Bighorn Backcountry of Alberta

Protecting Vulnerable Wildlife and Precious Waters

JOHN WEAVER

May 2017

WCS CANADA

WCS CANADA CONSERVATION REPORT #10

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SUMMARY

Some of the best-known and most-cherished mountains on Earth are set in the Canadian Rockies of Alberta. Indeed, the mention of Banff and Jasper National Parks evokes images of snow-capped peaks, thundering falls and turquoise waters, numerous natural wonders and majestic wildlife. More than nine million people visit the Canadian Rockies each year, a major boost to regional economies.

Adjacent to the eastern boundary of these two acclaimed *World Heritage Sites* – but quite similar in spectacular terrain and shared wildlife – lies an area known as the 'Bighorn Backcountry'. More sky-piercing mountains and beautiful river valleys coursing eastward through boreal forests in the foothills of the Eastern Slopes of Alberta. Here are the headwaters of the mighty North Saskatchewan River, fountain source of precious clean water for all life – including people on the farms, towns, and the Edmonton Metropolitan region with a population of >1.1 million. Here are the rare and vulnerable species – grizzly bears, wolverines, bighorn sheep and bull trout – that travel widely through various jurisdictions to sustain their needs. Of course, the indigenous people of the Stoney Nakoda First Nation have long hunted, fished, and gathered foods and medicinal plants throughout this, their traditional territory.

In recent decades, linear features such as roads, seismic lines and OHV trails have accumulated across the foothills of the Eastern Slopes of Alberta. Now, melting of the Athabasca and Saskatchewan glaciers 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 snowpack and earlier melting in spring, resulting in warmer streams and declining flows, and 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 vulnerable species, of course, is that the Eastern Slopes of Alberta have been fractured by roads, seismic lines and developments.

But here in the Bighorn Backcountry is an opportunity to match its wildlife and water treasures with stronger stewardship. The purpose of this scientific report is to inform discussions and decisions about wildlife and land management in this headwaters area of the North Saskatchewan River. The goal is to assess the conservation value of ~10,000 km^2 of Provincial lands for a suite of

vulnerable fish and wildlife species - grizzly bear, wolverine, bighorn sheep, and bull trout – and its headwater rivers.

The grizzly bear has been listed as a threatened species by the Alberta government. Ironically, grizzly bears have high vulnerability because they have very low reproduction and cannot quickly compensate for excessive mortality. Road access into high-quality habitats, such as berry patches or riparian zones along streams, can increase encounter rates with people and lead to displacement, habituation or mortality. Young females do not disperse very far, and adult females do not readily cross major highways where human settlements predominate. Protection of large areas of productive habitats with security from human disturbance and mortality are key conservation measures.

In DNA-based surveys of grizzly bears in the Bighorn Backcountry area, 93% of the 164 detections occurred west of the Forestry Trunk Road (FTR) #734 – including nearly all of the female grizzlies detected. Over the past five years, the four highest sources of mortality in Alberta have been: poaching (27%), accidental collisions with highway vehicles or trains (21%), self-defense claims (usually by hunters - 20%), and black bear hunters misidentifying and shooting a grizzly bear (13%). Areas with high or moderate habitat value and high security from human disturbance (called 'safe harbours') are the most important to grizzly bears. About 746,723 ha of safe-harbour lands occur on Provincial lands outside the two wilderness areas, and most (76%) of these occur west of the FTR #734. These lands help provide the foundational capacity for grizzly bear recovery in Alberta. Other key areas east of the FTR#734 road offer strategic opportunities to restore needed security for grizzly bears.

Wolverines exhibit high vulnerability. Within their range in Alberta, wolverines usually occupy higher elevations in alpine, subalpine, and upper foothill zones, as well as northern boreal forests. Wolverines have very low reproductive rates and cannot sustain high mortality rates, which can be exacerbated by trapping pressure. Linear features such as roads and seismic lines facilitate motorized access into wolverine habitat – the cumulative effects of which can degrade habitat suitability and increase risk of trapping or hunting mortality. Due to their multi-faceted adaptation to snow environments, wolverines appear vulnerable to reductions in suitable habitat at lower elevations resulting from a projected warming climate. Numerous wolverine researchers have recommended refugia – created by restricting/eliminating trapping or designating roadless sanctuaries – as a crucial element in the overall conservation of wolverine. About 60% of primary habitat for wolverine in the Bighorn Backcountry occurs on Provincial lands outside Wilderness. Most (83%) of the primary habitat and all of the maternal habitat occurs west of the Forestry Trunk Road #734.

Rocky Mountain bighorn sheep – the Provincial *Mammal* – are managed as a trophy big game species in Alberta. Bighorn sheep exhibit moderate vulnerability. Female sheep have moderate reproduction, but wild sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. They have a narrow feeding niche on grasses and are constrained to live on or near cliffs for escape terrain. In winter, deep snow can hinder movements of bighorn sheep (especially ewes and lambs) and their access to grass forage. Close interspersion of rocky terrain/cliffs with south-facing or wind-swept grassy slopes delimits critical habitat during winter for bighorn sheep. Although sheep appear to habituate to predictable motorized disturbance along highways, low-level helicopter overflights can be quite stressful to them. About 2,000 bighorn sheep occur in three major areas in the Bighorn Backcountry. Approximately 75% of the winter habitat (total = 272,986 ha) for bighorn sheep occurs on Provincial lands on 16 recognized winter ranges. About 96% of these critical winter ranges lie west of the Forestry Trunk Road #734.

Bull trout – the Provincial *fish* of Alberta – have high vulnerability and have been listed by the Alberta government as a *species of special concern*. Bull trout have the most demanding requirement for cold and clean waters – particularly for spawning and rearing – and are especially vulnerable to warming temperatures and drought conditions in late summer. Bull trout exhibit slow growth, late age at maturity, low fecundity, longevity, and high catchability – which renders them particularly susceptible to over-fishing (even catch-and-release practice can result in mortality). They have low resistance to hybridization by non-native brook trout and competition/predation by lake trout, too. Some adult bull trout in the Rocky Mountains migrate long distances from wintering areas in lower rivers to spawning areas in the headwaters; dams and poorly-installed hanging culverts can block vital connectivity.

The historical range of bull trout in Alberta extended from the mountains and foothills out to the prairie as far as Calgary and Lethbridge. Although bull trout still occur in all of the major watersheds of the Eastern Slopes, they have declined significantly (33%) in range and numbers due to cumulative effects of these multiple factors. About 75% of the waters in the Bighorn Backcountry are deemed thermally suitable for spawning/rearing, whereas the remainder is suitable for foraging, migrating, and/or overwintering. (Some 17% are un-occupied due to impassable waterfalls on the lower Ram, Siffleur, and Bighorn Rivers). The Blackstone River is ranked very high for relative density of juvenile trout, and the upper North Saskatchewan, Cline, and Nordegg Rivers are ranked high. The Brazeau River and Pinto Lake/Cline River have the highest relative abundance of adult bull trout (1,000-2,500), while the Blackstone River and middle North Saskatchewan River have moderate abundance (250-1,000) of adults.

Nearly all of the occupied streams suitable for spawning/rearing occur west of the FTR#734, whereas lower sections of the main rivers east of the road are suitable for overwintering and migrating. Protection of clean, cold, complex and connected habitat from invasion by non-native fish remains the principal strategy in conserving bull trout.

Major highways and settlements fracture habitat connectivity for wide-ranging species such as grizzly bears and wolverines. Such fragmentation can diminish 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 11 is a major east-west route across the Canadian Rockies and foothills. Although the current traffic volume on the highway is comparatively low, connectivity is blocked by Abraham Reservoir, which closely parallels the highway for 30 km and is 1-3 km wide. Based upon habitat mapping and field reconnaissance, I identified and mapped four potential linkages across Highway 11: two north of the reservoir and two south of it.

Gravel-bed river floodplains in the valleys of the Rocky Mountains are exceptionally important to regional biodiversity of aquatic and terrestrial species. Throughout the year, water is constantly flowing out of the river channel and into the gravels below and laterally beyond the channel ('hyporheic zone' meaning 'under-river'). These waters extend across the U-shaped valley bottom, often from valley wall to valley wall and upwards of a kilometer laterally from the river channel. These moving ground waters cool surface waters during the summer and keep them warmer during the winter. The complex and dynamic landscapes of river valleys concentrate diverse habitats at small scales, cycle nutrients, and provide natural corridors for movement. They are the ecological stage where daily dramas shape the survival and behaviour of prey and predator alike. Structural modifications to floodplains such as roads, railways, housing, and hydroelectric dams have severe impacts on floodplain habitat diversity and productivity, restrict local and regional connectivity, and reduce the resilience of both aquatic and terrestrial species, including adaptation to climate change.

River valleys and riparian zones have been noted as natural corridors or 'hotspots' for climate-driven movements because they span the temperature gradients animals are likely to follow as they attempt to track shifting areas of climatic suitability. To characterize the climate-corridor capability of river valleys, we devised a method for quantifying the range of temperatures along rivers from mouth to headwater, measuring the width of the river valley floor, and accounting for displacement effects of roads. Several rivers in the Bighorn Backcountry – notably the North Saskatchewan, Clearwater, Red Deer, and Brazeau – ranked very high. Rivers in the mountains west of the Forestry Trunk Road #734 typically traverse a greater range of temperature gradient and have sections with wide valley bottoms. River sections in the foothills east of the FTR #734 have broad valley bottoms, but longer stretches of warmer temperatures.

With scientific consensus on projections of warming of 2°-4° C over the next 50-100 years, a smart strategy going forward is to protect large landscapes with high topographic and environmental diversity from river valley to mountain peak and to connect such large, diverse core areas. The Bighorn Backcountry offers an opportunity to secure a vital refugium for changing conditions, but a critical question remains: where are the most effective places to safeguard its wildlife and water treasures?

In terms of the composite value across all four species plus the river climate-corridor score, a large majority (75%) of the Bighorn Backcountry area has high to moderate value for wildlife and river valleys. For this suite of species, most of the high scores are found on Provincial lands in the remote mountains and subalpine valleys of the Front Range of mountains west of the Forestry Trunk Road #734.

In terms of importance values for any of the focal species, nearly all (92%) of the Bighorn Backcountry area of Alberta has very-high (75%) or high (17%) value for one or more of these vulnerable species. Most of these occur on non-wilderness Provincial lands: 64% of very-high scores and 89% of high scores.

A large majority of the species importance values are concentrated on Provincial lands west of the Forestry Trunk Road #734.

Environmentally Significant Areas (ESAs) are non-legislated areas recognized by the Alberta government as important for conservation of biodiversity, water and other natural attributes. Methods and maps for ESAs were updated in 2014 for the province. A large majority (71%) of the Rocky Mountain Natural Region contains ESAs due to the relatively high degree of ecological integrity and important sources of water. About 72% of the Bighorn Backcountry area has been delineated as ESAs, which comprises the largest, most-intact block of ESAs in the entire North Saskatchewan River basin. Importantly, 75% of the ESAs occur on non-wilderness Provincial lands, mostly west of Forestry Trunk Road #734.

In the Bighorn Backcountry area, there are 1 million hectares (ha.) of Provincial lands (excluding existing Wilderness Areas). The area east of the Forestry Trunk Road #734 has its own set of conservation values for various wildlife species, habitat for grizzly bears and bull trout, downstream sections of these major rivers, and boreal forests. These values are identified in the report "Conservation Blueprint of Northern Alberta" (Canadian Parks and Wilderness Society 2015) and should be recognized with improved management on Crown lands.

Provincial lands west of the Forestry Trunk Road #734, however, have a concentration of critical habitat for vulnerable wildlife and the headwaters of the North Saskatchewan River. These lands comprise 68% of the study area but provide a higher proportion of the most important habitats for the following species/features:

- ✔ wolverine 100 %
- ✔ bighorn sheep 96 %
- ✔ bull trout 84 %
- ✔ grizzly bear 75 %
- ✔ composite score 93 %
- ✔ ESA 78 %
- ✔ species importance 77 %.

Accordingly, I recommend 690,800 ha. west of the Forestry Trunk Road #734 be designated as a *Wildland* Provincial Park. *Wildland* Provincial Parks are a type of Provincial Park established specifically to protect natural heritage over large areas and provide opportunities for backcountry recreation. Designation of a Wildland Park would signal a first-order commitment to conservation and recovery for several vulnerable species. Moreover, the recommended Wildland Park would protect the headwaters of the North Saskatchewan River, the 'water towers' which provide much of the water for people in west-central Alberta, including the capital Edmonton. These rugged and diverse lands also provide more options and lesser impacts from warming climate trends. It would have *added* value by protecting Provincial lands adjacent to Banff and Jasper National Parks in the Canadian Rockies and foothills of Alberta. **The concentration of high conservation values for vulnerable wildlife and valuable waters makes a compelling case and 'best-buy' for designation of a 'Bighorn *Wildland* Provincial Park'.**

RÉSUMÉ

Les Rocheuses Canadiennes de l'Alberta comptent parmi les montagnes les plus renommées et aimées du monde. De fait, la simple mention des Parcs Nationaux de Banff et de Jasper évoque des images de sommets enneigés, de cascades tumultueuses et d'eaux turquoises, un grand nombre de merveilles naturelles et une faune majestueuse. Les Rocheuses Canadiennes accueillent plus de neuf millions de visiteurs chaque année, un coup de pouce majeur aux économies régionales.

Adjacent à la frontière est de ces deux célèbres *Sites de l'Héritage Mondial* – et relativement similaire en terme de terrain spectaculaire et en partageant la faune – se trouve un lieu connu sous le nom de « Bighorn Backcountry », qui abrite d'autres montagnes gigantesques et de belles rivières courant vers l'est au travers de forêts boréales dans les piémonts des Coteaux de l'Est de l'Alberta. Ici se trouvent les sources de la majestueuse rivière North Saskatchewan, fontaine d'eau claire pour toute vie – y compris celle des habitants des fermes, des villes, et de la région métropolitaine d'Edmonton avec sa population supérieure à 1,1 million. Ici aussi se rencontrent des espèces rares et vulnérables – les ours grizzly, les gloutons, les mouflons et la truite fauve – qui voyagent sur une grande étendue à travers diverses juridictions pour sustenter à leurs besoins. Bien sûr, les habitants indigènes de la Nation Première Stoney Nakoda ont depuis longtemps chassé, pêché, et glané nourriture et plantes médicinales dans ce lieu, leur territoire traditionnel.

Les décennies récentes ont vu l'accumulation d'empreintes linéaires telles que routes, lignes sismiques et chemins pour véhicules tout-terrain à travers les piémonts des Coteaux de l'Est de l'Alberta. Aujourd'hui, la fonte des glaciers Athabasca et Saskatchewan annonce des changements climatiques qui pourraient devenir encore plus prononcés au cours des décennies à venir. Les climatologues projettent des hivers plus doux et des étés plus chauds, une diminution du manteau neigeux et une fonte des neiges plus précoce au printemps, ayant pour conséquences une hausse de la température de l'eau et un déclin de l'écoulement des torrents ainsi qu'une augmentation de la sévérité des feux de forêt. En réponse, la faune aura besoin d'espace pour parcourir la région alors qu'elle tente de traquer la localisation changeante de son habitat. Pour les espèces vulnérables, le problème est bien sûr la fracture des Coteaux de l'Est de l'Alberta par les routes, les lignes sismiques, et d'autres développements.

Mais ici, dans le Bighorn Backcountry, se trouve l'opportunité de mettre en place in intendance plus appuyée des trésors faunistiques et aquatiques. L'objectif de ce rapport scientifique est d'informer les discussions et les décisions concernant la faune sauvage et la gestion des terres dans ce pays des sources de la rivière North Saskatchewan. Le but est d'évaluer la valeur conservatrice d'environ 10.000km^2 de terres Provinciales pour une série d'animaux vulnérables : ours grizzly, glouton, mouflon et truite fauve ; ainsi que pour les rivières.

L'ours grizzly est listé comme espèce <u>menacée</u> par le gouvernement de l'Alberta. Ironiquement, les ours grizzly ont une vulnérabilité <u>élevée</u> en raison d'un faible taux de reproduction qui ne leur permet pas de compenser une mortalité excessive. L'accès routier dans des habitats de haute qualité tels que les buissons à baies ou les zones riveraines des torrents peut augmenter le taux de rencontre avec les humains et contribuer au déplacement des ours, à leur accoutumance ou à leur mortalité. Les jeunes femelles ne se dispersent pas loin, et les femelles adultes ne traversent pas facilement les grands axes routiers où dominent les développements humains. Protéger de larges zones d'habitats productifs des dérangements et de la mortalité liés aux humains forme une mesure clé de la conservation des ours.

Dans les recensements basés sur l'ADN des ours grizzly dans le Bighorn Backcountry, 93% de 164 détections se trouvent à <u>l'ouest</u> de la Route Forestière Trunk (RFT) #734 – comprenant quasiment toutes les femelles détectées. Au cours des 5 années passées, les quatre sources de mortalité les plus élevées en Alberta ont été : le braconnage (27%), les collisions accidentelles avec les voitures ou les trains (21%), les revendications de self-défense (en général par les chasseurs) (20%), et les chasseurs d'ours noir faisant une erreur d'identification et tuant un ours grizzly (13%). Les lieux où l'habitat a une valeur élevée ou modérée et protégés des dérangements humains (appelés « abris sûrs ») sont les plus importants pour les ours grizzly. On trouve environ 746.723 ha de ces abris sûrs dans les terres Provinciales en dehors de deux Wilderness, et la plupart (76%) se trouvent à <u>l'ouest</u> de RFT #734. Ces terres aident à pourvoir à la capacité fondatrice du rétablissement de l'ours grizzly en Alberta. D'autres sites-clés à l'est de RFT #734 offrent des opportunités stratégiques pour restaurer la sécurité dont les ours grizzly ont besoin.

Les gloutons présentent une vulnérabilité <u>élevée</u>. En Alberta, on les trouve en général à haute altitude dans les zones alpines, subalpines et des piémonts supérieurs, ainsi que dans les forêts boréales du nord. Les gloutons ont un taux de reproduction très faible et ne peuvent subir de forts taux de mortalité, lesquels peuvent être exacerbés par la pression de piégeage. Les dérangements linéaires tels que les routes et lignes sismiques facilitent l'accès motorisé dans l'habitat du glouton – et leurs effets cumulés peuvent dégrader la qualité de l'habitat et augmenter le risque de mortalité lié au piégeage ou à la chasse. En raison de leur adaptation multi-facette aux milieux enneigés, les gloutons seraient vulnérables à la réduction de leur habitat de basse altitude résultant du réchauffement climatique projeté. De nombreux spécialistes du glouton ont recommandé des refuges – créés en limitant ou éliminant le piégeage, ou en désignant des sanctuaires sans routes – comme élément crucial dans la conservation globale du glouton. Environ 60% de l'habitat primaire du glouton dans la Bighorn Backcountry se trouve dans les terres Provinciales à l'extérieur des Wilderness. La plupart (83%) de l'habitat primaire et la totalité de l'habitat maternel se trouvent à l'ouest de la Route Forestière Trunk #734.

Le mouflon des Montagnes Rocheuses – le Mammifère Provincial – est géré comme espèce trophée en Alberta. La vulnérabilité du mouflon est modérée. Les femelles ont un taux de reproduction modéré, mais les moutons sauvages sont hautement susceptibles aux épidémies de maladies (certaines transportées par les moutons domestiques) qui peuvent rapidement décimer un troupeau. Leur niche alimentaire herbivore est étroite et ils sont contraints à vivre sur, ou près des falaises qui leur servent de terrain de fuite. En hiver, la neige profonde peut entraver le mouvement des mouflons (en particulier celui des femelles et des agneaux) et leur accès au fourrage herbeux. Un entrecroisement de terrains rocheux/falaises et de pentes herbeuses orientées au sud ou balayées par le vent délimite l'habitat critique du mouflon durant l'hiver. Bien que les mouflons semblent s'habituer aux dérangements motorisés prévisibles le long des autoroutes, les vols d'hélicoptères à basse altitude peuvent être stressants. On dénombre environ 2.000 mouflons dans trois zones majeures dans la Bighorn Backcountry. Approximativement 75% de l'habitat hivernal du mouflon (total = 272.986 ha) se trouve en terres Provinciales, dans 16 zones hivernales reconnues. Environ 96% de ces zones se trouvent à l'ouest de la Route Forestière Trunk #734.

La truite fauve – le Poisson Provincial de l'Alberta – est hautement vulnérable et a été listée comme *espèce à préoccupation spéciale* par le gouvernement de l'Alberta. La truite fauve a les exigences les plus élevées pour des eaux froides et propres – en particulier pour la ponte et l'élevage des alevins – et est particulièrement vulnérable à l'augmentation des températures et aux conditions de sècheresse de fin d'été. Les truites fauves ont une croissance lente, sont âgées à maturité, ont une faible fécondité, une grande longévité, et sont facilement attrapable – ce qui les rend particulièrement susceptibles à la surpêche (les pratiques de pêché-et-relâche pouvant aussi contribuer à leur mortalité). Elles ont une faible résistance à l'hybridation avec l'omble de fontaine non-indigène, ainsi qu'à la compétition/prédation par la truite de lac. Dans les Montagnes Rocheuses, certaines truites fauves adultes migrent de longues distances entre les habitats hivernaux des rivières de basse altitude et les zones de ponte en tête de bassins versants ; les barrages et caniveaux suspendus mal installés peuvent bloquer cette connectivité vitale.

Le domaine historique de la truite fauve en Alberta s'étendait des montagnes et piémonts jusqu'aux prairies aussi éloignées que Calgary et Lethbridge. Bien qu'encore présentes dans tous les bassins versants majeurs des Coteaux de l'Est, les truites ont décliné de façon significative (33%) en étendue et en nombre suite aux effets cumulés des facteurs présentés ci-dessus. Environ 75% des eaux dans la Bighorn Backcountry sont estimées être thermiquement favorables à la ponte et à l'élevage des alevins, le reste étant propice à l'alimentation, la migration, et/ou l'hivernage (environ 17% sont inoccupés en raison de cascades impassables sur les rivières Lower Ram, Siffleur, et Bighorn). La rivière Blackstone est classée très haute pour la densité de truite juvéniles, et les rivières

Upper North Saskatchewan, Cline et Nordegg sont classées hautes. Les rivières Brazeau et Pinto Lake/Cline ont la plus grande abondance relative de truites adultes (1.000-2.500), tandis que les rivières Blackstone et Middle North Saskatchewan ont une abondance d'adultes modérée (250-1.000).

Pratiquement tous les torrents favorables à la ponte et à l'élevage des alevins se trouvent à l'ouest de RFT #734, tandis que les sections aval des rivières majeures à l'est de la route conviennent à l'hivernage et à la migration. La protection, contre l'invasion par des espèces non-indigènes, d'habitats propres, froids, complexes et connectés reste la principale stratégie de conservation de la truite fauve.

Les principaux axes routiers et le peuplement humain fracturent la connectivité de l'habitat des espèces à large domaine telles que le grizzly et le glouton. Une telle fragmentation peut réduire les populations et l'échange génétique, et entraver le mouvement d'animaux traquant des conditions climatiques changeantes. Par conséquent, de nombreux spécialistes de la faune sauvage recommandent des liens paysagers pour faciliter les mouvements présents et futurs. L'autoroute 11 est un axe majeur est ↔ ouest à travers les Rocheuses Canadiennes et les piedmonts. Bien que le volume de trafic actuel sur l'autoroute soit relativement faible, la connectivité est bloquée par le Réservoir Abraham, qui suit étroitement l'autoroute sur 30 km et mesure entre 1 et 3 km de large. En me basant sur la cartographie de l'habitat et des reconnaissances de terrain, j'ai identifié quatre zones de lien potentiel en travers de l'autoroute 11 : deux au nord du réservoir et deux au sud.

Les plaines inondables aux lits de gravier dans les vallées des Montagnes Rocheuses sont exceptionnellement importantes à la biodiversité régionale des espèces aquatiques, aviaires, et terrestres. Durant l'année, l'eau s'écoule constamment à l'extérieur du lit des rivières, dans les gravières inferieures et latérales en-deçà du lit ('zone hyporhéique' signifiant 'sous-rivière'). Ces eaux s'étendent en travers du fond de vallée en forme de U, souvent d'un bord à l'autre de la vallée et jusqu'à un kilomètre latéralement du lit de la rivière. Ces courants souterrains refroidissent les eaux de surface durant l'été et les gardent plus chaudes en hiver. Les paysages complexes et dynamiques des vallées concentrent divers habitats à petite échelle et forment des corridors naturels pour le mouvement de la faune. Ils forment la scène écologique sur laquelle les drames journaliers façonnent la survie et le comportement des proies et de leurs prédateurs. Les modifications structurales des plaines inondables, telles que routes, voies ferroviaires, habitations et barrages hydroélectriques ont un impact sévère sur la diversité et la productivité des habitats de ces plaines. Elles restreignent la connectivité locale et régionale et diminuent la résilience des espèces aquatiques et terrestres, y compris leur adaptation au changement climatique.

Les vallées et zones riveraines ont été identifiées comme « points chauds » pour les déplacements liés au climat car elles englobent les gradients de température que les espèces suivront probablement en tentant de traquer les zones changeantes du climat leur convenant. Pour caractériser l'aptitude des vallées riveraines à servir de corridors climatiques, nous avons conçu une méthode pour quantifier la variation des températures le long des rivières, de l'embouchure à la source ; mesurer la largeur du fond de vallée ; et prendre en compte les effets de déplacement liés aux routes. Plusieurs rivières de la Bighorn Backcountry – notamment North Saskatchewan, Clearwater, Red Deer, et Brazeau – sont classées très haut. Typiquement, les rivières de montagnes à l'ouest de la Route Forestière Trunk #734 traversent un gradient de température plus important et comprennent des sections à large fond de vallée. Les rivières à l'est de RFT #734 présentent de larges fonds de vallée, mais aussi de plus longues sections de températures élevées.

Les scientifiques s'accordant sur des projections de réchauffement de 2° à 4°C au cours des 50 à 100 années à venir, la stratégie la plus intelligente pour aller de l'avant consiste à protéger et à connecter de larges paysages à la topographie et aux environnements variés, allant des vallées riveraines aux sommet des pics montagneux. La Bighorn Backcountry offre l'opportunité de sécuriser un refuge vital en cas de conditions changeantes, mais il reste une question critique : où se trouvent les endroits les plus efficaces pour sauvegarder ses trésors faunistiques et aquatiques ?

En terme de valeur composée comprenant les scores des quatre espèces ainsi que celui des rivières « corridor climatiques », une large majorité (75%) de la Bighorn Backcountry présente une valeur haute a modérée. Pour cette suite d'espèce, la majorité des scores élevés se trouvent dans les montagnes isolées et dans les vallées subalpines de la chaine montagneuse à l'ouest de la Route Forestière Trunk #734.

En terme de valeur d'importance pour n'importe quelle espèce clé, pratiquement toute (92%) la Bighorn Backcountry d'Alberta est classée comme très élevée (75%) ou élevée (17%) pour au moins une espèce vulnérable. La plus grande partie se trouve dans les terres Provinciales (en dehors des Wilderness), qui contiennent 64% des scores très élevés et 89% des scores élevés. Une large majorité des valeurs d'importance des espèces se concentre sur les terres Provinciales à l'ouest de la Route Forestière Trunk #734.

Les Zones Environnementales Significatives (ZES) sont des régions non-légiférées reconnues par le gouvernement de l'Alberta comme étant importantes à la conservation de la biodiversité, des sols, de l'eau, et d'autres caractéristiques naturelles. Les méthodes et les cartes des ZES de la province ont été mises à jour en 2014. Une large majorité (71%) de la Région Naturelle des Montagne Rocheuses contient des ZES en raison de son degré d'intégrité écologique relativement élevé et de ses sources aquatiques importantes. Environ 72% de la Bighorn Backcountry est placée en ZES et comprend le plus grand bloc intact de ZES du bassin versant de la rivière North Saskatchewan. Il est important de noter que 75% des ZES se trouvent dans les terres Provinciales non classées en Wilderness, en majorité à l'ouest de la Route Forestière Trunk #734.

La Bighorn Backcountry comprend 1 million d'hectares de terres Provinciales (en dehors des zones de Wilderness existantes). La région à l'est de la Route Forestière Trunk #734 présente son propre ensemble de valeurs de conservation pour diverses espèces animales. On y trouve de l'habitat pour les ours grizzly et la truite fauve, les sections aval de majeures rivières, et des forêts boréales, valeurs identifiées dans le rapport « Conservation Blueprint of Northern Alberta » (Canadian Parks and Wilderness Society 2015) et qui devraient être reconnues par une gestion améliorée dans les terres de la Couronne.

Cependant, les terres Provinciales à l'ouest de la Route Forestière Trunk #734 présentent une concentration d'habitats critiques à la faune vulnérable et contiennent les sources de la rivière North Saskatchewan. Ces terres forment 68% de l'aire d'étude mais pourvoient une plus grande proportion des habitats les plus importants des espèces/traits suivants :

✔ Glouton	100%
✔ Mouflon	96%
✔ Truite fauve	84%
✔ Ours grizzly	75%
✔ Score composé	93%
✔ ZIE	78%
✔ Importance par espèce	77%

En conséquence, je recommande que 690.800 ha à l'ouest de la Route Forestière Trunk #734 soient désignés comme Parc Provincial *Wildland*. Les Parcs Provinciaux *Wildland* sont un type de Parc Provincial établi spécifiquement pour protéger l'héritage naturel de larges régions et pour fournir la possibilité de loisirs en milieu sauvage. La désignation d'un Parc Wildland serait le signe d'un engagement de premier ordre à la conservation et restauration de plusieurs espèces vulnérables. De plus, le Parc Wildland recommandé ici protègerait les sources de la rivière North Saskatchewan, ces « tours d'eau » qui fournissent beaucoup de l'eau nécessaire aux populations humaines dans le centre-ouest de l'Alberta, y compris à celles de sa capitale Edmonton. Ces terres accidentées et variées fournissent aussi des options supplémentaires pour réduire les impacts du réchauffement climatique. Le Parc Wildland aurait une valeur *ajoutée* en protégeant les terres Provinciales adjacentes aux Parcs Nationaux de Banff et de Jasper dans les Rocheuses Canadiennes et les piémonts de l'Alberta. **La concentration de valeurs de conservation élevées pour la faune vulnérable et de précieuses rivières est un argument irrésistible et de « meilleur achat » en faveur de la désignation d'un « Parc Provincial *Wildland* Bighorn ».**

1. THE BIGHORN BACKCOUNTRY OF ALBERTA

Introduction: Vulnerable Wildlife, Precious Waters

Some of the best-known and most-cherished mountains on Earth are set in the Canadian Rockies of Alberta. Indeed, the mention of Banff and Jasper National Parks evokes images of snow-capped peaks, thundering falls and turquoise waters, numerous natural wonders and majestic wildlife. More than nine million people visit the Canadian Rockies each year, a major boost to regional economies.

Adjacent to the eastern boundary of these acclaimed *World Heritage Sites* – but quite similar in terrain and shared wildlife – lies an area known as the 'Bighorn Backcountry'. More sky-piercing mountains and beautiful river valleys coursing eastward through boreal forests in the foothills of the Eastern Slopes of Alberta. Here are the headwaters of the mighty North Saskatchewan River, fountain source of precious clean water for all life – including people on the farms and towns downstream. Here are the rare and vulnerable species – grizzly bears, wolverines, bighorn sheep and bull trout – who travel widely through various jurisdictions to sustain their needs. Of course, the indigenous people of the Stoney Nakoda First Nation have long hunted, fished, and gathered foods and medicinal plants throughout their traditional territory.

In recent decades, linear features such as roads, seismic lines, and OHV trails have accumulated across the foothills of the Eastern Slopes of Alberta. Now, melting of the Athabasca and Saskatchewan glaciers 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 snowpack 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 vulnerable species, of course, is that the Eastern Slopes of Alberta have been fractured by roads, seismic lines and developments.

But here in the Bighorn Backcountry is an opportunity to match its wildlife and water treasures with stronger stewardship. But where are the key remaining places for wildlife and native fish? Where are the linkages across highways that will enable wildlife to move to meet both short-term and long-term needs? What land management options will protect these headwater havens? This report compiles and synthesizes scientific data from Alberta sources to address these questions.

For this conservation assessment of wildlife and waters, I delineated an area called the 'Bighorn Backcountry Area' that encompasses 14,334 km^2 of the headwaters of the North Saskatchewan River (NSR) basin in Alberta (Figures 1 and 2). The western boundary is the Continental Divide which lies in Banff National Park. The north boundary is the border with Jasper National Park along the Brazeau River. The south boundary follows the upper section of the Red Deer River. The eastern boundary is delineated by the eastern edge of the *Core* recovery zone for grizzly bears in Alberta (wherein it is the intention of the Government of Alberta to manage for recovery of grizzly bears: Alberta Environment and Parks 2016). The mountain section of the Bighorn Backcountry is nestled between Jasper and Banff National Parks – essentially a continuation of that spectacular terrain (Figure 2). In fact, during the period 1917-1930, an area of 1907-km^2 between the Clearwater and Panther Rivers *was* part of Banff National Park (Lothian 1976, Great Plains Research Consultants 1984).

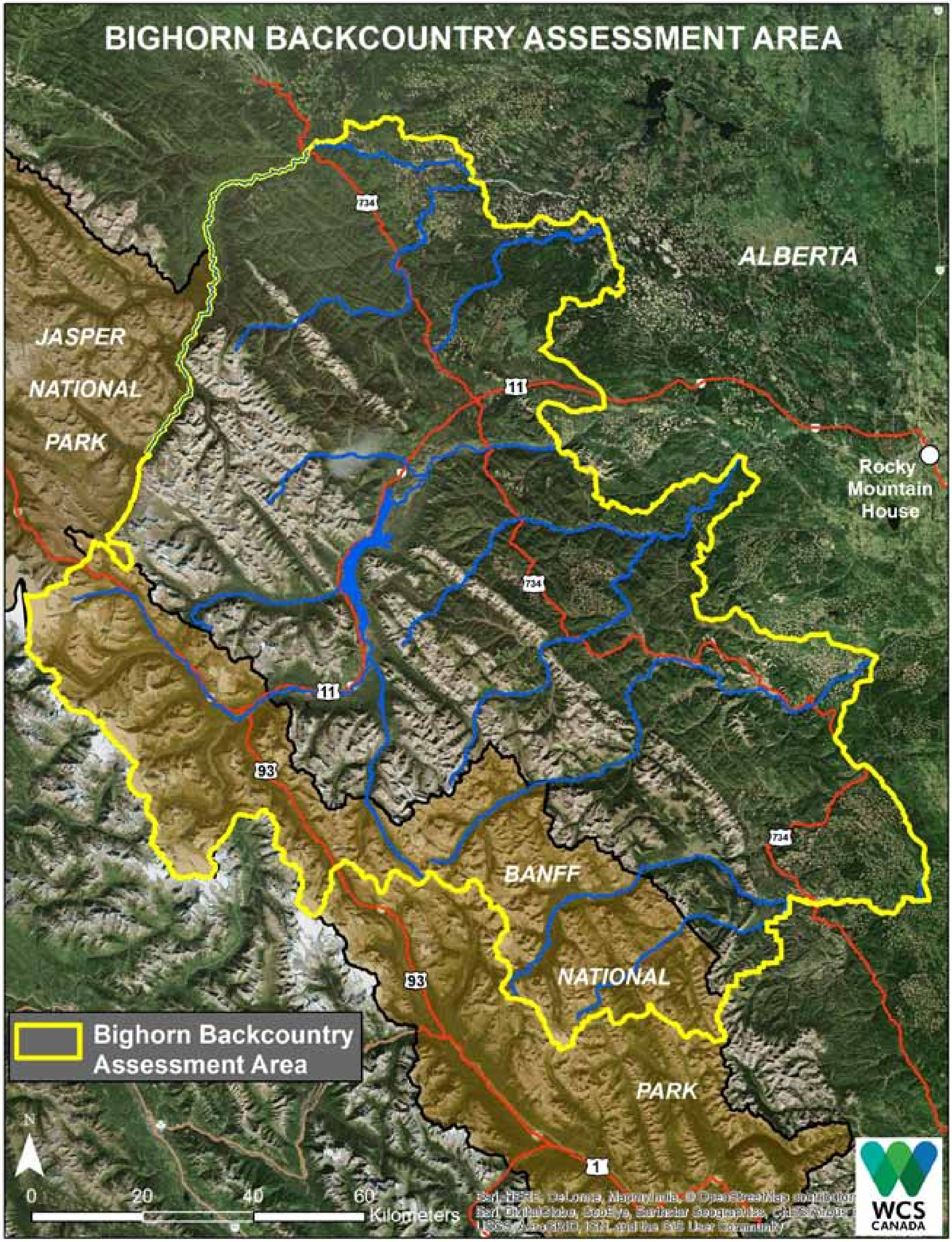
The study area is characterized by a cool continental climate. Mean annual temperature during the1981-2010 period was -0.44° C (± 1.8), with min and max temperatures of -4.80° C and 2.81° C. (Wang et al. 2012). Mean annual precipitation during the 1981-2010 period was 916 mm, with an average of 114 mm during summer. Because it lies on the eastern slopes of the Continental Divide, there is a declining gradient in precipitation from west east. The watershed is topographically diverse, with an elevation range from 1046 m to 3529 m.

