribution of bighorn sheep summer ranges, I developed a step-wise model similar to the one described for mountain goats. First, we calculated terrain ruggedness following a method developed by Poole et al. (2009) to define escape terrain for mountain goats. We used the curvature function in ArcGIS to generate a curvature grid (at 30m resolution) and then did a moving window analysis for standard deviation within a 90m radius of each grid cell. This provided a measure of the variability of the rate of change in slope for each grid cell where a high ruggedness value would indicate a high degree of change in slope. Escape terrain was defined as pixels from the ruggedness grid with a value ≥ 1.854 (the top 3 of 5 classes when displaying the grid using natural breaks). Next, we constrained the model to escape terrain between elevation 1700 m and 2500 m. We buffered those areas by 210 m as a conservative estimate of foraging distance away from escape terrain (Sweaner et al. 1996). As a last step, we excluded major mountain blocks of predicted occurrence where ≤ 1 hunter kill of bighorn sheep was recorded. We plotted 1973 locations (to nearest km) of kill sites during 1975-2010 provided by Fish, Wildlife and Habitat Section of the B.C. Ministry of Forests, Lands and Natural Resource Operations. Approximately 83.3% of 623 summer locations fell inside or within 90m of predicted summer habitat.

Accordingly, I assigned the following importance scores for bighorn sheep:

- Very High (3) = known winter ranges
- High (2) = suitable summer habitat
- Moderate (1) = n.a.

Key Conservation Areas

More than 20 herds of bighorn sheep numbering about 2200 animals are distributed throughout the Southern Canadian Rockies of British Columbia and Montana (Irene Teske, *personal communication*). Populations have fluctuated between 1200 and 2100 animals through time, particularly marked by epizootic outbreaks of disease (Demarchi et al. 2000). In the Southern Canadian Rockies of B.C. (East Kootenays), bighorn sheep use three distinct types of winter range: (1) low-elevation grassy slopes along the eastern foothills of the Rocky Mountain Trench, and (2) (a) near the Continental Divide, high-elevation, wind-swept alpine grasslands and (b) unique high-elevation grassland slopes in the montane forest of the Fording River valley (Demarchi et al. 2000). About 75% of winter ranges and summer habitat are located north of Highway 3 (Table 8, Figure 14).

Trans-border Flathead River Watershed: In Montana, some of the bighorn sheep that winter on the east side of Glacier National Park will spend the summer in the alpine and subalpine basins on the west side of the Continental Divide in the Park (K. Keating, *personal communication*). Similarly, bighorn sheep that winter in Waterton Lakes National Park and Alberta Provincial lands will spend the summer just inside the Flathead basin in British Columbia all along the Continental Divide from the U.S. border north to Andy Good Peak. Other sheep will spend the summer west of the Flathead River in places like Inverted Ridge, Trachyte Ridge, and Flathead Ridge (D. Baranek, *personal communication*); these animals may winter on Wigwam Flats.

Lower Elk River/Koocanusa Reservoir Watershed: This area contains 2 major winter ranges for bighorn sheep: Wigwam Flats near Elko and the one near Roosville at the border. Upwards of 300 sheep winter on the flats along the north side of the Wigwam River/south-facing slopes of Mount Broadwood and lower Elk River; some use the area on the north side of Hwy 3 between Elko and Tunnel Creek (Shannon et al. 1975, Demarchi et al. 2000). This area might be important connectivity for sheep moving from the Wigwam/Mount Broadwood winter area to the Lizard Range for summer.

A trans-border herd of approximately 100 bighorn sheep is known as the 'Ten Lakes' herd in Montana and the 'Phillips Creek' herd in British Columbia (Johnson 1993). On the Canadian side, some of these sheep winter on low-elevation slopes from Roosville north and migrate to the higher country of the Galton Range to spend the summer. On the Montana side, sheep spend the summer and fall in the Ten Lakes area (essentially an extension of the Galton Range) and winter and spring on the Woods Ranch Wildlife Management Area (Montana FWP) and Kootenai National Forest lands near the Canadian border at Roosville (Johnson 1993; Montana FWP 2009). It may be the only hunted herd of bighorn sheep that is shared between the United States and Canada (\approx 1-2 rams taken per year). Notably, this is one of only two herds native to northwest Montana, and these sheep possess a different genotype than bighorn sheep elsewhere in Montana (Montana FWP 2009). Montana FWP has invested considerable effort and funds toward the conservation of this herd.

Upper Elk River Watershed: Numerous winter ranges occur on the east side of the upper Elk River basin from Highway 3 north all the way to Tobermory Pass. Some are located on wind-swept alpine ridges, but most are associated with high-elevation grasslands from about Elkford north. These small patches of high-elevation grasslands are considered unique landscape elements with high conservation value (D. Martin, B.C. MWLAP and R. Neil, Nature Trust, *personal communications*). Preliminary mapping included 613 grassland polygons totaling 4,792 ha with an average size of 7.8 ha (EBA Engineering Consultants 2005). Some of the larger herds of bighorn sheep occur around Ewin Creek, Sheep Mountain, Brownie, Deadman Pass, and Todhunter. A few of these unique grasslands also occur on the west side of the Elk River basin on Mount Bleasdel and ridges above Quarrie, Forsyth, and Bingay Creeks; most have bighorn sheep winter ranges associated with them. These interesting sites warrant additional ecological investigation and conservation attention.

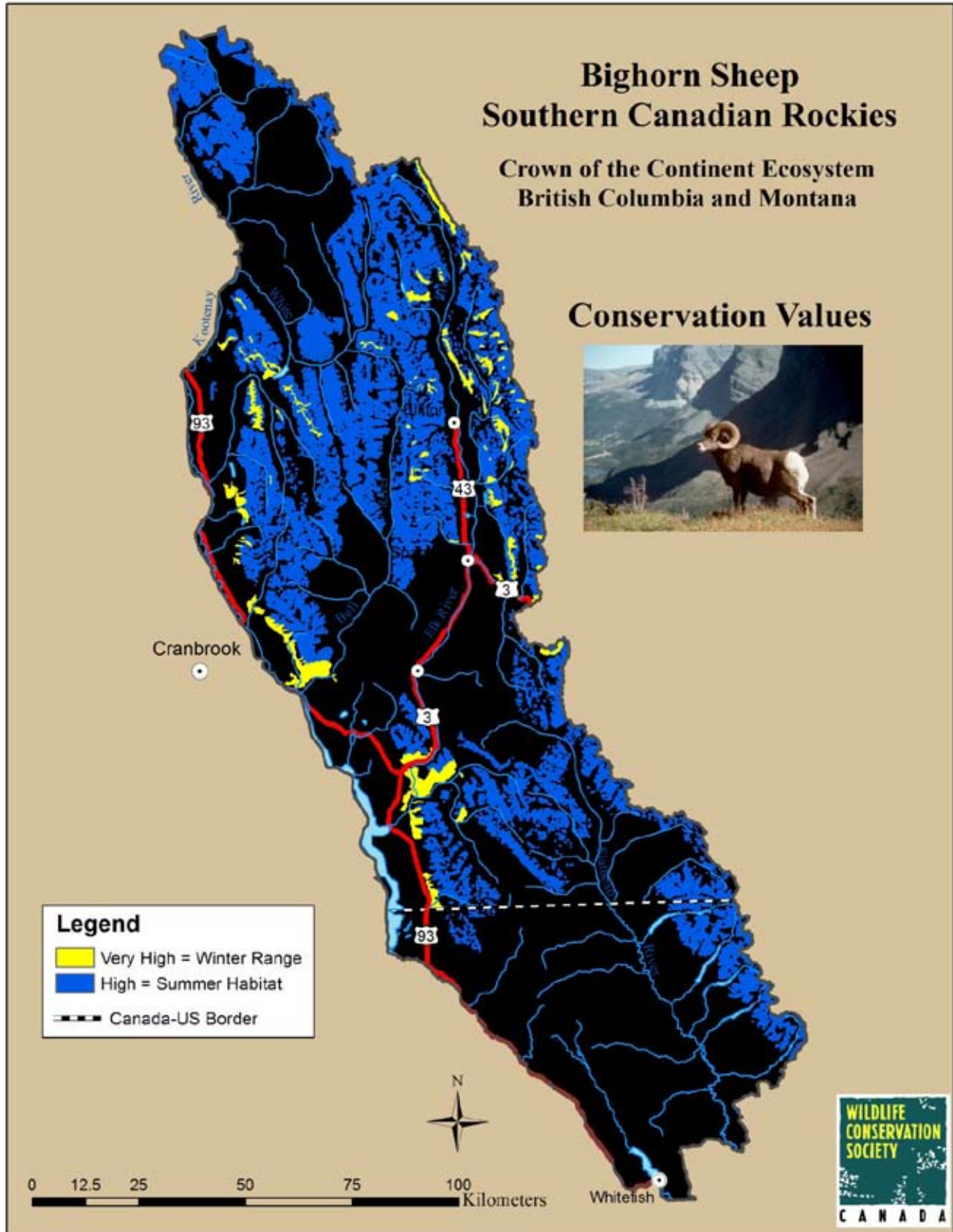
Bull River Watershed: Over 100 bighorn sheep use a traditional winter range on the lower slopes of Bull Mountain, north of the dam on the Bull River. Other smaller winter ranges are scattered along the eastern foothills of the Rocky Mountain trench and south of Lussier hot springs. These sheep migrate eastward and northward to higher-elevation range for the summer (Kinley and others 2007).

Palliser-White River Watershed: This area has considerable extent of summer habitat but very little winter range, which is limited to the ridges above the East White River and northwest of Whiteswan Lake. Most of the hunter kills have occurred in these areas and also in the Mitchell Range near Kootenay National Park.

Table 8. Amount (ha) and percentages of bighorn sheep habitats in various watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Total Area	Winter Habitat (3)			Summer Habitat (2)		
		Area	% Area	% WH	Area	% Area	% SH
B.C.	1,312,318	39,521	3.0	98.7	435,134	33.2	93.7
Montana	385,479	530	0.1	1.3	29,416	7.6	6.3
TOTAL	1,697,797	40,051	2.4	100.0	464,550	27.4	100.0
S Hwy 3	748,955	9,678	1.4	25.2	114,866	15.3	24.7
N Hwy 3	948,842	30,373	3.4	74.8	349,684	36.9	75.3
TOTAL	1,697,797	40,051	2.5	100.0	464,550	27.4	100.0
Flathead	470,223	0	0.0	0.0	70,374	15.0	15.1
Lower Elk	289,938	10,348	4.0	26.9	42,154	14.5	9.1
Upper Elk	308,689	15,488	5.5	39.9	132,418	42.9	28.5
Bull	317,750	12,172	3.8	28.4	103,334	32.5	22.2
PalliserWhite	311,197	2,043	0.7	4.8	116,270	37.4	25.0
TOTAL	1,697,797	40,051	2.5	100.0	464,550	27.4	99.9

Figure 14. Location of key winter ranges and summer habitats for bighorn sheep, Southern Canadian Rockies, British Columbia and Montana.



Synthesis of Conservation Values in the Southern Canadian Rockies, British Columbia and Montana

Composite Values and Species Importance Values

To derive a *composite* score, conservation values for each species were projected onto a grid of 1-km² cells across the study area (n = 16,978 cells). Then, I simply summed up the values across all 6 species for each cell. Although the maximum tally for a cell could have been 18 (6 species x highest score of 3), the maximum realized score was 16. I present the top 50% (values 9-16) and top 75% (values 5-16) of the composite values. In some places, the composite score might be low, but the site has very high value for 1 of the vulnerable species. So, I mapped *species importance* values whereby a grid cell with a score of 3 (*very high*) or 2 (*high*) for any species was highlighted. It should be noted that the SI value of 2 may represent a less critical but still essential component of the species' annual range (e.g., summer range for bighorn sheep). Here, I synthesize these two measures of conservation values across the Southern Canadian Rockies of British Columbia and Montana.

