Assessing Cumulative Impacts to Wide-Ranging Species Across the Peace Break Region of Northeastern British Columbia

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For and in collaboration with:

YELLOWSTONE TO YUKON
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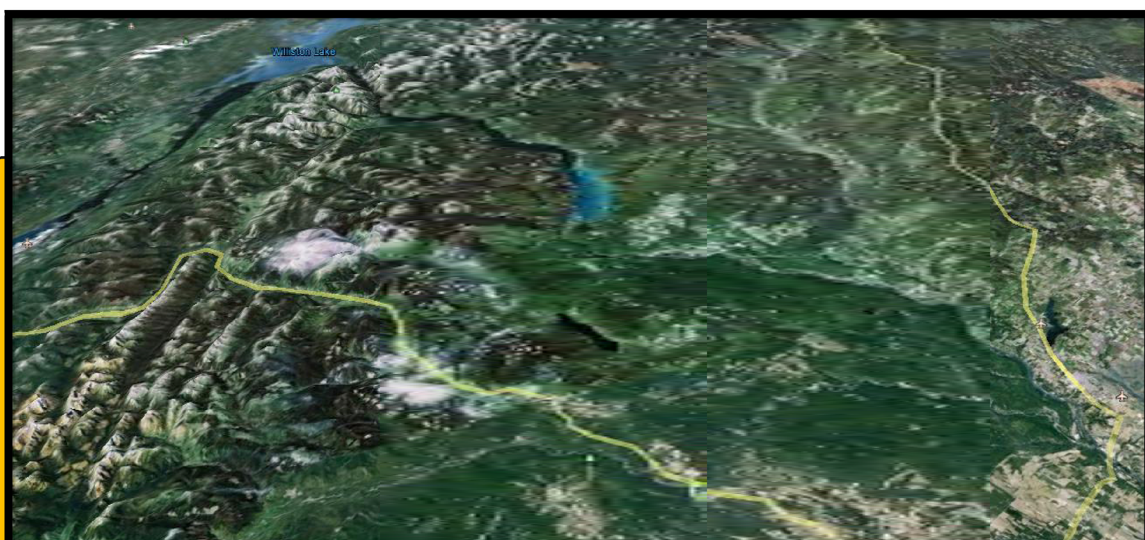

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PREFACE

This report was prepared under the auspices of the Yellowstone to Yukon Conservation Initiative (Y2Y). The impetus for the assessment herein was concern regarding contribution of the Site-C dam and hydro-electric development on the Peace River toward adverse regional cumulative effects. Because the underlying mandate of Y2Y pertains to advocacy for ecological connectivity from local to continental scales, my focus in this assessment has been on wide-ranging species potentially sensitive to broad-scale population fragmentation. For these species, assessing cumulative impacts specific to any one development must be considered in the context of regional populations and underlying habitat conditions and influential human activities. Hence, it is in the context of regional-scale assessment that this report considers the impacts of the Site-C development and its constraints to future conservation opportunities. While this report may be submitted by Y2Y for consideration in the environmental assessment process for the Site-C development, it is also intended to inform regional conservation planning through a wider audience that includes resource managers, resource stakeholders, private land stewards, environmental advocates, the general public, and other researchers.

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ACRONYMS & ABBREVIATIONS USED

BAFA	Boreal Altai Fescue Alpine Biogeoclimatic Zone
BEC	Biogeoclimatic Ecosystem Classification
BEI	Broad Ecosystem Inventory
BWBS	Boreal White and Black Spruce Biogeoclimatic Zone
BTM	Baseline Thematic Mapping
CEA	Cumulative Effects Assessment
CEAA	Canadian Environmental Assessment Agency
COSWEIC	Committee on the Status of Endangered Wildlife in Canada
DRA	Digital Road Atlas
EA	Environmental Assessment
EAO	British Columbia Environmental Assessment Office
EOSD	Earth Observation for Sustainable Forest Development
ESSF	Englemann Spruce / Subalpine-Fir Biogeoclimatic Zone
EVI	Enhanced Vegetation Index
FLNRO	Ministry of Forests, Lands and Natural Resource Operations
FRPA	Forests and Range Protection Act
GBPU	Grizzly Bear Population Unit
GIS	Geographic Information System
GWM	General Wildlife Measures
ICH	Interior Cedar-Hemlock Biogeoclimatic Zone
MELP	Ministry of Environment, Lands and Parks
MODIS	Moderate Resolution Imaging Spectroradiometer
MOE	Ministry of Environment
NDVI	Normalized Difference Vegetation Index
NDT	Natural Disturbance Type
NTS	National Topographic Survey
PWFWCP	Peace/Williston Fish and Wildlife Compensation Program
RIG	Caribou Recovery Implementation Group
SBS	Sub-Boreal Spruce Biogeoclimatic Zone
SMNEA	Southern Mountains National Ecological Area
UNBC	University of Northern British Columbia
UWR	Ungulate Winter Range
WHA	Wildlife Habitat Area
WMU	Wildlife Management Unit
Y2Y	Yellowstone to Yukon Conservation Initiative