Photo: John Weaver

North Saskatchewan River landscape

Figure 1. Delineation of the Bighorn Backcountry area in Alberta used for this conservation assessment. It encompasses the multi-branched headwaters of the North Saskatchewan River watershed nestled between Banff and Jasper National Parks in the Canadian Rockies.

Figure 2. Satellite image of the Bighorn Backcountry assessment area, Alberta. Notice its continuity of the Canadian Rockies terrain with Banff and Jasper National Parks.



The Bighorn Backcountry area includes a diversity of Alberta's Natural Regions and Subregions (Table 1, Figure 3) (Natural Regions 2006). The Rocky Mountain Natural Region covers about 67% (955,609 ha) – with 33% Alpine, 31% Subalpine, and 3% Montane Subregions. The Alpine Subregion above treeline is characterized by strong winds, high snowfall, and the coldest summers. Vegetation consists of complex mosaics of low-growing forms – lichens on bedrock, heather and mountain avens, willow–bog birch. The Subalpine Subregion occupies mid-slopes of the Front Ranges. Although environmental conditions are relatively less harsh than in the alpine, this is still a cold, unproductive zone. At higher elevations, coniferous forests of Engelmann spruce and subalpine fir are interspersed with grass/forb meadows, and intervals between natural fires tend to be long (>200 years). Stands of fire-successional lodgepole pine and white spruce with shorter fire intervals occur at lower elevations. The Montane Subregion occurs on lower slopes of the Front Ranges and valley bottoms. Here, winters are warmer and drier than other zones, while summers may be cool. Douglas fir, lodgepole pine, and aspen stands occur on east-north aspects and grasslands on south-west aspects at lower elevations. The Montane zone typically provides favorable sites for wintering ungulates such as elk and deer. In the Bighorn area, it occurs around the Ya Ha Tinda ranch and along Highway 11 following the North Saskatchewan River.

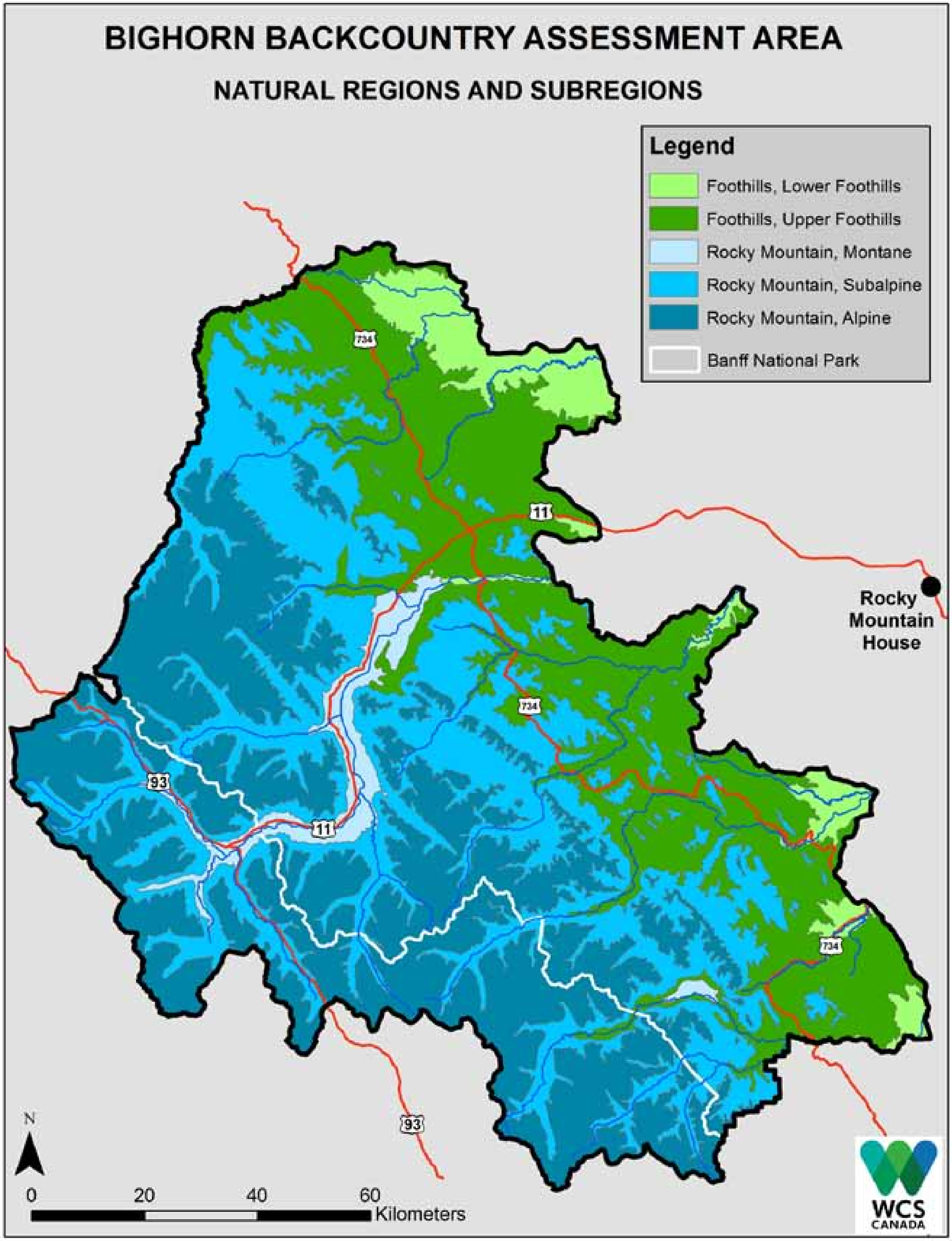
The Foothills Natural Region covers about 33% (477,812 ha) – with 28% Upper and 5% Lower Subregions. The climate is cool and moist, especially during the summer. Mixed forests with aspen, lodgepole pine, white spruce and balsam poplar occur in the Lower Foothills on rolling hills and plateaus; wetlands occupy low-lying sites. The Upper Foothills consists of extensive stands of lodgepole pine forests with feathermoss ground cover.

Oil and gas exploration and development and timber harvesting have been the predominant industrial activities in the Foothills across the eastern portion of the study area. Hydroelectric dams on the Bighorn and Brazeau have the capacity to produce ~408,000 and 397,000 MWh, respectively, on an annual basis. The North Saskatchewan River provides drinking water for several downstream urban areas, including the Edmonton Metropolitan region with a population of >1.1 million (City of Edmonton 2010).

Table 1. Area (ha) of Natural Regions and Subregions in the Bighorn Backcountry area, Alberta.

Region	Subregion	Subtotal	Percent
Rocky Mountain	Alpine	467,979	32.7
	Subalpine	443,058	30.9
	Montane	44,572	3.1
Foothills	Upper	401,451	28.0
	Lower	76,361	5.3
TOTAL		**1,433,421**	**100.0**

Figure 3. Distribution of Natural Regions and Subregions across the Bighorn Backcountry assessment area, Alberta. See Natural Regions Committee (2006) for full descriptions.



Banff National Park occupies 23% of the study area, and the Siffleur and White Goat Provincial Wilderness Areas another 6% (Table 2, Figure 4). About 36% of Provincial lands west of the Forestry Trunk Road #734 have been designated as 6 Public Land Use Zones (PLUZ). The remaining Provincial lands comprise about 34.6%, all within the Green Area. There is scant private land.

Table 2. Area (ha) of various lands comprising the Bighorn Backcountry Assessment Area in the upper North Saskatchewan River basin, Alberta.

Land Status	Individual Areas	Area (ha)		Percent
Provincial Public Land Use Zones (PLUZ)		517,335		36.1
	Blackstone/Wapiabi PLUZ		48,603	
	Job/Cline PLUZ		137,841	
	Kiska/Willson PLUZ		110,034	
	Upper Clearwater/Ram PLUZ		190,813	
	Panther Corners PLUZ		19,416	
	Dormer/Sheep PLUZ		10,628	
Other Provincial Lands		496,469		34.6
Provincial Wilderness Areas		87,135		6.1
	White Goat Wilderness Area		44,575	
	Siffleur Wilderness Area		42,560	
Banff National Park		328,278		22.9
Ya Ha Tinda Ranch		4,204		0.3
TOTAL		**1,433,421**		**100.0**

Figure 4. Delineation of the Public Land Use Zones (PLUZ) across the Bighorn Backcountry assessment area, Alberta. Other Crown lands are within the Green Area, with minor amounts of private land.

Threats to Waters and Wildlife

One challenge in 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. These infrastructure developments have obliterated terrestrial and aquatic habitats, fragmented landscapes, and imperiled species across the world. Even as this relentless march of human impacts continues, scientists are alerting us to a new challenge for the next century: climate change. In this section, I examine these twin threats to waters and wildlife.

Overarching Threat of Climate Change

What changes in climate can we anticipate over the next 50-100 years? What will be the ecological consequences? What are thoughtful responses to this new challenge? Here, I synthesize the major findings from recent research to describe climate patterns in western North America over the past 50-100 years as well as projected changes over the next 25-50 years (2040-2070). This lays the foundation for anticipating changes in future conditions that may threaten waters and vulnerable fish and wildlife.

To characterize climate change patterns in the Bighorn Backcountry, we used the ClimateWNA tool developed by climatologists at the University of Alberta (Wang et al. 2012: Version 5.21 released June 2015). We generated a grid of equally-spaced points (every1 km) (n= 14,334 points) across the Bighorn Backcountry study area in ArcGIS 10.2.2. Next, we extracted elevation for each point using a 20m DEM. Finally, we created a continuous raster surface (20 m pixels) by a spatial interpolation technique known as kriging. Because there are typically few weather stations in remote mountains, such modeling necessarily has to rely on the closest weather stations which are usually in valleys. Moreover, mountain landscapes are quite complex, which makes spatially-precise prediction notoriously difficult. Nonetheless, the broader patterns and implications of climate change are clear and compelling.

- **Warmer winters and hotter summers**

The dramatic shrinkage of the Athabasca and Saskatchewan glaciers in the Canadian Rockies are emblematic of the warming trends in climate (Figure 5). The Athabasca glacier has receded >1.5 km and lost over half its volume over the past 125 years (Luckman 1998, Parks Canada 2014). The adjacent Saskatchewan Glacier at the head of the North Saskatchewan River has been receding over the last century at a rate of about 50 m per year (Rutter et al.2006). Most large glaciers in the headwaters of the Bow, Saskatchewan, and Athabasca rivers have shrunk by ~25% in the last century (Watson and Luckman 2004).

In the Bighorn Backcountry area, annual temperatures have been getting warmer (on average) in recent decades. The mean annual temperature (MAT) increased 1.47° C from -1.03° C during 1951-1980 to 0.44° C during 1981-2010. Most of the annual warming has occurred during the winter months (Jan-Mar) as both nighttime lows and daytime highs increased by 2.0° C. Much of this warming likely occurred at lower elevations east of the FTR #734 (Figure 6).

To model future climate change possibilities, we followed the current use of '*representative concentration pathways*' (rcp) (*see* van Vuuren et al. 2011, Thomson et al. 2011). Essentially, these are scenarios of carbon emissions to the year 2100. We chose (a) rcp 4.5, an intermediate-level 'CO_2-Mitigation' scenario such that emissions peak around 2040, then decline by mid-century, and (b) rcp 8.5, a high-level "Business-as-Usual' scenario where emissions continue rising throughout the century.

Projections indicate that the MAT will increase an *additional* 1.54° C and 2.31° C over the next 25-50 years under scenario models rcp 4.5 and rcp 8.5, respectively (Figure 7). Even under the 'CO_2-Mitigation' scenario (rcp 4.5), this warming trend extends progressively westward into the montane and subalpine natural regions. Under the "Business-as-Usual' scenario (rcp 8.5), all lands east of the FTR may warm by 2° - 4° C compared to the 1951-1980 baseline. The coldest areas (MAT < -2° C) vanish completely under either scenario, while the extent of the next coolest class (MAT from -2° to 0° C) may shrink by 35% and 80% under scenarios rcp 4.5 and 8.5, respectively (compare Figures 6 and 7).

Figure 5. The dramatic shrinkage of the Athabasca Glacier in the Canadian Rockies is emblematic of the impacts of warming climate on water sources.

Figure 6. Mean Annual Temperature C° (MAT) across the Bighorn Backcountry study area, 1951-1980 (top) and 1981-2010 (bottom) using the ClimateWNA toolset (Wang et al. 2012).

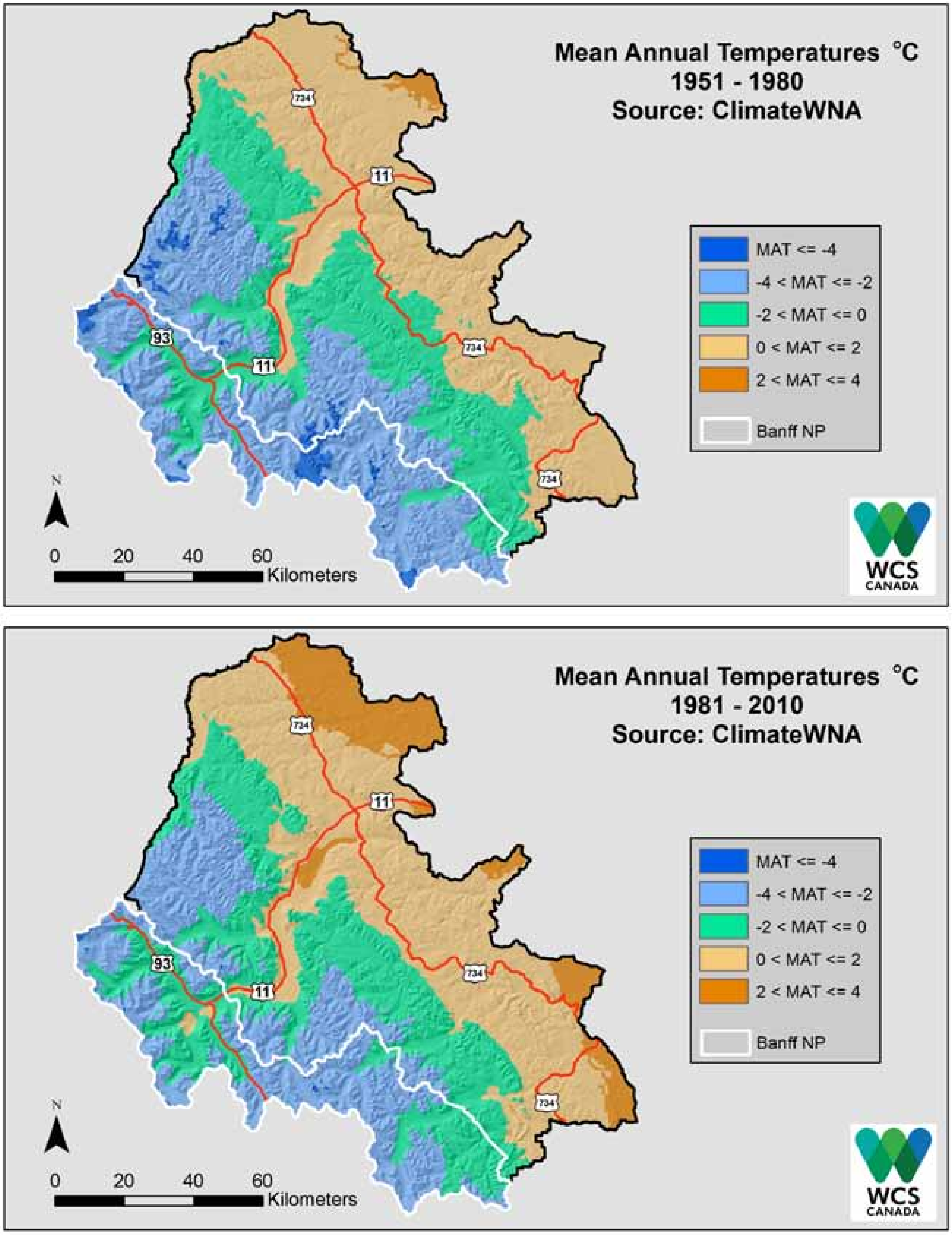
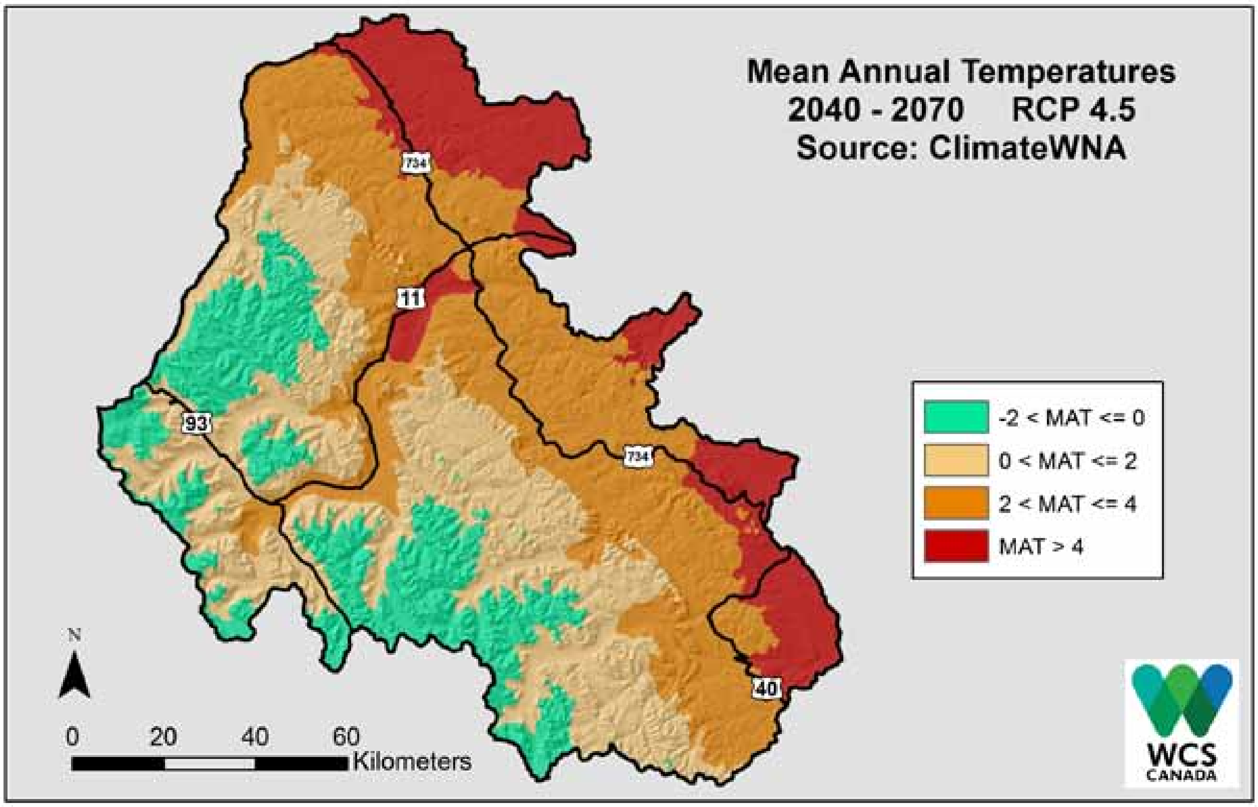
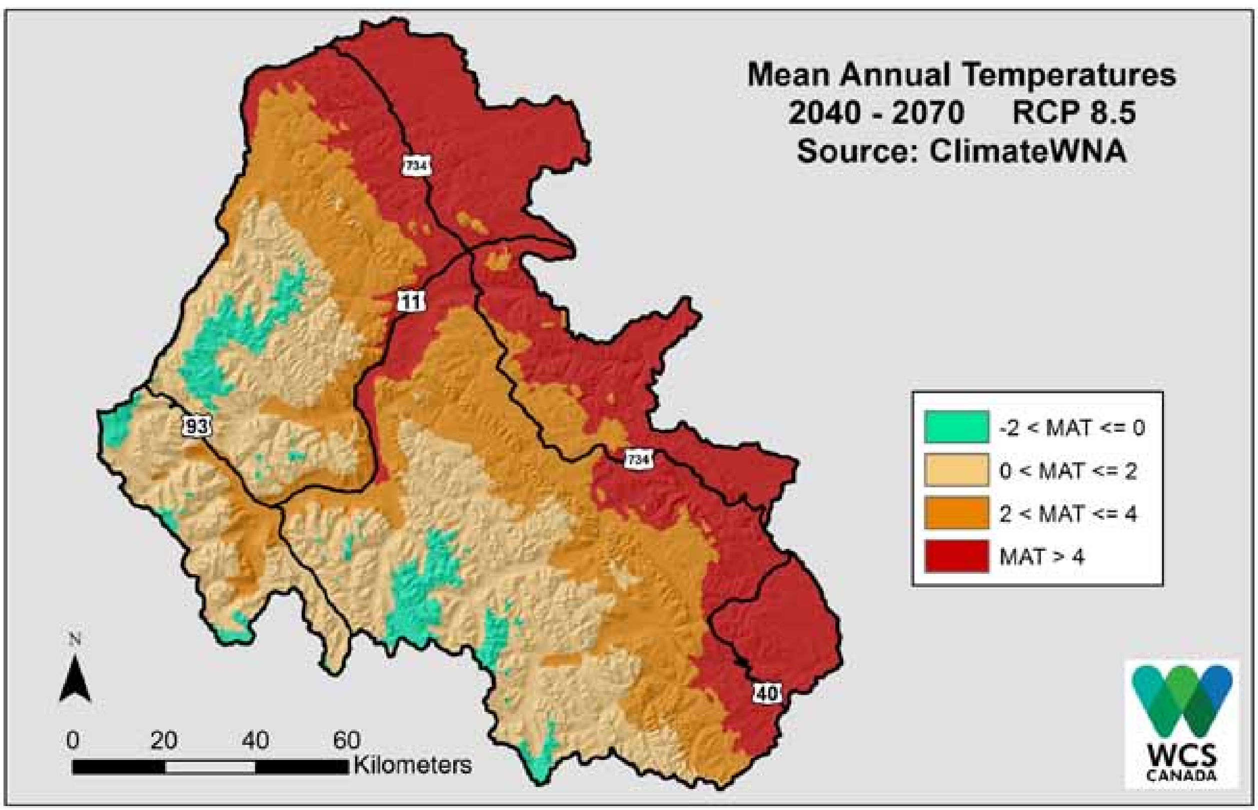


Figure 7. Mean Annual Temperature C° (MAT) across the Bighorn Backcountry study area, 2040-2070 based upon rcp 4.5 = CO2- mitigation scenario (top) and rcp 8.5 = business-as-usual scenario (bottom) using the ClimateWNA toolset (Wang et al. 2012). Warm areas expand, while cool areas shrink.





These warming trends and patterns are consistent with those observed elsewhere in western North America. Over the past 100 years, mean annual temperature (MAT) in the Crown of the Continent region has increased by 0.7° – 1.7° C (Pederson et al. 2010, 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 (Murdock and Werner 2011). Temperatures have warmed dramatically since the early 1980s and hot temperatures have occurred longer through the summer (Mbogga et al. 2009, Pederson et al. 2010). This increase in summer temperature has been 3*x* greater at higher elevations, a trend reported from many areas across the globe (Pepin and Lundquist 2008). Embedded within these trends, however, is notable variability in temperatures between years and decades due to ENSO and PDO events (Murdoch and Werner 2011).

- **Diminishing snowpack and declining water flows**

Mountain snowpack on the Eastern Slopes of the Canadian Rocky Mountains provides a critical source of water for the western prairie provinces of Alberta, Saskatchewan and Manitoba (Schindler and Donahue 2006). For example, the headwaters of the North Saskatchewan River provide 88% of annual water yield for this basin (North Saskatchewan Watershed Alliance 2012). From the perspective of streamflow, the mountain snowpack serves as 'water in the bank' - with accumulation during the cold winter, melting in late spring, and moderate baseflows lasting through late summer. The amount of snowpack varies, however, not only with the amount of precipitation but with its form (snow or rain).

Some simulations of future snowpack suggest there may be little change in annual maximum snow accumulation over the entire North Saskatchewan River watershed (Macdonald et al. 2012). These researchers point out, however, that projected increases in winter temperature would reduce the proportion of winter precipitation falling as snow, advance the date when snowpack reaches maximum, and shorten the duration of the snowmelt period. The net effect would be reduction in water storage in the snowpack, resulting in diminished supply of water during summer.

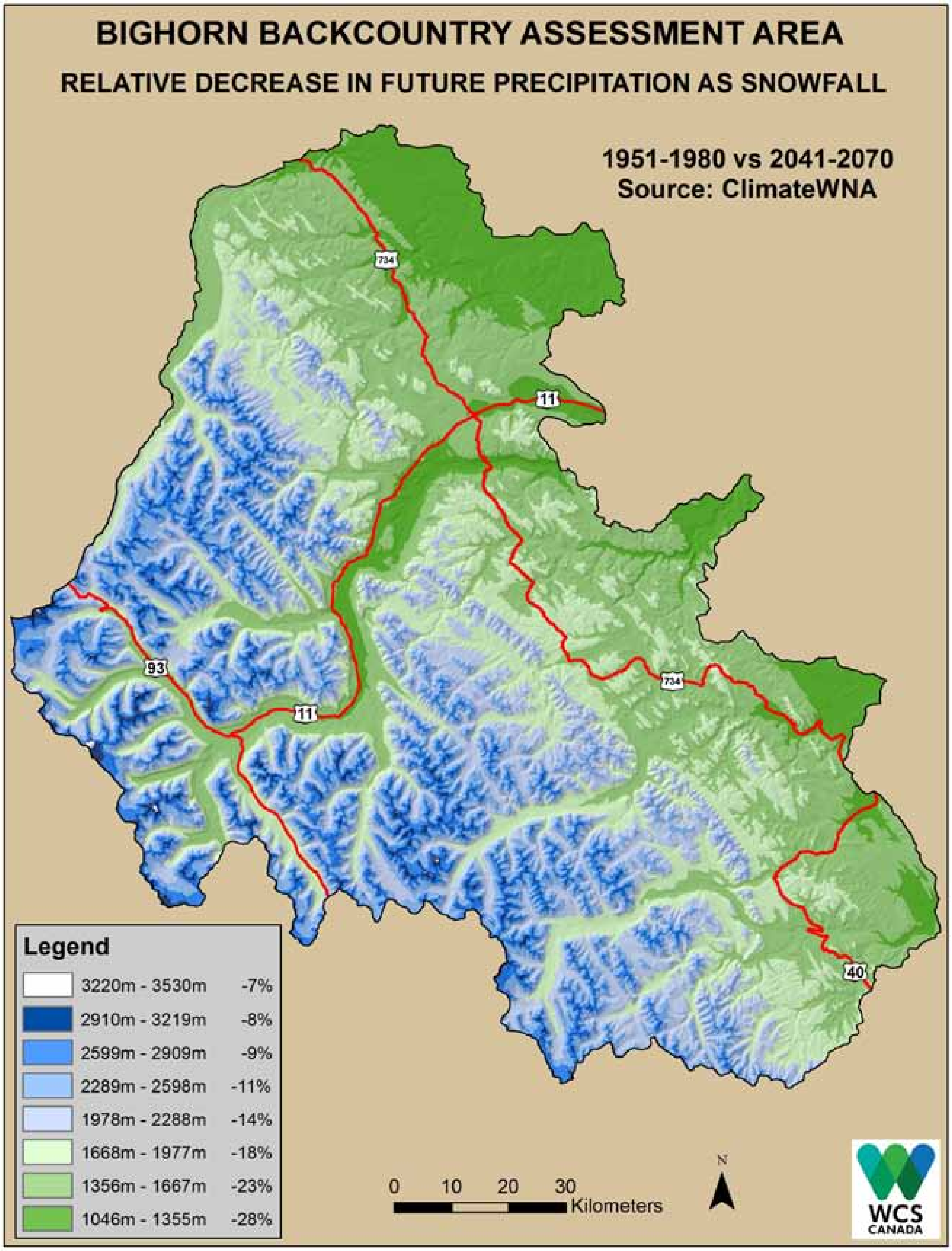
In the Bighorn Backcountry encompassing headwaters of the North Saskatchewan River, the average annual amount of precipitation changed very little (1.3% decrease) between 1951-1980 and 1981-2010 periods (ClimateWNA data). Simulations using an ensemble of 14 climate-scenario models for the Bighorn Backcountry indicate a modest increase in annual precipitation of 5.9% to 7.5% for the rcp 4.5 and 8.5 scenarios, respectively (ClimateWNA modeling tool). On a seasonal basis, however, summers may be drier and evapotranspiration rates likely will be higher due to increased temperatures. This will overwhelm any increases in precipitation and result in progressively drier soils and vegetation (Schneider 2013).

A greater proportion will likely fall as rain rather than snow - especially at lower elevations (Figure 8). The Lower and Upper Foothills Natural Region and the Montane - Rocky Mountain Natural Region are projected to have a 23-28% decrease in precipitation falling as snow (PAS). This will include the eastern sector of the study area and along the North Saskatchewan River valley up to Saskatchewan Crossing. Subalpine areas of the Rocky Mountain Natural Region may have 14-18% changeover from snow to rain. Alpine areas likely will have the smallest changeover from snow to rain in the range of 7-11%. This changeover would reduce snowpack in both the foothills and mountains (MacDonald et al. 2012).

This projected decrease in snowpack and suite of hydrological changes is consistent with recent trends and future predictions elsewhere along the Eastern Slopes of Alberta and western North America. Over the past 100 years, streamflows along the Eastern Slopes have declined approximately 15-25% (Rood et al. 2005, Gill et al. 2008, Rood et al. 2008). Decline in snowpack has reduced re-charge of aquifers, resulting in less groundwater flow into streams and decreasing the base flow during the key summer period. If trends continue, this would lead to further declines in streamflow of 10-15% by 2050 for the Red Deer (Gill et al. 2008) and Oldman Rivers (Shepherd et al. 2010). Due to the influence of the Pacific Decadal Oscillation (PDO), there will continue to be clusters of wetter and drier years.

Throughout western North America, annual snowpack levels have declined by 15-30% during the second half of the 20th century (Barnett et al. 2005, Mote et al. 2005, Pederson et al. 2010). 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). 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 summer and autumn across western United States (Stewart et al. 2005, Hildago et al. 2009). Continuing decline (10-40%) in mountain snowpack, an advance in the timing of spring melt, and a reduction in snow season are projected by 2050 (Pederson et al. 2013, Gergel et al. 2017). Conserving a dwindling supply of water in the face of cumulative effects arising from climate-driven changes on top of increasing demands for water will be challenging (Schindler and Donahue 2006).

Figure 8. Relative decrease in future precipitation as snowfall, Bighorn Backcountry area, Alberta. More of the annual precipitation will fall as rain, especially at lower elevations.



- **Larger severe wildfire across more of the landscape, with longer fire season**

Wildfires, of course, have long been a feature of landscapes and driver of ecological processes across western North America. Changes in climate such as diminished snowpack, earlier snowmelt, and drought conditions affect the timing, extent, and severity of wildfire (Westerling 2016, Gergel et al. 2017). In Canada, the area burned by wildfires have increased over the past 50 years as summer temperatures have increased with climate change (Gillette et al. 2004). Canadian studies suggest that average area burned per decade in the western boreal forest will double by 2041–2050 (Balshi et al. 2009), with larger and more severe fires over a longer fire season (Flannigan et al. 2011, Wang et al. 2015).

These findings parallel those reported for climate change and fire in the Northern Rocky Mountains of the U.S. Beginning in the mid-1980s, forest fires there have become more frequent, larger and much more severe than in previous decades (Dennison et al. 2014, Westerling 2016). Compared to the 1973-1982 period, for example, there has been a 4-fold increase in number of acres burned each year and the fire season is about 85 days longer (Westerling 2016). Notably, much of the increased fire activity has occurred in forests at higher elevations (1675 to 2600 m), 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 (Dunham et al. 2007). Increasing fire activity in the Northern Rockies has coincided with earlier depletion of mountain snowpack and drier summers, resulting in more flammable fuels that have built up during decades of fire suppression (Higuera et al. 2015, Westerling 2016). As temperatures continue to climb in the future accompanied by earlier snowmelt and warmer summers, there will likely be a longer fire season with severe fires across more of the landscape (Westerling 2016, Gergel et al. 2017).

- **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, including western Alberta (Schneider et al. 2010). 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 whitebark pine (Wilson 2007). Along with warmer temperatures and prolonged droughts, roads and land disturbances have promoted spread of invasive plant species. As streams warm due to climate change, non-native brook trout likely will expand their range to the detriment of native, cold-water fish like bull trout (Warnock and Rasmussen 2013).

- **<u>Shifting distribution of plants and animals</u>**

Schneider (2013) provides a detailed analysis and discussion of past and future climate effects on the Natural Regions of Alberta. During the warm climate of the Hypsithermal period (4,000-8,000 years BP) summer temperatures in Alberta likely were 1.5°- 3° C warmer than at present (which is on the low end of what is projected by 2090). Reconstruction of vegetation history suggests that_the Foothills and Rocky Mountain Regions were relatively stable during the Hypsithermal. Distribution of some tree species of shifted upslope, and there was an increase in the proportion of lodgepole pine. In the future, plant communities in the Rocky Mountain Natural Region generally will shift to higher elevations and/or different aspects as the climate warms. But individual species will respond differently, so various plants from the Alpine, Subalpine, and Upper Foothills sub-regions may blend and form new patterns of composition. The Lower Foothills likely will remain mostly forested (depending upon the extent and severity of forest fire), but there could be a transition to shrub-dominated sites and grasslands.

During warming episodes in past millennia, distribution of animals in North America generally shifted north in latitude and upward in elevation, too (Huntley 2005). 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 animals. 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 as suitable conditions and connectivity shrink (Beever et al. 2011, Stewart et al. 2015, Schwalm et al. 2016).

Multiple Effects of Roads and Human Access

Roads, vehicle traffic, and associated human activity can have a variety of substantial effects upon species and ecosystems (see reviews and hundreds of references in Trombulak and Frissell 2000, Gucinski et al. 2001, Havlick 2002, Forman et al. 2003, Coffin 2007, Fahrig and Rytwinski 2009, Beckman et al. 2010, Selva et al. 2015, Brady and Richardson 2017). These authors concluded that roads and associated human activities often have negative effects on behavior and abundance of animals and ecological processes. In particular, the spreading and intensifying effect of all linear features (highways, roads, seismic lines, trails) can result in cumulative effects – a wicked problem accruing from the 'tyranny of small decisions' that add up. Here are some of the <u>principal</u> effects that roads, vehicle traffic, and human activity can have on ecosystems and fish and wildlife. In addition, I have included some recent findings on the effects of seismic lines and off-highway vehicles – which is a growing issue, particularly in Alberta. Effects of motorized activity along roads and trails upon grizzly bears, wolverines, and bighorn sheep are covered in the vulnerability profiles of each species later in this report.

- ★ ***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. 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 draw herbivores to the green verge but increase drivers' visibility of them. Recent modifications such as wildlife underpasses and overpasses have reduced mortality and facilitated passage of larger wildlife (see Safe Passages: Highways, Wildlife, and Habitat Connectivity by Beckman et al. 2010 for recent examples and innovations; and Barrueto et al. 2014, Clevenger and Barrueto 2014 for recent findings on wildlife use of crossings along the Trans-Canada Highway in Banff National Park).
- ★ ***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 weaknesses 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 nonnative organisms.*** 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. A fascinating example comes from northeast Alberta where about 9 % of the boreal forest has been invaded by European earthworms, which are predicted to spread to 50 % of suitable forests over next 50 years (Cameron et al. 2007, Cameron and Bayne 2015). 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 result in 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, bighorn sheep, and bull trout 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.