Overall, the top 50% of composite values were located on 18 % (3,060 km²) of the study area, whereas the top 75% were found on 62% (10,550 km²) (Table 9) (Figure 15). The density of top 50% scores was 2x greater on the British Columbia side. The Upper Elk River watershed had the highest density for both the top 50% and 75% composite values (27.5% and 79%, respectively), followed by the trans-border Flathead River basin (21.5% and 58%). In terms of Species Importance values, the very high scores (3) occurred on 56% of the area and high scores (2) on 68% (Table 10 and Figure 16). Interestingly, the Palliser-White watershed had the greatest density of very high and high scores (67.6% and 81.8%), followed closely by the Upper Elk River (62.5% and 77.0%) watershed.

Trans-border Flathead River Watershed: This Flathead River basin had the greatest area of top 50% and 75% conservation values watershed (33.0% and 25.8%, respectively). The top 50% values were clustered in Glacier National Park, Akamina-Kishenena Provincial Park, and notably throughout much of the upper Flathead in British Columbia. In particular, these top values were concentrated in Howell and Twenty-nine Mile Creek, Harvey Creek, Trachyte Ridge, and from Middlepass Creek northward to Mount Borsato. A few of the top 50% composite values were scattered along the Whitefish Range in Montana. As expected, distribution of 75% scores was more widespread, especially in the higher terrain. Species importance scores were very high throughout much of the trans-border Flathead River basin, including the Whitefish Range.

Lower Elk River/Koocanusa Reservoir Watershed: This area had the lowest density and amount of top 50% and 75% composite values. The top 50% values were located along Inverted Ridge in the Wigwam drainage, Mount Broadwood, and the Lizard Range. On the other hand, composite values in the lower range (5-7) of the top 75% values were widespread across the watershed. Species importance values were lower here than in the other watersheds, too.

Upper Elk River Watershed: As noted, the upper Elk River watershed had the highest density of top 50% and 75% conservation values and ranked second in terms of area. Top 50% values occurred though much of the high country on the west side of the Elk River from west of Sparwood all the way north to Elk Lakes. Notable concentrations included the following tributary drainages: Cummings, Brule, Weigert, Boivin, south Crossing, Bingay, and lower Forsyth. Elk Lakes and Height of the Rockies Provincial Parks also had top 50% values. Along the east side of the Elk River valley, key clusters included upper Alexander Creek - Grave Creek, upper Fording River - Henrietta Creek, Aldridge - Weary Creek, and the Elk River valley bottom south of the lakes. Species importance scores followed these same patterns.

Bull River Watershed: The Bull River basin had intermediate levels of both composite and species importance values. Notable areas with clustered 50% values included headwaters of Galbraith Creek and along the west side of the upper Bull River from Quinn Creek north to the headwater basins. Along the east side of the upper Bull River, most of the short tributaries have top 50% conservation values and connect with corresponding drainages noted above for the west side of the upper Elk River.

Palliser-White River Watershed: Higher terrain of these watersheds contained intermediate levels of composite and species importance values. Drainages in the White River watershed with concentration of top 50% values included Blackfoot Creek, high ridges northwest of Whiteswan Lake, Rock Canyon Creek, and the area between North and Middle White Rivers. In the northerly watersheds, top 50% values were located in the Mitchell Range and Tangle Peaks, and in the upper sections of the Palliser and Cross River basins.

To summarize: The top 50% composite values for these vulnerable fish and wildlife species were especially clustered in Glacier National Park, the upper sections of the Canadian Flathead River basin, upper White River, and the entire west flank of the upper Elk River valley and adjacent areas of the Bull River. These areas provide a high return on investing in conservation lands.

Figure 15. Distribution of composite scores for six vulnerable fish and wildlife species, Southern Canadian Rockies, British Columbia and Montana.

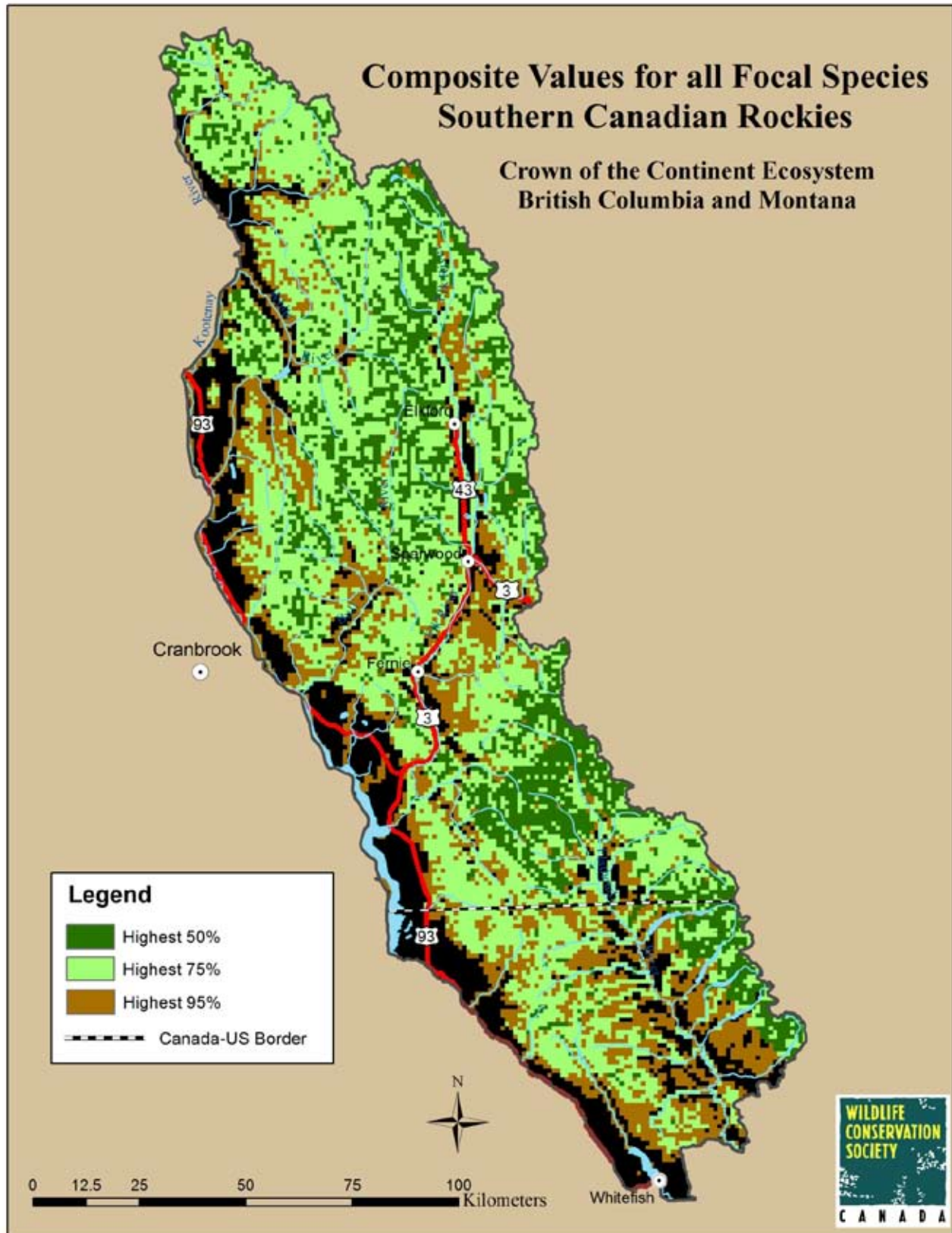


Figure 16. Distribution of species importance scores for any one of 6 vulnerable fish and wildlife species, Southern Canadian Rockies, British Columbia and Montana.

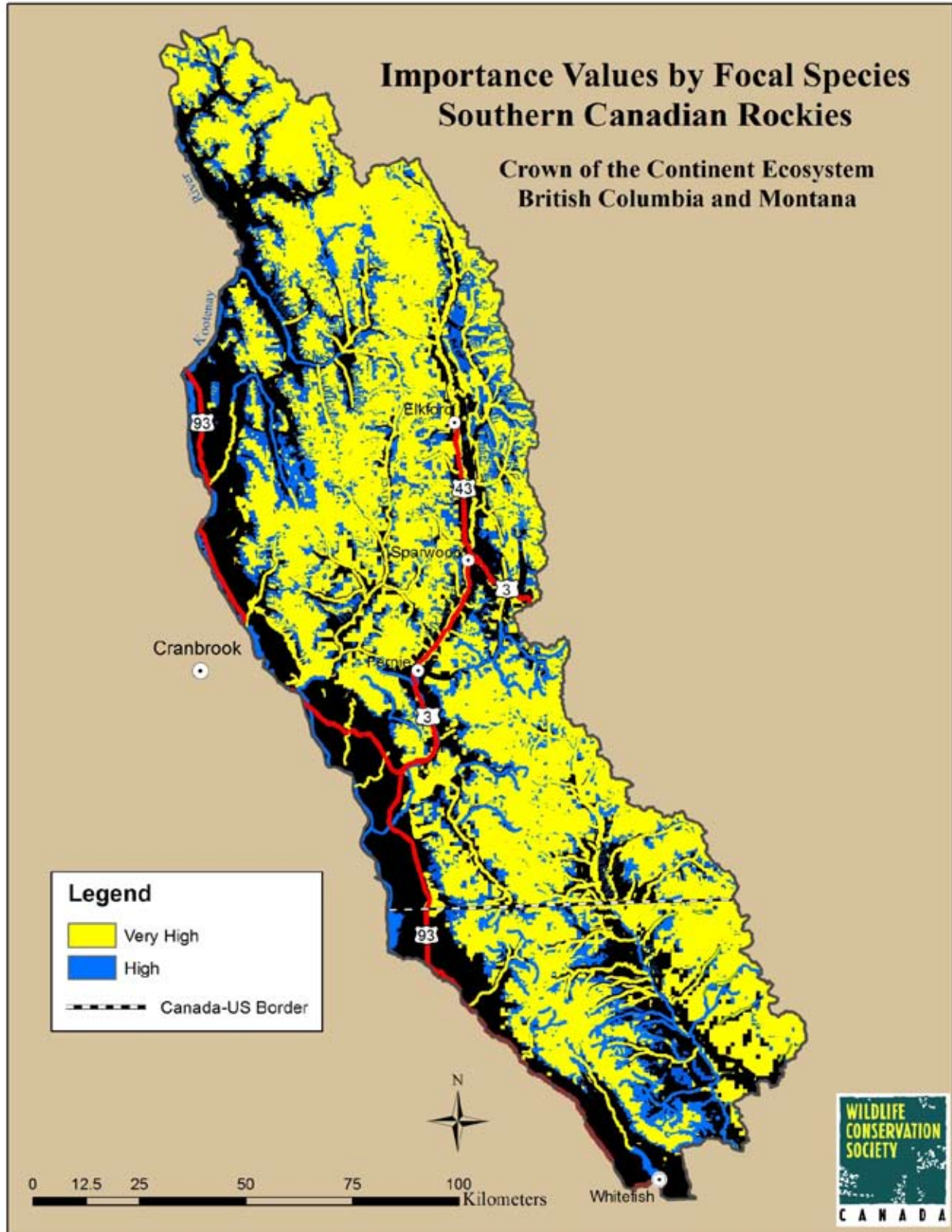


Table 9. Amount (km²) and percentage of composite values in watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Area (ha)	50% Conservation Values			75% Conservation Values		
		Area	% Area	% CV	Area	% Area	% CV
British Columbia	13,123	2,703	20.6	88.3	8,976	68.4	85.1
Montana	3,855	357	9.3	11.7	1,574	40.8	14.9
TOTAL	16,978	3,060	18.0	100.0	10,550	62.1	100.0
S Hwy 3	7,490	1,257	16.8	41.1	4,040	53.9	38.3
N Hwy 3	9,488	1,803	19.0	58.9	6,510	68.6	61.7
TOTAL	16,978	3,060	18.0	100.0	10,550	62.1	100.0
Flathead	4,702	1,009	21.5	33.0	2,728	58.0	25.8
Lower Elk	2,899	222	7.6	7.3	1,222	42.2	11.6
Upper Elk	3,087	850	27.5	27.8	2,439	79.0	23.1
Bull	3,178	476	15.0	15.6	1,800	56.7	17.1
Palliser White	3,112	503	16.2	16.4	2,361	75.9	22.4
TOTAL	16,978	3,060	18.0	100.0	10,550	62.1	100.0

Table 10. Amount (ha) and percentage of species importance values in watersheds across the Southern Canadian Rockies, British Columbia and Montana.