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This assessment and report was commissioned by the Yellowstone to Yukon Conservation Initiative (Y2Y). Funding was contributed by the Conservation Alliance, the Vancouver Foundation and the Canadian Environmental Assessment Agency. Valuable direction, assistance and feedback were provided by Juri Peepre and Wendy Francis of Y2Y. I am also grateful to many individuals who took the time to respond to my inquiries and provide assistance in tracking down multiple types of relevant information such as reports, papers and data. Peter Lee of Global Forest Watch Canada shared several datasets of importance in my analysis. Bruce Muir of West Moberly First Nations also facilitated the acquisition of specific data. Libby Williamson of the University of Northern British Columbia (UNBC) contributed helpful products derived from her modeling for northern caribou within the analysis area. Other individuals who were generous with their time in responding to my requests include Dale Seip of the BC Ministry of Forests, Land and Natural Resource Operations (FLNRO), Rich Weir, Tony Button, Tony Hamilton, and Eric Lofroth of the BC Ministry of Environment (MOE), Chris Johnson of UNBC, Scott McNay and Viktor Brumovsky of Wildlife Infometrics Inc., and Rick Hendriks of Camerado Energy Consulting Inc. Helpful review of an earlier draft was provided by Trevor Kinley.

SUMMARY

Introduction

Within the Y2Y expanse, the ecologically diverse Peace River Break is a region with a long history of settlement, industry and development, with relatively little protected area representation and a significant human "footprint" at present. Population connectivity for several wide-ranging terrestrial species and some aquatic species is likely to be highly constrained with the potential for fracture. This impact could be exacerbated by additional cumulative effects resulting from current trends and several proposed major developments including the Site-C hydro-electric dam and impoundment. This report describes a broad-scale assessment of those existing and potential cumulative impacts.

1. Background

Central to the Peace Break region of northeastern BC is the Peace River Valley which "breaks" the Rocky Mountains and funnels warm, moist Pacific air east of the Rockies. Owing to this and other physiographic and climatic influences, the Peace Break region is ecologically diverse, with inherent variation in the potential for species occurrence and distribution. For this report, I define a "regional" assessment area of 74,325 km^2 within which is embedded a "local" 13,416 km^2 assessment area defined by a 25 km buffer surrounding the original course of the Peace River.

Both local and regional areas have a long history of human use. After thousands of years of First Nations use, European influence began with the fur trade followed by agriculture and permanent settlement in the early 1900s. Highways, logging, oil and gas, and hydro-electric development continued through the latter part of the century. Today, many types of human activities emanate from several major population centres and many other smaller communities, with a current annual growth rate of 6.7%.

In the mid-twentieth century, four major hydro-electric dams on the Peace River were proposed. Two were built while the other two were rejected in the early 1980s. However, one dam that was initially rejected has been resurrected for proposed development. This "Site C" dam would impound the Peace River and its tributaries about 7 km southwest of Fort St. John, flooding 5,550 ha of land. The Site C development plan is presently in the final of a three-stage joint federal/provincial assessment process.

Given the existing human activities and impacts within the Peace Break region, the issue of cumulative effects has been raised in the evaluation of the Site C development. That is, this particular major development should be considered in context of the plethora of existing impacts that have and will continue to accrue over space and time. There are several ways in which cumulative effects can be manifested, but the end result is degradation that is greater than would be expected if impacts were considered individually. For wide-ranging species, regional evaluation of cumulative effects is especially important since population viability and stability are greatly affected by spatial patterns of

distribution and the broad-scale movement of individuals and their genes. Moreover, such an assessment should be comprehensive with respect to human use and underlying conditions since the requirements of these species can be affected by development associated with multiple resource values as well as natural factors. Finally, cumulative effects assessment should consider the spatial pattern of impacts since most species are greatly affected by habitat connectivity and fragmentation at different scales.