★ ***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 bears often return to the original site) or kill the animal after repeat episodes.

★ ***Roads fracture core areas and 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 <u>cumulative</u> 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.

★ ***Construction of seismic lines can affect ecological conditions in similar ways as roads.*** Since the 1950s, seismic lines for oil & gas exploration have proliferated across western and northern Alberta. Conventional clearing methods of bull dozing and/or cutting trees resulted in linear swaths 5-15 m wide and tens of km long. This fragmentation has affected ecological conditions in several ways.

- These cleared strips remain open for decades. In upland forest sites across Alberta, 65% of seismic lines were still in low plant cover (forbs) after 35 years – prompting the name 'legacy' seismic lines (Lee and Boutin 2006). Where seismic lines crossed fragile wetlands such as fens and bogs, these sites did not regenerate to a height of 3m even after 50 years

(Van Rensen et al. 2015). In particular, mineral-rich fens are fundamentally altered after clearing for seismic assessment, and these habitats will be a major challenge for future restoration (Caners and Lieffers 2014). Continued use from off-highway vehicles can increase damage to young seedlings, erosion, soil compaction, and water channelization (Revel et al.1984)(Figure 9).

- Fragmentation by legacy seismic lines of the boreal forest has affected use of preferred habitats of several wildlife species. The ovenbird, a dweller of the forest interior, did not include newly cut lines >3-m wide within its territory due to absence of tree/shrub cover and reduced food resources (Machtans 2006, Lankau et al. 2013). This resulted in lower density of ovenbirds in areas with high density of seismic lines. American marten, another inhabitant of forest interiors, also avoided open seismic lines ≥ 3 m wide (Tigner et al. 2015). Marten declined in occurrence as density of seismic lines increased, with trapping facilitated by new access as one of several possible causes.
- Cleared seismic lines also facilitated faster travel by predators such as wolves, which can alter predator-prey relationships. In northeast Alberta, wolves travel and hunt along seismic lines, especially during snow-free months. This increased risk of predation caused woodland caribou (a threatened species) to avoid bogs and fens, which are their preferred habitat (James and Stuart-Smith 2000, Latham et al. 2011).

★ **Motorized activity using Off-Highway Vehicles (OHVs) can impact vegetation and wildlife behavior and populations.**

- One recent study northeast of Grande Cache, Alberta reported that OHV use was observed on 40% of legacy seismic lines (Pigeon et al. 2016). Natural regeneration of legacy seismic lines is impeded by ongoing damage, ground compaction, and active clearing by OHV users, so that repeated OHV use keeps these routes open (Lee and Boutin 2006, Van Rensen 2015). In some cases, OHV users seem to select for seismic lines on dry sites with low vegetation, which enables easier travel (Pigeon et al. 2016).
- OHV traffic along seismic lines also affects wildlife behavior and populations. In a new study in the foothills of west-central Alberta, grizzly bears selected habitats close to trails and streams in the absence of human recreational activity (Ladle 2017). In the closed canopy of boreal forests, bears may be drawn to these narrow linear features for nutrient-rich foods (Nielsen et al. 2004b, Stewart et al. 2013). But male bears accelerated their pace of movement in response to high levels of motorized activity (OHVs) – which likely diminished time spent by wary individuals in these more productive habitats (Ladle 2017). OHV traffic may also increase time spent by elk in vigilance for predators, thereby reducing their time spent foraging (Ciuti et al. 2012). In southwest Idaho, increased OHV activity resulted in declines in territory occupancy and nesting success for golden eagles (Steenhof et al. 2014).

Figure 9. Over the past half-century, seismic lines for oil & gas exploration proliferated across the Eastern Slopes of Alberta, and most remain open linear features across the landscape (top). From a scientific perspective, motorized off-highway vehicle (OHV) on these routes can increase sediment into streams, disrupt and displace animal use of key habitats, spread non-native weeds, and facilitate expanded access by hunters and trappers. Although many OHV users conduct themselves in a respectful manner on designated trails, irresponsible use can damage fragile wet meadows for decades (bottom).

Photo: John Weaver

The expansive literature on roads and other linear features 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 good intention by humans*.
- ➢ Increasing levels of traffic volume on backcountry roads and secondary highways reduce amount of useable habitat via displacement (or shifts to nighttime use) and reduces permeability of roads to wildlife crossing – *regardless of good intentions by humans*.
- ➢ Risk of mortality from direct shooting (legal hunting or poaching) and spread of invasive species increases as access expands – *regardless of traffic volume*.
- ➢ *New roads and other linear features facilitate "contagious development"* by enabling access to previously remote areas – thus opening them up for more roads, associated resource extraction, and disturbances by motorized recreation.

In the Canadian Rocky Mountains and foothills along the Eastern Slopes of Alberta, roads and seismic lines proliferated dramatically starting in the 1950s. The initial purpose of these new roads and lines 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 along with recent prosperity in the regional economy, recreational access into the backcountry has exploded across western Alberta.

We used the map (scale 1:15,000) of 'human footprint' produced by the Alberta Biodiversity Monitoring Institute (ABMI 2015). This comprehensive layer includes all the spatial features related to the energy, forestry, and agriculture industries, as well as urban development. Today, there are approximately 1,073 km of hard-surface roads, 2,040 km of secondary forest roads and trails, and 8,304 km of seismic lines across the Bighorn Backcountry region (Table 3). Most of these linear features are east of FTR#734, or just west of it (Figure 10). As human populations and affluence increase in the region, the importance of managing proliferating roads and human access will become ever more critical.

It is crucial to keep in mind that both of these substantial influences – accelerating climate change and ever-expanding human developments and activities – comprise a joint threat to conservation of biodiversity and ecosystem services. Sometimes, the flurry of new information about climate change can override the consideration of current impacts from human developments (Tingley et al. 2013, Maxwell et al. 2015). To make thoughtful and integrative decisions, it is imperative to address both factors in cumulative impact assessments (Yamasaki et al. 2008).

Figure 10. Location of various types of human access and disturbance ('footprint'), Bighorn Backcountry, Alberta. Data from the Alberta Biodiversity Monitoring Institute - ABMI 2014). Density of the human footprint is especially high east of the Forestry Trunk Road #734.

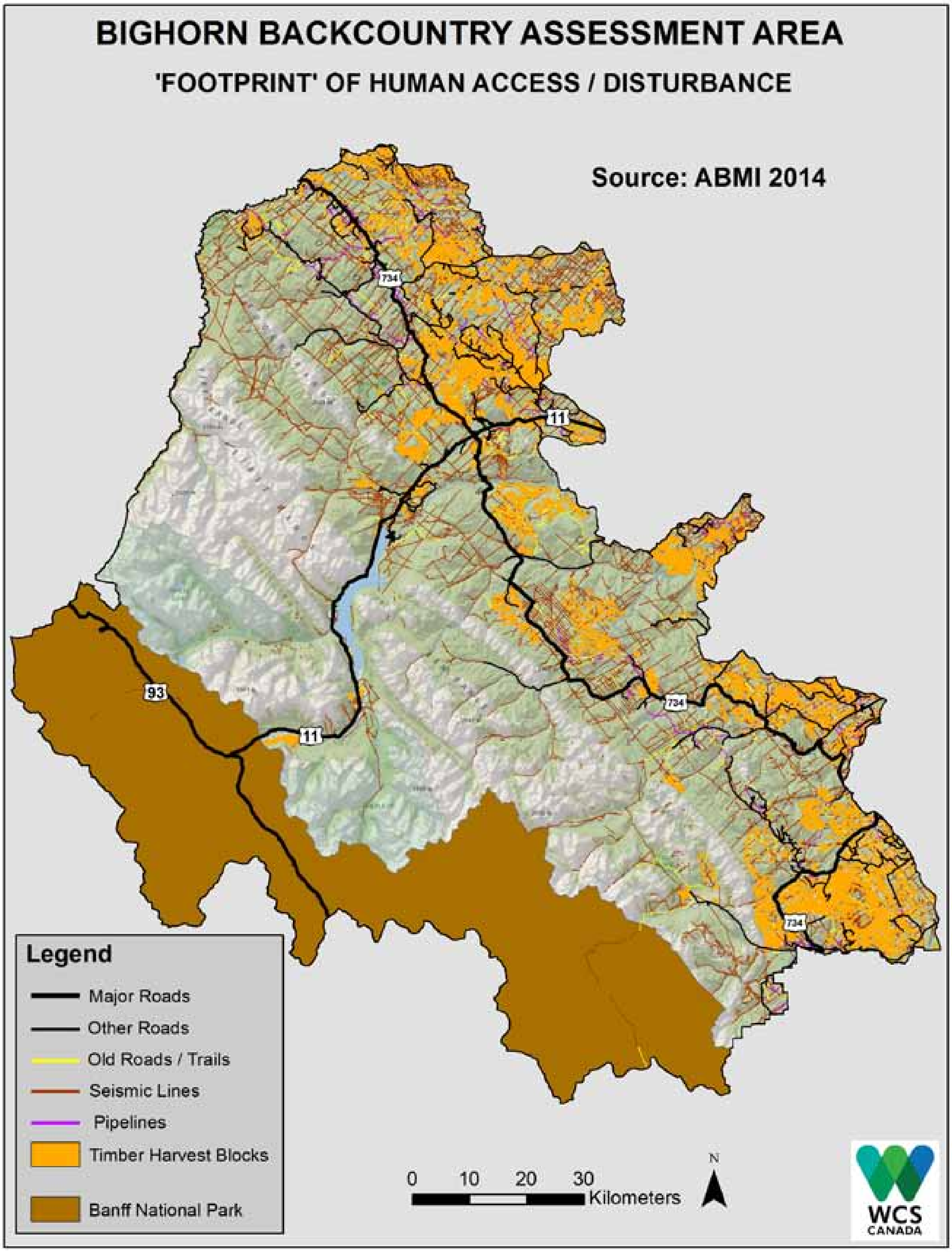


Table 3. Amount (km) and percent of roads, trails and seismic lines west and east of the Forestry Trunk Road (FTR) #734, Bighorn Backcountry assessment area, Alberta. Data from ABMI (2015).

	West of FTR #734		East of FTR #734		Total	
Type	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent
Hard Roads	366	7.1	707	11.2	1,073	9.4
Roads/Trails	678	13.2	1,362	21.7	2,040	17.9
Seismic Lines	4,085	79.7	4,219	67.1	8,304	72.7
TOTAL	5,129	100.0	6,288	100.0	11, 417	100.0

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). Plants and animals evolved in ecosystems where natural disturbances varied in frequency, intensity, duration, and extent – thereby resulting in different spatial and temporal patterns of change (Pickett et al. 1989, Folke et al. 2004). 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. 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 (Heller and Zavaleta 2009, Anderson and Ferree 2010, Graumlich and Francis 2010, Hansen et al. 2010). Schneider (2014) also provides a useful review and analysis of climate adaptation measures for conserving Alberta's biodiversity. 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 environmental diversity to conserve the 'ecological stage',**
- **Enhance connectivity among such core protected landscapes, and**
- **Reduce other pressures on species and ecosystems.**

In a world where impacts of habitat loss and fragmentation, invasive species, and climate change are accelerating, vulnerable species will persist longer with well-designed networks of core refugia ('safe havens') and connectivity ('safe passages') that offer ecological options (Carroll et al.2009, Morelli et al. 2016).

Purpose, Goal and Objectives, and Structure of the Report

The purpose of this scientific report is to inform discussions and decisions about land and resource management in the headwaters of the North Saskatchewan River basin of Alberta. The goal is to assess the conservation values across 14, 334 km2 in the Bighorn Backcountry amid the Canadian Rockies and foothills.

Specific objectives are to: (1) compile and critically examine the latest scientific information about conservation needs of a suite of vulnerable fish and wildlife species, (2) identify current and future key areas for these species using empirical data from Alberta and models, (3) assess options for connectivity across Highway 11, and (4) examine the central importance of river floodplains for diversity of species and processes and map the potential of these river corridors for climate adaptation. The approach involves synthesis of available spatial data into maps of conservation value for vulnerable species and valuable waters 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 functionality, and socioeconomic significance. For assessing the conservation value of the Bighorn Backcountry, I selected the following suite of fish and wildlife species: grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), Rocky Mountain bighorn sheep (*Ovis canadensis*), and bull trout (*Salvelinus confluentus*). These species are not only important from a conservation perspective but also galvanize public interest and support.

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, a vulnerability profile is presented based upon its ecology, demography, and behavior. Next, I describe my method for scoring conservation importance of lands or waters for the species. This data comes from biologists with Alberta Environment and Parks and various universities in Alberta. Based upon results of that mapping, key conservation areas are identified for each species. I identify likely sites where grizzly bears and wolverines may cross Highway 11, which would facilitate vital connectivity across the larger landscape of the Canadian Rockies and foothills.

In Chapter 3, I discuss the importance of river floodplains as a nexus of biodiversity and fascinating ecological processes. I present a new approach for mapping the temperature gradients along river valleys from mouth to headwaters, which may facilitate adaptive movements by wildlife in response to warming climate. In the final Chapter 4, I sum up the critical importance of the Bighorn Backcountry for long-term conservation of these vulnerable wildlife and the precious waters at the headwaters of the North Saskatchewan River.

2. SENTINELS OF THE HEADWATERS: VULNERABLE FISH AND WILDLIFE SPECIES

Introduction

Certain species have life history and spatio-ecological traits that make them vulnerable to human impacts, including climate change (Weaver et al. 1996, Pearson et al. 2014). Here, I focus on 4 species who are vulnerable in the modern world: grizzly bear, wolverine, bighorn sheep, and bull trout. For each of these focal species, 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. I provide GIS-based maps of key conservation areas for the species, as well as a table summarizing the amount of area in each conservation value. Lastly, I discuss one or two of the principal conservation issues for that species.

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?

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. 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 cannot readily compensate for excessive mortality with increased reproduction and/or survivorship, and populations will decline. High survivorship and longevity of 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 4 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. I present a synopsis of the key vulnerability traits at the beginning, but I encourage reading of the full profile to better understand the particular vulnerabilities which form the basis for sound conservation.

Methods for Scoring Conservation Importance

To assess the relative importance of areas across the Bighorn Backcountry of Alberta, 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 Canadian Rocky Mountains and foothills comprise one of the most ecologically intact and important areas for native fish and wildlife and watersheds and will likely serve as a large refugia as climate changes, and (2) each of the vulnerable species has significant importance due to Provincial listing and/or COSEWIC assessment as a threatened species or species-of-concern (e.g., bull trout, grizzly bear) and/or iconic prominence (bighorn sheep). I customized the scoring criteria for each vulnerable species to reflect attributes that are important to the long-term persistence of that species. Details of the scoring system are provided under each species. I also discuss on the potential effects of climate change on the species.

Description of Key Areas of Conservation Value

I used the scored maps to identify key conservation areas for each species. Although synthesis of existing information was central to this assessment, I spent ~30 days during 2016 ground-truthing maps, evaluating habitat conditions, and checking motorized routes in the Bighorn Backcountry.

Grizzly Bear (*Ursus arctos*)

Photo: Milo Burcham

Status The western population of the grizzly bear (including Alberta) was assessed as a species of '***Special Concern***' – one whose characteristics make it particularly sensitive to human activities or natural events – by COSEWIC (Committee on the Status of Endangered Wildlife In Canada) in 2012 (COSEWIC 2012). The grizzly bear, though, has not been listed under the Species At Risk Act (SARA). The Alberta government listed the grizzly bear as a '**Threatened**' species in 2010 due to concerns that human-caused mortality and deteriorating habitat conditions threatened a significant decline of this relatively small population (Festa-Bianchet 2010). A revised recovery plan was released in 2016 (Alberta Environment and Parks *In Review*).

Vulnerability Profile

Synopsis: Despite their resourcefulness, grizzly bears exhibit **high vulnerability** due to low population resiliency. As omnivores, grizzly bears exhibit considerable variability and flexibility in their foraging and habitat use over space and time. They seek a mixed diet to maximize their energy intake, while optimizing the balance of macronutrients. Areas with complementary resources (ungulate meat and berries) support more bears than those with only one such resource. Bears require secure access to quality forage in spring and late summer-fall, but roads with moderate traffic volume can displace bears from key habitats. Most importantly, grizzly bears have very low reproduction and cannot quickly compensate for excessive mortality. Most mortality of grizzly bears is human-caused – either from direct shooting or removal by agency personnel if bears become conditioned to human food and garbage or habituated (loss of wariness) Numerous studies have demonstrated that road access into high-quality habitats can increase encounter rates with people and lead to displacement, habituation, or mortality. Grizzly bear populations are susceptible to landscape fragmentation because young females do not disperse very far and adult females do not readily cross major highways. With climate change resulting in milder fall and spring climes and shorter winters, bears may spend more time roaming and searching for food. This likely will increase their spatio-temporal interface with humans and potential for conflicts. As human populations scramble for dwindling fossil-fuel and water resources, associated expansion of road access will bring additional cumulative effects. Securing access for bears to high-quality habitats with low risk of human-caused mortality is the key to their conservation.

Niche Flexibility: As omnivores, grizzly bears exhibit considerable variability and flexibility in their foraging and habitat use over space and time (Schwartz et al. 2003). It's well-known that bears focus upon berries in late summer and fall for weight gain and fat deposition necessary for successful hibernation and reproduction by females (McLellan 2011). But bears also seek a mixed diet to maximize their energy intake, while optimizing the balance of macronutrients such as protein (17%) with lipids or carbohydrates (Coogan et al. 2014, Erlenbach et al. 2014). In west-central Alberta, areas with *complementary* resources (ungulate meat *and* fruit) were more important in predicting areas of higher local abundance of bears than either food source *alone* (Nielsen et al. 2016).

Although grizzly bears in the Canadian Rockies and boreal foothills eat 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) (Hammer and Herrero 1987, McLellan and Hovey 1995, Nielsen et al. 2004a, Munro et al. 2006, Nielsen et al. 2010). Grizzly bears feed on: (1) ungulates (usually carrion of winter-killed moose, elk, or deer or new-born calves), grasses/sedges, and sweet vetch (*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) russet buffaloberries (or soopolallie) (*Shepherdia canadensis*) at lower elevations (especially in Alberta) and huckleberries (*Vaccinium membranaceum*) at moderate-high elevations in late summer-early fall; and (4) berries, ungulates (hunter-killed gut-piles, weakened animals), and roots in fall.

Several key habitats provide one or more of these seasonally important foods. Riparian areas adjacent to streams and wetlands represent a critical habitat for grizzly bears, particularly during spring and again in fall. Key foods include moose (carrion and calves), grasses, and forbs (McLellan and Hovey 2001a, Munro et al. 2006). In Glacier National Park in Montana, abundance of female grizzly bears has been positively correlated with riparian and mesic cover types (Graves et al. 2011).

Both buffaloberry and huckleberry flourish on relatively mesic, open-conifer sites burned by wildfire between 20 and 80 years ago, depending upon fire intensity and site conditions (Martin 1983, Hamer 1996, McLellan and Hovey 2001a, Nielsen et al. 2010, McLellan 2015). In the boreal forests of the foothills of west-central Alberta, natural openings are rare and fire suppression has been effective for many decades. Clearcuts can provide a diverse array of food resources for grizzly bears (particularly sweet vetch, horsetail, and ants). In these closed coniferous forests, grizzly bears select for edges of forestry clearcuts of older ages during summer and fall (Nielsen et al. 2004a, Nielsen et al. 2004b, Stewart et al. 2013). Due to the impact of mechanical scarification upon roots of huckleberry and buffaloberry, however, broadcast burning would be a better technique for maintaining these important fruiting shrubs for bears (Martin 1983, Zager et al.1983, Knight 1999).

Avalanche chutes on steep mountain slopes produce a diversity of herbaceous foods and berry-producing shrubs in the lower sections of the chute and huckleberry in the adjacent stringers of open conifer trees (Mace and Bissell 1985, Waller and Mace 1997, McLellan and Hovey 2001a, Serrouya et al. 2011). Although not as pervasive along the eastern slopes of Alberta as in British Columbia, avalanche chutes do occur in the higher elevations of Bighorn Backcountry. They are especially important to females with cubs-of-the-year who choose to reside in high, secluded basins in rugged terrain (McLellan and Hovey 2001a, Theberge 2002). Altogether, diverse landscapes having mountain valleys with broad riparian zones and adjacent slopes of open-conifer stands (older burns) or avalanche chutes provide variety of key foods spring through fall and between years (McLellan and Hovey 2001a, Theberge 2002, Nielsen et al. 2010, Nielsen et al. 2016).

Hibernation by grizzly bears is an adaptive strategy to avoid harsh conditions and seasonal limitations in food. Critically, it is also the time and place where pregnant female grizzlies give birth. Female grizzly bears spend an average of 150-200 days (late October to early May) in winter hibernation in dens (Ciarniello et al. 2005, Stevens and Gibeau 2005, Graham and Stenhouse 2014). Pregnant females who birth cubs enter dens earlier and emerge later than other bears (Graham and Stenhouse 2014). Later date of den entry in the fall has been linked to greater availability of berries, whereas low winter precipitation and high spring temperature prompted an earlier exit (Pigeon et al. 2016). Grizzly bears in the Rocky Mountains typically select den sites at mid-high elevations (usually >2000 m) in alpine to upper subalpine forest types, on steep slopes (10°- 60° but usually 25°- 40°), in dry stands of older conifer trees or open alpine sites (Vroom et al. 1980, Ciarniello et al. 2005, Stevens and Gibeau 2005, Pigeon et al. 2014). Some bears do den at lower elevations in the foothill boreal forests where they select dry sites on steep slopes (above river riparian zones) in older stands of conifers (Ciarniello et al. 2005, Pigeon et al. 2014). Grizzly bears select for remote areas with low road density (0-0.6 km/km^2) (Ciarniello et al. 2005, Pigeon et al. 2014) and >1 km from human activity (Swenson et al.

1997). Although den sites may not be limiting in the Canadian Rockies in terms of ecological suitability, denning areas warrant precautionary management given that denning is such a critical stage in the lives of bears. Researchers recommend protecting areas with *high* suitability for denning by minimizing road density (<0.6 km/km^2) and human disturbance in winter within 1 km of active sites (Swenson et al. 1997, Linnell et al. 2000, Pigeon et al. 2014).

Reproductive Capacity and Mortality Risk: Grizzly bears have very low reproductive potential and cannot readily compensate for high mortality (McLellan 1994, Craighead et al. 1995, Schwartz et al. 2003). Females produce their first litters at approximately 4-8 years of age and are most productive between 8-22 years of age. 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 *daughters* during a full lifetime that survive to adulthood.

Hence, 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 ≥ 92% to maintain stable populations (Eberhardt 1990, Garshelis et al. 2005), but this is a difficult and expensive metric to measure. The revised Alberta Recovery Plan (*In Review*) sets the following objective: known mortality rates from human causes is
≤ 4%, with deaths of females ≤ 1.2% (~30% of the overall rate).

In the Flathead River basin of southeast B.C., McLellan (2015) reported on the strong influence of huckleberry production (and bear density) upon the vital rates of grizzly bears over 3 decades (1979-2010). In comparison to the first decade of the study, huckleberry production during the last 12 years declined dramatically and failed completely in 6 of those years. Concurrently, the reproductive rate of adult female grizzly bears dropped by 50% (0.374 →0.192) because of smaller litters (2.37 →1.82), longer intervals between litters (2.9 years →4.2 years), and older age at first reproduction (6.6 years →10.5 years). Such annual variation in huckleberry and buffaloberry production occurs in many areas, seemingly due to varying weather conditions which may operate over large spatial scales (Hamer 1996, Hobby and Keefer 2010, Holden et al. 2012). Some individual bears appear more resourceful at obtaining sufficient nutrients from other foods (e.g., sweet vetch roots) and thereby ameliorate adverse conditions, but consecutive years of failure in key foods may have especially dire effects for a population.

In the face of a shortfall in nutritious foods, bears move even more widely in search of food – which may increase encounters with humans (Mattson et al. 1992, McLellan 2015). This substantially increases the risk of immediate human-caused mortality, management capture and translocation with problematic success, and/or food-conditioning or habituation which may lead to future problems.

Most mortality of grizzly bears is human-caused – either from direct shooting or removal by agency personnel if bears become conditioned to human food and garbage or habituated (loss of wariness) (McLellan et al. 1999, Pease and

Mattson 1999, Nielsen et al. 2004, 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). Note: 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, recreational camps and/or near roads – especially where roads are proximal to streams or bottom fans of avalanche chutes in spring and berry patches at lower elevations during late summer-fall (Mace et al. 1996, Nielsen et al. 2004, Benn et al. 2005, Ciarnello et al. 2007, Schwartz et al. 2006, Schwartz et al. 2010, McLellan 2015). In the Central Rockies Ecosystem of Alberta over the past 40 years, 89% of human-caused mortalities (n = 194) were within 500 m of a road (often closer) or 200 m of trails on Provincial lands (Benn et al. 2005, Herrero et al. 2005, Boulanger and Stenhouse 2014). On Provincial lands between Highway 1 and Highway 11, 72% of 128 human-caused mortalities of grizzly bears (74% of 43 females) occurred west of the Forestry Trunk Road #734 (Benn et al. 2005). Concentration areas for mortalities of females were clustered (1) near Ya Ha Tinda, south of Red Deer River to Panther River and Sheep Creek, and (2) south Ram River-upper Whiterabbit Creek north to Canary Creek, Onion Creek, and North Ram River. Recent studies in Alberta have demonstrated that female grizzly bears – especially those with cubs – are at higher risk because they use riparian areas and the edges of roads (Graham et al. 2010, Stewart et al. 2013, Boulanger and Stenhouse 2014). In recent years in the Rocky Mountains, increasing numbers of grizzly bears have been shot by hunters in camps or when returning to retrieve carcasses of ungulates they have killed (Schwartz et al. 2010, McLellan 2015).

As resource extraction (e.g., oil and gas exploration and development, logging, mining) and motorized recreation expands into hitherto remote areas, road access provides entry for bear poachers, ungulate hunters, and new sources of food and garbage which elevates mortality risk. The Alberta Grizzly Bear Recovery Plan emphasizes that "human access (specifically, motorized vehicle routes) is one of the primary threats to grizzly bear persistence" (AEP 2016). 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, Braid and Nielsen 2015). Consequently, provision of 'security areas' or 'safe havens' – 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, Ciarniello et al. 2007, Nielsen et al. 2010, Weaver 2013b, Braid and Nielsen 2015, AEP 2016).

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 southern Canadian Rockies, the average dispersal distance was 10-14 km for females (longest = 20 km) and 30-42 km for males (longest = 67 km) (McLellan and Hovey 2001b, Proctor et al. 2004). 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 highway-crossing 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 was detected as a migrant across Highway 3 in the Southern Canadian Rockies of B.C. (Apps et al. 2007). In contrast, researchers have documented both female and male grizzlies crossing the Continental Divide between Alberta and British Columbia in certain sections (Proctor et al. 2012, Weaver 2013a).

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, demographic fragmentation of south-north connectivity is a real conservation concern. Proctor et al. (2012) recommended (1) securing key linkage habitats across fracture zones to enable connectivity for female bears, and (2) maintaining large core populations as sources of dispersers.

Sensitivity to Human Disturbance: Grizzly bears exhibit variable sensitivity to human disturbance at different spatial and temporal scales. Bear response may vary by gender depending upon the class of road and volume of traffic, predictability of human activity, season and time of day, and local food availability (Graham et al. 2010). All of these variables may affect a bear avoidance or attraction to roads.

Earlier studies indicated that grizzly bears typically avoid roads 100-900 m away (Mattson et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990), and 500 m became a standard distance for displacement. But, the *level 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 day), bears used areas at night (even crossing roads); but (2) bears avoided or strongly avoided roads with moderate (20-100 vehicles per day) and high (> 100 vehicles per day), respectively. <u>Gated</u> roads had the lowest traffic volumes of any roads. 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 these roads 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 the boreal foothills of west-central Alberta, researchers found female grizzly bears with cubs using areas close (< 200 m) to roads during spring and subadult females during fall (Graham et al. 2010). Perhaps, the bears were attracted to lush herbaceous green-up in these induced openings and/or non-natural foods such as clover planted along the roadside (Roever et al. 2008a, Roever et al. 2008b). The majority of logging roads in the study area had low levels of traffic, which could help explain the lack of avoidance (Roever et al. 2008b). In situations where bears avoid roads, they may be displaced from utilizing important forage sources if the road passes through areas of high-value natural foods (riparian areas in spring, berry fields late summer-fall).

In a new study in the foothills of west-central Alberta, grizzly bears selected habitats close to trails and streams in the absence of human recreational activity, but male bears accelerated their pace of movement in response to high levels of motorized activity (OHVs) (Ladle 2017). In the closed canopy of boreal forests, bears may be drawn to narrow linear features or edges for nutrient-rich foods (Nielsen et al. 2004b, Roever et al. 2008, Stewart et al. 2013). This behavioral response likely diminished time spent by wary individuals in these more productive habitats (Ladle 2017). Controlling motorized recreation activity in areas/times with high-quality foods (for example, riparian areas along streams in spring, or linear openings with buffaloberry or huckleberry in late-summer fall) could be beneficial.

Human access during winter is an emerging concern in conservation of grizzly bears. Unlike true hibernators, grizzly bears can be aroused easily in winter dens. Human disturbance during denning can cost bears in terms of energy loss and cause bears to abandon the den, resulting sometimes in loss of cubs. Bears seemed to tolerate most activities >1 km from the den (Swenson et al. 1997, Linnell et al. 2000). In west-central Alberta, the relative probability of den selection dropped by 30% where road densities increased from 0 to 0.6 km/km^2 and by nearly 70% at road densities of 1.2 km/km^2 (Pigeon et al. 2014).

The larger, more critical concern with roads is the dramatic increase in risk of human-caused mortality. In the Central Rockies Ecosystem of Alberta over the past 40 years, 89% of human-caused mortalities were within 500 m of a road or 200 m of trails on Provincial lands (Benn et al. 2005, Herrero et al. 2005, Boulanger and Stenhouse 2014). Since the legal hunt of grizzly bears was discontinued in 2006, there have been 131 detected grizzly bear human-caused deaths (Grizzly Bear Recovery Plan: AEP *In Review*). The four highest sources of mortality (in order of prevalence) have been: poaching (27%), accidental collisions with highway vehicles or trains (21%), self-defense claims (usually by hunters) (20%), and black bear hunters misidentifying and shooting a grizzly bear (13%).

Bears are particularly vulnerable to mortality near low-volume roads because: (1) they may not perceive a human disturbance, and (2) poachers may be emboldened due to the relative privacy and lower probability of being detected by law enforcement (Roever et al. 2008b). At a larger spatial scale of composite home ranges (CHR), road density was lower (0.6 km/km^2) within the CHR of adult female bears than outside (1.1 km/km^2) in the Swan Mountains of western Montana (Mace et al. 1996). About 50% of their CHR was un-roaded and > 80% of their telemetry locations occurred in blocks of undisturbed habitat > 9 km^2. Female grizzly bears in west-central Alberta – especially adult females with cubs or yearlings – were especially vulnerable to human-caused mortality in areas of higher road density, which can result in lower survivorship and declining populations (Boulanger and Stenhouse 2014). Many land and resource agencies have embraced the conservation target: core habitat should have road densities below 0.6 km/km^2 and large, un-roaded sections (Alberta Grizzly Bear Recovery Plan *In Review*).

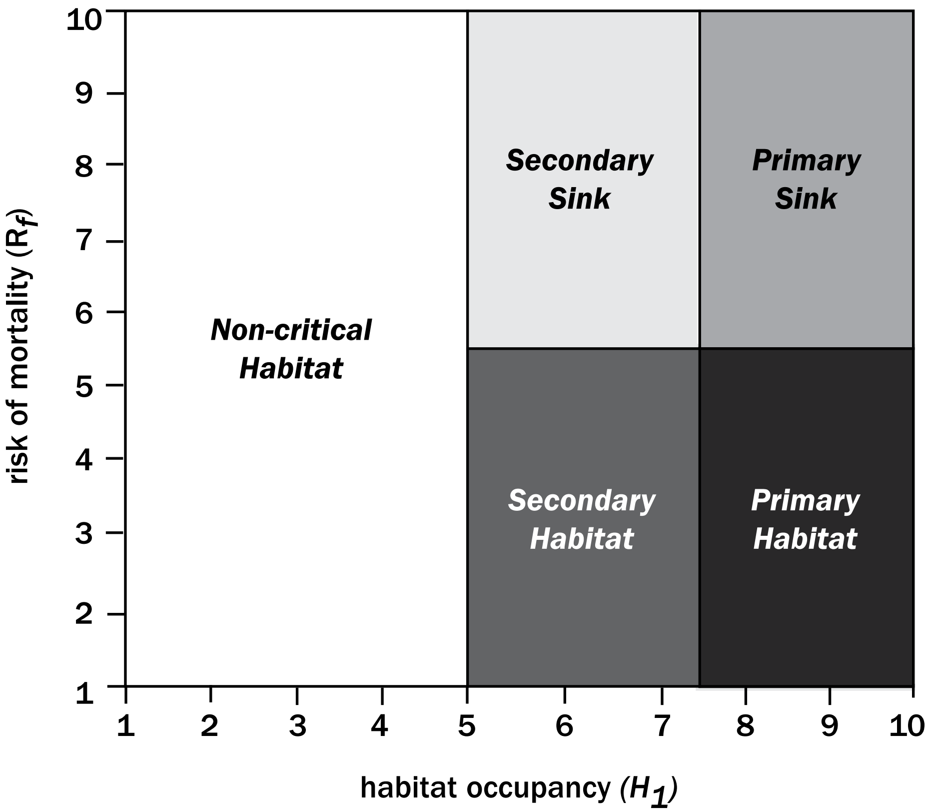
In summary, both the history of grizzly bears in the United States where grizzly bears have lost 99% of their historical range (Mattson and Merrill 2002) and contemporary studies indicate that grizzly bear populations persist longer in areas secure from human settlement and *motorized* access and associated mortality (Gibeau et al. 2001, Theberge 2002, Nielsen et al. 2006). Ultimately, it comes down to human appreciation for – and tolerance of – grizzly bears.

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. Projected changes in the distribution of key foods suggest that buffaloberry and huckleberry may increase in areal extent (Roberts et al. 2014) – especially if one considers the likely response of these fire-dependent species to more extensive fires concurrent with hotter, drier summers in the future. With warmer temperatures, male bears may shift foraging to cooler sites or times of the day (Pigeon et al. 2016b). With warmer shoulder seasons in fall and spring and shorter winters, however, bears may spend less time in dens and more time roaming and searching for food (Pigeon et al. 2016a). This is likely to increase their spatio-temporal interface with humans and potential for conflicts, especially during fall hunting season. As human societies scramble for dwindling fossil-fuel and water resources, associated expansion of road access will bring additional cumulative effects.

Methods for Scoring Conservation Importance of Lands

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. Researchers at the University of Alberta and the fRI Research Grizzly Bear Program (Hinton, Alberta) developed a conceptual framework that integrates these two essential dimensions of grizzly conservation into a very useful model (Nielsen et al. 2006). Graphically, habitat values 1-10 are represented on the x-axis and risk-of-mortality scores 1-10 are on the y-axis (Figure 11). **Primary habitats** (or 'safe-harbours') are those with high habitat scores and low risk-of-mortality, whereas **secondary habitats** are areas with moderate habitat scores and low risk-of-mortality. **Primary** or **'attractive' sinks** have high habitat scores but high risk-of-mortality.

Figure 11. Graphic representation of different 'states' of habitat quality and risk of mortality for grizzly bears (graphic from Nielsen et al. 2006).