Watershed	Area	Species Importance Value = 3			Species Importance Value = 2		
		Area	% Area	% SIV	Area	% Area	% SIV
British Columbia	1,312,318	777,002	59.2	81.1	945,145	72.0	81.7
Montana	385,479	180,706	46.9	18.9	212,327	55.1	18.3
TOTAL	1,697,797	957,708	56.4	100.0	1,157,472	68.2	100.0
S Hwy 3	748,995	389,454	52.0	40.7	469,294	62.7	40.5
N Hwy 3	948,842	568,254	59.9	59.3	688,178	72.5	59.5
TOTAL	1,697,797	957,708	56.4	100.0	1,157,472	68.2	100.0
Flathead	470,223	262,615	55.8	27.4	311,214	66.2	26.9
Lower Elk	289,938	119,506	41.2	12.5	144,902	50.0	12.5
Upper Elk	308,689	192,841	62.5	20.1	237,701	77.0	20.5
Bull	317,750	172,268	54.2	18.0	209,087	65.8	18.1
Palliser White	311,197	210,478	67.6	22.0	254,658	81.8	22.0
TOTAL	1,697,797	957,708	56.4	100.0	1,157,472	68.2	100.0

3. LANDSCAPE CONNECTIVITY ACROSS THE SOUTHERN CANADIAN ROCKIES

It appears that the most important mechanism by which species coped with previous large-scale climate changes has been to move and colonize newly suitable habitat (Huntley 2005). Such shifts have already been documented in numerous species in response to contemporary changes in climate (Parmesan & Yohe 2003). However, habitat fragmentation can interfere with the ability of species to track shifting climatic conditions. Consequently, many advocate the need for conservation corridors and linkages between existing and future habitats as a means to support necessary movements (Chetkiewicz et al. 2006, Rudnick et al. 2012). A complementary strategy is to increase the size and number of ecologically-diverse areas that are protected by various designations (Hodgson et al. 2009). The recent book Safe Passages: Highways, Wildlife, and Habitat Connectivity (Beckman et al. 2010) provides an outstanding overview of current projects, practices, and partnerships across the country – including several from the Crown of the Continent Ecosystem.

Highway 3 (and associated railroad) is a major east west transportation route across the Southern Canadian Rockies of British Columbia (Figure 18). Several investigations have examined potential linkages across Highway 3 between Elko and Crowsnest Pass, British Columbia for various wildlife species (Apps et al. 2007, Clevenger et al. 2010, Proctor et al. 2012). Here, we contribute an assessment of linkage options across Highway 3 and Highway 43 for wolverine. After presenting these findings, I synthesize findings from the other studies – all of which appear to converge on several key linkage zones along Highway 3. Lastly, I identify several key mountain passes which provide corollary connectivity east west across the Continental Divide between British Columbia and Alberta.

Figure 17. With its high traffic volume, Highway 3 (shown here near Fernie, B.C.) constitutes a significant fracture in north↔south landscape connectivity.



Photo: Clayton Apps

Modeling Wolverine Connectivity across Highway 3

(in collaboration with Dr. Meredith Rainey, Montana State University)

Methods: We modeled wolverine connectivity across Highways 3 and 43 using both least-cost distance (LCD) models (Walker & Craighead 1997) and circuit theory (CT) models (McRae et al. 2008). Both approaches require a resistance map quantifying the relative travel cost of movement through each cell in the landscape (see review by Zeller et al. 2012). Both produce a continuous surface quantifying the relative value of each map cell for movement among specified patches, accounting for the effects of both distance between patches and landscape resistance. They differ, however, in their assumptions, formulation, and interpretation; the approaches are generally considered to be complementary (McRae et al. 2008). Rainey (2012) provides an excellent examination of the 2 methods.

Least-cost modeling for focal species has been the most widely used method for designing corridors to connect patches of habitat (e.g., Beier et al. 2011). The objective of LCD modeling is to identify the swath of land that minimizes the ecological cost of movement through a landscape for a species (Adriaensen et al. 2003). LCD corridor models calculate the cumulative cost-weighted distance of all paths between pairs of patches by summing the resistance values encountered in each cell along the path, then assigning each cell the value of the least costly path passing through it. Thus, the least costly path between patches can be identified, along with other alternative low-cost paths.

Circuit theory models treat the landscape as an electrical circuit, quantifying the probability of current (dispersing animals) passing from a source patch through any given node (cell) in the landscape to a destination patch (McRae et

al. 2008). The CT approach is unique because it accounts for path redundancy. Cells with many possible paths passing through them (i.e. bottlenecks or pinch-points) are assigned high probability of movement.

We developed a single map of resistance for use with both connectivity models using the Inman model of wolverine habitat suitability (see overview in Chapter 2, details in Inman 2013). The model was modified slightly for application to Hwy 3 in British Columbia. First, the road density layer was calculated differently for the purposes of this study as the primary focus is on identifying highway crossing sites, which are expected to be strongly influenced by traffic volume and human development footprints. In the original model, primary highways were assigned a weight of 2, secondary roads (e.g., forest system roads) a weight of 1, other roads a weight of 0.75, and trails a weight of 0.35. To account for the impacts of highway traffic volume, we assigned Highway 3 a weight of 10 (~7,000 vehicles per day), Highway 43 a weight of 5 (~3,500 vehicles per day), and Highway 93 a weight of 2.5. Assigned weights remain unchanged for non-highway road classes. Weighted road density was calculated within a moving window with radius of 2.8 km.

Additionally, we excluded areas of human development surrounding along the major based on the conservative assumption that human settlements are simply impermeable to wolverine movement. Plans for connectivity will likely be more effective if they focus highway mitigation efforts away from footprints of human development. Within a 1 km-wide strip on either side of highways 3 and 43, we digitized all residential points (from a high-resolution Bing satellite image) and assigned circular buffers of 500 m (similar to Proctor et al. 2012). The resulting footprint of settlement was considered impermeable and applied as a mask to the wolverine habitat map. The final habitat suitability map was calculated at a resolution of 90 m. After rescaling the suitability values to be bounded by 0 and 1, we calculated landscape resistance as the inverse of suitability $[1 - \text{Suitability}]$.

For the purposes of this analysis, we identified primary habitat patches adjacent to highways 3 and 43 as source and destination patches (based upon cutoff values identified in Inman's original model: Inman 2013). Any patch intersecting a line drawn perpendicular from highway 3 or 43 that had not yet intersected another patch was considered adjacent, regardless of distance from the highway. We further limited our selection of patches to those encompassing a minimum of 100 km², which is considered the minimum patch size necessary to function as a source of dispersers (B. Inman, WCS, *personal communication*). Source patches were assigned to 1 of 3 zones: (1) north of Highway 3 and west of Highway 43, (2) north of Highway 3 and east of Highway 43, and (3) south of Highway 3. We ran the connectivity models on each pair of zones, and then overlaid pair-wise connections to form final composite corridor surfaces.

Least cost corridor models were run in ArcGIS 10.0 using the 'cost distance' and 'corridor' Spatial Analyst tools. We derived final composite maps by creating a mosaic of the three pair-wise surfaces, with each cell assigned the minimum cost-weighted distance value of the input maps. Circuit theory models were run in CircuitScape[®] (McRae & Shah 2008), with the final composite

map reflecting cumulative conductance. The resistance surface was re-sampled using bilinear interpolation to a resolution of 180 m due to memory limitations of CircuitScape® when working with large maps (> 1 million cells).

An alternative approach combined (1) the wolverine habitat model developed by Copeland et al. (2010) based on presence of persistent spring snow cover, and (2) weighted road density. In this snow-based model, habitat quality was quantified on an ordinal scale of 0-7, indicating the number of years that a given site retained snow through spring. Sites with persistent spring snow cover in at least one of the seven years were considered primary habitat, while sites that never retained spring snow cover were considered matrix habitat. Primary habitat patches adjacent to the highways and > 100 km² in area were considered source and destination patches. Thus, the Copeland model produced a slightly different spatial configuration of suitable primary habitats; moreover, the resistance surface was defined solely on the basis of weighted road density.

Results:

Inman model – The LCD model identified the southernmost portion of Highway 3 between Morrissey and Elko as the most suitable crossing site for wolverines (Figure 18). The section of Highway 43 closer to Elkford was also generally identified as having high permeability. The CT model indicated a similar pattern but also attributed high crossing probability to sections of Highway 3 northeast of Hosmer and southeast of Sparwood. There are 2 patches of primary habitat (smaller than 100 km²) south of Highway 3 that may serve as ‘stepping-stones’ for movement across the landscape.

Copeland model – The LCD model indicated that wolverines should avoid crossings Highway 3 by instead traveling around the north end of Highway 43 (Figure 19). This model suggested some permeability, though, along Highway 43 and along Highway 3 south of Morrissey. The CT model also indicates that the highest crossing probabilities along Highway 3 occur between Morrissey and Elko. Sections of Highway 3 northeast of Hosmer and southeast of Sparwood appear highly permeable, too. The model indicates some probability of wolverines circumventing Highway 43 by going closer to Elkford.

Discussion: All combinations of models suggest that the southernmost portion of Highway 3 is likely to be a suitable crossing site for wolverines. The Mount Broadwood ↔ Tunnel Creek area may provide a good stepping stone for wolverines crossing Highway 3 to access larger patches of primary habitat in the Lizard Range (N) or in the Wigwam River drainage (S).

The models also generally agree that the areas northeast of Hosmer and southeast of Sparwood (Alexander Creek) may support cross-highway dispersal. Although the Inman model suggests that primary habitat for wolverines in this area is further from Highway 3 than does the Copeland model, the results of the CT connectivity analyses of both wolverine models converge here.

The LCD model run on the Copeland habitat model indicates that the most suitable dispersal path is around the north end of Highway 43, avoiding

crossing Highway 3 entirely. This outcome results from the fact that the cost-weighted distances are driven primarily by high weights assigned to Highways 3 and 43, whereas other factors contribute to the resistance surface in the Inman wolverine model.

This pattern is not observed in the corresponding circuit theory model because the models are formulated differently and rely on different assumptions. LCD models identify *optimal* paths between a source and destination as those with the lowest cost-weighted distance. This assumes that dispersers have perfect knowledge of the landscape, allowing them to identify the optimal path among other possible paths. In contrast, circuit theory models predict *relative probability* of movement across the landscape. Imagine the movement of many random walkers between source and destination patches, each step of their paths guided only by perception of the habitat quality found within a 1-cell radius. This allows for chance movement via short yet high-resistance paths.