2. Focal Species Profiles

Aside from conservation issues that may be unique to individual species, wide-ranging species are appropriate surrogates for focus in the conservation of biodiversity and associated natural processes at broad, regional scales. In modeling for the assessment and mitigation of cumulative effects, I have therefore selected a suite of species representing the array of regional ecosystem conditions while also being sensitive in different ways to anthropogenic impacts. These focal species are: grizzly bear, lynx, fisher, wolf, wolverine and woodland caribou. Since the Site C development would have implications to the aquatic ecosystem, I have also considered bull trout and Arctic grayling but through qualitative assessment. For each species, I profile ecological requirements, local knowledge, impacts and threats as well as current status and conservation.

3. Evaluating Landscape Effectiveness & Connectivity in the Context of Cumulative Effects

For each terrestrial focal species, I evaluated the potential influence of present and future cumulative human impacts on the underlying potential for landscape-level habitat effectiveness and connectivity at the population level. Spatial modeling was based on the best available data and current understanding relevant to predicting species occurrence and distribution across the Peace Break assessment areas. This involved assembling GIS coverages from data sources of climate and physiography, land cover and vegetation, and human use. From this spatial database, I derived predictive factors for modeling species requirements and cumulative human impacts. Modeling approaches varied among species as did the nature and scale of information on which modeling was based. Modeling scales were determined for each species on the basis of known or expected female core home range size.

In addition to current habitat conditions and resulting landscape potential, human accessibility to the landscape is perhaps the most relevant predictor of population fragmentation among species. To account for cumulative human influence on each species, I therefore applied a modeling approach that considers human travel time to a given site on the landscape as influenced by biophysical conditions and human features that facilitate access and travel speed. Modeling accounts for accessibility from all centres of any resident human population and the size of those centres. Output is interpreted in terms of the ease of landscape accessibility by, and remoteness from, people. Considering the nature of human impacts to each focal species (Chapter 2), I approximated the shape of the relationship between human population access and the potential that each species may persist and move within or among occupied landscapes. Based on these curves, I transformed the index of human population access to human impact factors that I then applied to estimate realized landscape effectiveness for each species.

I compared model outputs among three scenarios: (1) "undisturbed" conditions with current land cover attributes but no human influence; (2) "current impact" considering all present human infrastructure, population and development; and (3) "future year 2036" involving projected regional population growth given existing demographic trends and completion of the proposed Site-C hydro-electric development. The latter scenario is likely to be a conservative estimate of future impacts in that it does not (cannot) account for additional features representing human use and development in the future. I compared impacts among scenarios, measuring average landscape effectiveness across defined assessment areas. I also quantified landscape connectivity for each species by calculating the area/perimeter ratio among four isopleths of landscape effectiveness. I interpreted impacts based on the change in both average landscape effectiveness and associated fragmentation.

Results reflect the differing nature of cumulative impacts and the potential for landscape occupancy and connectivity among species, with significant changes apparent among scenarios. Absolute reductions in regional landscape effectiveness among species range from 7% to 47% at present, and projected loss of 11% to 55% in 25 years. Within the local assessment area, reduction in landscape effectiveness among species ranges from 13% to 55% at present, and projected loss of 19% to 62% in 25 years. Impacts are compounded by increased fragmentation that is apparent for most species at either or both analysis scales.

In the specific consideration of landscape flooding due to hydro-electric impoundment, fishers have the greatest potential among species to suffer major loss of occupied landscapes. The loss of biologically productive and seasonally important riparian and floodplain habitats is also undoubtedly significant for other focal species. But it is the effect of such landscape flooding on the movements of individuals and hence the connectivity of the larger population that is of particular concern. For these species, major reservoirs are unlikely to constitute absolute barriers to movement but will clearly reduce landscape permeability. The potential for individuals to traverse such impoundments will depend on the proximity and effectiveness of core habitat areas. Hence, mitigation strategies should seriously consider the potential for enhancements to habitat protection, productivity and security in landscapes that have high inherent potential for given species and are adjacent to existing or proposed impoundments.