I followed this framework for identifying conservation importance of lands in the Bighorn Backcountry for grizzly bears. First, I mapped areas of important food sources using data kindly provided by the fRI Research Grizzly Bear Program. Researchers identified key habitat components where grizzly bears direct their foraging at various seasons. The model included several variables of land cover, forest canopy, soil wetness, and distance to streamside and forest edge. They analyzed 121,683 GPS telemetry locations acquired during 1999-2006 from 81 radio-collared grizzly bears (53 females, 28 males). Occupancy of female grizzly bears was based upon detections at 2,295 hair-snag survey sites and DNA genotyping across 27,733 km^2. Habitat values for each BMA were estimated as regional female grizzly bear occupancy *times* population-level RSFs. Habitat values were then categorized into 10 ordinal bins representing the relative probability of habitat selection. To map habitat components for grizzly bears in the Bighorn Backcountry, I used the maximum food value assigned to a cell (size 30m x 30m) for any of the 3 defined seasons (spring, summer, late summer-fall). I ranked grizzly bear habitat quality by sorting the bins as follows: (1) high = bins 8-10, (2) moderate = bins 5-7, and low = bins 1-4. Distribution of areas ranked as high, moderate, or low for foods is displayed in Figure 14.

Because winter denning is an important annual event for grizzly bears (especially pregnant females), I mapped areas that are highly suitable for denning as the second component of habitat. A map of denning habitat was generously provided by the Grizzly Bear Program at the Foothills Research Institute (Pigeon et al. 2010). The fRI model, however, only covered the portion of the Bighorn Backcountry north of Highway 11. We devised a simpler model based upon the denning attributes of that area, tested its performance, and then applied it to the area south of Highway 11. From the FRI model, we used the 2 highest-selected bins 5 and 6 (moderately-highly selected) which accounted for 70% of dens. We parameterize the model as follows:

Slope =	≥ 11° (average for bin 5 [17°] – 1 SD [6°]
Elevation =	≥ 1628 m (average for bin 5 [2009m] – 1 SD [381m])
Distance from road =	> 500 m

Using these parameters, our model mapped 217,356 ha (85%) north of Highway 11 compared to 254,534 ha according to fRI model. Our model mapped fewer areas east of the Forestry Trunk Road #734 at lower elevations. Application of our model to the area south of Highway 11 yielded a map of suitable denning habitat that appeared very similar to the fRI map (including some lands east of the Forestry Truck Road #734 (Figure 12). I categorized these areas as 'moderate' value due to their importance for denning; some of the areas at higher elevations may not have many foods.

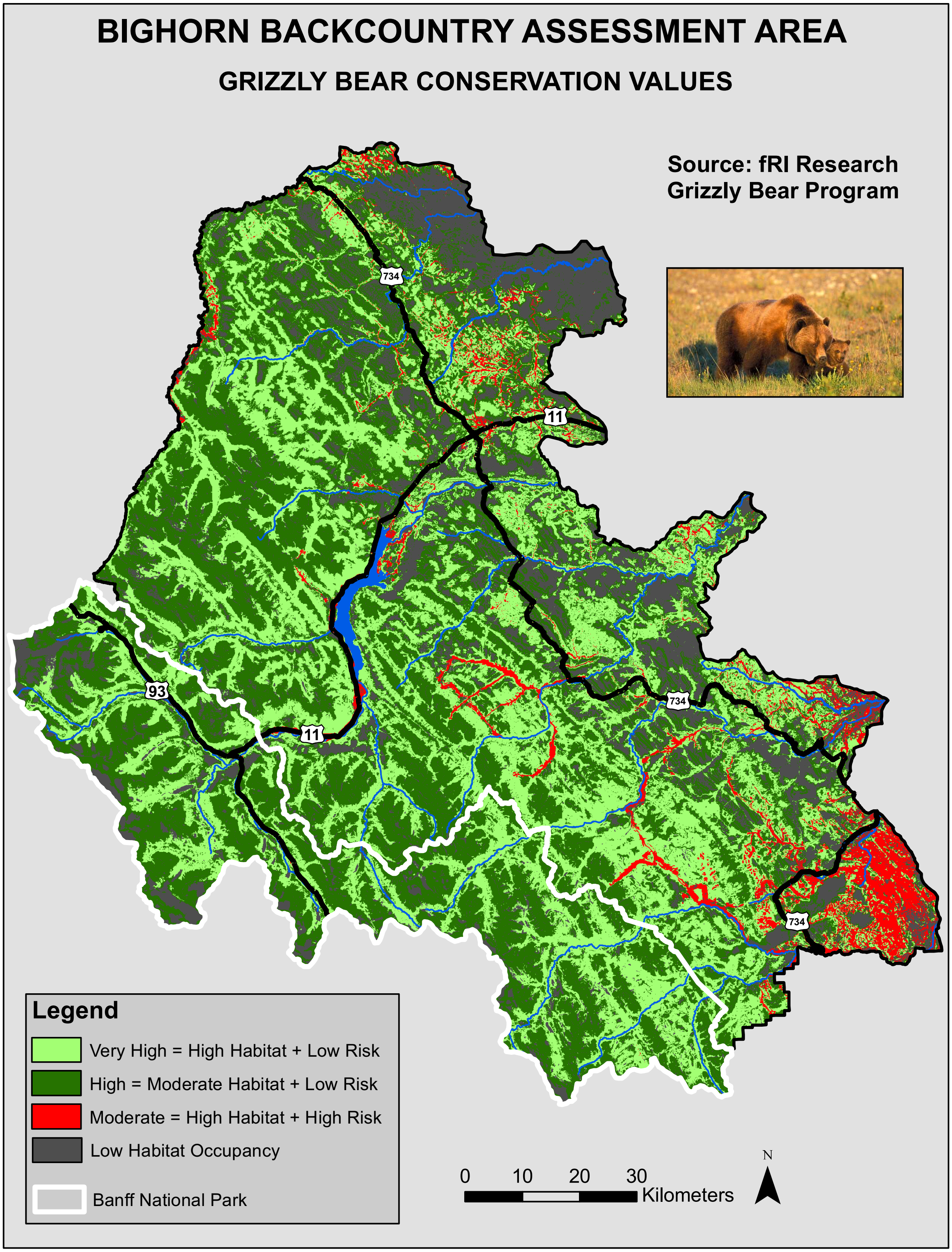
The final step in mapping conservation value of lands for grizzly bears was to identify areas of high habitat value which also involved the highest risk-of-mortality (bins 6-10). Such areas represent "attractive sinks' or 'ecological traps' for grizzly bears (Delibes et al. 2002, Nielsen et al. 2006). Risk of mortality is driven largely by proximity to roads, as modified by hiding cover provided by obscuring terrain or trees (Nielsen 2007). We used an updated script and file of mortality risk (bins 6-10) kindly provided by Grizzly Bear Program at the foothills Research Institute.

I used these various GIS data sets to map conservation values as follows (Figure 15):

(a) primary habitats/ 'safe harbours' (high-quality habitat and low risk-of-mortality) = score of 3,
(b) secondary habitats (moderate-quality habitat and low risk-of-mortality) = score of 2; These areas could be of moderate value for foraging, *or* high-value for denning, and
(c) primary 'attractive sinks' (high-quality habitat but high risk-of-mortality) = score of 1.

This approach facilitates identification of important conservation areas for grizzly bears. Importantly, it also enables managers to target *strategic* sites ('attractive sinks') to improve security by restraining motorized access. Hence, there are 2 mutually-supportive conservation strategies: (1) protection of existing safe-harbour or source areas, and (2) reducing road access to restore security in areas of high habitat quality but high mortality risk (Boulanger and Stenhouse 2014, Braid and Nielsen 2015).

Figure 15. Location of key conservation values for grizzly bears, Bighorn Backcountry, Alberta. Very High = Primary Habitat, High = Secondary Habitat, and Moderate = Attractive Sinks. Values adapted from Nielsen et al. (2009) and updated by Gordon Stenhouse (2016).



Key Conservation Areas

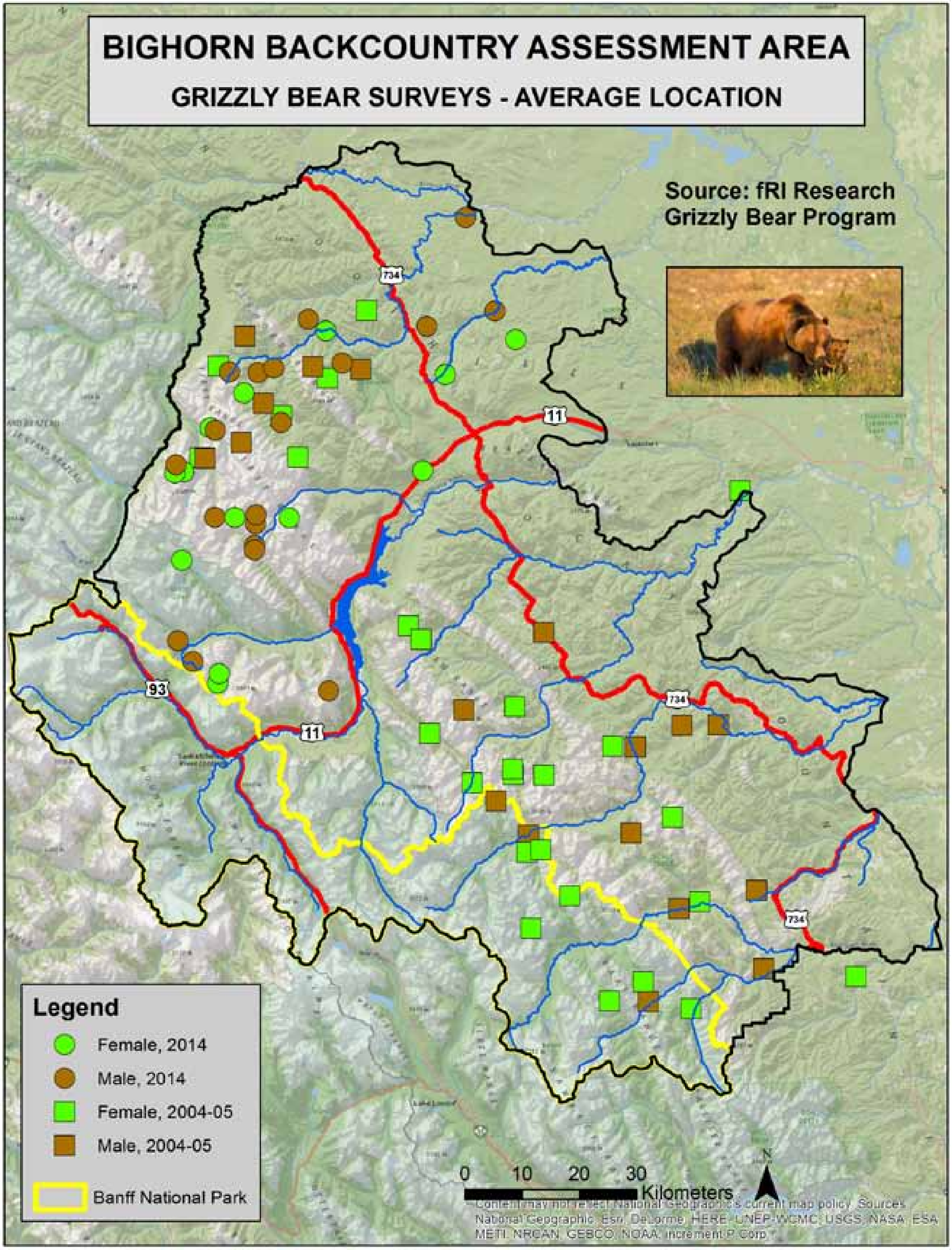
Occurrence: Several inventories of grizzly bears using non-invasive hair-snagging and DNA analyses have been completed in Alberta over the past dozen years. The Bighorn Backcountry north of Highway 11 is part of Bear Management Area (BMA) 3 (Yellowhead), which was surveyed in 2004 (Boulanger et al. 2005a) and re-surveyed over a larger area in 2014 (Stenhouse et al. 2016). The area south of Highway 11 comprises BMA 4 (Clearwater), which was inventoried in 2005 (Boulanger et al. 2005b). Estimated density of grizzly bears across these two BMAs was rather low (4.8 bears/1000 km^2 for BMA 3; 5.3 bears/1000 km^2 for BMA 4), compared to other areas in Canadian Rockies of Alberta and B.C. (Apps et al. 2016). Grizzly bears in this area have large home ranges: mean size for a radio-collared sample (n = 29) was 2,402 km^2 (G. Stenhouse, fRI Grizzly Bear Program, *unpublished data*).

Nonetheless, there were several concentration areas of greater density – particularly in remote valleys in the mountains (Figure 13). North of Highway 11, multiple bear detections were recorded during 2004 in the following areas: Job Creek, upper Blackstone River and tributaries, upper Wapiabi and Sunkay Creek, and Chungo Creek. Only 1 grizzly bear was detected east of the Forestry Trunk Road #734. In the replicate survey 10 years later, grizzlies were detected in many of these same areas but also a few in the Nordegg River basin east of the trunk road. In the expanded survey area, grizzly bears occurred in the upper Cline River and tributaries, upper Coral Creek and upper Bighorn Creek, and upper Job Creek. Some of these concentration areas in BMA 3 had bear density of 11-12 per 1000 km^2.

South of Highway 11, most of the grizzly bear detections also occurred in secluded portions in the mountains: Whiterabbit Creek, upper North Ram River, upper (south) Ram River and upper Ranger Creek, Clearwater River, and near Limestone Mountain. These areas exemplify the landscape pattern reported in a regional model for the Canadian Rockies of Alberta and B.C., where grizzly bear occurrence was associated with upper elevation, mesic landscapes, limited road access, and diversity of land cover (Apps et al. 2016).

Altogether, 93% of the 164 detections across the Bighorn Backcountry occurred west of the Forestry Trunk Road #734 – including nearly all of the female grizzlies detected. The regional model projected a similar landscape pattern for the Bighorn Backcountry (Apps et al. 2016). Clearly, the Bighorn Backcountry area west of the Forestry Trunk Road #734 is vital for conservation of Alberta grizzly bears.

Figure 13. Average location of grizzly bears from surveys during 2004 (BMA 3), 2005 (BMA 4) and 2014 (repeat survey and larger area BMA 3).



Habitat Value for Foods:

Most of the areas with important foods for grizzly bears occurred primarily in two kinds of sites (green areas in Figure 14):

1. in stream/river valleys at moderate-high elevations in the Subalpine sub-region of the Rocky Mountain Natural Region, and
2. along the edge of forestry clearcuts at lower elevations in the extensive coniferous forests of the Foothills Natural Region – Upper sub-region. Foods of high value were located mostly along the edge (Stewart et al. 2013); mapping the entire cut block overestimates the amount of habitat used by bears.

Two kinds of sites have little food value for grizzly bears (brown areas in Figure 14):

1. higher mountains above ~2300 m in the Alpine sub-region have comparatively few plants of food value due to the harsh growing conditions, and
2. cold coniferous forests in the Upper Foothills and/or boggy sites in the Lower Foothills.

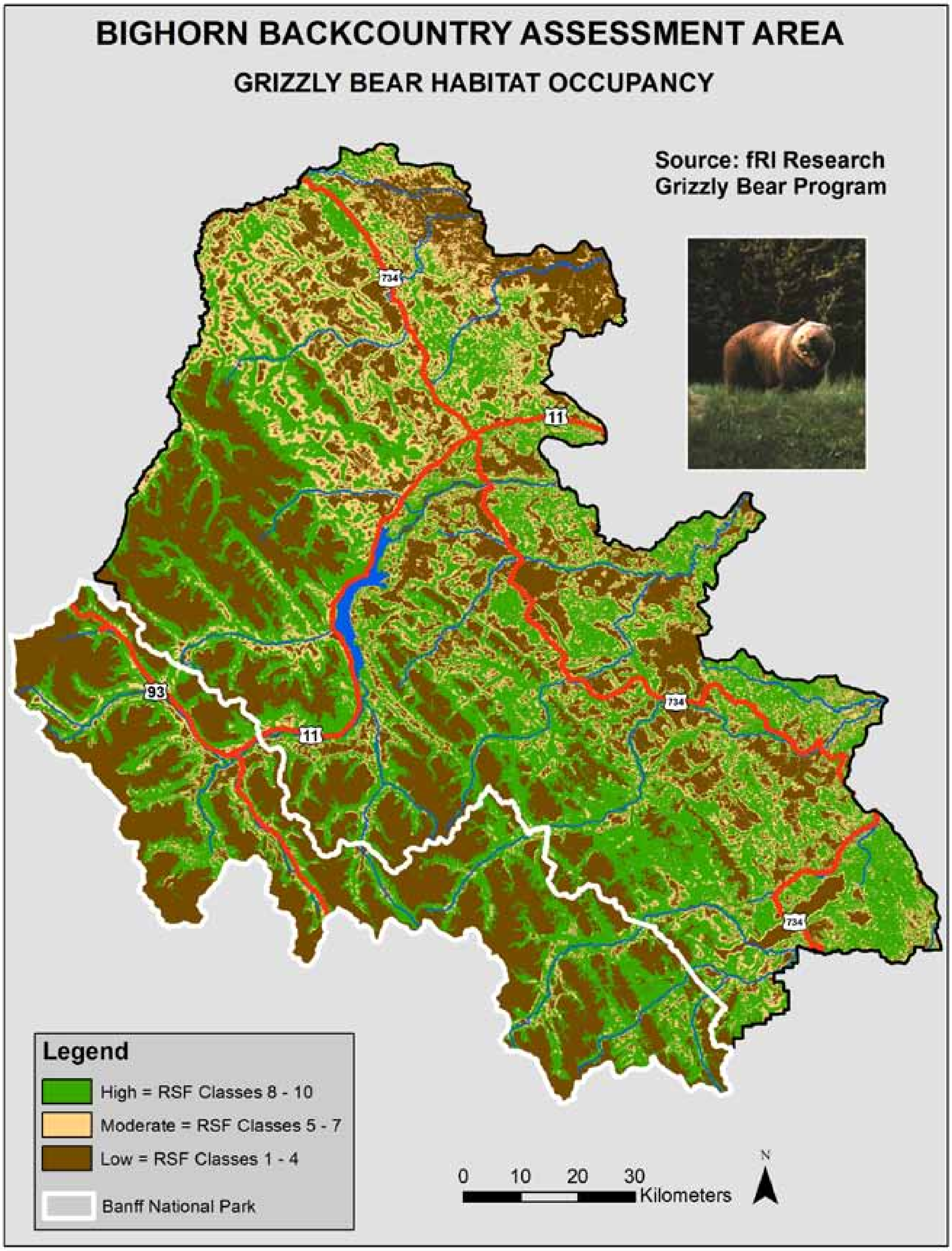
In the eastern portion of the Bighorn Backcountry area, patches of high forage value are smaller and more interspersed with patches of moderate or low value.

About 84% (1,202,582 ha) of the Bighorn Backcountry assessment area has high or moderate habitat value for grizzly bears (Table 4). High habitat values occur on 567,345 ha (39.6%), while another 638,237 ha (44.5%) have moderate habitat value. About 69% (832,031 ha) of these high and moderate habitats occur on Provincial lands outside the 2 wilderness areas. These lands provide the foundational capacity for grizzly bear recovery in Alberta.

Table 4. Area (ha) and percent of lands with grizzly bear habitat values in the Bighorn Backcountry Assessment Area, Alberta.

	High = 3		Moderate = 2		Low = 1	
Land Status	**Area**	**Percent**	**Area**	**Percent**	**Area**	**Percent**
Banff NP	117,888	20.8	175,328	27.4	38,759	16.9
Provincial WAs	28,066	4.9	52,995	8.3	6,072	2.7
Provincial Lands	421,391	74.3	410,640	64.3	181,437	80.4
TOTAL	567,345	100.0	638,237	100.0	225,545	100.0
%Total Land Base		**39.6**		**44.5**		**15.7**

Figure 14. Location of key habitats with important foods for grizzly bears, Bighorn Backcountry, Alberta. RSF classes adapted from Nielsen et al. (2006) and Nielsen et al. (2009).



Conservation Values: To complete this picture of conservation value, however, the spatial coverage of risk-of-mortality must be added. Primary habitats or 'safe harbours' have high food value and low risk of mortality (security) (green areas in Figure 15). The most extensive of these habitats are located in the remote river/stream valleys that thread through the mountains. Smaller, more fragmented patches of primary habitat occur in the Upper Foothills. Secondary habitats have moderate food value *or* high denning suitability and low risk-of-mortality (dark green areas in Figure 15). The alpine areas may provide some animal foods (marmots, ground squirrels), as well as security from human disturbance.

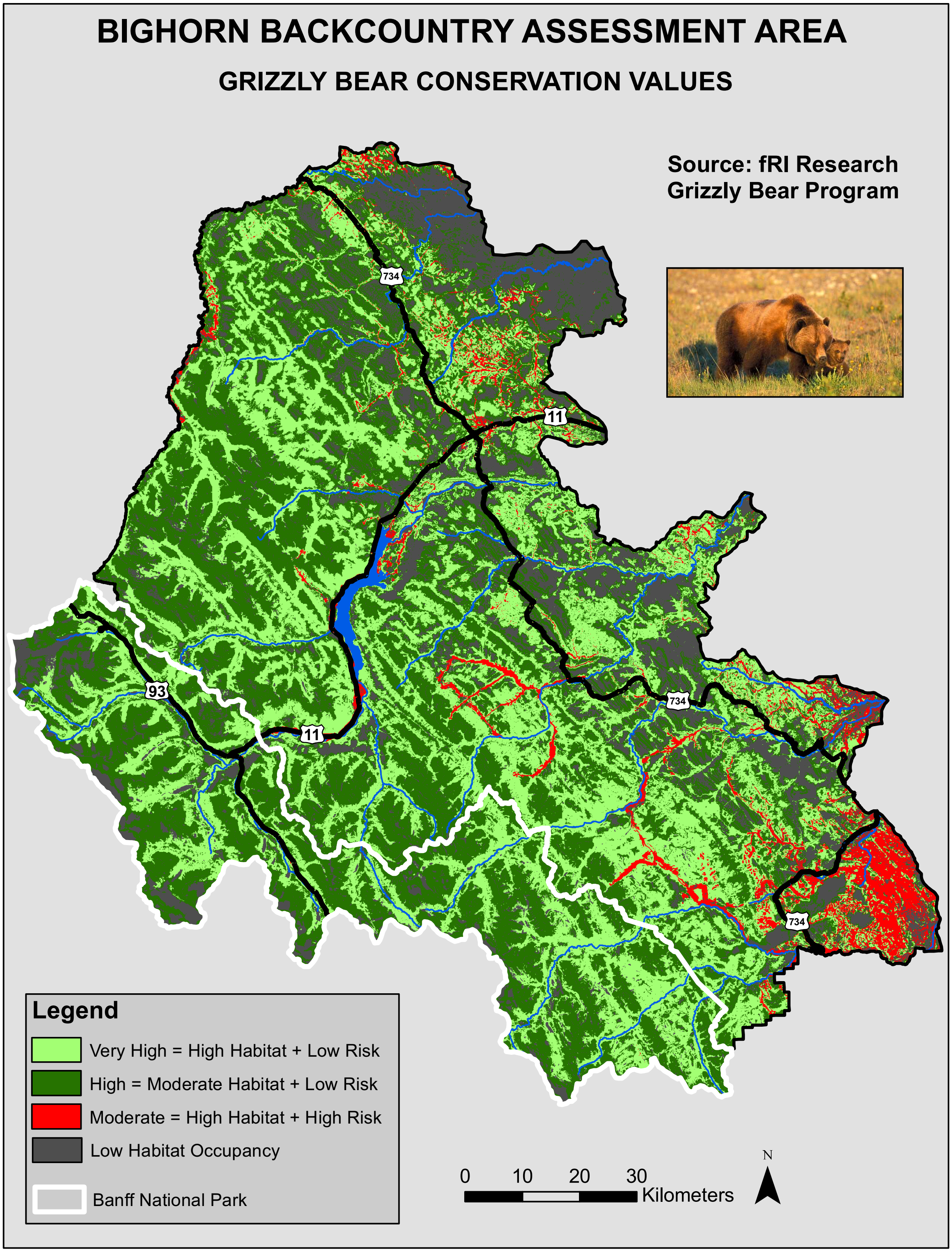
The 'primary sinks' represent areas that have high food value (bins 8-10) which attracts bears, but proximity of roads elevates the risk-of-mortality by humans (red areas in Figure 15) Although clearcuts may have valuable bear foods along the edges, there are roads to the block of clearcuts (and traversable skid trails to most of the units). From a conservation perspective, the risk-of-mortality far outweighs the value of the food resource (Nielsen et al. 2008, Braid and Nielsen 2015). In addition, the trails and seismic lines open for motorized use by OHVs may diminish or displace use by grizzly bears (Ladle 2017). Many of these existing 'attractive sinks' are located east of the Forestry Trunk Road #734. Some of the roads and trails west of FTR#734 offer strategic opportunities for restoring security to sites where high habitat value has been breached by roads or trails (see next section).

About 78% (1,116,111 ha) of the Bighorn Backcountry has very high or high conservation value for grizzly bears (high or moderate habitat value *and* low risk of mortality) (Table 5). About 67% (746,723 ha) of these important conservation lands (safe harbours) occur on Provincial lands outside the two wilderness areas. Most (76%) of these important safe harbours on non-wilderness Provincial lands occur west of the Forestry Trunk Road #734 (Figure 15).

Table 5. Area (ha) and percent of lands with grizzly bear conservation values in the Bighorn Backcountry Assessment Area, Alberta.

	Primary Habitats Very High = 3		Secondary Habitats High = 2		Primary Sinks Moderate = 1	
Land Status	**Area**	**Percent**	**Area**	**Percent**	**Area**	**Percent**
Banff NP	115,744	23.2	175,253	28.3	2,183	3.2
Provincial WAs	28,050	5.6	53,017	8.6	0	0.0
Provincial Lands	355,421	71.2	391,302	63.1	65,883	96.8
TOTAL	499,215	100.0	619,572	100.0	68,066	100.0
%Total Land Base		**34.8**		**43.2**		**4.7**

Figure 15. Location of key conservation values for grizzly bears, Bighorn Backcountry, Alberta. Very High = Primary Habitat, High = Secondary Habitat, and Moderate = Attractive Sinks. Values adapted from Nielsen et al. (2009) and updated by Gordon Stenhouse (2016).



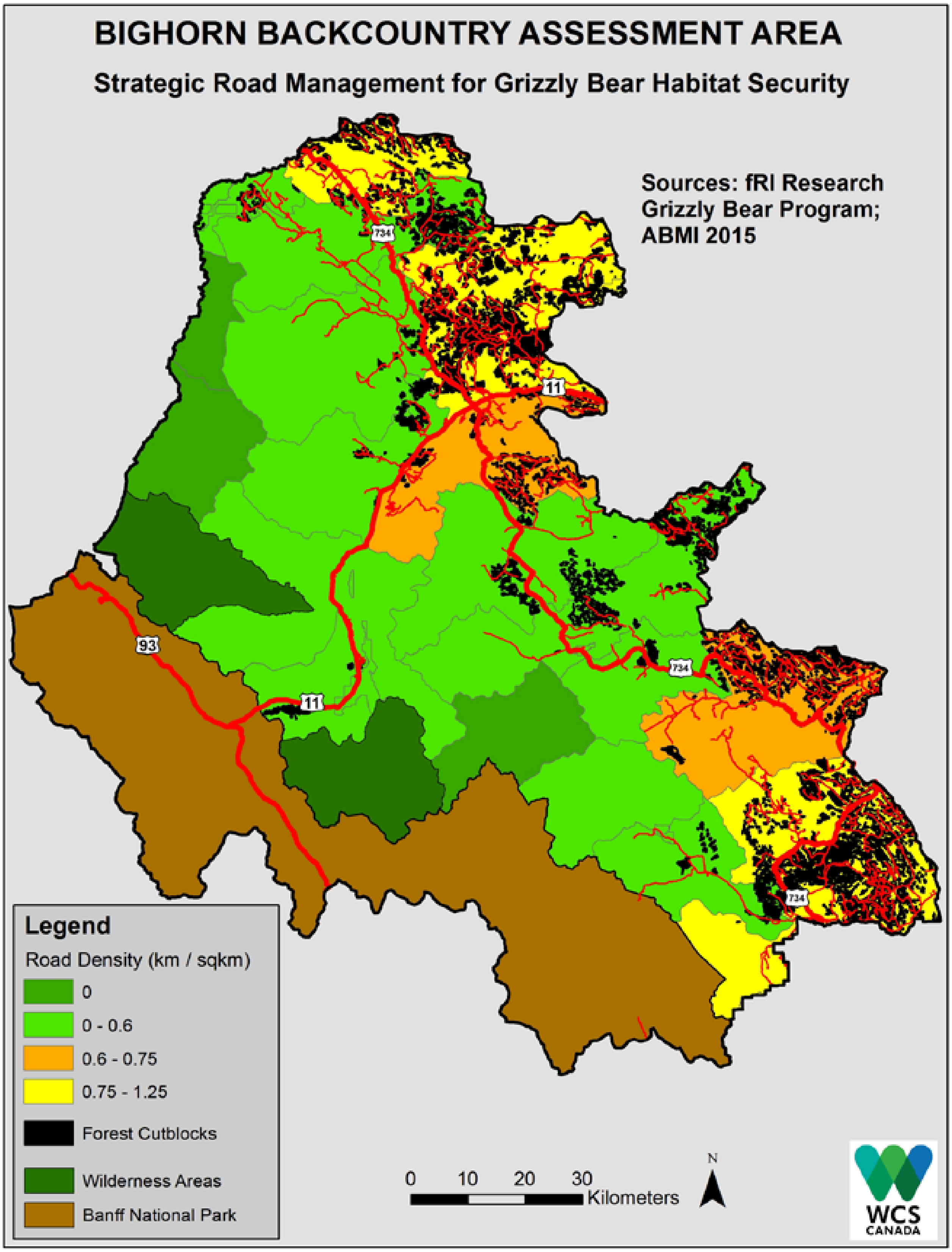
Conservation Issues

According to Alberta's Grizzly Bear Recovery Plan (AEP 2016), successful conservation of grizzly bears requires addressing and resolving four critical issues: (1) minimizing excessive human-caused mortality of bears, (2) protecting or restoring secure habitats, (3) maintaining or restoring connectivity across major highways, and (4) gaining support among people who live, work, or recreate in grizzly country. Here, I focus on the primary issue of human-caused mortality; in a subsequent section in this report, I provide an analysis and map of putative connectivity across Highway 11 for both grizzly bears and wolverines.

Since legal hunting of grizzly bears was discontinued in 2006, there have been 131 human-caused mortalities *detected* (2006-2013) for an average of 18.4 per year; of cases where gender could be determined, 40% were female (AEP 2016). Over the past five years, the 4 highest sources of mortality (in order of prevalence) have been: poaching (27%), accidental collisions with highway vehicles or trains (21%), self-defense claims (usually by hunters) (20%), and black bear hunters misidentifying and shooting a grizzly bear (13%). In the BMAs 3 (Yellowhead) and 4 (Clearwater) that overlap with the Bighorn Backcountry, known human-caused mortalities of grizzly bears (mostly illegal poaching) were lower (9 and 5 bears) than in other BMAs (average of 22 bears).

Accordingly, the revised recovery plan recommends an open-road density threshold of ≤ 0.6 km/km^2 for Core Zones and ≤ 0.75 km/km^2 for Secondary Zones. In the Bighorn Backcountry, several watershed units in the Core Recovery Zone along the eastern side exceed this threshold (Figure 16). Reducing road density in these areas – especially along streams or some blocks of clearcuts – to levels lower than the established threshold would help provide adequate security for grizzly bears. At a finer scale of inspection, 65,883 ha (8%) in the Bighorn Backcountry were mapped as *primary attractive sinks* (Table 5, Figure 15). These attractive sinks represent opportunities for the astute land manager to raise the conservation score (from 1 to 3) by strategically closing selected roads. I presume these mortality sinks in the Core Recovery Zone will be addressed by the Provincial agencies in consultation with the public.

Figure 16. Location of road density classes for grizzly bears, Bighorn Backcountry area, Alberta. All of the study area falls within Alberta's Core Recovery Zone. See text for details.



High levels of motorized recreation activity (Off-Highway Vehicle OHV) on trails can diminished time spent by wary individuals in productive habitats (Ladle 2017). Controlling motorized recreation activity in areas/times with high-quality foods (for example, riparian areas along streams in spring, or linear openings with buffaloberry or huckleberry in late-summer fall) could be beneficial. In particular, I suggest a precautionary approach regarding access by OHVs in headwater basins of river/stream valleys because these locales are favored haunts of female grizzly bears. Several of these strategic sites are found in watershed units where road density *overall* may be above threshold; nonetheless, they appear critical due to high habitat values. Along with other conservation measures, strategic closure of access in the following basins could be beneficial for grizzly bear recovery: North Ram River and Cripple Creek; Upper Onion Creek, Hummingbird, and Canary Creek; and Upper Blackstone River (beyond confluence with road up sw tributary).

Other proactive efforts for reducing conflicts and human-caused mortality of grizzly bears include: (1) keeping food attractants and garbage secured from bears at backcountry campsites, (2) hunter education programs on bear identification and retrieval of hunter-killed ungulates, and (3) outreach on the efficacy and proper use of bear spray. Investments to improve the capacity and acceptance of Alberta's BearSmart program would help support the successful recovery of grizzly bears in Alberta.

Figure 17. Areas of diverse topography from valley bottoms to peaks and secure from human disturbance can serve as important 'safe havens' for vulnerable wildlife under increasing pressures of resource extraction/motorized recreation and changing climates.

Photo: John Weaver

Wolverine (*Gulo gulo*)

Photo: Larry Master

Status The wolverine across Canada was assessed by COSEWIC in 2014 as a species of '***Special Concern***' (COSEWIC 2014) but has not been listed under Species At Risk Act. In Alberta, the wolverine has been recognized as a species that '**may be at risk**', but also one that is '**data deficient**' signifying a lack of information for legal assessment and protection (Alberta Endangered Species Conservation Committee 2014). In recent years, however, several broad surveys of wolverine occurrence and specific studies have been completed in Alberta; some have been published very recently and others will be soon. This should trigger a new assessment of current status of wolverine and Provincial designation (Fisher 2014).

Vulnerability Profile

Synopsis: Wolverines exhibit **high vulnerability**. Wolverines have a broad and flexible foraging niche, mostly scavenging opportunistically on dead ungulates in winter and predating on larger rodents in summer. Within their range in western North America, wolverines usually occupy higher elevations in alpine, subalpine, and upper foothill zones, as well as northern boreal forests. There appears to be a strong concordance between the extent of persistent snow cover during spring and habitats that wolverine use for denning, summer habitat, and dispersal routes. (Note: This relationship may not be as strong in the boreal forests of northern Alberta.) Wolverines have very low reproductive rates. Consequently, they cannot sustain high mortality rates, which can be exacerbated by trapping pressure – especially in areas of limited or disjunct habitat patches. Trapping also may obviate the likelihood of successful dispersal by juvenile wolverines, which could impact the viability of meta-populations across a larger region. Linear features such as roads and seismic lines facilitate motorized access into wolverine habitat – the cumulative effects of which can degrade habitat suitability and increase risk of trapping or hunting mortality.

Wolverines appear sensitive to human disturbance near natal den sites during winter, and their distribution at coarse scales excludes some suitable habitats near human settlement or intensive industrial activity. Major highways or large reservoirs may impede movements leading to fragmentation of populations. Due to their multi-faceted adaptation to snow environments, wolverines appear vulnerable to reductions in suitable habitat at lower elevations resulting from projected warming climate. Although climate change likely will shrink the extent of suitable habitat, the more immediate and consequential threats are contemporary industrial and recreational human activities resulting in excessive trapping and displacement. Numerous wolverine researchers have cautioned that trapped populations will likely decline in the absence of immigration from *un-trapped* populations and have recommended refugia – created by restricting/eliminating trapping or designating roadless sanctuaries – as a crucial element in the overall conservation of wolverine.

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). Hoary marmots and ground squirrels 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, Banci 1987, Lofroth et al. 2007). Other carnivores such as wolves may be important provisioners of carrion (Banci 1987), but there may be a tradeoff for wolverines between scavenging the food resource and avoiding competition and predation with larger predators (Van Dijk et al. 2008, Inman et al. 2012b).