In a recent study of broader-scale wolverine dispersal movements, the CT model detected small, stepping-stone patches of primary habitat and routed many possible paths through them ((Rainey et al. 2012). The CT model appeared to match better with the movement behavior of wolverines than did the LCD model.

The volume of traffic may be a filter to wolverine movements across highways. As part of the WCS study of wolverines in the Greater Yellowstone Ecosystem, Packila et al. (2007) documented 43 crossings of U.S. or State highways by 12 wolverines. Subadults making dispersal or exploratory movements comprised the majority (76%) of road crossings, most of which were made during January–March. Five (62%) of 13 road crossings occurred at night. On the highway (WY 22, ID 33) that goes over Teton Pass west of Jackson, Wyoming, traffic volume commonly exceeded 4,000 vehicles per day (more similar to traffic volume along highway 43 than Highway 3 in British Columbia). Four different wolverines (2F, 2 M) crossed this highway a total of 16 times, suggesting that it was not an absolute barrier. WCS researchers determined that at least 3 crossings occurred within a 4-km section where forest cover bordered close to the highway, about 4 km from the nearest human settlement. They identified a broader linkage zone encompassing a 14-km section of this highway (Packila et al. 2007).

Figure 18. Location of most likely linkage zones for wolverines across Highways 3 and 43 using Least-Cost Distance (LCD) and Circuitscape® (CT) methods on the Inman wolverine model, Southern Canadian Rockies, British Columbia.

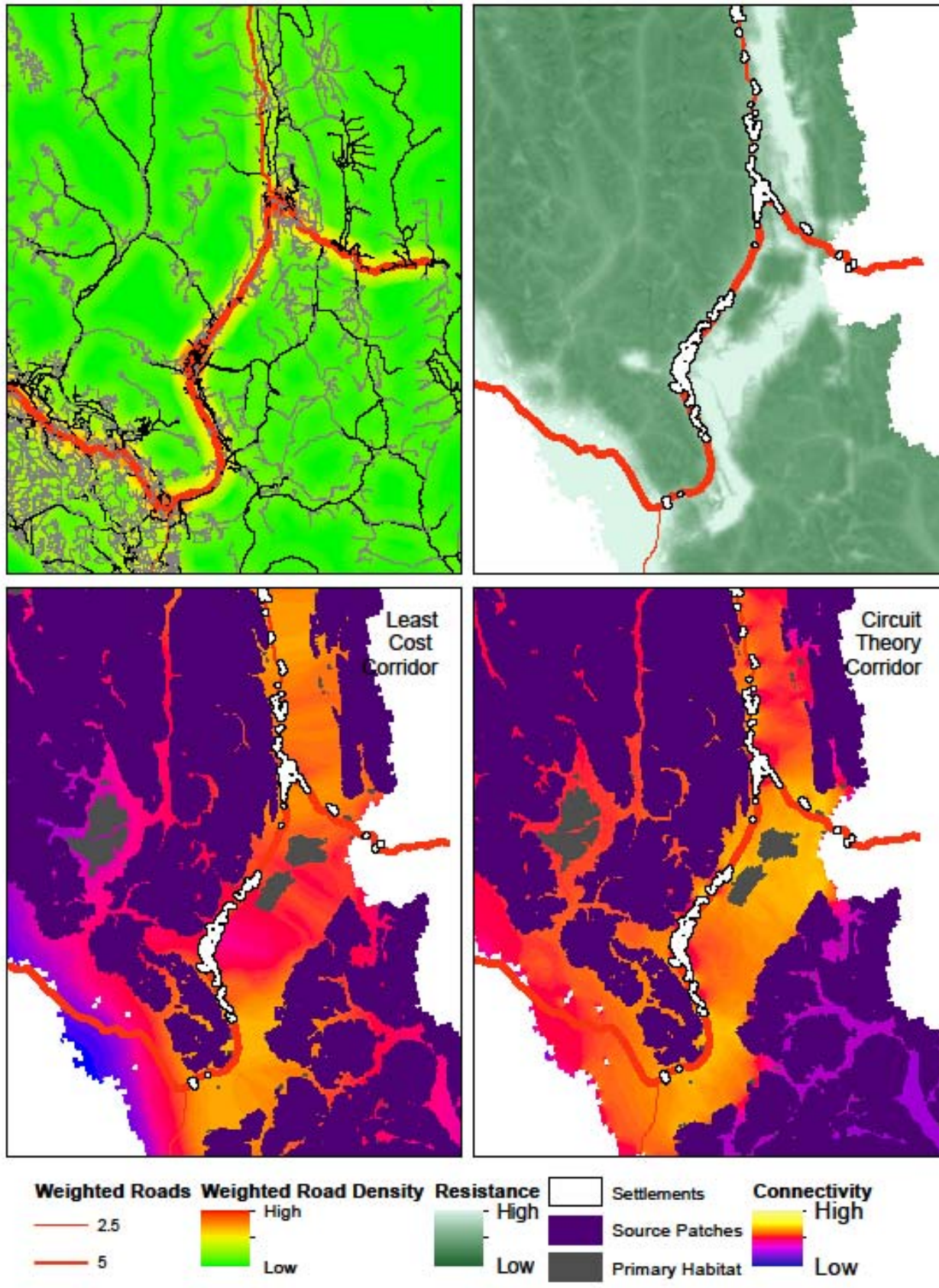
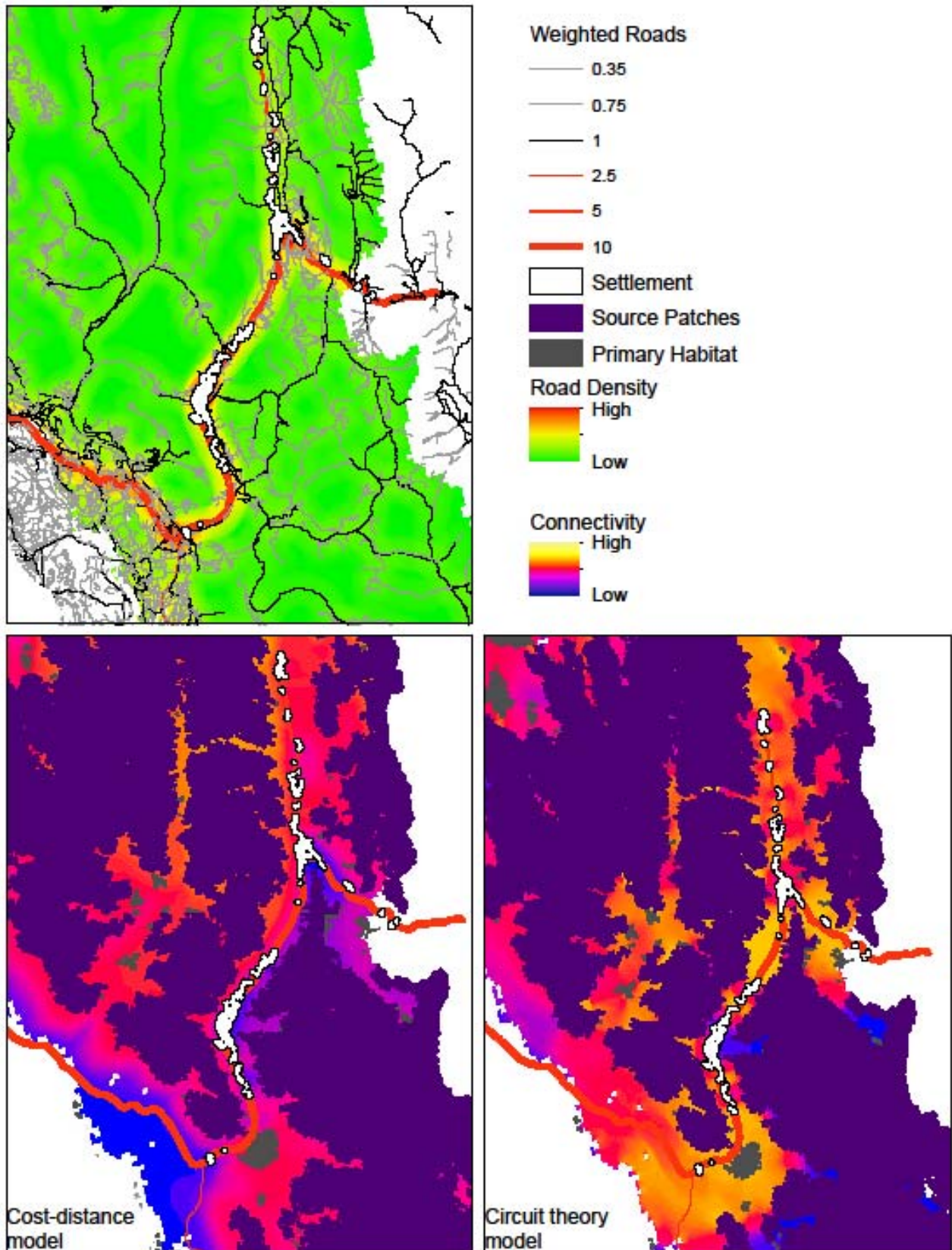


Figure 19. Location of most likely linkage zones for wolverines across Highways 3 and 43 using Least-Cost Distance (LCD) and Circuitscape® (CT) methods on the Copeland wolverine model, Southern Canadian Rockies, British Columbia.



Multi-species Linkages across Highway 3

In this section, I coalesce results from our connectivity analysis for wolverine with findings from previous studies for grizzly bears (Apps 1997), several carnivore species (Apps et al. 2007), and ungulates/vehicle collisions (Clevenger et al. 2010). In a very thorough and detailed assessment, Clevenger et al. (2010) identified several high-priority locations within various linkage zones along Highway 3 (their Figure 10). They assigned a subjective score from 1 (low) to 5 (high) based on the following criteria: (1) local conservation value, (2) regional conservation significance, (3) land-use security, (4) highway mortality, and (5) opportunities for highway mitigation. Here, I use their location names for linkage zones and sites as a handy reference (see Figure 20 below). I also bring forward their recommendations to reduce mortality and facilitate movements, should re-construction or twinning of Highway 3 occur in the future. The narrative starts near Elko, B.C. and proceeds up Highway 3 to Crowsnest Pass.

Elko to Morrissey Linkage Zone

This section of Highway 3 separates the Elk River floodplains and Mount Broadwood to the South and the south end of the Lizard Range to the north. This is an important area for elk, deer and bighorn sheep, which frequently cross the highway to move from valley bottom to higher slopes, particularly near Elko.

EM 1 (Score 3.8) – Vehicle collisions with ungulates are very high through this section. There is the potential for subdivision of the private lands north of the highway. A *wildlife underpass* could be placed here, likely with a bridge or large culvert.

EM 3 (Score 3.8) – This area represents a likely crossing zone for wolverines moving between Mount Broadwood (Nature Conservancy Canada) and Lizard Range. It is a very high collision zone for bighorn sheep, where they are often observed licking winter-road salt. The nearby tunnel access pit is used as a dumping site for wildlife carcasses killed in vehicle collisions, which could expose scavengers like wolverines to collision mortality (Packila et al. 2007). Road salt should be replaced with alternative de-icing agents, and carcasses should be removed to another site well away from highways. A *wildlife underpass* should be placed here if the highway is reconstructed.

Fernie to Morrissey Linkage Zone

Across the lower Elk Valley, this linkage zone connects the valleys of Morrissey Creek with the east slopes of the Lizard Range. The zone is very important for carnivore connectivity (Apps 1997, Apps et al. 2007, Proctor et al. 2012). While there is some human development within the valley bottoms, extensive movement by resident GPS-collared female grizzly bears has been documented (C. Apps and B. McLellan, *unpublished data*). Our analysis indicated high potential for wolverine connectivity, especially near Morrissey.

FM 1 (Score 3.8) – This site is recognized for its importance to carnivore connectivity. Grizzly bear crossings of the highway here have been documented, and models indicate connectivity for wolverines, too. The site has a high rating for security as there are Crown lands to the west and private conservation lands to the east. A *wildlife underpass* could be situated in this area as slopes are gentle and the highway is raised.

FM 3 (Score 2.8) – This site received a high rating for regional conservation significance but lower ratings in other categories. There has been extensive grizzly bear movement in this vicinity, particularly by females. Our modeling suggested a narrow route across the highway here for wolverines. This site is within a natural movement conduit associated with Lizard Creek and closely links private conservation lands east of the Elk River with Crown lands to the west. A small piece of private land is, however, integral to this connection.

FM 4 (Score 3.6) – Despite relatively high human activity associated with the Fernie ski area and private land, this site is within a multi-species movement route associated with Lizard Creek. This site has high scores for regional and local conservation significance (both = 5) Many highway crossings by grizzly bear have been documented, as the site is adjacent to core habitats. It's a very high collision zone, with kills of moose, elk, deer, and bears. Opportunities for highway mitigation, however, appear limited. Surrounding lands are mostly in private ownership, subject to development with a minimum of 2-4 ha parcels. Minimizing potential for bear-human conflicts with a B.C. 'Community Bear Awareness' program could be helpful.

Fernie to Hosmer Linkage Zone

Hartley Creek (Score 3.4) – Despite substantial human presence near the highway, grizzly bears cross through this area to and from Hartley Pass. Movements by grizzly bears movements (and 1 highway kill) are focused within a narrow conduit where Hartley Creek passes under the highway and enters the Elk River. Our wolverine modeling also indicates connectivity potential in a narrow zone here. This section has a very high level of vehicle collisions with wildlife, primarily elk and deer. The specific highway crossing site is, however, between private lands, with adjacent land in the Dicken Road area zoned for 2-8 ha parcels.

Hosmer to Sparwood Linkage Zone

HS 1 (Score 4.4) – This site had the highest average score of all sites along Highway 3 in both British Columbia and Alberta. It received top score of 5 for both local and regional conservation significance and for land-use security (Nature Conservancy of Canada lands abut both sides of the highway). Safe passage across the highway is central to the efficacy of the adjacent conservation lands. All the wolverine models give this area a high

potential for connectivity. Given the high water table in the area, a *wildlife overpass* and *fencing would be the* most suitable design should the highway be upgraded or expanded to four lanes.

HS 2 (Score 3.6) –This site received moderately high scores (4) for regional conservation and land-use security. It is located near Lladner Creek, which some grizzly bears may use to move into and out of the Elk Valley. The wolverine models map potential connectivity here, too. There have been numerous collisions, mainly with elk. Another carcass pit for wildlife involved in collisions with vehicles is located near the Olsen railway crossing. This is likely an attractant for carnivores like wolverines, drawing them closer to Highway 3 and the Canadian Pacific railway. East of the highway is private conservation trust land on which there are corporate timber rights. Lands to the west are also mostly under free-hold ownership by a land trust. Recommendations to reduce collisions include: (1) remove the existing carcass pit to keep bears, wolverines and other carnivores away from the highway, (2) use de-icing alternatives rather than road salt in winter, and (3) install variable message signs warning motorists of wildlife on highway. If the highway is re-constructed, a *wildlife underpass* is recommended.

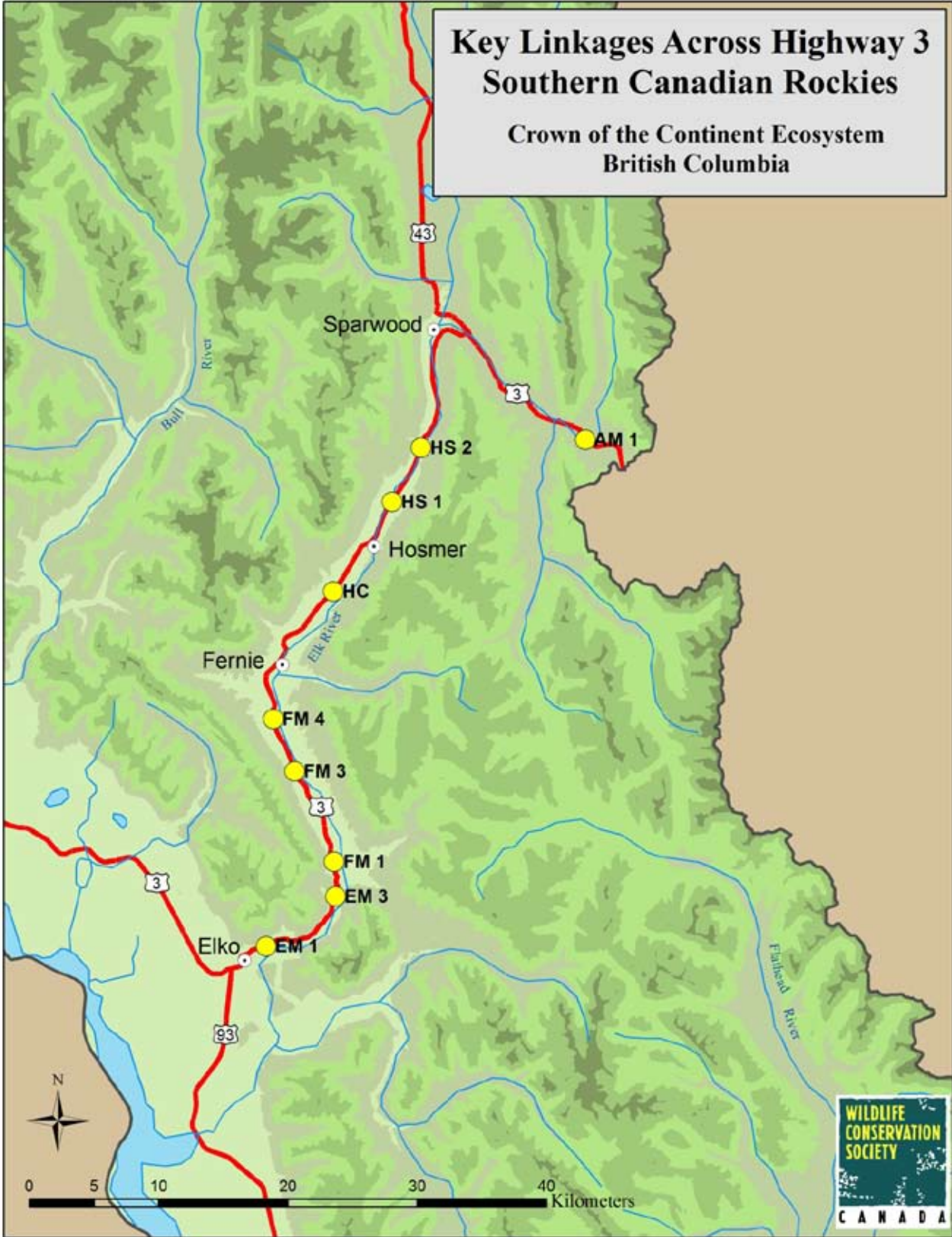
Alexander to Michel Linkage Zone

This is a very important, intact linkage zone for multiple carnivore species. A private company has restricted motorized access north of the highway on the east side of Michel Creek. Private corporate lands south of the highway are gated.

Alexander–Michel 1 (Score 3.8) – This is considered the most critical landscape linkage in the entire Highway 3 corridor, with top scores (5) for local and regional significance. It offers security cover on both sides of the highway, and human influence appears relatively minimal. Grizzly bears and wolves have crossed the highway here, and models indicate strong potential for wolverine connectivity as well. Hopefully, security will be maintained on the surrounding private lands. The base of Alexander Creek appears to provide the best option for facilitating movements with a bridge construction project.

In closing this chapter, securing connectivity across fracture zones like Highway 3 in the Elk Valley is important for demographic and genetic resiliency of vulnerable wildlife species, as well as for broader movements in response to climate change. Time for addressing this issue is ticking, though, because expanding developments and highways leave permanent infrastructures. As these build up, options for providing wildlife connectivity vanish ... and another critical landscape becomes fragmented.

Figure 20. Location of important linkage zones for several wildlife species across Highway 3, Southern Canadian Rockies, British Columbia and Montana. Based upon information in reports by Apps et al. (2007), Clevenger et al. (2010), and Weaver (this report).



Connectivity across Continental Divide between Alberta and B.C.

The mountain passes along the Continental Divide on an east-west axis between Alberta and British Columbia are very important for landscape connectivity for grizzly bears, wolverines, and likely other wildlife species in the Southern Canadian Rockies. This is especially critical for female grizzly bears whose movements across Hwy 3 have become quite restricted (Proctor et al. 2012). I compiled information from scientific studies (Carr 1989, Eastern Slopes Grizzly Bear Project - Herrero 2005, Apps et al. 2007, Grizzly Bear Inventory Team 2008, and interviews with local researchers and guides/outfitters to identify the most important of these passes. In the following narrative, the name of the connecting river/creek on the B.C. side is provided in parentheses, and the numbers correspond to the passes shown on the accompanying map (Figure 21). Passes in **bold** are perhaps more important for regional connectivity.

For bears moving between Banff National Park and the north end of the Southern Canadian Rockies in British Columbia, Marvel Pass (east Assiniboine Creek), Leman Pass (Albert River) and **Palliser Pass** (Palliser River) are important (#1-3). Bears around the Kananaskis Lakes area of Peter Lougheed Provincial Park use the North Kananaskis Pass and South Kananaskis Pass (northeast tributaries of Palliser River headwaters) (#4-5). In the same vicinity, **Elk Pass/Tobermory Pass** (Elk River) likely is a major N S movement corridor for many wildlife species, including bears (#6).

Coming south along the Divide east of the upper Elk River, grizzly bears use Weary Gap (Weary Creek) and **Fording Pass** (Fording River), which connect to the Don Getty Wildland Provincial Park in Alberta (#7-8). **Racehorse Pass and Deadman Pass** (east tributaries of Alexander Creek) have tremendous importance for safe passage of both male and female grizzly bears and may be used by bighorn sheep as well (#9-10).

South of Hwy 3, terrain along the Continental Divide becomes less rugged which allows animals more options in crossing. Nonetheless, certain passes are regularly used by grizzly bears and other wildlife. Tent Mountain Pass (Tent Mountain Creek) and **Ptolemy Pass** (Ptolemy Creek) are especially important (#11-12) for grizzly bears. On the east side of the Canadian Flathead, grizzly bears, wolverine and other wildlife cross various gaps in the vicinity of **North Kootenay Pass** (Pincher Creek) and through **Middle Kootenay Pass** (Middlepass Creek) to connect with the Castle River Special Management Area in Alberta (#13-14).

For passage between Waterton Lakes National Park and the Canadian Flathead in British Columbia, grizzly bears and perhaps wolverines use **Sage Pass** (Sage Creek) and **South Kootenay Pass** (Kishenena Creek) (#15-16).

Figure 21. Location of important mountain passes for connectivity across Continental Divide, Southern Canadian Rockies, British Columbia and Alberta.