In western North America, wolverines occur at higher elevations in the subalpine and alpine life zones (Aubry et al. 2007, Copeland et al. 2007, Krebs et al. 2007, Inman et al. 2012b) and also at lower elevations in the northern boreal forest of Alberta (Webb et al. 2016). Several researchers have pointed out the strong concordance of wolverine occurrence and persistence of spring snow cover (SSC) from mid-April thru mid-May, which covers the end of wolverine denning period (Aubry et al. 2007, Copeland et al. 2010). Although trapping records and recent surveys suggests this relationship may not be so strong in the boreal forests of northern Alberta (Webb et al. 2016), the snow model does predict occurrence of wolverines in the Rocky Mountains fairly well (Copeland et al. 2010, Fisher et al. 2013, data *in* Clevenger and Barrueto 2014, Webb et al. 2016).

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 has been postulated that these snow dens provide thermal insulation and refuge from predators, which aids survival of the young. 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). During summer, females 'park' their young at 'rendezvous sites' in talus fields composed of large boulders, often in subalpine cirque basins (Copeland and Yates 2006). Additional factors such as terrain ruggedness, avalanche chutes and boulder fields, and areas remote from motorized activities may also help explain habitat selection by wolverines (Krebs et al. 2007, Inman et al. 2012b, Fisher et al. 2013). 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. 2012). In such low-productivity environments, though, wolverines must range widely in constant search for food (Chadwick 2010, Inman et al. 2012b). Thus, their home ranges are large relative to their body size, with average annual home ranges (MCP and adaptive kernel methods) of 280 - 400 km^2 for adult females and 775 - 1,525 km^2 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. Post-mortem analyses of trapped wolverines across North America revealed that an average of 63% of females (range of averages 50-85%) had fetuses at 2+ years of age (nearly 3-yr-old), and average litter size *in utero* varied from 2.2 to 3.5 kits (Rausch and Pearson 1972, Liskop et al. 1981, 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; 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 kits/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 *daughters* during her lifetime that survive to reproduce. This is very low, even compared to other large carnivores (Weaver et al. 1996).

With such low reproductive capacity, wolverines cannot sustain or compensate for high mortality. Of particular relevance to resilience is the interactive combination of significant natural mortality and excessive human-caused mortality. In 12 telemetry studies of wolverines across western North America during 1972-2001, starvation accounted for 29% and trapping and hunting 35% of 62 recorded mortalities (Krebs et al. 2004). Wolverines are susceptible to trapping at bait sites during winter, particularly in years when carrion availability is low. These researchers stated that trapping appeared to be an *additive* cause of mortality (not compensatory) and cautioned that high annual survival (≥0.85) of adult female wolverines is requisite to sustaining populations. Trapping accounted for 21 (88%) of 24 wolverine mortalities recorded during 1972-1977 in the South Fork of the Flathead River basin (Hornocker and Hash 1981). More recently, researchers working in western Montana reported that licensed trapping accounted for 9 (64%) of 14 recorded mortalities of instrumented wolverines during 2002-2005 (Squires et al. 2007). They estimated that this additive mortality from trapping reduced annual survivorship from 0.80 down to 0.57 and determined that population stability was most sensitive to adult survival.

Wolverine researchers have cautioned that trapped populations will likely decline in the absence of immigration from un-trapped populations (Krebs et al. 2004, Squires et al. 2007). Small populations in isolated mountain ranges are especially vulnerable to over-harvest and local extirpation (Squires et al. 2007). In a rudimentary assessment of the sustainability of the wolverine harvest in British Columbia, researchers urged particular attention and precautionary approach for units in southeast B.C. (Lofroth and Ott 2007). An assessment using new population data is planned for the southern Canadian Rockies of Alberta and British Columbia (A. Clevenger, *personal communication*).

Numerous wolverine researchers have recommended refugia – such as those created by restricting/ eliminating trapping or designating large non-motorized sanctuaries – as a crucial element in the overall conservation of wolverine (Weaver et al. 1996, Krebs et al. 2004, Squires et al. 2007). Due to the large home ranges of wolverines and their low density, these safe havens need to be managed at trans-border (provincial/international) and/or metapopulation scales (Inman et al. 2012b).

Dispersal and Connectivity: Wolverines are capable of dispersing long distances. Juvenile dispersals between 168 km and 378 km have been reported in various studies (Magoun 1985, Gardner et al. 1986, Copeland 1996, Vangen et al. 2001, Copeland and Yates 2006, Inman et al. 2012b). Most interesting, a young male wolverine left Grand Teton National Park in northwest Wyoming, crossed expanses of the Red Desert (atypical habitat) and Interstate Highway 80 in southern Wyoming, and pulled up in Rocky Mountain National Park in northern Colorado – an astounding distance of 900 km (R. Inman, WCS, *unpublished data*). Young wolverines also make extensive exploratory movements >200 km prior to actual dispersal (Vangen et al. 2001, Inman et al. 2004). Usually males but also females make long-distance movements, typically during their second year prior to reaching sexual 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) for wolverines has been estimated at 30% of the total number of animals) (Schwartz et al. 2009). Due to such low effective population size and the patchy or peninsular 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 (Cegelski et al. 2006, Schwartz et al. 2009, Inman et al. 2012b). Researchers have reported that areas with persistent snow cover during late spring and sparse human footprint (housing density) characterize the least-cost pathways for successful movements among sub-populations of wolverines across the northern U.S. Rocky Mountains (Schwartz et al. 2009, Inman et al. 2012b, Rainey et al. 2012).

Major highways can have a significant impact on wolverine movements, too. In winter, wolverines avoided areas within 100 m of the Trans-Canada Highway (TCH) between Yoho and Banff National Parks and only crossed 3 of 6 times (Austin 1998). After 17 years of monitoring 24 crossing structures along the TCH in lower elevations of Banff National Park, only 10 crossings (9 at underpasses) by wolverines had been detected (Clevenger 2013). In more recent hair-snagging surveys and genetic analyses, researchers detected 7 wolverines (2 females, 5 males) that crossed the TCH during a 3-year period (Sawaya and Clevenger 2014). Average daily traffic volume on the TCH is very high, ranging from 9,000 to 17,000 vehicles per day. On-going analysis indicates that this major highway may be restricting female wolverines but not males (A. Clevenger, *personal communication*).

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. On a Wyoming highway where traffic volume commonly exceeded 4,000 vehicles per day, four different wolverines (2F, 2 M) crossed the highway 16 times. 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.

Sensitivity to Human Disturbance: Wolverines – adult females in particular – may select habitats that integrate (or trade-off) factors of human disturbance, food sources and predation by larger carnivores such as wolves (Krebs et al. 2007, Fisher et al. 2015). Maternal female wolverines appear sensitive to human activity near maternal dens, which are used February through mid-May (Magoun and Copeland 1998). With the advent of more powerful snow machines as well as heli-skiing, such motorized access may disturb maternal females and young during the critical mid-winter and spring period and warrants closer management attention (Krebs et al. 2007). Researchers have been studying interactions between wolverines and winter recreation in several areas of Idaho, Montana, and Wyoming 2010-2015 and should have final reports available soon (Heinemeyer and Squires 2015). Notwithstanding, researchers report wolverines regularly using heavily-industrialized landscapes in the boreal forests of northern Alberta (Scrafford and Boyce 2015).

Recent surveys of wolverines across the Canadian Rocky Mountains clearly show that wolverines are more abundant in the national parks, which are characterized both by fewer and more clustered human developments and also by no trapping or hunting (Clevenger and Barrueto 2014, Clevenger et al. 2016). Outside of national parks, research suggests that occupancy by wolverines (at 100-km^2 scales) appears to be negatively correlated with linear features of human activity such as roads and seismic lines (Krebs et al. 2007, Fisher et al, 2013, Heim 2015, Clevenger et al. 2016).

Response to Climate Change: Warming climate will likely shrink the extent of suitable habitat for wolverines. As noted, several aspects of wolverine ecology and their distribution appear linked to areas characterized by persistent snow cover during spring (Copeland et al. 2010, Inman et al. 2012a), (but less so at large scales in the northern boreal forest of Alberta - Webb et al. 2016). Some of the biggest changes wrought by climate warming may be substantial reductions in SSC at low to moderate elevations as winter precipitation shifts from snow to rain (Mote et al. 2005, Knowles et al. 2006, Pederson et al. 2010, MacDonald et al. 2012). Some researchers estimate that the extent of persistent SSC could decrease by 27% in Montana by year 2045 (McKelvey et al. 2011). Because SSC may be lost disproportionately at lower elevations, I approximated this loss by subtracting snow class 1 from the Copeland model (2010), which resulted in a loss of 25% in spring snow cover. This exclusion also matched well spatially with the mapped areas where the greatest change in precipitation from snowfall to rain is projected (see Figure 8). Warmer temperatures during summer could force wolverines to seek cooler habitats at higher elevations, too (Copeland et al. 2010). In terms of food sources for wolverines, a warmer climate could reduce the abundance of ungulate carrion due to milder winter conditions (Wilmers and Post 2006) and impact wolverines' alpine prey such as hoary marmots (Lofroth et al. 2007). Although climate change likely will shrink suitable habitat at lower elevations of the Rocky Mountains, the more immediate and consequential threats are contemporary industrial and recreational human activities resulting in excessive trapping and displacement.

Methods for Scoring Conservation Importance

I identified key conservation areas for wolverines using a model developed by several veteran wolverine researchers from North America and Scandinavia (Copeland et al. 2010). The 'Spring Snow Cover' (SSC) model uses snow cover in late spring to predict geographic occurrence of the wolverine across its circumboreal range. 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. They assigned snow classes 1-7 on the basis of how many years during that time period an area was covered by snow in late spring (e.g., snow class 3 = 3 years of 7). About 89% of summer and 81% of winter telemetry locations from 8 study areas in western North America concurred with SSC. Moreover, 90% of 62 known wolverine den sites in western North America occurred within SSC for 5-7 years (J. Copeland, *unpublished* *data*). Modelling of dispersal by wolverines suggest that areas of spring snow cover may provide likely travel routes (Schwartz et al. 2009), too. The timing of reproduction, caching of foods, and avoidance of competition may also be linked with snow (Inman et al. 2012a). Thus, many central features of wolverine niche – historical occurrence in the U.S., habitat use across gender/age/seasons, den sites and dispersals – seem to correspond to this 'bioclimatic envelope' of spring snow cover.

Nevertheless, it may be argued (reasonably) that this simple 1-variable model does not explicitly account for factors such as topography (i.e., rugged terrain), plant communities or cover types, food sources, risk of predation or competition by other carnivores, or human disturbance. So, I evaluated performance of the SSC model with other models that include such factors. Based upon long-term studies in the Greater Yellowstone Ecosystem, Robert Inman developed an alternative model (Inman 2013). The 'Inman' 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 tree cover), and 2 human variables (human population density, road density). The Inman model performed well with 3 independent data sets from Greater Yellowstone, Montana, and Utah. A different study in Yellowstone National Park reported that both models accounted for >90% of telemetry locations of 4 wolverines (Murphy et al. 2011).

I tested the performance of each wolverine model with data 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 199 locations of adult wolverines during all seasons fell within the areas predicted by the SSC and Inman models, respectively (J. Weaver, Wildlife Conservation Society, *unpublished data*). Both models missed many of the same locations, which were at slightly lower elevation during winter than predicted by the models.

Further north in the Yellowstone-to-Yukon region, wolverine habitat identified by the more complex Inman model corresponded closely with the SSC model in southeast B.C. (see Weaver 2013). I found that 89% and 86% of 36 wolverine observations/trapping records fell within the areas predicted by the SSC and Inman models, respectively. Again, a few locations in winter occurred at slightly lower elevation than the models projected. Hence, in several mountain landscapes, there was strong agreement between the models – which provides confidence in using the simpler SSC model. (Note: unfortunately, the Inman model has not been extended as far north as the Central Canadian Rockies.)

More recently, large-scale surveys of wolverines have been completed using hair-snagging and cameras at baited stations in the Willmore Wilderness area of west-central Alberta and in the Southern Canadian Rockies of Alberta and British Columbia. In the Willmore study, researchers reported that wolverines were more likely to occur at sites with rugged topography and low human footprint (seismic lines), but they did not test the SSC model (Fisher et al. 2013). In the southern Canadian Rockies, a multi-variate model including dense conifers at higher elevations, human footprint (seismic lines), and spring snow cover better explained wolverine distribution than a single factor (Heim 2015).

As a preliminary analysis, I pooled and mapped the approximate locations of these survey sites (Fisher et al. 2013, Clevenger and Barrueto 2014, Clevenger et al. 2016) onto a map of the suitable habitat as predicted by the SSC model (Copeland et al. 2010). It should be noted that the scale of these surveys was much coarser (12 km x 12 km) than the scale of the snow class mapping (500 m x 500 m). Wolverines were detected at 110 (39%) of the 280 total stations. My preliminary analysis suggests that – overall – the SSC model correctly predicted the occurrence and non-occurrence of wolverines in 200 (71%) of the 280 stations. The greatest mis-classification occurred at 71 stations (25%) where wolverine presence was predicted by the SSC model but was not detected. The majority (39) of these sites involved snow class 1; many were isolated patches at the edge of predicted wolverine habitat, particularly in southwest Alberta and the lower montane valleys in southeast B.C. The mechanisms accounting for mis-classification could include lack of adequate foods, competition with other carnivores, displacement by motorized human activity, and/or the 'ghost' of recent trapping (Heim 2105). Wolverines were not detected at some stations with predicted suitability but were detected at the nearest-neighbor station. In 9 cases (3%), wolverines were observed but not predicted by the SSC model (class 0).

Further north in Alberta (> 54° N latitude) where the boreal forest arcs northeastward with greater expanse, however, long-term trapping records and recent camera surveys document the widespread occurrence of wolverines (including lactating females) in areas with low or nil snow cover during late spring (Webb et al. 2016). Thus, wolverines may not be obligate to the SSC *model* in some northern boreal forests. Nonetheless, these researchers reported that in the Rocky Mountain Natural Region, trapped wolverines (including females) did occur on traplines with greater portion of the area with spring snow cover – particularly in snow classes 4-7 (Webb et al. 2016). In the Bighorn Backcountry area specifically, 12 of 13 wolverines (all but 1 were males) were trapped during 1985-2011 in primary habitat (snow classes 1-7) (Webb et al. 2013). Four other wolverines were trapped east of the Forestry Trunk Road #734 in areas with no or infrequent snow cover during late spring. No non-invasive surveys have been carried out for the Bighorn Backcountry using current techniques (J. Fisher, *personal communication*).

To summarize: Distribution and habitat selection of species typically involve a complex of factors at multiple scales. Wolverines appear adapted (but not necessarily *obligate*) to snow in several aspects of their morphology, reproduction, ecology and behavior. The SSC model has performed well empirically across telemetry studies and bait-station surveys of wolverines in the Rocky Mountains. Its application to the mountains and upper foothills of the Bighorn Backcountry appears reasonable.

Primary Habitat includes all snow classes 1-7. I distinguished snow classes 5-7 at higher elevation as maternal habitat and assigned a higher score. Also, I mapped snow class 1 separately because it appears less consistent for predicting wolverine occupancy, occurs at lower elevations in patchier and isolated pattern, most likely to diminish over the next 40 years from climate warming. Moreover, it is heavily impacted by roads, trails, and seismic lines.

I assigned the following importance scores for wolverine:

(3) Very High	= snow classes 5-7	Maternal Habitat
(2) High	= snow classes 1-4	Primary Habitat

Key Conservation Areas

Based upon the Spring Snow Cover (SSC) model, much (70%) of the Bighorn Backcountry area is primary habitat for wolverines (SSC 1-7) – most of it lies west of the Forestry Trunk Road #734 (Figure 18). All of the maternal habitat for denning and rearing young also occurs west of the FTR in the subalpine and alpine areas in the mountains. East of the FTR, wolverine habitat is mostly scattered fragments of the lowest SSC of 1, which is projected to diminish significantly in a warming climate.

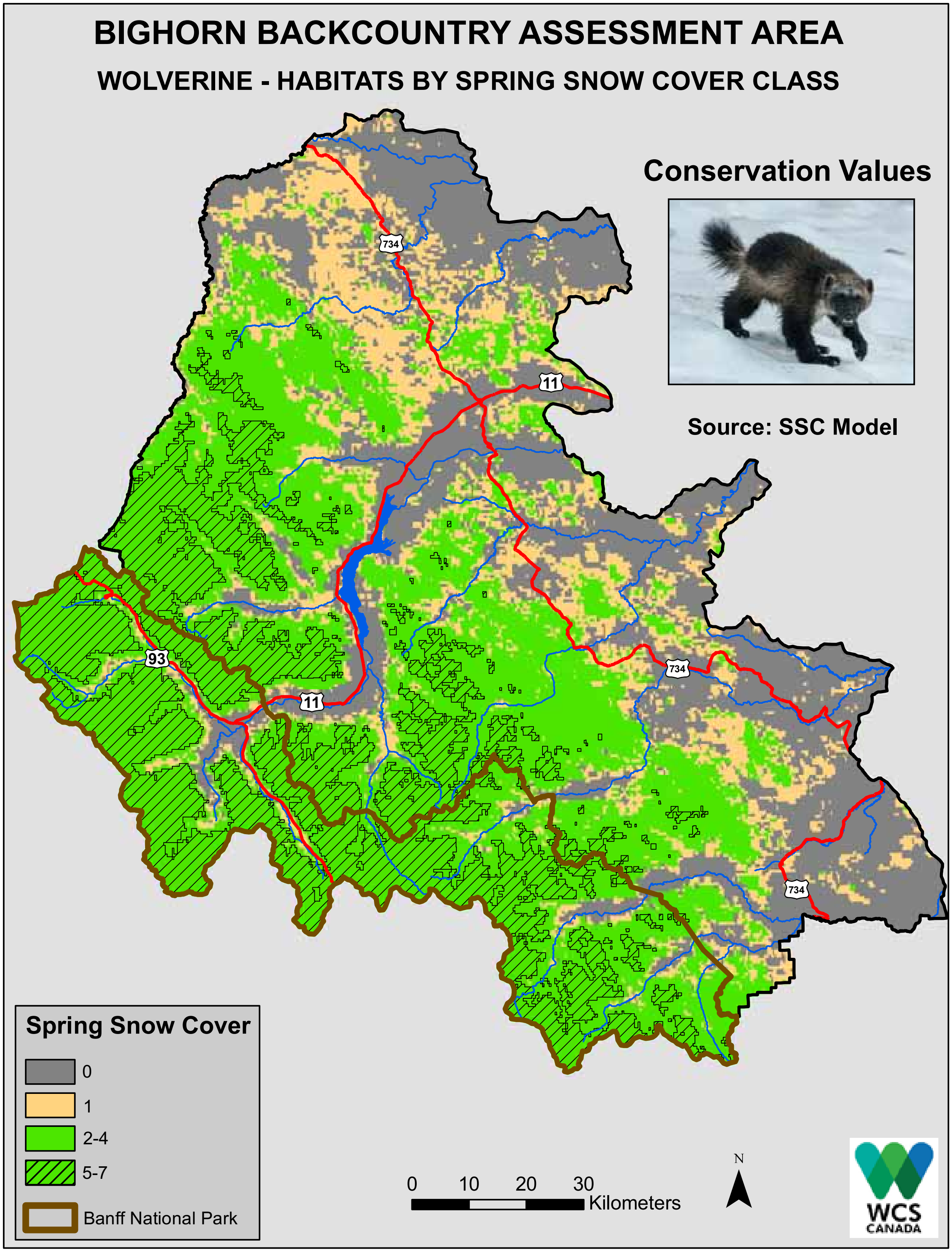
In terms of area, 1,011,201 ha of the Bighorn Backcountry area is primary habitat for wolverine (Table 6). About 61% of that occurs on Provincial lands outside Wilderness, 8% within the 2 Wilderness Areas, and 31% in Banff National Park.

Maternal habitat (SSC 5-7) comprises 324,916 ha (23%) of *Very-High* value habitat, and a significant amount (72,897 ha) exists on Provincial lands outside Wilderness. The remaining snow cover classes 1-4 comprise 686,285 ha (48%) ranked as *High-value* habitat, with 542,733 ha on Provincial lands outside wilderness. SSC 1 at the lower elevations makes up 25% of the current wolverine habitat (Figure 18).

Table 6. Amount (ha) and percentages of wolverine habitat (SSC model) in the Bighorn Backcountry of Alberta. See text for details.

	Very High = 3 (SSC 5-7)		High = 2 (SSC 1-4)		TOTAL (SSC 1-7)	
Land Status	**Area**	**%**	**Area**	**%**	**Area**	**%**
Banff NP	195,826	60.3	115,964	21.8	311,790	30.8
Provincial WAs	56,193	17.3	27,588	5.1	83,781	8.3
Provincial Lands	72,897	22.4	542,733	73.1	615,630	60.9
TOTAL	**324,916**	**100.0**	**686,285**	**100.0**	**1,011,201**	**100.0**
% of BBA		**22.7**		**47.9**		**70.6**

Figure 18. Location of key habitats and conservation values for wolverines using SSC model, Bighorn Backcountry assessment area, Alberta.



Conservation Issues

One of the potential threats to wolverine populations is excessive harvest by trappers and/or hunters – especially for small populations with narrow peninsular or patchy distribution where even the loss of 1 adult female may be critical (COSEWIC 2014). Technological advances in OHV (off-highway vehicles such as all-terrain vehicles and snowmobiles) have made travel into remote country easier than ever (Webb et al. 2016). Expanding networks of roads and seismic lines for industrial activities (such as logging and/or oil & gas) have increased access into previously roadless areas, which may be impacting wolverine occupancy (Fisher et al. 2013, Heim 2015). Many wolverine researchers have recommended designation of 'refugia' as a crucial component in the overall conservation plan for this vulnerable species (Krebs et al. 2004, Squires et al. 2007, COSEWIC 2014). Due to the low density (3-6 animals/1000 km^2) and large home ranges of wolverines, national park sanctuaries are not sufficient to maintain viable populations; hence, some large refugia on Provincial lands are needed.

According to the human-footprint database of the Alberta Biodiversity Monitoring Institute (2014), there are 400 km of hard-surface roads, 675 km of smaller roads and trails, and 4,651 km of seismic lines in wolverine habitat in the Bighorn Backcountry area (Table 7). Most of these (65-75%) occur in SSC class 1 of moderate value at lower elevations. Of perhaps greater concern is that about 1,000 km of seismic lines occur in SSC class 2, as well as 147 km of smaller roads/trails. There are also designated snowmobile sledding areas in high-elevation bowls. This expanded access can increase the potential risk of disturbance during denning time (Feb-Apr), risk of mortality during trapping/hunting season, and risk of predation and competition with other carnivores who follow packed trails.

In the Bighorn Backcountry, designating protective refugia for wolverines and their habitat encompassing SSC classes 2-7 could help safeguard these rare animals.

Table 7. Amount (km) and percent of roads, trails and seismic lines by spring snow cover (SSC) representing wolverine habitat, Bighorn Backcountry assessment area, Alberta. Data on linear features from ABMI (2014).

	Hard Roads		Roads/Trails		Seismic Lines		Total	
SSC	km	%	km	%	km	%	km	%
1	293	73.3	507	75.2	2,315	64.7	3,115	67.0
2	87	21.5	147	21.8	1,009	28.2	1,242	26.7
3	5	1.3	12	1.8	181	5.1	198	4.3
4	4	1.0	2	0.3	46	1.3	52	1.1
5	3	0.8	1	0.1	17	0.5	21	0.4
6	2	0.5	2	0.2	4	0.1	8	0.2
7	6	1.5	4	0.6	5	0.1	15	0.3
TOTAL	**400**	**100.0**	**675**	**100.0**	**3,577**	**100.0**	**4,651**	**100.0**

Bighorn Sheep (*Ovis canadensis*)

Photo: John Weaver

Status Rocky Mountain bighorn sheep – the Provincial Mammal – are managed as trophy big game species in Alberta. Historically, bighorn sheep may have numbered up to 10,000 in Alberta (Stelfox 1971). By 1915, sheep numbers had dropped to ~2000-3000 animals due to excessive and non-selective hunting. On Provincial lands, population numbers have increased to a minimum of ~7,000 animals. Alberta has the largest population of bighorn sheep in North America, which – combined with those sheep in National Parks – accounted for >15% of all sheep in North America. In 2016, Alberta Environment and Parks released a draft Bighorn Sheep Management Plan (In Review).

Vulnerability Profile

Synopsis: Bighorn sheep exhibit moderate 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 wild sheep are highly susceptible to outbreaks of disease (some carried by domestic sheep) that can decimate a herd quickly. Bighorn sheep have low capacity to rebound rapidly from these disease events; hence, prevention of transmission is crucial. 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. But this behavior may serve to *compartmentalize* herds and retard transmission of disease. Although sheep appear to habituate to predictable motorized disturbance along highways, helicopter overflights can be quite stressful. 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 to move up or down as needed in response to changing conditions.

Niche Flexibility: Rocky Mountain bighorn sheep have relatively low flexibility in their foraging and habitat niche (Geist 1971). They 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 DFWP 2009). 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). Prescribed fire may increase the diversity, abundance and distribution of forage plants, enhance accessibility and connectivity of grasslands, and change the occurrence of other ungulates using some of the same resources (Rucksthul et al. 2000, Michalsky and Woodard n.d., cited in AEP 2016). 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 (Ayotte et al. 2008, Jokinen et al. 2013).

In winter, 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, sheep usually select sites where deep snow does not accumulate due to low elevation, south exposure, and/or wind. Bighorn sheep (particularly ewes with lambs) usually stay within 400-500 feet of rocky terrain and cliffs with slopes > 27° that provide escape habitat from terrestrial predators (Sweanor et al. 1996). Cliffs also provide available forage when snow events preclude use of other sites. This close interspersion of rocky terrain/cliffs with south-facing or wind-swept grassy slopes delimits critical habitat during winter for Rocky Mountain bighorn sheep (Demarchi et al. 2000, Dicus 2002, AEP 2016).

Reproductive Capacity and Mortality Risk: Rocky Mountain bighorn sheep have moderate reproductive potential (Demarchi et al. 2000). Usually, a ewe does not breed until ≥2 years of age but even yearlings – under favorable conditions of good habitat and low density – can breed. Typically, a ewe carries only a single lamb each year but pregnancy rates can exceed 90 % (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, Martin and Festa-Bianchet 2011). The timing and duration of high-quality forage can affect breeding success, lamb growth and survival, and distribution of bighorn sheep (AEP 2016).

Survivorship of adult ewes typically is high in Alberta (0.89-0.92) (Jorgensen et al. 1997, Loisan et al. 1999). Survival of lambs to 1 year in Alberta can be low (0.41) and varies substantially – better maternal nutrition, warm and wet spring weather, and lower population density can result in higher survival (Festa-Bianchet 1988a, Jorgensen et al. 1997, Portier et al. 1998, Jokinen et al. 2008). Ram survival at Sheep River, Alberta was low (0.68) for yearlings but improved (0.82-0.94) for ages 2-9; hunting resulted in ram mortality increasing by 6-38% beginning in the fourth year (Festa-Bianchet 1989).

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 (Onderka et al. 1988, Bunch et al. 1999, Demarchi et al. 2000, Monello et al. 2001, 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 have endorsed the conclusion that domestic sheep should be kept away from bighorn sheep range (e.g. MDFWP 2009, WAFWA 2012).

There is no evidence that predation by cougars, wolves, or bears has caused declines in any of Alberta's bighorn populations or in the number of mature rams (AEP 2016). Cougar predation accounted for 9% of 320 kills by cougars in southwestern Alberta during 9 winters (Ross et al. 1997), and 3.4% of 1428 kills in west-central Alberta (Knopff et al. 2010). These researchers concluded that cougar predation was a learned behavior exhibited by one or a few skilled individuals. Conceivably, such predation could become a concern for small, isolated herds of bighorn sheep (Bourbeau-Lemieux et al. 2011). Wolf predation on bighorn sheep has ranged from *zero* during extensive studies in west-central Alberta (Webb 2009, Knamiller 2011) to 9% in another study in that area (DeCesare 2012). Bears have not been reported as significant predators of bighorns in Alberta, either.

Hunting of rams may be additive to 'natural' levels of mortality (rather than compensatory) for prime age classes. At Sheep River, Alberta, hunting resulted in ram mortality increasing by 6-38% beginning in the fourth year (Festa-Bianchet 1989). In contrast, adult ram survival averaged 0.92 in a protected population in Colorado that was increasing (Singer et al. 2000).

Dispersal and Connectivity: Bighorn sheep find their niche in patches of montane and alpine grassland that remain stable through time, and they exhibit high fidelity to these ranges (Geist 1971, Festa-Bianchet 1986). 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 (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). Actually, this behavior could serve to *compartmentalize* herds and retard transmission of disease.

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). The most-disturbing activity is helicopter overflights within 400 m (MacArthur et al. 1982, Stockwell et al. 1991), especially repeated overpasses (Stemp 1983). Vehicle traffic and human activity impacted use of a nearby mineral lick by sheep in Rocky Mountain National Park in Colorado (Keller and Bender 2007). Bighorn sheep may react negatively to approaching humans on foot, especially when people are accompanied by a dog (MacArthur et al. 1982). In other circumstances, sheep seem to habituate to predictable, repeated activities such as highway traffic (MacArthur et al. 1982). Sheep may tolerate some industrial activities and readily use open-pit coal mines that have been reclaimed (MacCallum 1991); but high levels of selenium in blood samples of sheep at such sites is of concern to managers (MacCallum 2006). Severe and/or chronic disturbance and subsequent abandonment of critical ranges (lambing and wintering areas, mineral licks) can compromise the health and productivity of bighorn sheep populations (AEP 2016).

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). Warmer winters with less snow could result in milder conditions and more expansive range for 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 can create a hard-crusted snow that would reduce sheep access to ground forage. More rapid snowmelt in spring could shorten the duration of high-quality forage in spring-summer (Pettorelli et al. 2007). Perhaps the best conservation strategy for now is to provide stress-free security along an elevation gradient of south-facing or wind-swept slopes interspersed with cliffs. This would allow bighorn sheep options for moving up or down in response to changing conditions.

Methods for Scoring Conservation Importance

Seasonal Ranges: Bighorn sheep typically spend 8-9 months on winter ranges (Geist 1971, Alberta 2016). For location of winter ranges, I used the most recent map of winter ranges (2016) delineated by local bighorn sheep biologists (kindly provided by Anne Hubbs, Alberta Environment and Parks). We edited the map slightly to include the latest survey locations and to connect a few winter ranges separated by < 5 km of suitable habitat. Insufficient data was available to map sheep occurrence on summer range, or to model habitat suitability for the summer season. Many sheep continue to occur on or very near winter range during summer, while some (particularly rams) may move into different areas for the summer. Accordingly, I assigned an importance scores for bighorn sheep: Very High (3) = known winter ranges.

Key Conservation Areas

Alberta Fish and Wildlife Division has delineated Sheep Management Areas (SMAs), which may represent genetically distinguishable sub-populations based upon preliminary DNA analysis (AEP 2016). There are 3 Sheep Management Areas that occur in the Bighorn Backcountry area: (1) Ram-Shunda, (2) Nordegg-Chungo, and (3) Clearwater-Ram (Figure 19). Some 16 major herds totaling ~2,000 bighorn sheep spend the winter on 21 winter ranges across the Bighorn Backcountry of Alberta (Table 9: AEP 2016). The Ram-Shunda SMA near the town of Nordegg currently includes about 80 sheep in the vicinity of Ram Mountain. It is the only winter range east of the Forestry Trunk Road #734. The Nordegg-Chungo SMA currently has about 580 sheep in the mountains north of Highway 11. The Clearwater-Ram SMA currently has about 1300 sheep in the mountains south of Highway 11.

Approximately 75% of the winter range (total = 272,986 ha) for bighorn sheep in the Bighorn Backcountry area occurs on Provincial lands east of Banff National Park (Table 8).

Table 8. Area (ha) and percent of lands with bighorn sheep winter range in the Bighorn Backcountry Assessment Area, Alberta.

	Very High (WR) = 3	
Land Status	**Area**	**Percent**
Banff NP	67,276	24.6
Provincial WAs	1,351	0.5
Provincial Lands	204,359	74.9
TOTAL	272,986	100.0
%Total Land Base		**19.0**

Conservation Issues

According to Alberta's draft Management Plan for Bighorn Sheep (2016:88): "Current hunting demand exceeds the supply and cannot be maintained at present levels without further compromising the quality of bighorn sheep in Alberta." In the North Saskatchewan region, harvest of trophy rams has declined considerably over the past 40 years. Excessive harvest occurred in the 1980's in both SMAs 4B and 4C (e.g., from 70 rams per year down to 35 per year in 4B) – essentially the Bighorn Backcountry area (Festa-Bianchet et al. 2014).

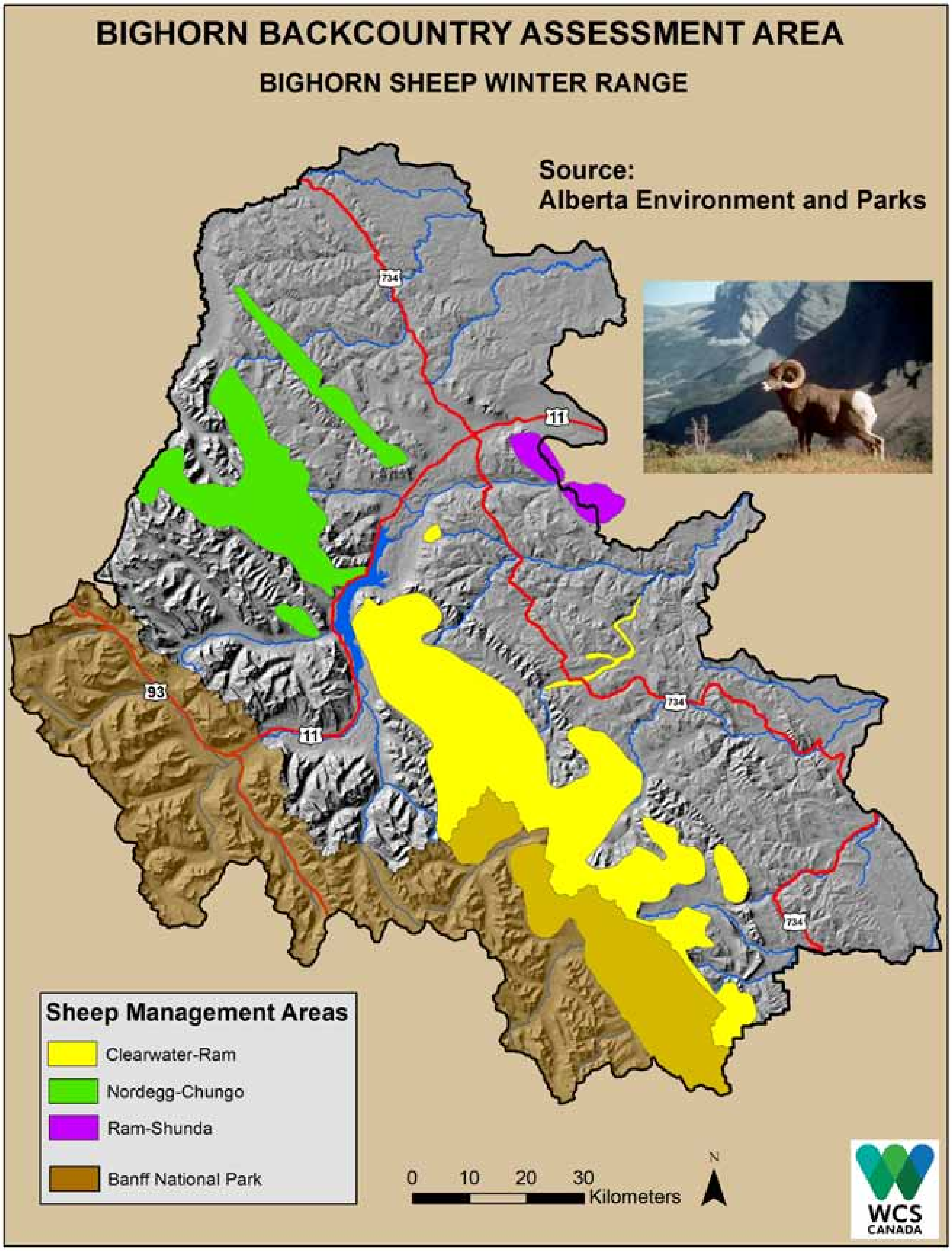
Roads, ATV use, and helicopter-based activities have proliferated throughout the Eastern Slopes in Alberta since the 1950s, impinging upon key winter ranges and altering hunting experiences. Motorized access by OHVs, snowmobiles, and helicopters can be an issue in some circumstances.