4. CHARTING NEW DIRECTIONS FOR CONSERVATION IN THE SOUTHERN CANADIAN ROCKIES

Matching Stewardship with Wildlife Riches and Challenges

The Southern Canadian Rockies of British Columbia and Montana have long been recognized as beautiful landscapes, rich in fish and wildlife and plants. This conservation assessment has documented the critical importance of the Southern Canadian Rockies for a unique suite of vulnerable fish and wildlife species that have been vanquished or diminished in so many other areas of their original range. Some of the highlights include:

- ✘ Regional strongholds for populations of bull trout are found in the trans-border Flathead River, Wigwam River, and upper White River drainages.
- ✘ Populations of westslope cutthroat trout with intact genetic integrity occur throughout the Elk River, Bull River, and upper portion of the trans-border Flathead River drainages. Large watersheds like these represent rare bastions of viable, genetically-intact populations of westslope cutthroats having greater viability than smaller, more isolated populations.
- ✘ The trans-border Flathead River basin sustains the highest density of grizzly bears recorded thus far for non-coastal populations in North America. The area between the Elk River and the Bull River appears to have suitable habitat to sustain high densities of grizzly bears, too.
- ✘ Highly suitable habitat for the rare wolverine occurs throughout the higher country of the Southern Canadian Rockies; these areas appear rather similar to Glacier National Park in Montana where a concentration of wolverines has been documented. Because the wolverine's niche seems linked to

colder, snowy environments, this region may provide suitable conditions longer into the warming future.

- ⊗ Abundant populations of mountain goats are found in various mountain ranges, particularly in the rugged terrain north of Fernie all the way to Banff and Kootenay National Parks.
- ⊗ The East Kootenays of British Columbia have long been known for outstanding populations of bighorn sheep. Several critical low-elevation winter ranges are located along the eastern side of the Rocky Mountain Trench, whereas numerous high-elevation winter ranges occur east of the upper Elk River on wind-blown ridges and ecologically-unique grasslands.

For many years, the Southern Canadian Rockies enjoyed ‘de-facto’ protection due to the few roads, local economies, and modest resource extraction. That situation has changed, however, as roads now penetrate all major valleys and most tributary valleys, with increasing use by 4-WD and ATVs. A warming climate will push fish and wildlife to roam as they try to track the shifting location of their habitats. Past practices may not be adequate in the face of these new pressures. Outstanding Provincial Parks such as Elk Lakes and Height of the Rockies comprise only 5.7% of the Southern Canadian Rockies of British Columbia, and they protect between 2.6 % and 16.9 % of key habitat for these vulnerable species (Table 11). Hence, there is a mis-match between the level of current protection of valuable fish and wildlife habitat and multiplying threats. The challenge, then, is provide a higher level of committed stewardship commensurate with these remarkable treasures of native fish and wildlife. Clearly, it is time to chart new directions for conservation in the Southern Canadian Rockies.

Conservation Lands in British Columbia

Here, I discuss and recommend various conservation options for matching a higher level of stewardship commensurate with the high public values of vulnerable fish and wildlife in the Southern Canadian Rockies that have been vanquished or diminished elsewhere in North America (see Figure 23).

National Park or Provincial *Wildland* Park in the Canadian Flathead

The trans-border Flathead River basin has very high conservation values for this suite of vulnerable native fish and wildlife species and harbours remarkable biological diversity (Weaver 2001, Hauer and Muhlfield 2011, this report). A number of conservation groups and citizens have advocated for establishment of a National Park in southeastern British Columbia adjoining Glacier National Park (U.S.) to the south and Waterton Lakes National Park in Alberta to the east. This area has very high importance values for several vulnerable species, along with scattered sites of very high composite values interspersed with a matrix of high composite scores (Figures 15-16). Importantly, numerous fish and wildlife species move between these trans-border jurisdictions. For example, bull trout migrate some 250 km from Flathead Lake in Montana up the North Fork Flathead River into British Columbia. Large mammals like grizzly

bear, wolverine, wolves, moose, elk, white-tailed deer, and others move between Montana and Alberta and B.C. in this region (Weaver 2001). Moreover, a wildland park (National or Provincial) would make sense in terms of spatial congruity with the adjoining National Parks. It would be commensurate with other recent actions by elected officials and non-governmental land trusts in both countries to conserve the trans-border Flathead River basin. Therefore, I recommend such a wildland park for this portion of the Canadian Flathead.

Figure 22. A *wildland* park (National or Provincial) in the Canadian Flathead would be commensurate with bi-national efforts to conserve the remarkable biological diversity and landscape integrity of the trans-border Flathead River basin.



Photo: Harvey Locke

Southern Canadian Rockies Wildlife Management Area

A primary designation tool for conservation lands in British Columbia is the ‘Wildlife Management Area’ (WMA) under section 4 of the BC Wildlife Act. Presently, there are 25 wildlife management areas in B.C. Here, I quote verbatim from the Provincial website which provides more details about WMAs (<http://www.env.gov.bc.ca/fw/habitat/conservation-lands/wma>).

“A WMA is an area of land designated for the benefit of regionally to internationally significant fish and wildlife species or their habitats. Conservation and management of fish, wildlife and their habitats is the priority in a WMA but other compatible land uses may be accommodated [emphasis added].”

“There are various reasons why an area may be considered for WMA designation including:

- An area’s fish, wildlife or habitat values are of regional to international significance.
- Special management zones or objectives for wildlife, fish and their habitats have been identified in a local or regional strategic land use plan.

- A need to conserve or manage important species and habitats while still allowing certain activities to continue which may not be allowed in a ‘protected area’ designation.
- A buffer zone or linkage for a core protected area is desirable. Such linkages may be essential to enable movements of species during seasonal migrations or in response to short-term ecological variations or longer-term climate changes.”

“WMAs may be used to conserve or manage various habitats including:

- Habitat for endangered, threatened, sensitive, or vulnerable species.
- Habitat required for a critical life cycle phase of a species such as spawning, rearing, calving, denning, nesting, or winter feeding;
- Migration routes or other movement corridors; and
- Areas of especially productive habitat or high species richness.”

“A WMA can be designated by the Minister [of Forests, Lands, and Natural Resources] on any area of Crown land in the province that is not in a park, conservancy or recreation area. While the priority for WMAs is to maintain or manage species and their habitats, other resource uses may sometimes be accommodated (e.g., forestry or mining). For this reason, WMAs are not part of the formal ‘protected area’ designation under land use planning in British Columbia. The appropriate regional manager under the Wildlife Act may establish orders that prohibit or restrict certain WMA activities that may impact wildlife or habitat.”

“First Nations may continue to exercise their aboriginal rights in WMAs but may be limited by conservation concerns and public health and safety legislation. First Nation interests will be accommodated within the management plan. Designation and management of WMAs is without prejudice to future land claim settlements.”

“A management plan, developed in consultation with partners, First Nations, agencies, stakeholders and the public, is used to help guide activities in a WMA.”

To summarize: Designation of a Wildlife Management Area represents an explicit recognition of the outstanding and significant fish and wildlife values in an area. It accommodates multiple uses of the land under the over-arching priority of conserving species and their habitats. In this respect, a WMA is similar to areas on National Forests in the U.S. where the Forest Plan directs conservation of fish and wildlife as the top priority in certain areas, while permitting various kinds of compatible uses. Indeed, designation of a WMA seems like a *promising* path for matching conservation stewardship commensurate with the very high values of fish and wildlife in this region – depending upon a commitment in action.

The Southern Canadian Rockies of British Columbia have an internationally-significant assemblage of fish and wildlife species. Therefore, I strongly recommend designation of 719, 297 ha as the ‘*Southern Canadian Rockies Wildlife Management Area*’.

This recommendation is based upon a bottom-up, scientific analysis of the conservation values for vulnerable fish and wildlife and their habitats – rather than an arbitrary number. (The tabulated area includes the section of the Flathead proposed for a National Park.) The WMA would comprise about 54.1% of the assessment area in B.C. but bring proportionately greater percentage of key habitats under this designation for conservation lands. Specifically, the recommended WMA would include 66.7% of the area containing the top 50% of the composite scores, and 83.3% of the top 75%. It would cover an average of 66.6% of the very high-value habitats and 56.5% of the high-value habitats for the 6 vulnerable species (Table 11). Hence, it would be efficient in terms of conservation gains for land area. I consider this a minimum area for designation as arguments could be made in support of an even larger area.

Table 11. Percentages of Species Importance values in British Columbia within the B.C. Provincial Parks and proposed Southern Canadian Rockies Wildlife Management Area.

Species	Provincial Parks		SCR WMA	
	Very High	High	Very High	High
Bull Trout	2.4	2.7	73.3	34.5
WCT	4.8	0.8	71.2	51.1
Grizzly Bear	6.5	13.6	72.2	59.6
Wolverine - C	16.9	10.8	62.5	65.3
Wolverine - I	13.0	10.2	61.4	64.8
Mtn Goat	4.8	13.7	67.5	67.2
Bighorn Sheep	3.7	11.3	53.6	61.5

The Southern Canadian Rockies Wildlife Management Area would include the following areas in southeast British Columbia (exclusive of private lands and Provincial Parks) (Figure 23):

- Canadian Flathead River basin (some area may be designated a National/Provincial Park)
- Wigwam River drainage and the Lizard Range in the lower Elk River watershed
- Crown land along the west side of the upper Elk River valley from Fernie north to Elk Lakes PP
- east side of Bull River and portion of west side from Galbraith Creek north
- upper portion of White River watershed east of Whiteswan Lake, and
- headwaters of the Albert and Cross Rivers that border Banff National Park to the east. (Note: these headwater areas could be appended to the Height of the Rockies Provincial Park.)

Figure 23. Location of recommended conservation lands, Southern Canadian Rockies, British Columbia and Montana.

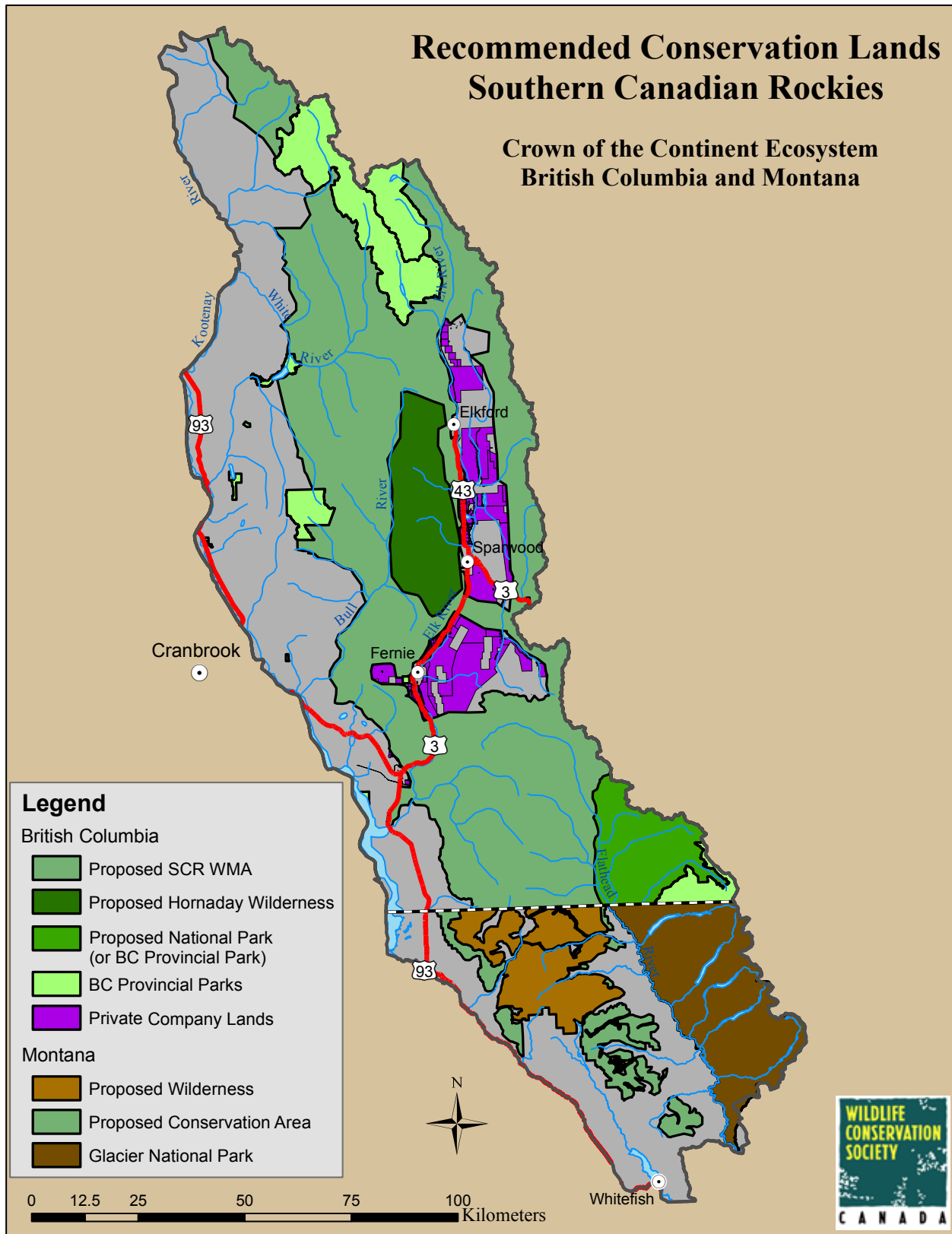


Figure 24. WCS Canada Biologist Dr. John Weaver in one of the last wild areas in the Southern Canadian Rockies of British Columbia. A successful campaign by pioneering naturalist William T. Hornaday led to the area's designation as the Elk River Game Preserve in 1908, which remained in effect until 1963. In recognition of its value for wildlife, Weaver endorses a campaign by local groups to have the area protected as the 'Hornaday Wilderness'.



Photo: Casey Brennan

Hornaday Wilderness (Hornaday Conservancy)

In September 1905, the American naturalist William T. Hornaday hunted big game with local guides in the mountains west of Elkford in the upper Elk River valley. He wrote a book about their adventures entitled Campfires in the Canadian Rockies, wherein he extolled the beauty and wildlife of the area (Hornaday 1906). Around the campfire, the group formulated their thoughts about protecting the area. Hornaday and others waged a 3-year campaign for establishment of what they called 'Goat Mountain Park'. On November 15, 1908, the legislative council of British Columbia proclaimed a park (game preserve) of approximately 115,000 ha (~450 square miles) called the 'Elk River Game Preserve'. This protection, it seems, was rescinded 10 years later as wildlife populations began to recover. It was established as a game reserve again in October, 1922 and remained in effect until 1963. Although opened to hunting then, it was recommended that "*particular attention be given to park values in the Reserve*" (Smith 1963).

Over the following decades, more and more logging roads penetrated several of the tributary valleys on the west side of the Elk River. In recent years, local citizens and guides/outfitters have re-invigorated the campaign to provide more lasting protection for this – the last intact wildland in the Southern Canadian Rockies – as the 'Hornaday Wilderness' (or perhaps 'Hornaday Conservancy').

Based upon this scientific assessment, I concluded that this area has high conservation value for vulnerable wildlife species. Sites having the top 50% of *composite* scores are common throughout the area, and the remaining areas contain the top 75% of scores. With numerous avalanche chutes, burned areas

with huckleberries, and remote subalpine basins, about 73% of the area provides good habitat and security for grizzly bears. The wolverine models suggest that 87-94% of the area is wolverine habitat, with upwards of 65% suitable for maternal habitat. About 68% of the area provides summer and winter habitat for mountain goats, which are abundant. There are 5-6 winter ranges mapped for bighorn sheep, and summer habitat is extensive (61% of area). Lower reaches of Cummings Creek and Brule Creek provide spawning and rearing habitat for bull trout. Populations of genetically-pure westslope cutthroat trout are found in several drainages, including Cummings, Brule, Weigert, and Boivin Creeks. Lastly, many candidate sites for 'safe havens' were identified here (Figure 26). Perhaps the most outstanding feature is simply the wildness and splendor of the place.

Accordingly, I recommend approximately 64,048 ha be designated as the *Hornaday Wilderness* (or *Hornaday Conservancy*). It would extend from Crossing Creek on the north end (northwest of the hamlet of Elkford) south to Lladner and Sulphur Creeks (west of the town of Sparwood) (Figure 23). The eastern border would run along the edge of Crown land flanking the west side of the Elk River valley, while the western boundary would parallel the east side of the upper Bull River.

“Safe Havens”

Recent efforts in southeast British Columbia have focused on Access Management Areas (AMA) and Motor Vehicle Hunting Closure Areas (MVHCA) to manage expanding human access. In the AMAs, some roads remain open year-round, whereas others are closed for various seasons or open only to snowmobiles during winter. In the MVHCAs, vehicle access is restricted during the fall hunting season in certain drainages. There are 19 AMAs and 14 MVHCAs designated at present, but they cover only a very small part (15.6% and 9.4%, respectively) of the Southern Canadian Rockies of B.C. Although this represents a good starting effort, these designations still allow motorized vehicles all the way to the back end of numerous drainages for much of the year. In extensive travels throughout this region, I found only 3 closure gates – all on the same road – and ATVs had driven around each of them. The net result is that there is very little security provided for sensitive wildlife through active management in the Southern Canadian Rockies.

During times of uncertainty, a common strategy among managers facing risk to valued resources is to minimize their exposure by placing them in 'safe havens' or refugia (Weaver et al. 1996). Indeed, the powerful role of refugia in persistence of populations has emerged as one of the most robust concepts in modern ecology (Fahrig 1988). Conceptually, refugia can be identified and managed as population *sources* (Pulliam and Danielson 1991) by (1) maximizing birth rates (natality) through enhancement of habitat productivity, or (2) minimizing mortality through reduced access or curtailment of harvest. In the broader sense, then, refugia are 'safe havens' from habitat loss and overexploitation and serve as sources of population spillover and dispersers to the larger region (Weaver et al. 1996). Both the ecological profiles and the historical record of extirpations attest to the need for some form of refugia or safe havens for vulnerable fish and wildlife species.

Figure 25. Areas of diverse topography from valley bottoms to peaks and secure from human disturbance can serve as important 'safe havens' for vulnerable fish and wildlife under increasing pressures of resource extraction/motorized recreation and changing climates.

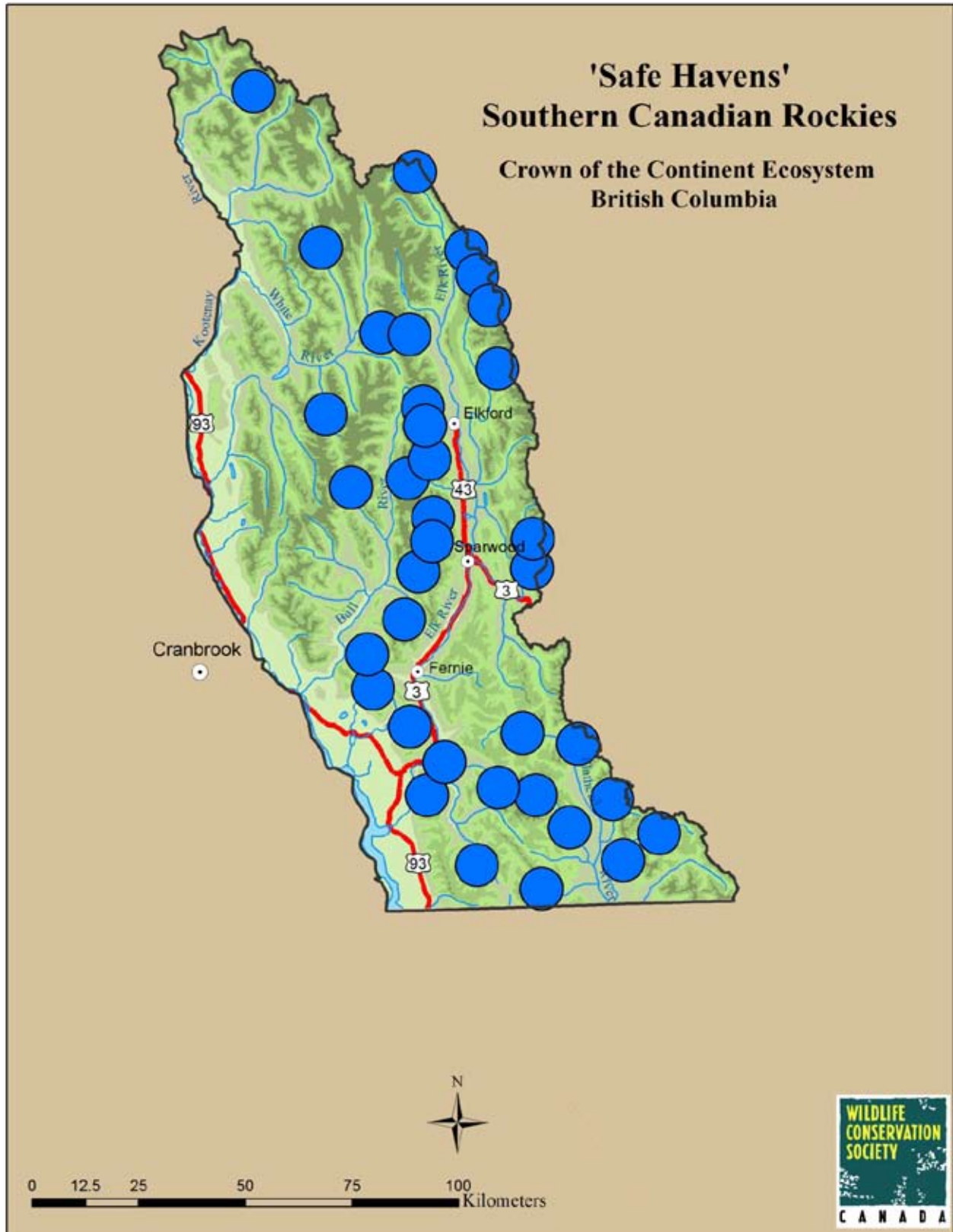


Photo: John Weaver

More recently, conservation biologists have applied the concept of safe havens for biodiversity in the context of climate change (Keppel et al. 2012). With scientific consensus on projections of warming of 2°- 4° C and increasing aridity in some places over the next 50-100 years, it's reasonable to expect shifts upward in elevation or northward in latitude where *comparatively* cooler and mesic (not dry) conditions once common may still occur (Parmesan 2006). Moreover, topographic complexity will provide more micro-refugia from mosaic disturbances such as fire, insects, etc. These are robust, strategic responses to both the trend and the variability of climate change. In the Central Interior of British Columbia, ecologists and land planners have been modeling climate refugia for vulnerable species to identify conservation areas (Kittel et al. 2011, Rose and Burton 2011).

Safe havens can be set up and scaled to meet various conservation concerns. One fundamental tenet might be to encompass the full array of seasonal or annual habitats used by a vulnerable focal species. Grizzly bears provide a useful example in this regard. Numerous studies have emphasized that high survivorship of adult female grizzly bears is of paramount importance to persistence of populations (e.g., Garshelis et al. 2005) and have called for provision of 'security areas' (Gibeau et al. 2001) or 'safe harbours' (Nielsen et al. 2006). In the mountains of western Montana, grizzly bear biologists characterized core areas used by adult female grizzlies as (1) predominantly roadless ($\geq 60\%$ of area ≥ 0.5 km from a road), (2) providing a range of elevations, and

Figure 26. Location of candidate 'Safe Havens' for security and resiliency for vulnerable fish and wildlife, Southern Canadian Rockies, British Columbia.