The draft Management Plan for Bighorn Sheep (AEP 2016:88-90) discusses several conservation strategies, including (1) legislation/policy to maintain effective separation between wild bighorn sheep and domestic sheep to prevent disease transmission, (2) more conservative hunting regulations, (3) improved policies and standards for protecting sheep on wintering and lambing ranges from disturbance by industrial and recreational activities – especially helicopter activities, and (4) well-planned habitat enhancement using prescribed fire in key sites.

Table 9. Number of winter ranges and estimated pre-season population size of bighorn sheep in the Bighorn Backcountry area of Alberta, 2013. Source: Alberta Environment and Parks (2016).

SMA	WMU	Major Winter Ranges	Total No. Winter Ranges	Pre-season Population
4 B	416	Sheep Creek	1	
Clearwater-Ram	418	Ya Ha Tinda	4	
	420	Clearwater	3	
	422	Hummingbird	1	
	426A	Whiterabbit	1	
	428	North Ram	1	
	430A	Bighorn (south)	1	
				1300
4 C	426B	Windy/Whirlpool Point	1	
Nordegg-Chungo	430B	Bighorn (north)	1	
	432	Job-Coral	1	
	434	George Creek	1	
	434	Chungo-Blackstone	1	
				580
5	328	Shunda	1	
Ram-Shunda	429	Ram Mountain	1	
				80
		Siffleur Wilderness Area	1	20
		White Goat Wilderness Area	1	20
TOTAL		**16**	**21**	**2000**

Figure 19. Location of winter ranges for bighorn sheep in three Sheep Management Areas, Bighorn Backcountry area, Alberta.



Bull Trout (*Salvelinus confluentus*)

U.S. Fish & Wildlife Service

Status Prior to European settlement, native bull trout were common in the streams, rivers, and lakes along the Eastern Slopes of Alberta (Alberta SRD 2012). The *Provincial* fish of Alberta, the range of bull trout extended from the mountains out to the prairie as far as Calgary and Lethbridge. Bull trout still occur in all of the major watersheds of the Eastern Slopes of Alberta, but have experienced significant reductions in both range (33% decrease) and numbers. (Alberta SRD 2012, COSEWIC 2012).

Alberta listed the bull trout as a '***Species of Special Concern***' in 2002 following years of declining populations (Rodtka 2009, Alberta SRD 2012). In 2012, COSEWIC assessed the status of bull trout in the Saskatchewan-Nelson Rivers basin of Alberta as '***Threatened***' but it has not been listed under SARA. In adjacent jurisdictions, bull trout are listed in British Columbia as a *species of special concern* (Hagen and Decker 2011) and listed federally as a *threatened* species in the United States (US Fish and Wildlife Service 2015).

Vulnerability Profile

Synopsis: Bull trout exhibit **high vulnerability** due to several factors. They have a demanding requirement for cold and clean waters – particularly for spawning and rearing – and are especially vulnerable to warming temperatures and drought conditions in late summer. Bull trout exhibit slow growth, late age at maturity, low fecundity, longevity, and high catchability – which renders them particularly susceptible to over-fishing (even catch-and-release practice can result in mortality). They have low resistance to invasion by non-native brook and lake trout, too. Some adult bull trout in the Rocky Mountains migrate long distances from wintering areas in lower rivers to spawning areas in the headwaters; dams and poorly-installed hanging culverts can block vital connectivity. Bull trout have declined due to cumulative effects of habitat degradation from industrial and motorized recreational activities, impacts from non-native fish, over-fishing and catch-and-release mortality, and loss of stream connectivity. Finally, climate change may heat lower elevation streams beyond the tolerance of bull trout, resulting in smaller, more isolated and less viable populations. Protection of clean, cold, complex and connected habitat from invasion by non-native fish remains the principal strategy in conserving bull trout.

Niche Flexibility: Bull trout select streams that are cold, clean, complex, and connected. In fact, they are one of the most thermally-sensitive coldwater species in western North America. Laboratory studies suggest that peak growth in bull trout occurs between 10°-15° C, whereas the upper lethal temperature is about 21° C (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 (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 (and often < 9° C) and foraging, migrating, and overwintering habitat at <1 4° C (Jones et al. 2014). Bull trout select stream reaches for spawning where hyporheic exchange and upwelling of ground water provides cooler and well-oxygenated conditions (Baxter and Hauer 2000, USFWS 2010, Bean et al. 2015). In winter, warmer groundwater and beaver ponds inhibit formation of anchor ice, which otherwise would cause high mortality of eggs, alevins and emergent young trout (Jakober et al. 1998, McCullough et al. 2009).

Spawning and Rearing: Bull trout are slow growing and late maturing, with age at first spawning from 5 to 7 years. In migratory populations, fish move toward spawning streams in summer and may stage in large pools or at the mouth of the spawning streams. Spawning occurs between mid-August to early October. Bull trout have very stringent preferences for spawning sites in gravels with low levels of fine sediment (< 10%), often where upwelling of ground water provides well-oxygenated conditions (Baxter and Hauer 2000, USFWS 2010, Bean et al. 2014). They show strong fidelity to such high-quality spawning sites (Rhude and Rhem 1995).

Eggs overwinter within the gravel interstices and fry emerge in early spring. This long incubation period makes bull trout eggs susceptible to sedimentation, low winter flows and freezing, and mid-winter flooding/scouring events (Shellburg et al. 2010). Young-of-year bull trout seek waters with low velocity, often in side channels or backwaters. Rearing streams are typically small, low-order streams with few predators at higher elevations (Alberta SRD 2012, US Fish and Wildlife Service 2015).

Susceptibility to Hybridization and Competition: Because fish have external fertilization, hybridization is more common in fish than in any other vertebrate taxa. 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. Brook trout (*S. fontinalis*) can hybridize with bull trout, thereby producing mostly sterile hybrids which reduce reproductive potential in populations (Kitano et al. 1994, Leary et al. 1995).

In addition, brook trout 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, Warnock and Rasmussen 2013). Conversely, they may invade from higher elevation if introduced to a headwater lake (Adams et al. 2001). With warming climate, brook trout are moving into higher elevation streams that once were considered refugia for bull trout (McMahon et al. 2007).

Competition with non-native lake trout (*S. namaycush*) in lakes is considered the most significant threat to recovery and conservation of bull trout in several areas (USFWS 2015). 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). Lake trout occur in Abraham Reservoir.

Migration 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*). Bull trout have migrated upwards of 160 km in the Oldman River drainage (Warnock 2008), and 250 km upriver from Flathead Lake in Montana to spawn in their natal tributaries in southeast 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 in specific reaches (Rhude and Rhem 1995). Much of the genetic variation in bull trout occurs at very fine geographic scales, even between adjacent streams (Kanda and Allendorf 2001, Spruell et al. 2003, Warnock et al. 2010, Meeuwig et al.2010, Ardren et al. 2011), especially below and above barriers (Costello et al. 2003). Hence, it's vital to maintain local populations to safeguard genetic diversity and to promote long-term persistence (Ardren et al. 2011).

Ensuring connectivity in the dendritic or branching structure of stream networks, however, can be challenging (Fagan 2002). In linear features like streams, all patches may be at risk regardless of distance when a toxic pollutant enters at the headwaters and flows downstream. Conversely, fragmentation near the bottom of a network can affect much more of the watershed than if it happens at a higher branch.

Sensitivity to Human Disturbance: Bull trout are vulnerable to a wide range of human disturbances (Alberta SRD 2012).

- The combination of slow growth, late age at maturity, low fecundity, longevity, and high catchability render 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 - particularly in small lakes and tributary streams where bull trout are especially vulnerable (Parker et al. 2007).

- Dams can block fish movements, resulting in genetic isolation and loss of migratory populations that require diverse, connected habitats for different life stages (Muhlfeld and Marotz 2005). Dam operations can alter natural flow regimes, temperatures and habitats downriver, too (Hagen 2008, Muhlfeld et al. 2011). Conversely, a large reservoir may provide abundant fish as prey base and support large, migratory populations if connected to high quality spawning and rearing habitat up-river (e.g., Koocanusa dam in B.C.).
- 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 (Alberta SRD 2012).
- Finally, purposeful stocking in the past and continued illegal releases of non-native trout pose threats to genetic integrity and demographic vigor of native bull trout (USFWS 2015).

When these activities overlap in space and time, significant cumulative effects can arise. A common denominator in these various impacts is roads, which can affect hydrology of streams and increase access to vulnerable fish populations. In the Kakwa River basin of Alberta, the likelihood of bull trout occurrence decreased with an increase in the percentage of sub-basin harvested for timber and road density (Ripley et al. 2005).

Response to Climate Change: Bull trout likely will be vulnerable to several manifestations of climate change. Projected changes include: 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 and loss of shading cover along streams due to more wildfires (Byrne et al. 2015; see Chapter 1 for fuller discussion of climate change). Warmer stream temperatures may raise the lower-elevation limits for spawning and/or disjoin this zone from the over-wintering zone

(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 tall shrubs (Issak et al. 2010). In addition, warmer temperatures could enable non-native brook trout to invade higher reaches of streams, raising the prospects of competition and hybridization (McMahon et al. 2007).

The net outcome for bull trout will be continued shrinkage of its cold-water niche, thereby reducing both the size and genetic/demographic connectivity of remaining populations. Identifying cold-water 'climate shields' or refugia at higher elevations is an important, proactive step toward long-term conservation of bull trout (Issak et al. 2015). Although recognition of impending climate change is imperative, it will be a moot point if cumulative effects of *current* cumulative human impacts on bull trout are not resolved to keep options open (Reilly et al. 2016 *In Review*, Kovach et al. *In Press*).

Methods for Scoring Conservation Importance

Bull trout are one of the most thermally-sensitive cold water fish in western North America (Selong et al. 2001). Alberta's Fish Sustainability Index (FSI) has a *preliminary* temperature chart for juvenile occupancy of bull trout based on data records and modelling by Alberta fishery biologists (Table 10: Alberta Environment and Parks 2013). Their chart accords well with other published studies which indicate that maximum temperatures during the August-September spawning period are typically <13° C (Dunham et al. 2003, Jones et al. 2014). However, there is some uncertainty about the lower temperature cut-off point due to a dearth of surveys in remote areas where cold temperatures prevail at higher elevations (J. Reilly, *personal communication*). Based upon extensive stream sampling in the Flathead River basin of Montana and southeast British Columbia, researchers reported that 94% of the spawning habitat had August stream temperatures > 8° C but < 13° C (Jones et al. 2014). Therefore, we selected the 7.73° C for the lower threshold from the chart. More recently, Alberta biologists have assigned a ranking of 5 for adult occupancy for temperatures ≤ 14° C (J. Reilly, *personal communication*).

Table 10. Fish Sustainability Index (FSI) bull trout natural limitation thresholds and their relation to juvenile occupancy for the North Saskatchewan and South Saskatchewan River Basins.

Temperature	Rank	Occupancy
6.697 - 7.73	5	0.75
7.73 - 8.688	4	0.75 - 0.5
8.688 - 10.64	3	0.5 - 0.25
10.643 - 12.43	2	0.25 - 0.125
>12.43	1	<=0.125

Many streams in the remote headwater portions of the North Saskatchewan River have not been surveyed. Therefore, we modeled distribution of thermal suitability for (1) spawning and rearing, and (2) adult occupancy in lower sections of rivers used for foraging, migrating, and/or over-wintering. Due to few available data on stream temperature, we followed the approach used by Alberta fishery biologists and modeled air temperature, which has a 1:1 linear relationship with stream temperatures across the range of 0°-20° C (Mosheni and Stephan 1999). We generated a grid of equally-spaced points (every1 km) (n= 14,334 points) across the Bighorn Backcountry study area in ArcGIS 10.2.2. Next, we extracted elevation for each point using a 20m DEM. In the program ClimateWNA (Wang et al. 2012), we selected mean warmest month (August) temperature for the period 1981-2010. From the output, we created a continuous raster surface of August temperatures (20 m pixels) by extrapolating the point file by kriging. We mapped 3 classes of thermal suitability: (1) unsuitable habitat < 7.7° C, (2) spawning/rearing habitat with temperatures 7.7° to 12.4° C, (3) adult occupancy 12.4° C to 13.9° C (maximum in the Bighorn Backcountry area).

Fishery biologists with Alberta Environment and Parks kindly provided spatial data on streams with known bull trout occurrence: (1) redds for spawning, and (2) sites where juvenile or adult fish were collected. We plotted location records within the Bighorn Backcountry area using (1) documented redds (n = 74) and (2) collection of juvenile fish with lengths of tail fork <150 mm (n = 2,746) for the period 1980-2013. The average modeled stream temperature at redd sites was 11.9° C (± 0.9° C). About 46 % of the redds occurred at locations with modeled stream temperature <12° C, whereas 51 % occurred where modeled stream temperatures were 12°-13° C. The average modeled stream temperature at locations with juvenile fish was 12.1° C (± 0.9° C). About 36 % of the juvenile fish occurred at locations with modeled stream temperature <12° C, whereas 53 % occurred where modelled stream temperatures were 12°-13° C. Thus, 97% of the redds (spawning habitat) and 89% of the juvenile fish (rearing habitat) occurred in waters with modeled temperatures ≤ 13° C. Lastly, we vetted this map with the local Alberta fishery biologists. Accordingly, I assigned the following importance scores for bull trout:

Very High (3) = spawning and rearing habitat in upper rivers and tributaries
High (2) = rivers/streams for foraging, migration, over-wintering.

Key Conservation Areas

Much (93%) of the Bighorn Backcountry area has waters considered thermally suitable for occurrence of bull trout (Table 11, Figure 20). As current management is viewed at a sub-watershed scale, I calculated habitat suitability in terms of area, rather than km of stream. Approximately 1,331,608 ha of the Bighorn Backcountry area has waters considered thermally suitable for bull trout, with the majority on Provincial lands. About 75% is thermally suitable for spawning and rearing, whereas another 18% is within thermal limits for foraging, migrating, and over-wintering. About 7% is considered unsuitable due to temperatures < 7.7° C; most of these very-high elevation areas occur inside Banff National Park and the Siffleur Wilderness.

Current density of juvenile bull trout varies across the Bighorn Backcountry watersheds (Figure 21). The Blackstone River is ranked *very high* for relative density of juvenile trout, and the upper North Saskatchewan, Cline, and Nordegg Rivers are ranked *high*. The Brazeau, Clearwater, and lower North Saskatchewan have a *moderate* ranking. The most-easterly waters of the lower Rams River (below falls) and the James River are ranked *very low*, which coincides with their marginal thermal suitability for spawning and rearing. Some 17% of the Bighorn Backcountry area, however, is not occupied by bull trout due to impassable waterfalls in the lower section of the Ram, Siffleur, and Bighorn Rivers (Figure 21)(Table 11).

Table 11. Area (ha) and relative percent of conservation values for bull trout in the Bighorn Backcountry Assessment Area, Alberta. Thermal classes are: spawning/rearing = 7.7°-12.4° C, adult occupancy = 12.4°-13.9° C, and unsuitable = < 7.7° C. See text for details.

	Very High (Spawning/Rearing)		High (Adult Occupancy)		Unsuitable Habitat (too cold)	
Land Status	**Area**	**Percent**	**Area**	**Percent**	**Area**	**Percent**
Banff NP	256,854	17.9	0	0.0	75,550	5.3
Provincial WAs	72,416	5.1	0	0.0	14,720	1.0
Provincial Lands	738,661	51.5	263,676	18.4	11,425	0.8
TOTAL	**1,067,932**	**74.5**	**263,676**	**18.4**	**101,696**	**7.1**

Figure 20. Distribution of suitable habitat classes for spawning/rearing and adult occupancy by bull trout based upon modeled stream temperatures, Bighorn Backcountry area, Alberta.

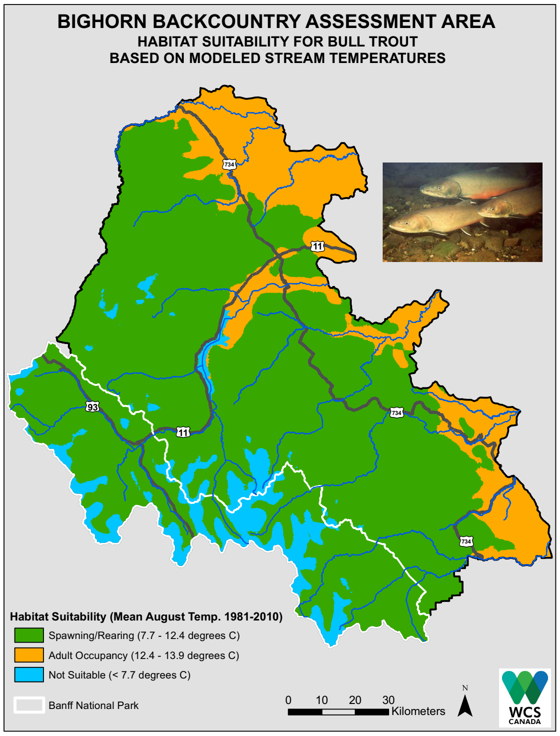
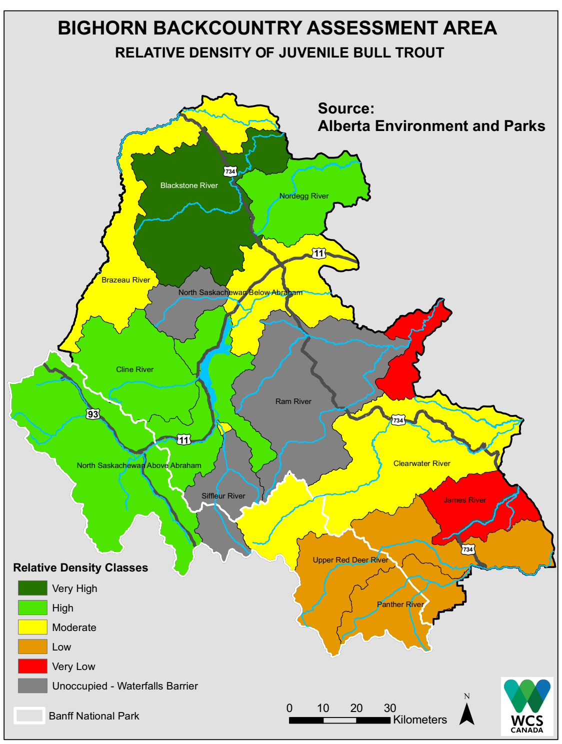


Figure 21. Relative density of juvenile bull trout in the headwaters of the North Saskatchewan River, Bighorn Backcountry area, Alberta. Data from Fish Sustainability Index, Alberta Environment and Parks (2014). About 17% of the area is un-occupied due to impassable barrier of waterfalls (gray areas).



Conservation Issues

According to the FSI report, adult bull trout once occurred throughout the headwaters of the North Saskatchewan River in very high or high abundance (Figure 22 left). The North Saskatchewan River above Abraham Reservoir, Cline, Brazeau, Blackstone, Nordegg, Clearwater, and Panther Rivers were considered to have very high abundance. Currently, the abundance of adult bull trout has dropped in ranking across every major watershed (Figure 22 right). The upper North Saskatchewan River above Abraham Reservoir and the Cline River (mostly protected areas) still have high ranking. Current density of adult bull trout has declined most dramatically (2-4 ranking levels) in the upper Red Deer, James, and Panther River watersheds.

Currently, the Brazeau River and Pinto Lake/Cline River have the highest abundance of adult bull trout (1,000-2,500), with a stable trend (Table 12). The Blackstone River and middle North Saskatchewan River have moderate abundance (250-1,000), also with stable trend. But the trend for other rivers with moderate abundance (upper North Saskatchewan, Clearwater, and Red Deer) appears to be declining. The lower North Saskatchewan has low but stable population abundance (50-250), whereas the low population in the Nordegg River appears to be declining. The bull trout in the Nordegg face the most imminent threats, followed by those in the Red Deer, Clearwater, and middle North Saskatchewan Rivers. Even small populations, however, should not be 'written off' as lower priority as they make important contributions toward overall genetic diversity and resiliency (Rieman and Allendorf 2001). In areas where native fish populations have been compromised, management should focus on maintaining overall genetic diversity and conserving all populations and habitats (Warnock et al. 2010).

The current conservation status of bull trout in the North Saskatchewan River basin involves populations of very low to modest numbers, with stable or declining trends. These populations are likely far below historical population levels. The populations with lowest risk (comparatively) occur in the more remote headwaters with low human access or industrial impact (Brazeau, Blackstone, and Cline Rivers). According to the Province's Bull Trout Conservation Management Plan (Alberta SRD 2012), the dismal status of bull trout

> "has largely been a consequence of the increasing cumulative impacts of industrial and recreational activities within the species historic range as well as competition from introduced fish species. Conserving healthy aquatic ecosystems requires the adoption of disturbance thresholds that will not be exceeded, and a commitment to restoration and protection of degraded habitats."

Fishery biologists for Alberta Environment and Parks have developed a new cumulative effects model of land uses for ascertaining the relationship between various threats and the status of adult bull trout in a watershed (Reilly et al. 2016 *In Review*). Application of this CEM could be useful in bull trout conservation at a sub-watershed scale; in addition, protected-area designations could benefit bull trout at a higher strategic level.

Figure 22. Historic and current density of adult bull trout in the headwaters of the North Saskatchewan River, Alberta. Data from Fish Sustainability Index, Alberta Environment and Parks (2014).

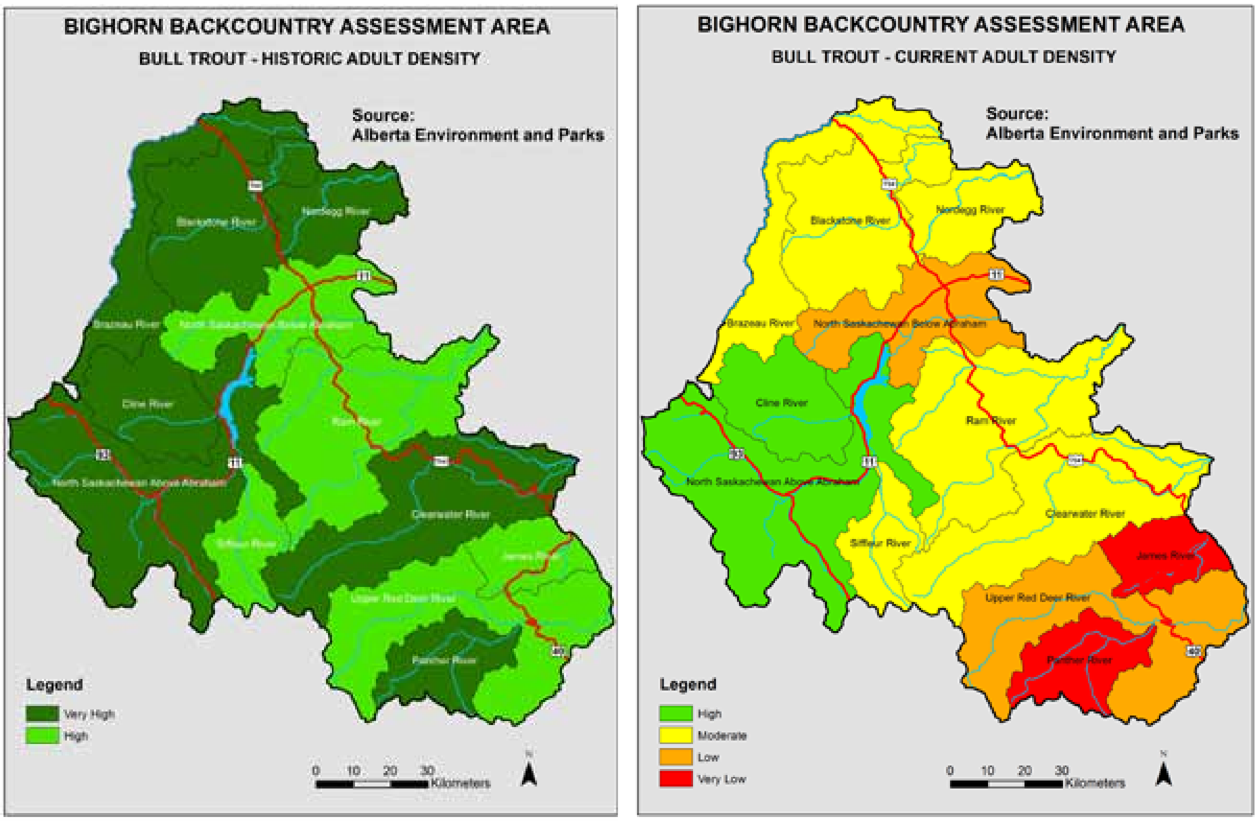


Table 12. Population characteristics of bull trout rivers, Bighorn Backcountry area, Alberta (from Rodtka 2009, Alberta SRD 2012).

River	Sub Pops	Pop Size	Length (km)	Trend	Risk	Threats
Brazeau	4	1,000-2,500	200-1,000	Stable	Potential	Widespread, low
Blackstone	4	250 -1,000	200-1,000	Stable	Potential	Widespread, low
Nordegg	2	50-250	40-200	Declining	High	Moderate, imminent
Upper North Saskatchewan	1	250 -1,000	40-200	Declining	Potential	Slight
Pinto Lake / Cline	2	1,000-2,500	40-200	Stable	Potential	Slight
Mid North Saskatchewan	1	250 -1,000	40-200	Stable	At Risk	Moderate, imminent
Lower North Saskatchewan	1	50-250	40-200	Stable	At Risk	Moderate, not-imminent
Clearwater	3	250-1,000	40-200	Declining	High	Moderate, imminent
Red Deer	4	250-1,000	200-1,000	Declining	At Risk	Moderate, imminent

Connectivity for Grizzly Bears and Wolverines across Highway 11

Where large intact areas have not been conserved for wide-ranging species, maintaining or restoring connectivity is a central component of modern conservation strategies - especially to provide resiliency during climate change. Major highways can block movements or dispersal, thereby fragmenting the genetic and demographic connectivity among wildlife populations. In the Canada-US border region, Proctor et al. (2012) reported extensive 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.

The revised Alberta Grizzly Bears Recovery Plan (*In Review*) lists habitat linkages as a major objective and calls for identification of highway linkage zones to maintain or enhance the ability of grizzly bears to move across a highway between adjacent Bear Management Areas. The Recovery Plan specifically notes that connectivity between BMAs 3 and 4 and the larger population of grizzly bears in British Columbia is naturally limited (due to extensive icefields: Proctor et al. 2012), which makes maintaining north-south connectivity across Highways 11 and 16 a high recovery priority.

At present, vehicle traffic volume along Highway 11 is not as busy as Highway 1 or 16. Average annual daily traffic (AADT) for Hwy 11 during the past 5 years (2011-2015) has been 366 vehicles just east of the Banff Park gate and 880 vehicles west of Nordegg, Alberta. But, in summer, the average daily traffic increased to 680 and 1360, respectively. Although this a modest traffic flow, connectivity across Hwy 11 is compromised by the large Abraham Reservoir, which is 1-3 km wide and borders the highway for 30 km. Both grizzly bears and wolverines are unlikely to cross such an open expanse of water/ice.

Based upon previous analyses of known grizzly bear highway crossings in Montana (Weaver 2015), we postulated that bears would cross at sites with minimal human disturbance that provided a least-cost path. To identify potential grizzly bear linkage zones, we overlaid a map of the 'human footprint' (settlements, roads, seismic lines/trails) onto the map of grizzly bear habitats (see Figure 14). We identified the following four potential crossing sites (Figure 23):

1. At approximate 18.2 km on Highway 11 and just west of Whirlpool Point, this linkage connects a large expanse of high-quality habitat north of the highway with high-quality habitat south of the river in the valley and following up Spreading Creek into the Siffleur Wilderness. There are essentially no human developments along an 18-km stretch of highway.
2. At approximate 29.6 km on Highway 11 and just south of the south end of Abraham Reservoir, this linkage zone also connects an extensive block of high-quality habitat on the north side of the highway with high-quality habitat in the valley south of the highway. This zone connects with the long valleys of Whiterabbit Creek and Siffleur River flowing in from the south, which connect further with the Ram and Clearwater River watersheds. This area was identified as a linkage zone in the revised Alberta Grizzly Bear Recovery Plan (Carra 2010, see Figure 5.5 in Alberta Grizzly Bear Recovery Plan).
3. At approximate 68.2 km on Highway 11 just north of the turnoff to the Big Horn Damsite, this linkage zone connects some variable-quality habitat on the north side of the highway (mainly along the Bighorn River) with a broader patch of high-quality habitat south of the highway leading down to the North Saskatchewan River. This linkage is sandwiched between the Big Horn dam site to the southwest and the Big Horn Indian Reservation settlement to the North.
4. At approximate 76.1 km on Highway 11 and north of the Big Horn Indian Reserve, this linkage connects a large block of high-quality habitat north of the highway and floodplain habitat along the North Saskatchewan River to the south. According to the fRI Research Grizzly Bear Program, a radio-collared grizzly bear crossed Highway 11 in the vicinity of these two linkages 3-4 (Carra 2010, see Figure5.5 in Alberta Grizzly Bear Recovery Plan).

To identify potential linkage zones for wolverines, we overlaid the same map of the 'human footprint' (settlements, roads, seismic lines/trails) onto the map of wolverine habitats (see Figure 18) We identified the following two potential crossing sites (Figure 24):

1. At approximate 7.7 km on Highway 11 just east of the Banff National Park entrance, this linkage occurs at one of the shortest distances between extensive patches of primary and maternal habitats. Moreover, there are few nodes of human activity along this stretch of highway.
2. At approximate 29.6 km on Highway 11 and just south of the south end of Abraham Reservoir, this is the same linkage identified as #2 on the grizzly bear linkage map. North of the highway, primary and maternal habitats are within 3-4 km. On the south side of the highway across the river, the valley floor is part of the Kootenay Plains Ecological Reserve. The remote valleys of Whiterabbit Creek and the Siffleur River provide corridors to higher country.

Figure 23. Potential linkage zones across Highway 11 for grizzly bears, Bighorn Backcountry, Alberta. This section of Hwy 11 extends from Saskatchewan Crossing in Banff NP to Nordegg, Alberta.

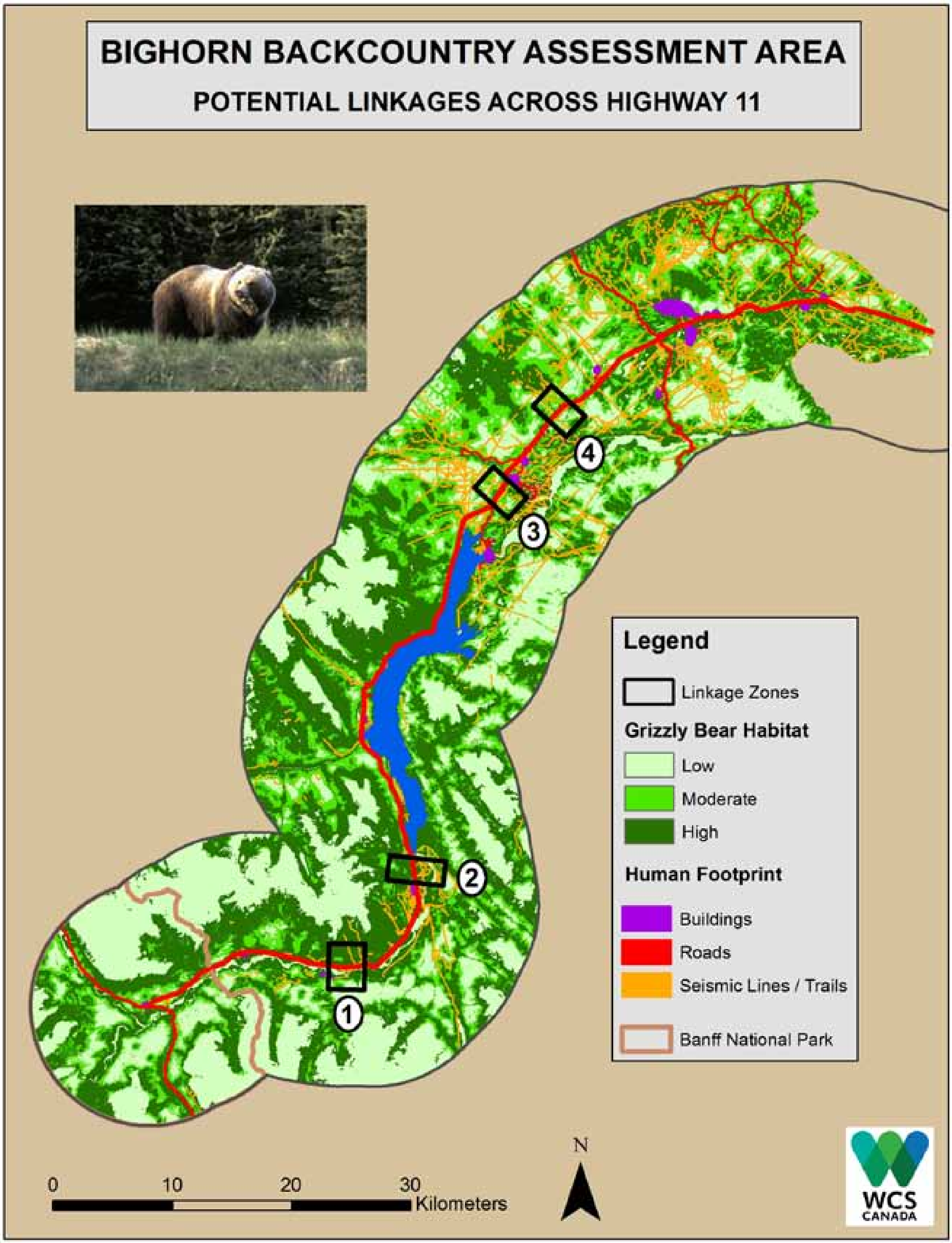
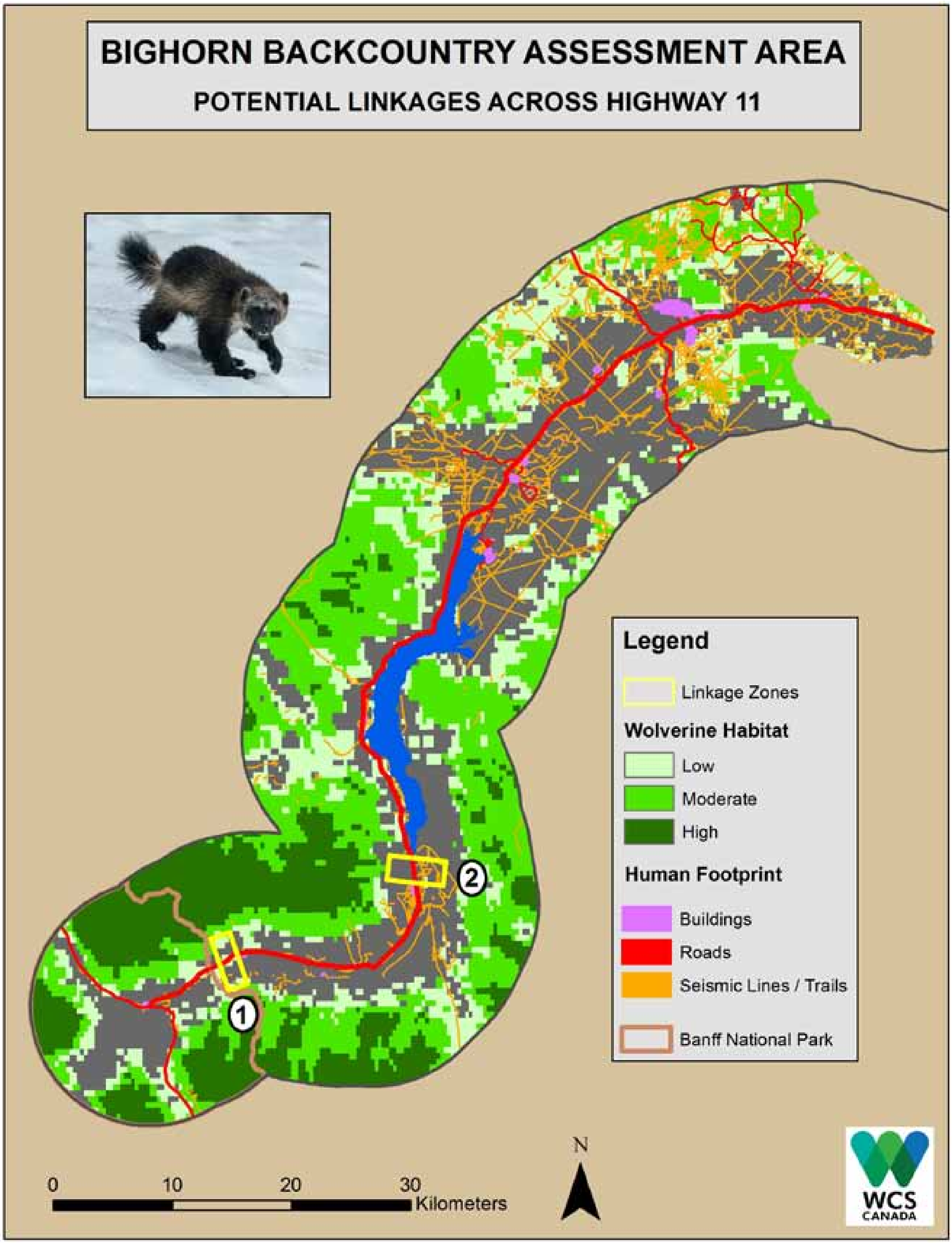


Figure 24. Potential linkage zones across Highway 11 for grizzly bears, Bighorn Backcountry, Alberta. This section of Hwy 11 extends from Saskatchewan Crossing in Banff NP to Nordegg, Alberta.