(3) containing at least 9% of avalanche chutes (Mace and Waller 1997). They recommended that such cores areas be high priority for habitat conservation. The seasonal home ranges of those adult females varied between individuals but averaged 58 km² in early season and 74 km² in late season. Another key tenet might be to provide a range of elevations, aspects, and topographic complexity to facilitate potential adaptation to changing climates. Depending on the species and landscapes, these can be overlapping and/or complementary features.

I identified candidate sites for safe havens across the Southern Canadian Rockies using the following approach. First, I scaled their size to that of seasonal home ranges of grizzly bears (~78 km²) by using a marker circle with a 5-km radius. Next, I searched for places where: (1) the top 50% of composite values were most dense, (2) conservation values for species needing security (e.g., grizzly bear) were very high, and (3) topography was complex with a considerable range of elevations from river valleys to mountain peaks. Finally, I used a common 500-m buffer around secondary roads to explore where management of human access would achieve the most gains in multi-species habitat value with the fewest restrictions.

I identified 36 candidate sites for safe havens across the Southern Canadian Rockies of British Columbia (Figures 25 and 26). Many of these were in the Canadian Flathead and upper Elk River watersheds (including the proposed Hornaday Wilderness). Hopefully, this map of candidate sites will be a catalyst for local and regional conversations capitalizing on a variety of knowledge and perspectives to accelerate planning for adaptation (Cross et al. 2013).

Conservation Lands in Montana

On the Montana side, there are several roadless areas totaling 110,340 ha (272,443 ac) remaining on the Flathead and Kootenai National Forests adjacent to the Canadian border. Some of these lands have considerable value for the suite of vulnerable fish and wildlife species (Weaver 2011, this report).

Wilderness Areas

I recommend the following areas totaling 64,986 ha (160,515 ac) be legislated as part of a new wilderness area (some suggest it be called the Winton Weydemeyer Wilderness) (Figure 23):

- ✓ Thoma-Mount Hefty area,
- ✓ Tuchuck area,
- ✓ Mount Thompson-Seton south to Lake Mountain, including the head-water basins of Williams Creek and Blue Sky Creek on the west side of the Whitefish Divide, and
- ✓ Ten Lakes Scenic Area and the area east of upper Wigwam River including Stahl Peak, Wam Peak, and north nearly to the Canadian border.

These additions would protect the highest-value habitats for these vulnerable fish and wildlife species, enhance connectivity with both Glacier National

Park and the Canadian Flathead/Wigwam, and provide options for future responses to climate change. It would underscore a strong American commitment to protecting the ecological integrity of the trans-border Flathead River basin.

Backcountry Conservation Areas

The US Forest Service and citizens have conceptualized a category called ‘backcountry area’ or ‘conservation area’ (e.g., Rocky Mountain Front Heritage Act). The purpose of these designations is to maintain the wildland character of roadless areas by relaxing some of the more stringent standards of formal Wilderness defined under the Wilderness Act of 1964 (e.g., use of chainsaws is allowed). Along with the designated Wilderness, these roadless backcountry areas would still serve as ‘safe havens’ for vulnerable fish and wildlife species and provide resiliency in the face of warming climate. I recommend the following areas totaling 41,887 ha (103,460 ac) be designated for roadless backcountry conservation (Figure 23):

- ✓ southerly end of the Whitefish Range encompassing roadless portions of Red Meadow Creek, Hay Creek and Coal Creek south to Werner Peak,
- ✓ the Smoky Range,
- ✓ Mount Marston-Patrick Ridge, and
- ✓ lower roadless slopes south and west of Ten Lakes Scenic Area from Gibraltar Ridge northwest to the Canadian border.

Several primitive roads extend westward from main road up the North Fork Flathead River and penetrate deeply into the Whitefish Range. Most of these were constructed for timber harvest back during the 1960-1970s. In recognition of the important fish and wildlife values in the North Fork Flathead River basin, the Flathead National Forest has closed many of these roads on a year-round or seasonal basis. Nonetheless, some of these roads still receive unauthorized use by ATV and/or snowmobiles which, in some cases, may impact wildlife. I recommend that 17 miles of primitive roads in the following priority of headwater drainages be considered for wildland restoration (de-commissioned or otherwise permanently closed and returned to more natural condition) (north to south along the west side of North Fork Flathead River):

- ✓ Trail Creek – Thoma Creek past Frozen Lake,
- ✓ headwaters of South Fork Coal Creek and Mathias Creek, and
- ✓ upper Hallowat Creek
- ✓ upper Hay Creek and south tributary, and.
- ✓ Antley Creek (tributary to Yakinikak Creek).

Assuming a displacement effect of 150 m on each side of these roads, the total acreage would sum to about 2,025 acres. These measures would enhance habitat security for several species, as well as the spatial integrity (less fragmentation) of lands recommended for Wilderness and Backcountry designation.

Commitment to Conservation

One of the central tenets of the resilience viewpoint is that a capacity to predict the future with precision is not required, but rather a qualitative capacity to devise systems that can absorb and accommodate future events in whatever surprise form they may take (Walker and Salt 2006). Safe havens and safe passages will provide vulnerable fish and wildlife room to roam across changing landscapes as they seek suitable environs.

The spectacular landscapes of the Southern Canadian Rockies of British Columbia and Montana provide some of the best remaining strongholds for a suite of vulnerable fish and wildlife species. The prospect of ever-expanding human developments and warming climate, however, casts a shadow over the future. Designation of these conservation lands in British Columbia (wildland park in the Canadian Flathead, WMA and Hornaday Wilderness) and Montana (Wilderness and Backcountry Conservation Areas) will help ensure that this rich diversity of fish and wildlife will be enjoyed by generations yet to follow.

Innovative management approaches like WMAs (a.k.a. special management areas) offer flexibility in management, which has some advantages in dynamic landscapes with multiple uses. Too often, though, wildlife conservation values lose out in an arena of competitive pressures for development of commodity resources. Ironically, a higher level of responsibility comes along with management flexibility. The next challenge will be to chart and implement a detailed conservation plan with explicit standards and guidelines that honors these world-class values. For example, such standards and guidelines are part of Forest Plans for the National Forests in the U.S. Success of such flexible approaches is predicated on strong commitment in action to truly conserve fish and wildlife values. This will require proactive planning and rigorous environmental assessment of projects and cumulative effects by leaders in resource conservation who effectively engage the public.

And it will call upon such leaders to embrace the humble realization that we are but temporary stewards of the gift of wild life and wild lands.

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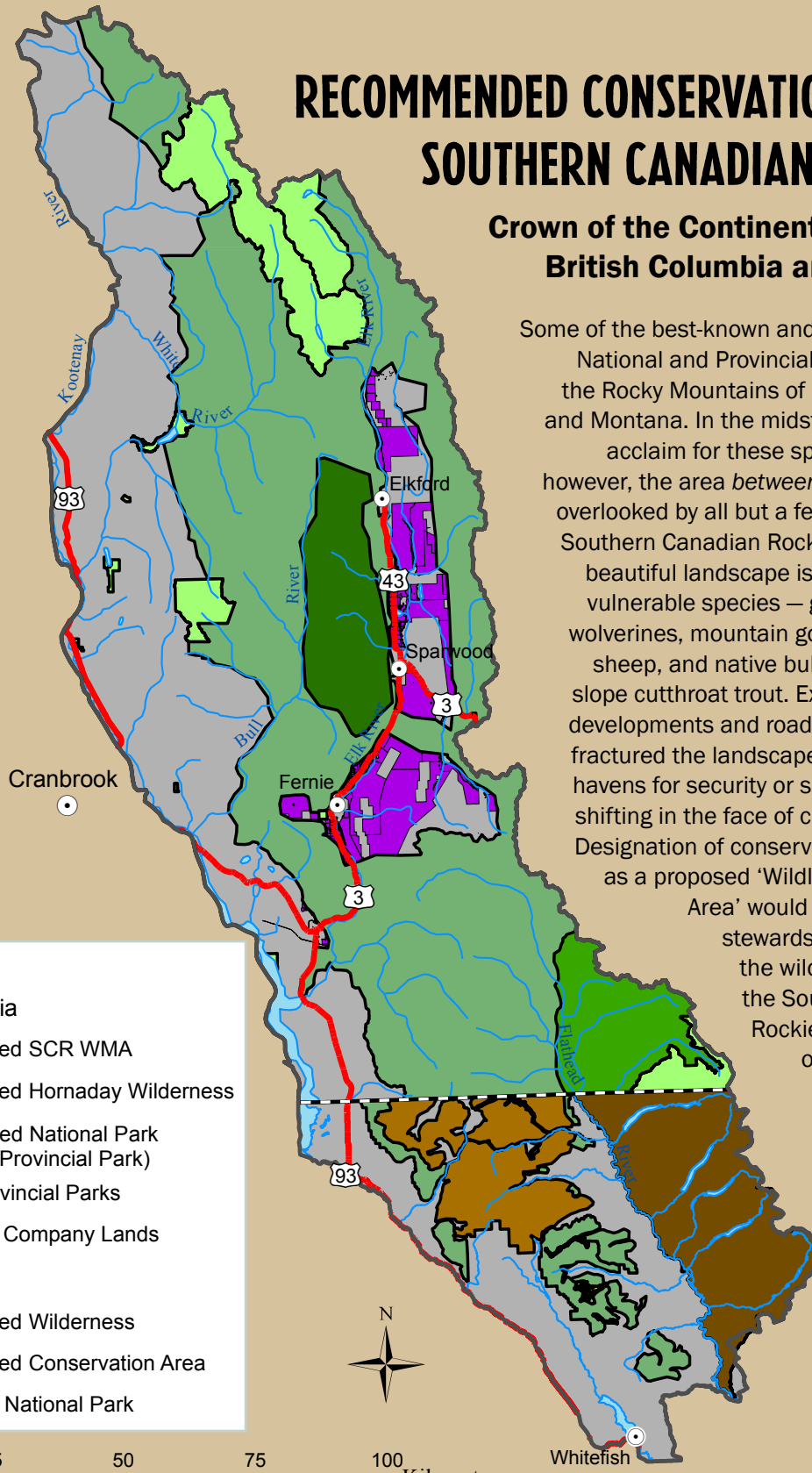
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RECOMMENDED CONSERVATION LANDS SOUTHERN CANADIAN ROCKIES

Crown of the Continent Ecosystem British Columbia and Montana

Some of the best-known and most-cherished National and Provincial Parks are set in the Rocky Mountains of British Columbia and Montana. In the midst of international acclaim for these spectacular Parks, however, the area *between* them has been overlooked by all but a few. Known as the Southern Canadian Rockies, this rugged, beautiful landscape is a stronghold for vulnerable species – grizzly bears and wolverines, mountain goats and bighorn sheep, and native bull trout and west-slope cutthroat trout. Expanding human developments and roads, however, have fractured the landscape – with few safe havens for security or safe passages for shifting in the face of changing climate. Designation of conservation lands such as a proposed 'Wildlife Management Area' would provide stronger stewardship to safeguard the wildlife treasures of the Southern Canadian Rockies while allowing other responsible land use.



Legend

British Columbia

- Proposed SCR WMA
- Proposed Hornaday Wilderness
- Proposed National Park (or BC Provincial Park)
- BC Provincial Parks
- Private Company Lands

Montana

- Proposed Wilderness
- Proposed Conservation Area
- Glacier National Park

0 12.5 25 50 75 100 Kilometers



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