3. RICH IN RIVERS WILD: NEXUS OF BIODIVERSITY AND CLIMATE CORRIDORS

The riparian zone adjacent to rivers and streams has been noted for its dynamic complexity, biodiversity, and ecosystem or natural services (Naiman et al. 2005). In a recent and significant scientific synthesis, Ric Hauer and colleagues have drawn attention to the importance of gravel-bed floodplains as the 'ecological nexus' of mountain landscapes (Hauer et al. 2016). Gravel-bed river floodplains in the valleys of the Rocky Mountains are exceptionally important to regional biodiversity of aquatic, avian, and terrestrial species. These complex and dynamic landscapes concentrate diverse habitats at small scales, cycle nutrients, and provide natural corridors for movement. They are the ecological stage where daily dramas shape the survival and behaviour of prey and predator alike. I extract several of the principal findings from the synthesis by these researchers, which is particularly relevant to mountain rivers of the Bighorn Backcountry. Next, I rank the relative value of these mountain rivers as corridors for adaptive movements in response to climate change and map their river valley 'print'.

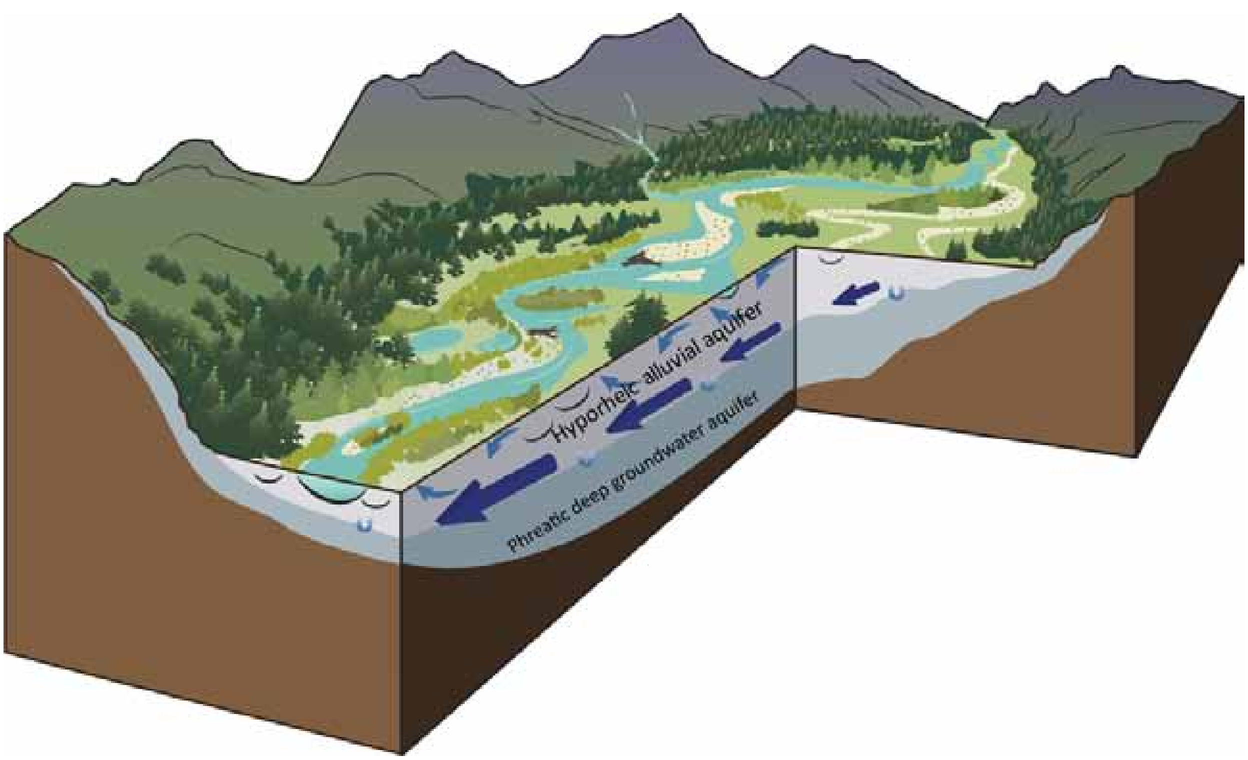
River Floodplains: Nexus of Biodiversity

➢ River Floodplains: Dynamic Complexity and Connectivity

Broad U-shaped river valleys are characteristic of glaciated mountain landscapes where large alpine valleys have been deepened and enlarged in the aftermath of Pleistocene glaciation. Their gravel-bed floodplains are extremely complex, creating an extraordinary diversity of habitats that support diverse communities of aquatic, avian, and terrestrial species. By contrast, canyon sections along the same river support comparatively less biodiversity than floodplain segments

Figure 25. Mountain rivers with wide gravel-bed floodplains - the legacy of Pleistocene glaciation -provide a shifting and complex mosaic of habitats, rich diversity of species, and complex ecological processes. The wide floodplain in this section of the Flathead River in southeast British Columbia is a classic example (H. Locke, Yellowstone to Yukon Conservation Initiative).

Figure 26. The three-dimensional structure of a gravel-bed river – lateral, longitudinal, and vertical. Water in the shallow alluvial aquifer flows laterally through the gravel subsurface from valley wall to valley wall. The under-river waters at the upper end of the floodplain flow longitudinally through the gravel substratum to discharge into the surface at the lower end of the floodplain. Waters up-well vertically into the surface waters repeatedly along the length of the floodplain. Some waters seep downward into the deeper groundwater aquifer and are stored for longer periods of time. (Used with permission from Hauer et al. 2016, E. Harrington, eh illustration, Missoula, MT).



because the narrow, linear corridor of confined river segments has much less physical complexity and habitat diversity.

During the annual spring snowmelt, high volumes of water will cut banks on the outer edge of river bends while depositing sediments to create gravel bars on the inside edge. Over time, this dynamic disturbance creates a mosaic of cobble, gravel, and finer deposits across both the surface and the subsurface of the floodplain. This results in a shifting mosaic of habitats – including very old channels, new channels, ponds, barren gravel bars, young vegetation stands, and gallery old-growth forests that are hundreds of years old.

Throughout the year, water is constantly flowing out of the river channel and into the gravels below and laterally beyond the channel ('hyporheic zone' meaning 'under-river'). These waters extend across the U-shaped valley bottom, often from valley wall to valley wall and upwards of a kilometer laterally from the river channel. The water that flows in and out of the channel, both vertically and laterally, re-appears as springs upwelling directly in the river or in lateral side channels, spring brooks, and ponds on the floodplain. Thus, the complex mosaic of surface and subsurface habitats is interconnected longitudinally downstream, laterally from the river channel across the floodplain, and vertically from the river channel into the subsurface gravels (Figures 25 and 26).

➢ Plant Diversity and Disturbance across the Floodplain

On gravel-bed river floodplains, riparian plant communities actually extend hundreds of meters to kilometres from the active channel to the lateral edges of the floodplain. The expansive river valley contains a complex set of micro-relief habitats with soil moisture ranging from extremely xeric to mesic. This hosts an extraordinarily high diversity of plant species. More than 60% of plant species from valley floor to alpine occur on gravel-bed floodplains which comprise 3% of the area. These rich floodplain plant communities are shaped by (often dependent upon) the natural dynamic processes of the river.

Many plants of gravel-bed river floodplains are pioneering species not only tolerant of flooding but actually dependent on the physical disturbance. Native cottonwoods (*Populus* spp.) and willows (*Salix* spp.) dominate early succession of gravel-bed river floodplains in the Rocky Mountains. Their seeds require barren sites newly formed by floods that scour other plants. Although these species are prolific seed producers, the tiny seeds are released in a short interval after the spring snowmelt peak and are only viable for a few weeks. The seeds are blown or floated onto moist and barren sites left behind on the exposed cobble bars by the receding river water. Without periodic flooding, conifer trees predominate – resulting in lesser diversity of plants and lower productivity.

➢ **Organic nutrients, microbes, and aquatic insects form the foundation of the food web**

Decomposition of leaves/needles of forbs, shrubs, and trees by fungi and bacteria provides a primary source of organic matter and nutrients to streams. The group of macro-invertebrates known as *shredders* (caddisflies, stoneflies, some midges and beetles) perform an important role by shredding and consuming plant litter. Nutrient-rich waters below and lateral to the river channel support a complex food web composed of microbes, small crustaceans, and aquatic insects that are hydrologically connected to the river and dependent on the surface water and groundwater exchange. Dissolved organic matter filters down into the gravels, where microbes further decompose it – thereby releasing nitrogen and phosphorus. These nutrients re-emerge at the surface resulting in blooms of algae growth which attract concentrations of grazing aquatic insects. Many small crustaceans and large aquatic insects spend early stages of their life histories in these nutrient-rich subsurface gravels throughout the gravel-bed river floodplain, again hundreds of meters lateral to the river channel. They return to the river channel, emerge and reproduce – thus becoming the foundation of the food web.

➢ **Native Fishes and the Groundwater Thermostat**

Many of the habitats that are essential for growth, survival, and persistence of native fishes in the Y2Y region are found almost exclusively on gravel-bed river floodplains. This is particularly true for native and threatened fish such as bull trout and westslope cutthroat trout that occupy gravel-bed river floodplains for their entire lives or travel hundreds of kilometres to spawn. These native fish find their critical spawning sites where cool groundwater upwells into the river gravels, which also are ideal overwintering habitat because relatively warm, hyporheic return flows help maintain ice-free conditions in the river. Moreover, juveniles typically use side channels, springbrooks, and low-velocity shoreline habitats for early rearing and feeding.

➢ **Amphibians in Ephemeral Floodplain Habitats**

Many amphibians select ephemeral ponds and disconnected backwaters of gravel-bed river floodplains for breeding to avoid predation. The short hydroperiod of such ephemeral ponds prevents predatory fish from accessing the same habitat that amphibians select for eggs and immature aquatic stages. Ponds on open floodplains are warmer at surface than at the bottom, whereas those in floodplain forests are usually cooler from top to bottom due to shading effect. This array of thermal and hydroperiod conditions supports not only a diverse amphibian assemblage but also high levels of intraspecific genetic diversity.

➢ Birds of the River Floodplain

In the Rocky Mountains, more than 70% of bird species is associated with gravel-bed rivers and floodplains to complete at least part or all of their life cycle. Expansive floodplains containing a variety of aquatic and terrestrial habitats, large and complex patches of deciduous gallery forests intersected by side channels, and a range of successional plant communities support both high diversity and high density of birds. Bird species breeding in the uplands may use gravel floodplains during migration, too.

➢ Predator-Prey Interactions in the Valley

Beaver (*Castor canadensis*) are well-known 'ecological engineers' whose dam-building creates ponds and wetlands in the side-channels of major rivers, where they reside year-round. Prey animals such as moose and elk occur in or near floodplains in winter and spring and follow river valleys during part of their seasonal migrations. In the Y2Y region, wolves commonly den in bluffs or banks along the edge of floodplains and hunt these areas both during spring-summer (for beaver and newborn ungulates) and later in winter. Ungulates in uplands often will run down to adjacent floodplain as they attempt to find refuge in the river. The unsuccessful ones are killed on the floodplains, where the decomposing remains furnish nutrients to the aquatic system.

Predation that occurs on gravel-bed floodplains also affects the health and reproduction of cottonwoods and upland aspen forests. Eradication of wolves from Yellowstone to Banff in the 1930s to 1960s led to the extreme overpopulation of elk throughout many river valleys. Abundant elk browsed heavily on aspen, cottonwoods, and willow, which then led to declines in beaver and riparian passerine birds ('trophic cascade'). In the last several decades, the recovery of wolves in Banff and restoration to Yellowstone as the missing link of predation has reversed the loss of woody plant species on gravel-bed river floodplains and upland aspen.

➢ Linkage Zones for Grizzly Bears across Floodplain River Valleys

When grizzly bears emerge from hibernation in the spring, they often descend to the valley floodplains at low elevations where forage is 'greening-up'. Roads and human settlements along these river corridors, however, lead to greater risk of human-caused mortality and partial or complete blockage of movements. Female movements decreased markedly when the settlement 'footprint' increased to >20% of a valley, whereas male movements declined gradually up to 50% settlement. Dispersal by young female grizzly bears is a gradual process over time and over relatively short distances (10-20 km). Linkage areas need to be large secure areas (kilometres long and across the valley floor) where female bears can live portions of their lives with minimal mortality risk. Conservation of secure linkage zones on private and public lands in river valleys is essential for maintaining connectivity for grizzly bear populations (see Figure 27).

Figure 27. The gravel-bed river floodplain as the ecological nexus of regional biodiversity. Illustration shows the complexity of the shifting habitat mosaic, the biophysical interactions among organisms from microbes to grizzly bears, and the importance of gravel-bed river floodplains as the nexus of glaciated mountain landscapes. (A) Microbes of the interstitial spaces of the gravel bed showing the products of processing of organic matter in the subsurface. (B) Crustaceans and insects that inhabit the gravels of the floodplain. (C) Temperature modification of surface habitats from upwelling hyporheic zone waters. (D) Native fishes spawning in floodplain gravels. (E) Riparian obligate birds. (F) Amphibian spawning in floodplain ponds and backwaters. (G) Ungulate herbivory of floodplain vegetation. (H) Wolf predation on ungulate populations. (I) Early-spring emergence of vegetation. (J) Wolf dens located along floodplain banks. (K) Use by grizzly bears and other carnivores as an intersection of landscape connectivity and sites of predation interactions (Hauer et al. 2016: E. Harrington, eh illustration, Missoula, MT).

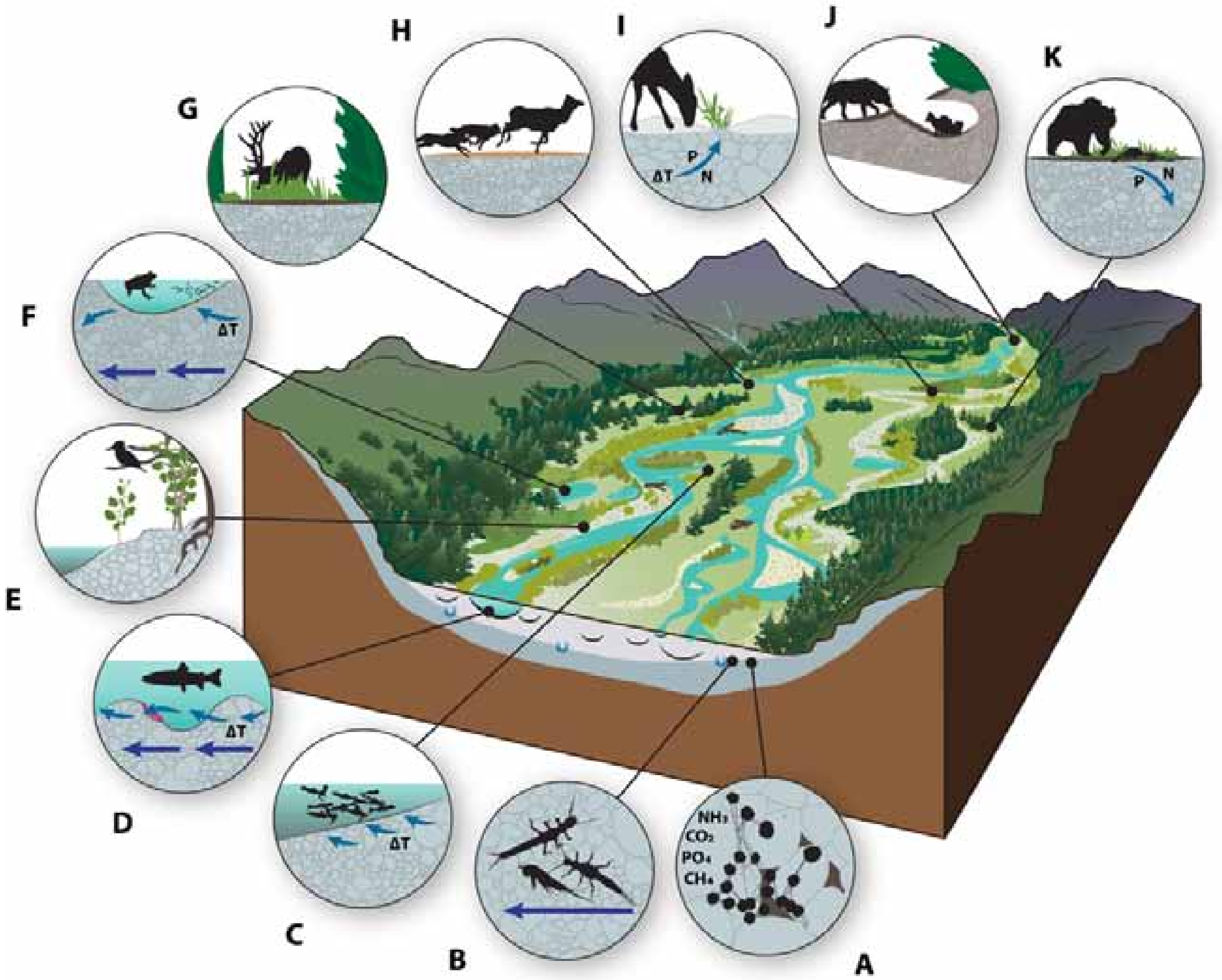
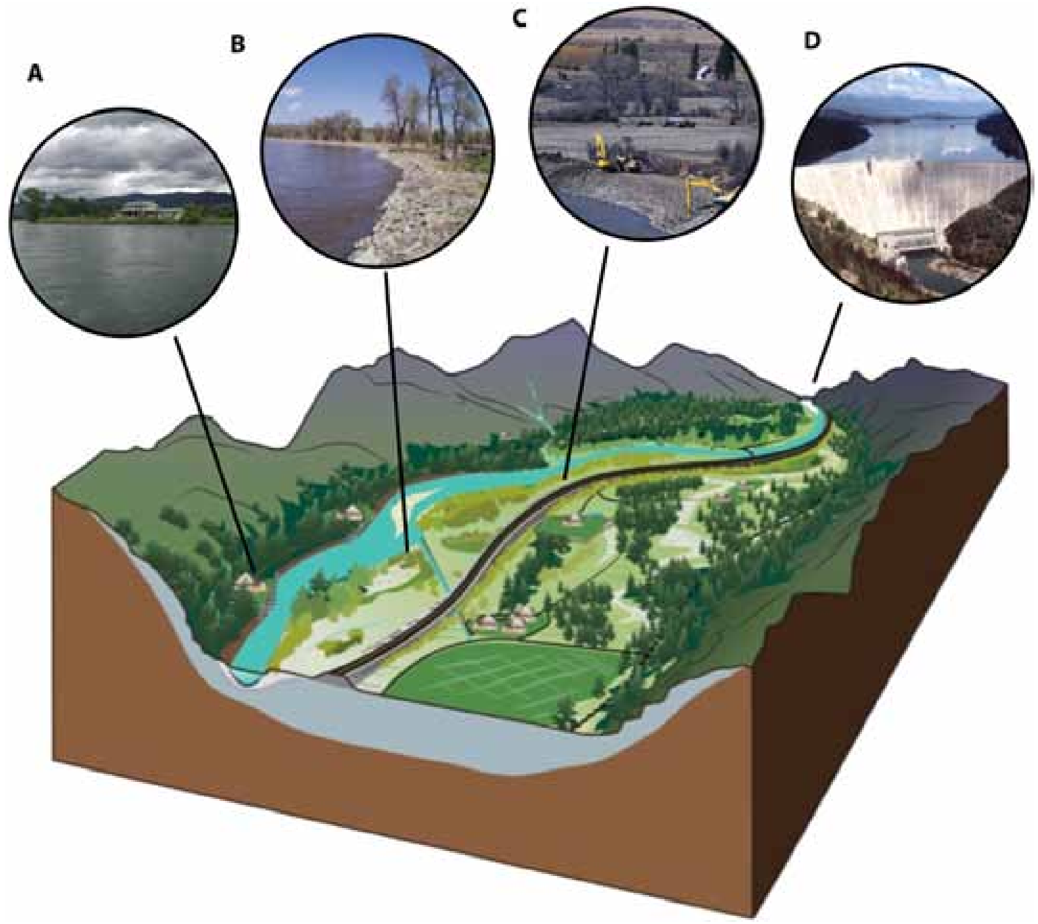


Figure 28. A gravel-bed river floodplain loses its natural complexity as a result of human infrastructure (A) shoreline housing and transportation corridor, (B) rip-rap as a bank-hardening structure, (C) geomorphic modification of levee construction, and (D) a dam at the top of the floodplain. Note that the river is converted into a functional single-thread river with little spread across the floodplain. When so modified, most of the rich ecosystem components are significantly reduced or eliminated from the floodplain system (Hauer et al. 2016: E. Harrington, eh illustration, Missoula, MT).



➢ <u>A Threatened Landform</u>

Floodplains are recognized as among the most endangered landform types worldwide. Gravel-bed river floodplains are flat, rich, and attractive areas with abundant water for municipalities, agriculture, and recreation. In most mountainous systems, they are the first to be converted to permanent human settlement, agriculture, industry, and transportation corridors (Figure 28). Structural modifications to floodplains such as roads, railways, and housing and hydrologic-altering hydroelectric or water storage dams have severe impacts to floodplain habitat diversity and productivity, restrict local and regional connectivity, and reduce the resilience of both aquatic and terrestrial species, including adaptation to climate change. Residential development in the floodplains comprises an insidious threat when landowners call for hard structures such as rip-rap, levees and dikes to prevent natural lateral flows and eliminates the dynamics of the floodplain system. Maintenance of the dynamic processes and the resulting complex of habitats along the length and breadth of floodplain rivers is a smart strategy for conserving the biodiversity of the Bighorn Backcountry.

Floodplain River Valleys as Climate-Adaptation Corridors

Protecting and restoring ecological connectivity has been consistently identified as a 'smart climate-adaptation strategy' for biodiversity conservation (e.g., Hansen et al. 2010), because species will have difficulty tracking rapidly-shifting climatic conditions across fragmented landscapes (Hodgson et al. 2009). River valleys and riparian zones have been identified as natural corridors or 'hotspots' for climate-driven movements because they span the temperature gradients species are likely to follow as they track shifting areas of climatic suitability (Seavy et al. 2009, Capon et al. 2013). Riparian areas also feature micro-climates that are significantly cooler and more humid than immediately surrounding areas and likely will provide an 'oasis effect' (Olsen et al. 2007). Riparian areas already act as critical movement corridors for diverse taxa, particularly within heavily modified landscapes (Hilty and Merenlender 2004). Plants and animals will use other pathways to track suitable conditions (different aspects of a mountain side, ridges), but riparian corridors likely will be a principal one.

Methods for Ranking Riparian Climate-Corridors

Krosby et al. (2014) developed a method for identifying priority riparian areas for climate-adaptation corridors. It identifies riparian areas that span large temperature gradients, have high levels of canopy cover, are relatively wide, have low solar insolation, and low levels of human modification – characteristics expected to enhance their ability to move to cooler micro-climate refugia in response to warming climate. They developed a 'Riparian Climate-Corridor Index' (RCI) using the following formula:

$$RCI = \Delta MAT \times [(RA + CC)/ (PRR + LC)]$$

Where MAT= Mean Annual Temperature (° C) along length of river
RA = Riparian Area
CC = % Tree Canopy Cover
PRR = Potential Relative Radiation
LC = Landscape Condition due to human modification

We followed their approach for the Bighorn Backcountry but modified their methods due to lack of certain data sets. We also modified their RCI formula to

$$RCI = \Delta MAT \times (RA/RL - RI/RL)$$

Where MAT= Mean Annual Temperature for period 1981-2010 in spatial increments of 1° C for length of river
RA = Riparian Area (based on Valley Bottom proxy)
RI = Road Impact
RL = River Length

Note that we *subtracted* the road impact (rather than use it as a divisor) to ensure the relative influence of the MAT and RA values on the derived score.

We followed these steps to determine the Riparian Climate-Corridor Index:

Step 1. Spatial Variation in Mean Annual Temperature (MAT)
We used a grid of evenly-spaced points (1km) and the ClimateWNA tool (Wang et al. 2012) to generate Mean Annual Temperatures across the study area for the recent period 1981-2010. We converted the output to integers, resulting in 8 classes of Δ1° C from the warmest +2-3° C to the coolest -5° to -4° C. Spatial variation in MAT is the number of Δ1° C classes for each river from mouth to headwater.

Step 2. Extent of valley bottom, including riparian area (RA)
We used a python script from the USDA Forest Service - Remote Sensing Application Center to model valley bottoms as a proxy for riparian areas (Housman et al. 2012). The script first generates a number of predictor variables based entirely on the 20m DEM, then uses a set of user-provided training points in a logistic regression model to create a continuous raster of valley bottom probabilities ranging from 0 to 1. For our study area, we used a DEM-derived hillshade, high-resolution BING imagery, and 20m contours to guide the on-screen digitizing of 685 valley bottom and 602 non-valley bottom training points. Our model is based on 3 predictor variables (out of 13 available): Topographic Wetness Index, Height Above Channel, and Slope (radians). We used a threshold of 0.75 to turn the continuous output into a binary one: model value ≤ 0.75 is valley bottom, model value > 0.75 is not). We buffered major rivers by 1km.

Step 3. Road Impact (RI)
We used roads from the ABMI Human Footprint GIS layer and the Line Density command in ArcGIS with a search radius of 500m to calculate road density (km/km^2). We applied the following weights to reflect different amounts of traffic: 4 = highway 93; 3 = highway 11; 2 = road #734; and 1 = all other paved or gravel roads. Resulting raster values ranged from 0 to 23 km/km^2 after conversion from floating point to integer. They were normalized to a 0-1 range and multiplied by the corresponding number of pixels, then summed within each 1km river buffer to obtain a Road Impact value (ha) for each river.

An illustrative example is displayed in Figure 29 a-c.

Figure 29 a-c. Sequential steps in determining the RCI score of river valleys based upon spatial gradient of Mean Annual Temperature (a), width of valley bottom (b), and zone of disturbance influence from roads (c) for the Bighorn Backcountry, Alberta.

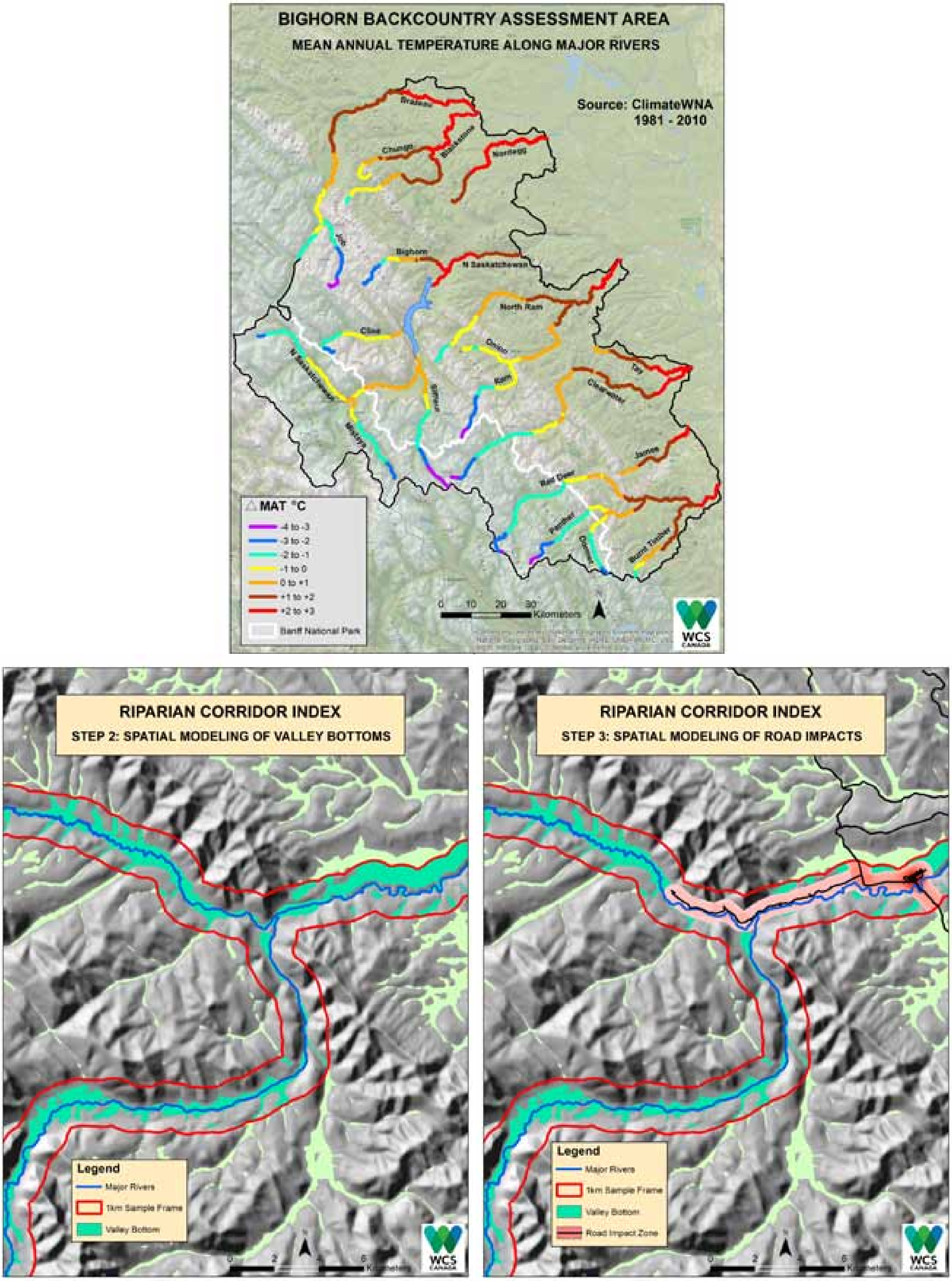


Table 13. Parameters for calculating the Riparian Climate-Corridor Index (RCI) for climate-change adaptation in the Bighorn Backcountry area, Alberta.
RCI = Δ MAT C° (Valley Bottom/River Length – Road Impact /River Length).

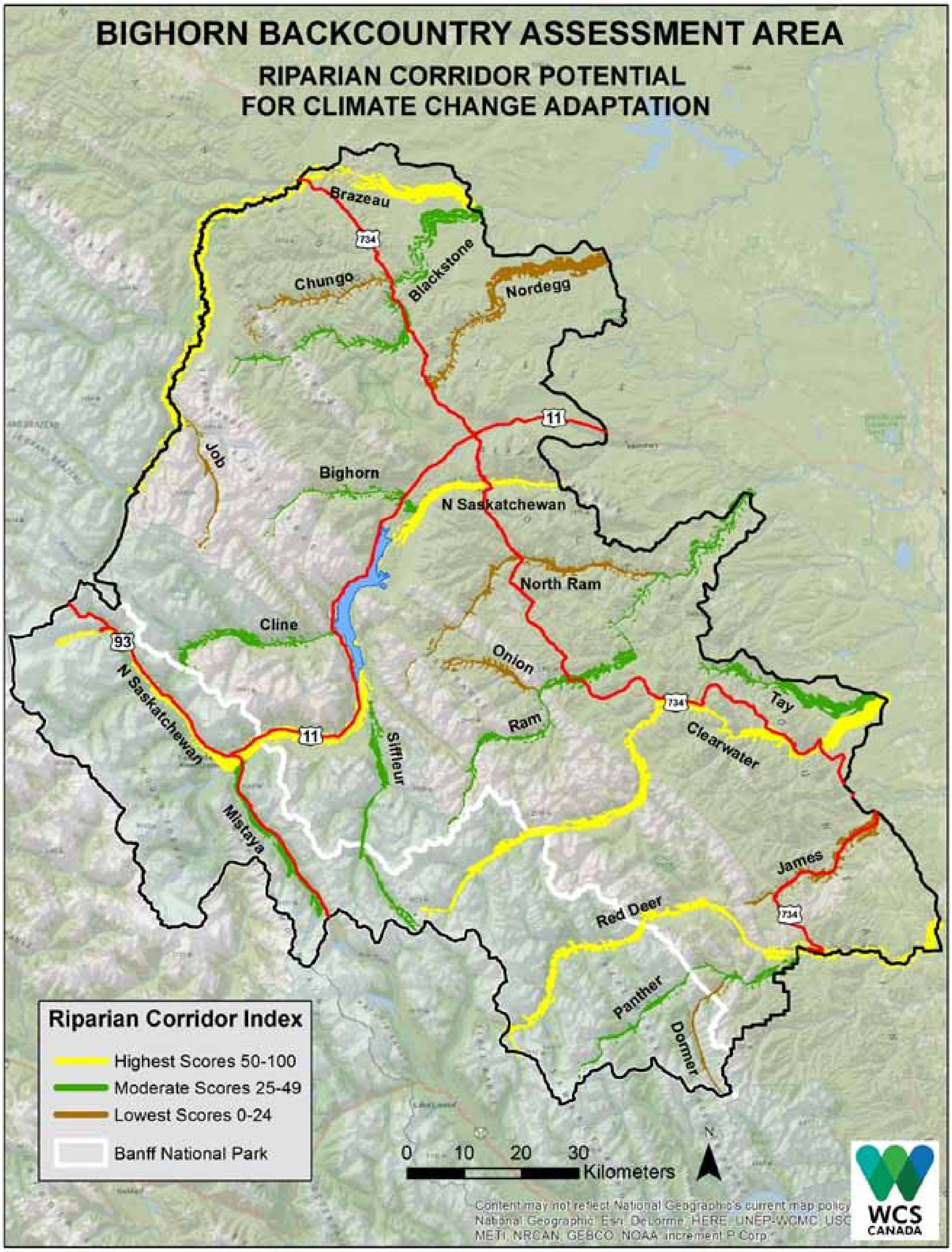
River	Δ MAT C°	Length (L) (km)	Valley Bottom (VB) (ha)	Road Impact (RI) (ha)	Climate Corridor Index	RCI Normalized
Bighorn	6	39.8	1,493	207	193.8	29.4
Blackstone	5	93.6	5,145	653	240.0	36.4
Brazeau	5	132.3	12,583	242	466.5	**70.8**
Chungo	4	42.9	1,074	208	80.8	12.3
Clearwater	7	130.8	12,582	694	636.3	**96.6**
Cline	5	41.0	2,700	101	317.0	48.1
Dormer	4	27.3	678	0	99.2	15.1
James	3	45.6	2,629	727	125.4	19.0
Job	4	32.2	881	0	109.6	16.6
Mistaya	4	37.2	3,179	1,048	229.2	34.8
Nordegg	2	73.9	5,411	323	137.6	20.9
North Ram	4	77.1	2,537	182	122.0	18.5
N Saskatchewan	6	118.3	15,733	2,743	658.8	**100.0**
Onion	2	26.3	1,184	41	86.8	13.2
Panther	6	57.2	2,182	136	214.2	32.5
Ram	7	122.1	5,002	271	271.6	41.2
Red Deer	7	119.3	9,270	883	492.1	**74.7**
Siffleur	6	54.8	2,809	63	301.2	45.7
Tay	3	62.4	4,508	530	191.1	29.0

Riparian Climate-Corridor Indices

The North Saskatchewan River had the top RCI score of 100, followed closely by the Clearwater River (96.6); the Red Deer (74.7) and Brazeau (70.8) Rivers which also scored high (Table 13, Figure 30). A high percentage (17.4%) of the North Saskatchewan River, however, is impacted by Highway 11 and 93; it also has the river barrier of Abraham Reservoir dam. The Brazeau (1.9%), Clearwater (5.5%), or Red Deer (9.5%) Rivers are less impacted by roads and have broad, braided floodplains. Thus, they are more likely to facilitate unimpeded movements and sustain biodiversity and resiliency at various scales. Other rivers with moderate scores in descending order included: Cline, Siffleur, and Ram (49-40); Blackstone, Mistaya, and Panther (39-30); and Bighorn and Tay (29-25).

Rivers in the mountains west of the Forestry Trunk Road #734 typically traverse a greater range of temperature gradient and have sections with wide valley bottoms. River sections in the foothills east of the FTR #734 have broad valley bottoms, but longer stretches of the warmest temperatures.

Figure 30. Location and relative ranking of river valleys as climate-corridors for adaptation to warming climate, Bighorn Backcountry, Alberta.



4. SAFEGUARDING THE WATERS AND WILDLIFE OF THE BIGHORN BACKCOUNTRY

Protecting the Headwaters: Smart Strategy Going Forward

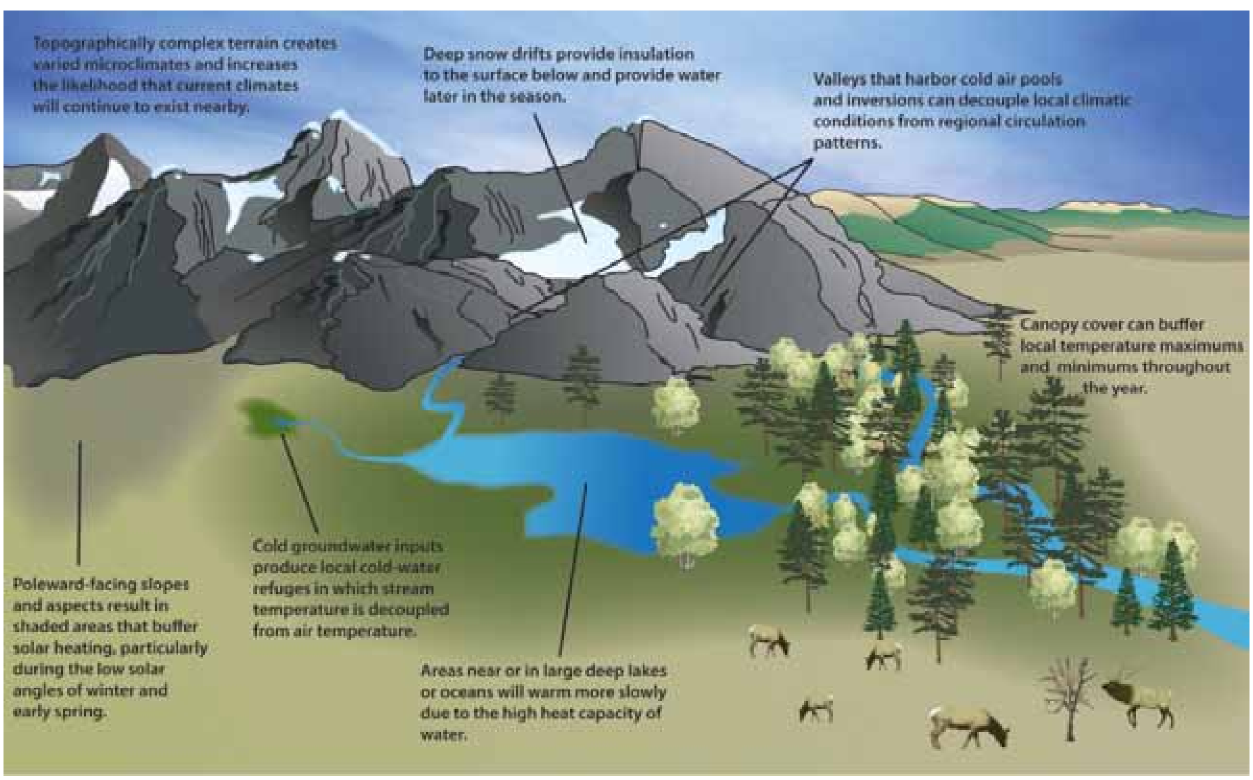
For many years, the Eastern Slopes of Alberta enjoyed 'de-facto' protection due to the few roads, local economies, and modest resource extraction. People lived a western lifestyle and enjoyed the open spaces, clean air and water, diverse and abundant fish and wildlife. The wild beauty of the land, however, began changing in the 1950s as extraction of oil & gas and timber expanded. An expanding network of new roads and seismic lines spread throughout the foothills. More recently, prosperous regional (globalized) economies have led to burgeoning outdoor recreation, facilitated by advances in 4-wheeled-drive and off-highway vehicles (OHVs). Once-secluded havens of security for these vulnerable species had been breached. Now, melting of glaciers such as the Athabasca and Saskatchewan signals changes in climate that will become even more pronounced and impactful in coming decades.

During times of change, 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). Both the ecological profiles and the historical record of extirpations attest to the need for some form of refugia for vulnerable fish and wildlife species. From a conservation perspective, refugia are places where plants and animals can move to, find new suitable habitats, and survive under changing environmental conditions (Keppel et al. 2012). In recent years, managers elsewhere in Canada and the U.S. have begun identifying key areas that may serve most effectively as refugia during climate change (Kittel et al. 2011, Morelli et al. 2016).

With scientific consensus on projections of warming of 2°- 4° C 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 may still prevail (Schneider 2013). A smart strategy going forward is to **protect** large landscapes with high topographic and environmental diversity and to **connect** such large, diverse core areas. To function most effectively, refugia or safe havens should be scaled in size to meet the needs of wide-ranging, vulnerable species and dynamic ecological processes. One fundamental tenet, for example, might be to encompass the full array of seasonal habitats used by an 'umbrella' species such as grizzly bears. Another key tenet might be to facilitate potential adaptation to changing climates by providing a range of environmental gradients from river valley to mountain peak (Figure 31).

Nestled between Banff and Jasper National Parks in the Canadian Rockies, the Bighorn Backcountry area encompasses the multi-branched headwaters of the North Saskatchewan River watershed. Like its better-known National Park neighbors, the Bighorn Backcountry is a spectacular landscape with towering mountains, wide river valleys, and a diversity of Alberta's Natural Regions. In addition to providing a source of treasured waters for the Provinces of Alberta and Saskatchewan, it also provides important habitat for several of the more vulnerable fish and wildlife species in Alberta. So, here in the Bighorn Backcountry is an opportunity to secure a vital refugium for changing conditions, but a critical question remains: where are the most effective places to safeguard its wildlife and water treasures?

Figure 31. Large landscapes with high topographic and environmental diversity can serve as refugia during warming climate (excerpted from Morelli et al. 2016).



Synthesis of Conservation Values for Vulnerable Wildlife and Precious Waters

In this section, I summarize the conservation values for vulnerable wildlife and valuable waters in the Bighorn Backcountry area of Alberta to provide a scientific basis for management recommendations. Conservation scores for each of the 4 species plus the Riparian Climate-Corridor Index were tallied for each 1-km^2 cell across the study area (n = 14,334 cells). Although the maximum **composite** tally for a cell could have been 15 (5 species/components x highest score of 3), the maximum realized score was 14.

I present composite scores 7-14 as *high* and scores 4-6 as *moderate*. The spatial pattern of composite scores provides an important perspective on where these multi-species values are concentrated. Yet, in some places, the composite score might be low, but the site is important nonetheless for at least one of the vulnerable species. So, **species importance values** (SIV) score of 3 (*very high*) or 2 (*high*) for any single species are mapped. It should be noted that a SIV of 2 may represent a less critical but still essential component of the species' annual range (e.g., primary habitat for wolverine). Lastly, I present Environmentally Significant Areas (ESAs) as mapped for Alberta Environment and Parks (Fiera Consulting 2014). Here, I summarize and display these measures of conservation values across the Bighorn Backcountry area by management jurisdiction or designation. Later, I tally these values on non-wilderness Provincial lands west *v*. east of the Forestry Trunk Road #734.

A large majority (75%) of the Bighorn Backcountry area of Alberta has moderate-high value for wildlife and river valleys on a composite basis (Figure 32). The largest and most intact block of *high* composite scores runs through the center of the Bighorn Backcountry to encompass the mountains and higher valleys of the Bighorn Range, Front Range and Ram Range. Moreover, these areas also will be the cooler refugia for sensitive species during mid-century as climate continues to warms. High scores occur elsewhere along river valleys and scattered locations in the upper foothills. Key locales include the headwater basins of the following rivers and primary tributaries: Brazeau and Blackstone, North Saskatchewan River above Abraham Reservoir, North and South Ram Rivers, Clearwater River; and Red Deer River, including Panther and Dormer Rivers and Sheep Creek. It's interesting that the two Wilderness areas do not capture many high composite scores. Much of the Bighorn Backcountry has *moderate* composite scores, too. In terms of extent, about 33% (469,983 ha) of the study area has high composite scores, with moderate composite scores on 42% (609,598 ha) (Table 14). Most of these values occurs on non-wilderness Provincial lands: about 71% of high scores and 58% of moderate scores.

Table 14. Area (ha) and percentage of *composite values* in the Bighorn Backcountry area, Alberta

Land Status	High Scores 7-14			High Scores 4-6		
	Area	% Area	% CV	Area	% Area	% CV
Banff NP	119,438	8.3	25.4	189,164	13.2	31.0
Provincial WAs	16,785	1.2	3.6	68,352	4.8	11.2
Provincial Lands	333,760	23.3	71.0	352,082	24.5	57.8
TOTAL	**469,983**	**32.8**	**100.0**	**609,598**	**42.5**	**100.0**

Nearly all (92%) of the Bighorn Backcountry area of Alberta has high-very high value for at least 1 of these vulnerable species (Figure 33). As expected, most of the very-high scores occur in the same areas as the high composite scores west of the Forestry Trunk Road #734. But, it is notable that many areas in the Upper Foothills east of FTR #734 have very-high scores for a particular species, whereas the composite score may have been moderate or even low. In terms of extent, very-high scores for species importance occurred on ~75% (1,072,194 ha) of the area and high scores on ~17% (240,451 ha) (Table 15).

Table 15. Area (ha) and percentage of *species importance values* (SIV) in Bighorn Backcountry area, Alberta.

Land Status	SIV = 3			SIV = 2		
	Area (ha)	% Area	% SIV	Area	% Area	% SIV
Banff NP	313,220	21.8	29.2	17,619	1.2	7.3
Provincial WAs	77,767	5.4	7.3	9,368	0.7	3.9
Provincial Lands	681,207	47.5	63.5	213,464	14.9	88.8
TOTAL	**1,072,194**	**74.8**	**100.0**	**240,451**	**16.8**	**100.0**

Figure 32. Distribution of composite scores for four vulnerable fish and wildlife species plus the Riparian Climate-Corridor Index (RCI), Bighorn Backcountry area, Alberta.

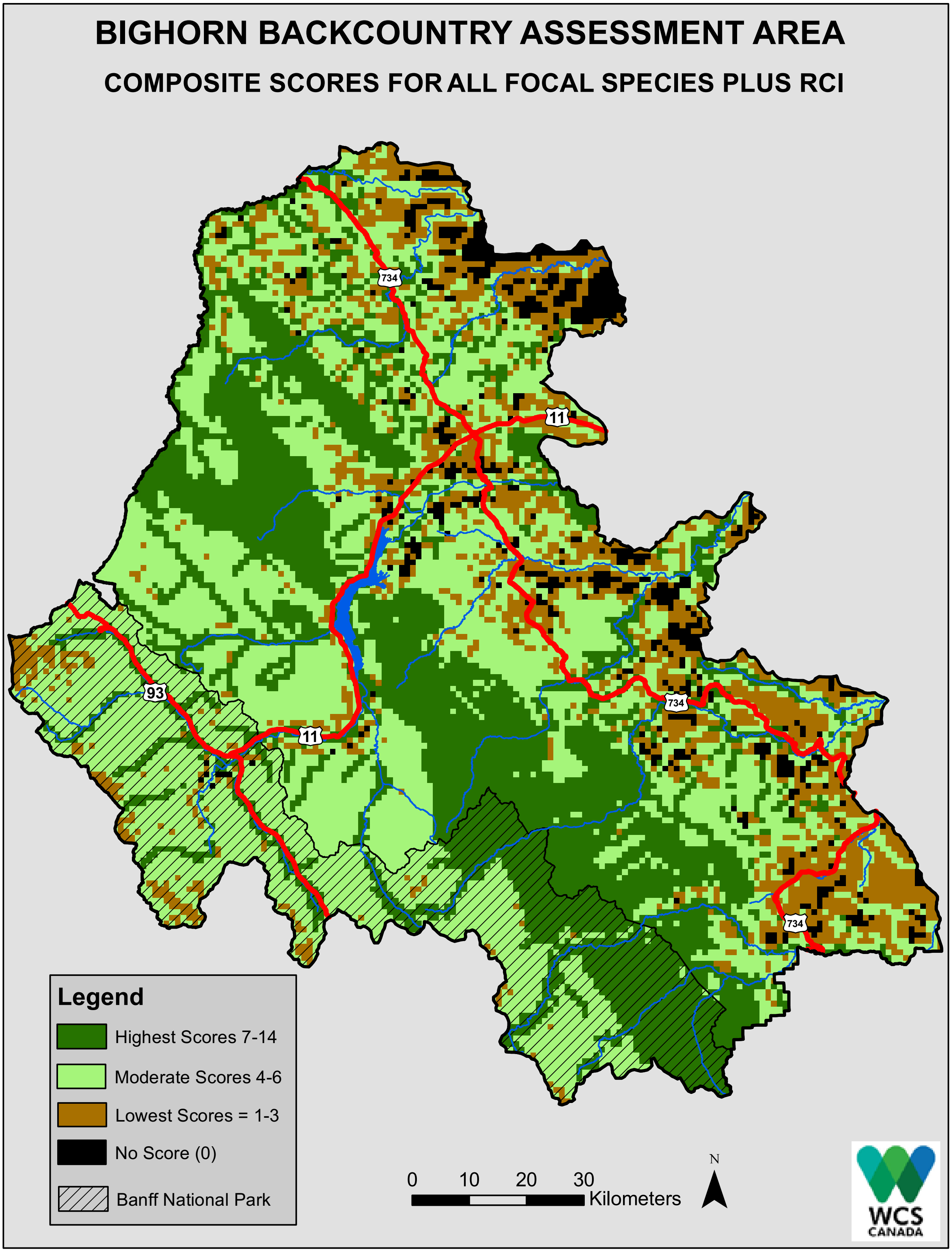
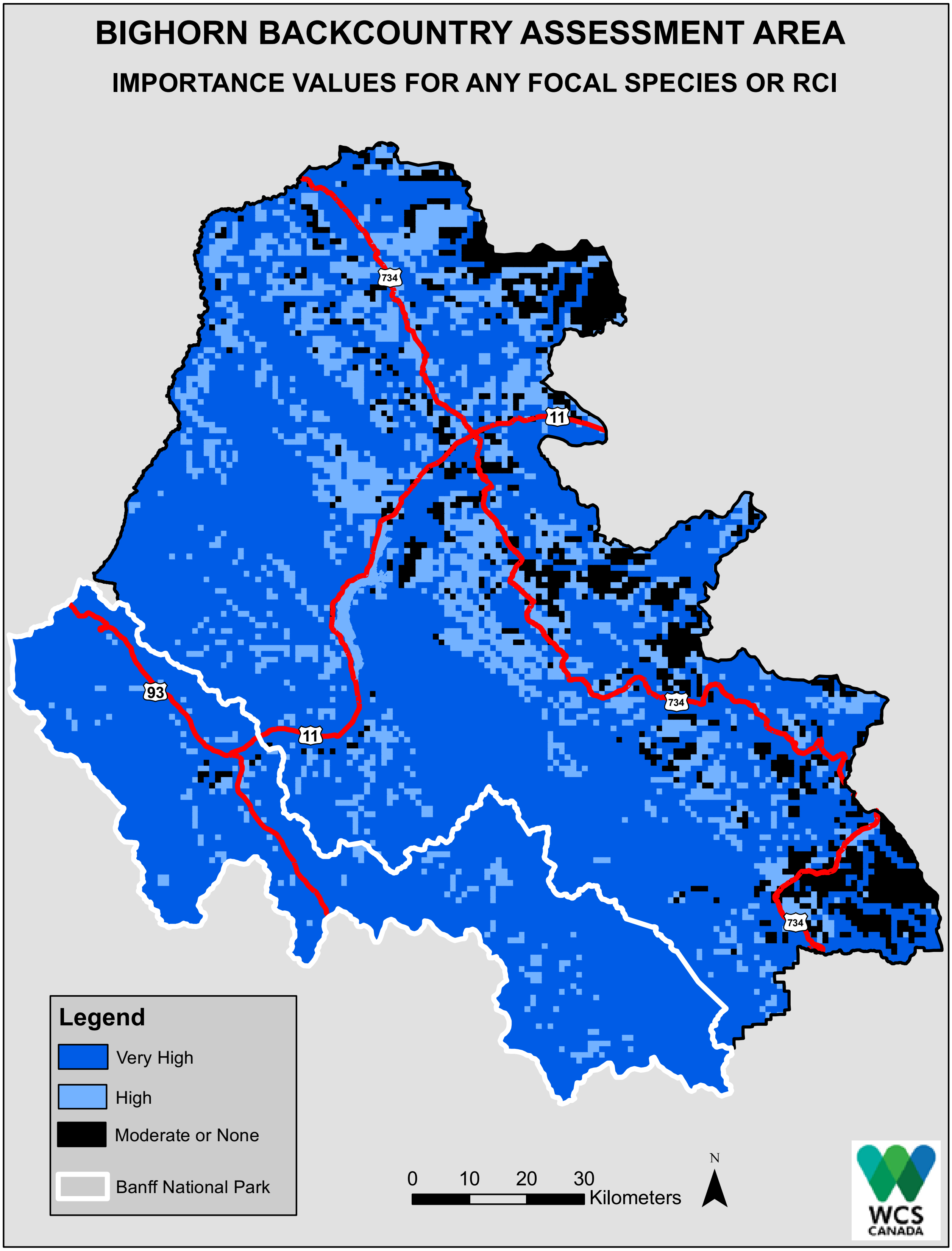


Figure 33. Distribution of species importance scores for any of 4 vulnerable fish and wildlife species or the Riparian Climate-Corridor Index, Bighorn Backcountry area, Alberta.



Environmentally Significant Areas (ESAs)

Environmentally Significant Areas (ESAs) represent areas in Alberta that are important for long-term stewardship of biodiversity, soils, water and other natural attributes. ESAs for both terrestrial and aquatic systems were amalgamated in a new report for the Alberta Government in 2014 (Fiera Consulting 2014). Criteria for ESAs represent a broad range of important environmental elements and included both coarse-filter and fine-filter indicators. Coarse-filter indicators have the goal of maintaining native biota and natural ecosystem function, while fine-filter indicators were developed to capture environmental features required to maintain populations, species, ecosystems, or other special features that are not accounted for under coarse filter criteria (Groves 2003). Altogether, 4 criteria, 10 sub-criteria, and 25 indicators were selected to define, measure, and map terrestrial and aquatic ESAs in Alberta (Table 16). Mapping of ESAs was done at a very coarse scale (provincial) using the quarter-section as the unit of analysis resolution (65 ha). Interested readers should consult the report for details of methodology and scoring, limitations, and references. Although ESAs do not have legislated protection, they are intended to inform municipal and regional land use planning processes and consideration of special conservation measures. I extracted their map and scores to provide an independent assessment of the conservation significance of the Bighorn Backcountry area.

Final provincial ESA values ranged between 0 and 0.4375, with a mean value of 0.172 (Fiera Consulting 2014). Based upon a consensus ESA cut-off value of 0.189, ~45% of the province was identified as an Environmentally Significant Area. The greatest proportion of ESAs were located in the Boreal Natural Region (67%) and the Rocky Mountain Natural Regions (12%). Both of these Natural Regions possess a relatively high degree of ecological integrity and contain elements that help maintain water quality and quantity. Because these two criteria received the highest weightings in the calculations, large portions of the Boreal (89%) and Rocky Mountain (71%) Natural Regions contained ESAs.

The Bighorn Backcountry contains one of the larger, intact blocks of ESAs in the Province. About 72% (1,030,382 ha) of the area has been delineated as ESAs – significantly more than the Provincial average of 45% (Table 17). Importantly, three-quarters of the ESAs (75% - 771,233 ha) occur on non-wilderness Provincial lands – mostly west of Forestry Trunk Road #734 (Figure 34).

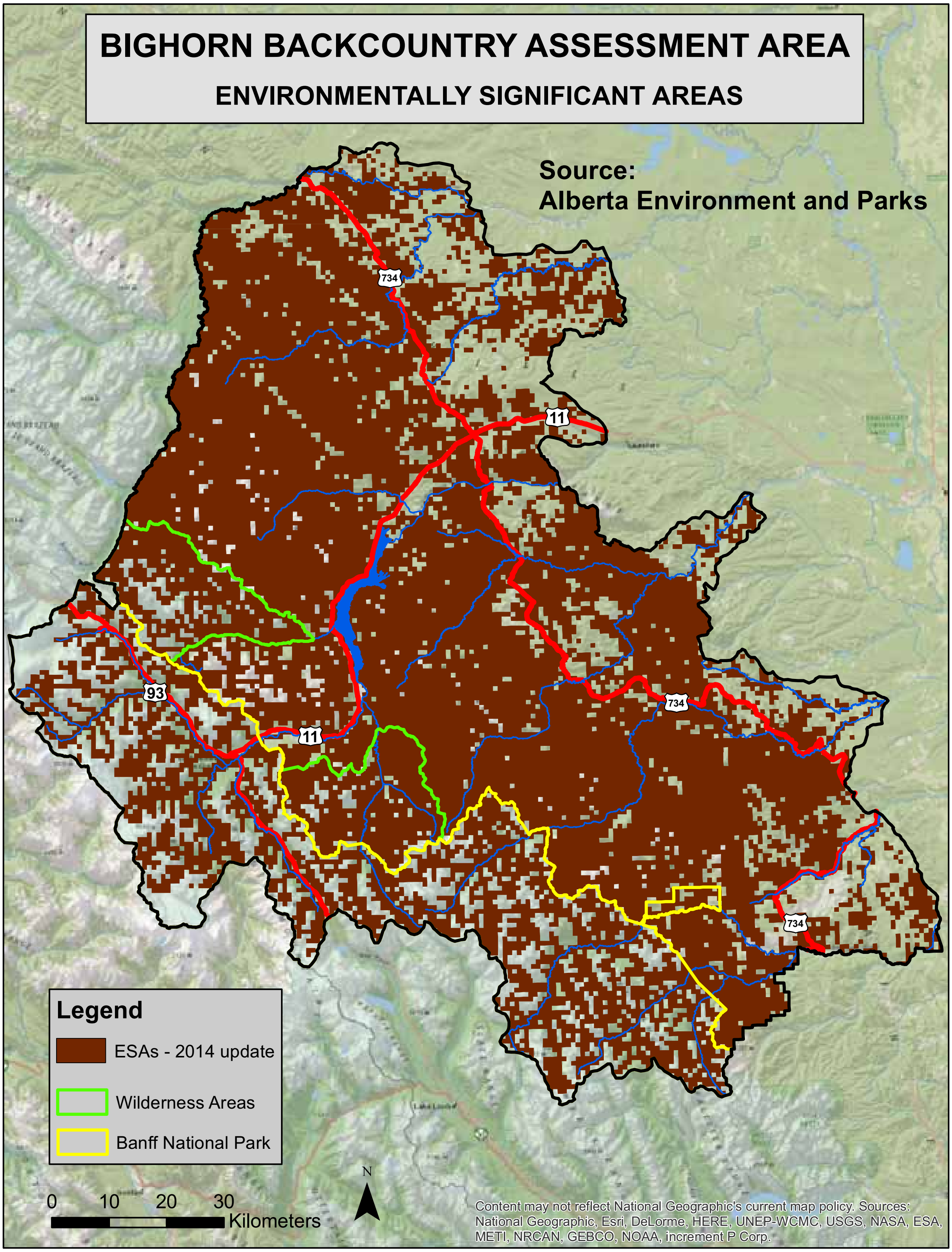
Table 16. Criteria, sub-criteria, and indicators used to delineate Environmentally Significant Areas (ESAs) in Alberta (Fiera Consulting 2014).

Criteria	Sub-Criteria	Indicators
1. Areas that contain focal species, species groups, or their habitats	1a. Conservation Hotspots	Rare, threatened or endangered species
	1b. Focal species groups	amphibians, aquatic breeding birds, and fish
	1c. Focal species habitat	Harlequin duck, grizzly bear, woodland caribou (boreal), western burrowing owl, sage grouse, arctic grayling
2. Areas that contain rare, unique, or focal habitat	2a. Rare habitats	Vegetation communities, peatlands
	2b. Unique habitats and landforms	Natural springs, nationally and internationally recognized landforms
	2c. Focal habitats	Class A and B rivers and streams, snake and bat hibernacula, waterfowl staging and foraging areas, sharp-tailed grouse leks
3. Areas with ecological integrity	3a. Habitat patch size	Terrestrial habitat patches
	3b. Habitat intactness and connectivity	Intact landscapes, lotic (rivers and streams) habitat connectivity, lentic (wetlands and lakes) habitat intactness
4. Areas that contribute to water quality and quantity	4a. Rivers and streams	River and stream density, lotic landscape intactness
	4b. Wetlands and lakes	Wetland landscape composition, water storage potential

Table 17. Area (ha) and percentage of *Environmentally Significant Areas* (ESAs) in Bighorn Backcountry area, Alberta.

	Occurrence of Environmentally Significant Area		
Land Status	**Area (ha)**	**% Area**	**% ESA**
Banff NP	189,053	13.2	18.3
Provincial WAs	70,096	4.9	6.8
Provincial Lands	771,233	53.8	74.9
TOTAL	1,030,382	71.9	100.0

Figure 34. Occurrence of Environmentally Significant Areas in Bighorn Backcountry, Alberta, as identified and mapped for Alberta Government (Fiera Consulting 2014).



A *Wildland* Provincial Park in the Bighorn Backcountry

Designation of 'Wildland Provincial Parks' offers the best option for protecting large important areas in the Bighorn Backcountry area of Alberta. Wildland Provincial Parks are a type of Provincial Park established specifically to protect natural heritage over large areas and provide opportunities for backcountry recreation. Wildland provincial parks are large, undeveloped natural landscapes that retain their primeval character. Notwithstanding, some commercial activities can occur. This is the type of designation used most frequently in recent years to provide some protection to larger areas. Some wildland parks provide significant opportunities for adventure activities such as backpacking, wildlife viewing, mountain climbing and trail riding. Designated trails for off-highway vehicle riding and snowmobiling are provided in some wildland parks. It's the responsibility of the Alberta Government to devise a management plan for each Wildland Park.

To safeguard vulnerable fish and wildlife species and treasured waters in the Bighorn Backcountry, I recommend 690,800 ha west of the Forestry Trunk Road #734 be designated as a *Wildland* Provincial Park (Figure 35). This represents 68.1% of the 1,013, 804 ha of Provincial lands (excluding existing Wilderness Areas) in the study area.

A Bighorn Wildland Provincial Park west of the Forestry Trunk Road #734 would help secure a high proportion of the most important habitats for the following species/features on 68 % of land (Table 18):

- ✔ composite score 93 %
- ✔ grizzly bear 75 %
- ✔ wolverine 100 %
- ✔ bighorn sheep 96 %
- ✔ bull trout 84 %
- ✔ species importance 77 %
- ✔ composite score 93 %
- ✔ ESA 78 %

Thus, the proposed boundary represents an efficient design by conserving a high proportion of conservation values relative to the proportion of the landscape.

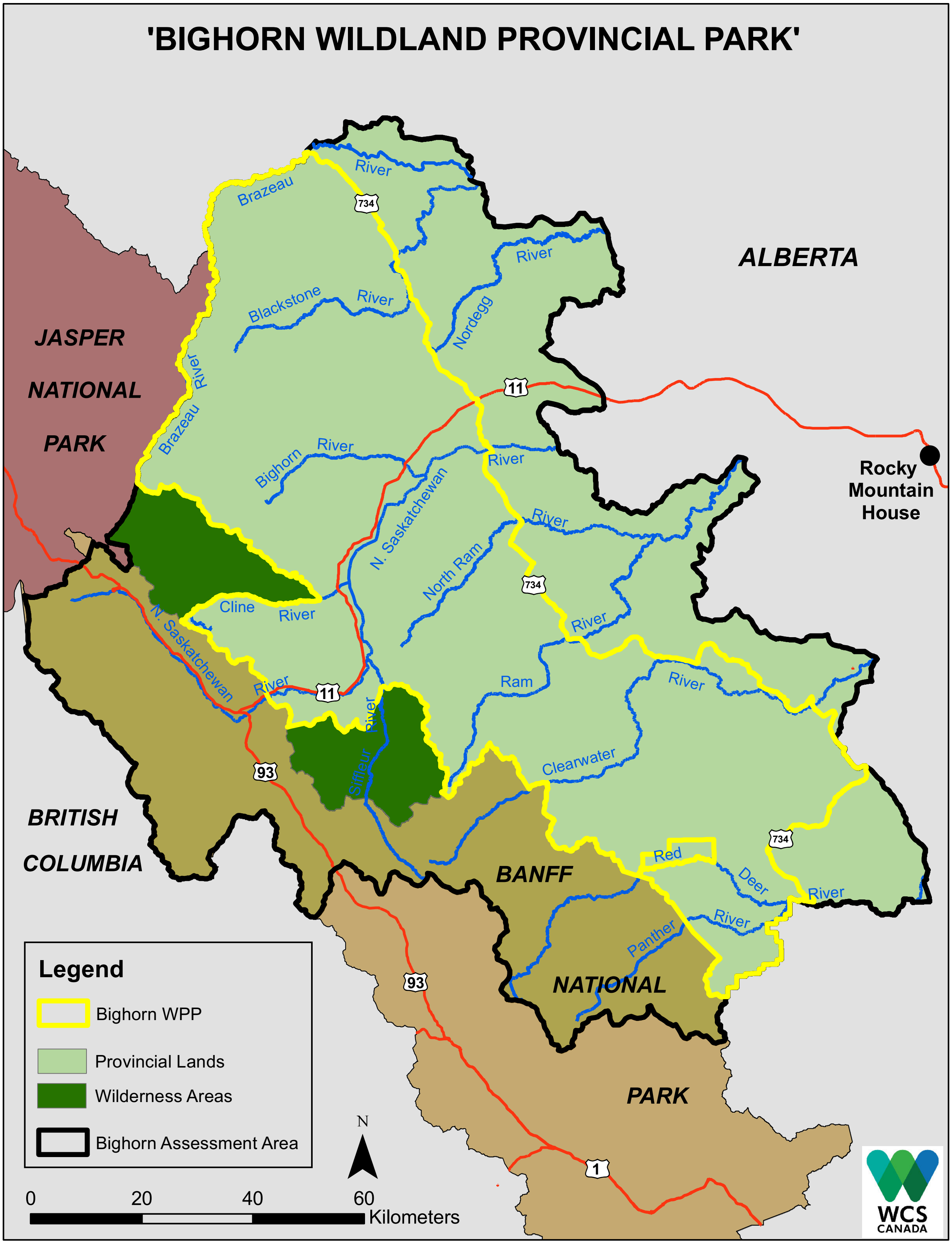
Designation of a Wildland Park would signal a first-order commitment to conservation and recovery for several vulnerable species. Indeed, there are renewed calls to protect roadless areas across the world in order to safeguard biodiversity and ecosystem services for humankind (Ibisch et al. 2017). Moreover, the recommended Wildland Park would protect the headwaters of the North Saskatchewan River, the 'water towers' which provide much of the water for people in west-central Alberta including the capital Edmonton. This Wildland Park would have added value by protecting Provincial lands adjacent to Banff and Jasper National Parks in the Canadian Rockies and foothills of Alberta. **The concentration of high conservation values for vulnerable wildlife sand valuable waters makes a compelling case and 'best-buy' for designation of a 'Bighorn *Wildland* Provincial Park'.**

Table 18. Area (ha) and percent of conservation scores west and east of Forestry Trunk Road (FTR) #734, in Bighorn Backcountry area, Alberta. These scores are presented here only for Provincial lands – excluding Provincial Wilderness Areas and Banff National Park. Nearly all of the 'best buys' (**% conservation scores** > % land area) occur west of FTR#734.

	Very High				High			
	West FTR		East FTR		West FTR		East FTR	
Species	**Area**	**%**	**Area**	**%**	**Area**	**%**	**Area**	**%**
Land Area	690,784	**68.1**	323,020	**31.9**	690,784	**68.1**	323,020	**31.9**
Grizzly Bear	264,632	**74.5**	90,790	25.5	302,973	**77.4**	88,329	22.6
Wolverine	72,897	**100.0**	0	0.0	438,857	**80.9**	103,876	19.1
Bighorn Sheep	196,822	**96.3**	7,536	3.7	-	-	-	-
Bull Trout	619,027	**83.8**	119,635	16.2	60,332	22.9	203,345	77.1
Species Import	498,380	**76.8**	150,391	23.2	163,314	64.2	90,948	35.8
Composite	283,606	**92.7**	22,384	7.3	273,870	**73.0**	101,482	27.0
ESAs	600,270	77.9	171,121	22.1	-	-	-	-

The area east of the Forestry Trunk Road #734 has varying value for these vulnerable species, but some portions are important for grizzly bear and bull trout. All of it has been mapped as Core Recovery Zone in the draft Alberta Grizzly Bear Recovery Plan (AEP 2016). About 25% of the very-high and high conservation values for grizzlies occur east of the FTR (Table 18, see Figure 15). Both male and female grizzly bears were detected during recent surveys in the area north of Highway 11 / north of Nordegg. For bull trout, some of this same area has very high (Blackstone River) and high (Nordegg River) density of juvenile fish (see Figure 21) and moderate density of adult bull trout (see Figure 22). The network of roads, seismic lines, and other linear disturbances, however, presents a contemporary challenge in realizing its full conservation value. The more extensive floodplains of the Brazeau and Blackstone Rivers and attendant conservation values are found here, as well. Lastly, the area east of FTR #734 has its own set of conservation values for other wildlife species and for boreal forests *per se*. These have been addressed in a report entitled "Conservation Blueprint of Northern Alberta: Prioritizing Areas for Protected Areas Planning" (CPAWS 2014). More formal recognition of the values there could be beneficial for conservation of biodiversity overall.

Figure 35. Proposed boundary of Bighorn Wildland Provincial Park to protect vulnerable wildlife and beneficial headwaters of the North Saskatchewan River, Canadian Rockies and upper foothills, Alberta. The eastern boundary follows the Forestry Trunk Road #734.



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Headwaters of the North Saskatchewan River

The Canadian Rockies of Alberta are among the best-known and most-cherished mountains on Earth. Adjacent to the eastern boundary of these two acclaimed *World Heritage Sites* – but quite similar in spectacular terrain and shared wildlife – lies an area known as the 'Bighorn Backcountry'. Here are the headwaters of the mighty North Saskatchewan River, fountain source of precious clean water for farms and cities downstream. With scientific consensus on projections of warming of 2°- 4° C over the next 50-100 years, a smart strategy going forward is to protect large landscapes with high topographic and environmental diversity from river valley to mountain peak. The area west of the Forestry Trunk Road #734 has a notable concentration of vital habitats for grizzly bear, wolverine, bighorn sheep and bull trout. Designation of a *Wildland* Provincial Park would help safeguard these vulnerable species and treasured waters to be enjoyed by people today and generations yet to follow.

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