4. Conclusions & Recommendations

Although the nature of impacts does vary among species, I judge that net cumulative impacts at both regional and local assessment scales are significant for all species at present. The threshold of population persistence has undoubtedly been exceeded in many landscapes and the resulting threat of population fragmentation is likely to increase, reducing the stability and viability of regional populations. There does also appear to exist for each species at least some secure and effective habitat areas that are likely to sustain productive individuals and connected population cores. The protection and enhancement/recovery of those landscapes comprising effective core habitat area and their linkages will be essential in conservation planning for these species. However, the direct and indirect impacts of the Site C hydro-electric development and impoundment will further erode the potential for local and regional landscapes to support the wide-ranging species considered herein. Effective conservation is, therefore, a less likely outcome if Site C is to proceed.

The species considered in this assessment are effective indicators for broad-scale conservation of intact terrestrial communities. The modeling and analytical outputs provided herein can assist in the planning process, particularly in defining landscapes where specific mitigations and/or zoning are likely to be most effective. Planning efforts should focus on the protection and enhancement of landscape conditions that facilitate core population areas and connecting linkage zones. Fundamental is the management and reduction of human access, especially motorized, coupled with appropriate habitat management. Conservation strategies should also address emerging fracture zones. These fractures are often associated with highways and associated concentrations of private land and residences. However, the course of the Peace River and its hydro-electric impoundments also contribute to potential fracture of populations for most of the species considered in this report. Here, connectivity may be best conserved and/or enhanced through increased protection of adjacent landscapes from further human access and impacts. Where attractive, secure and productive, these landscapes will increase the potential for successful movement across impoundments by a given species.

Primary concluding points are as follows:

- For wide-ranging species, evaluation and mitigation of cumulative human impacts is most relevant at broad scales of regional population distribution and should consider the potential for landscape occupancy, productivity and population connectivity.
- I judge the net cumulative impacts at both the regional and local assessment scales to be significant for all wide-ranging terrestrial species considered.
- A threshold of population persistence has undoubtedly been exceeded in many landscapes and resulting population fragmentation is a threat.
- The direct and indirect impacts of Site C hydro-electric development and impoundment will further erode the potential for local and regional landscapes to support the wide-ranging species considered herein.
- Bull trout and Arctic grayling fish are also under pressure from a number of inter-related impacts within the Peace Break region. The Site-C development will clearly affect these species in different ways but the net impact and the nature and extent of planned mitigation is unclear.

- Projected human population and development trends suggest that the stability and viability of focal species populations may be further compromised in the future without proactive conservation planning.
- There may be opportunities for increased protection of some landscapes, contributing to the enhancement and/or recovery of secure and effective habitat areas for multiple species.
- Management and reduction of motorized human access is central to effective conservation planning. Habitat management appropriate to local ecosystems and associated regimes of natural disturbance is also important. Habitat enhancement should be planned in concert with human-use management to avoid the potential for localized conflict with people and/or increased mortality among focal species.
- Special attention should be given to measures that can enhance habitat effectiveness and security adjacent to potential population fractures through which some movement by a given species is possible and desirable. The landscape directly east of the W.A.C. Bennett Dam that is not subject to flooding should be of high conservation priority as a multi-species linkage zone.

1.
BACKGROUND

INTRODUCTION

The Yellowstone to Yukon (Y2Y) conservation initiative was borne out of the need for coordinated, cross-jurisdictional advocacy for broad-scale ecological connectivity that is critical to the conservation of biodiversity and the protection of wilderness values. The Y2Y inter-jurisdictional focal region encompasses the Rocky Mountain cordillera, stretching from south of Yellowstone National Park to the arctic circle near the Yukon/Alaska border. This continuous swath envelopes core wild lands intermixed with landscapes managed for a range of other human uses and values. The state of ecological connectivity and associated threats varies among local regions, and wide-ranging species are often applied as surrogates in the conservation of biodiversity and associated natural processes across broad, regional landscapes.

Within the Y2Y expanse, the Peace River Break of northeastern British Columbia is a region of considerable physiographic and ecological diversity. But the Peace Break is also an area with a long history of settlement, industry and development, with relatively little protected area representation and a significant human "footprint" at present (Lee & Hanneman 2012). In this region, there are obvious impacts and notable threats to many species and ecological systems, and it can be expected that population connectivity for several wide-ranging terrestrial species and some aquatic species has already been highly constrained if not potentially fractured. This impact could be exacerbated by additional cumulative effects resulting from proposed major developments such as the Site-C hydro-electric dam and impoundment, the Northeast Transmission Line, and the Northern Gateway Pipeline as well as other industrial development trends.

This report describes an extensive, broad-scale assessment of cumulative human impacts and their influence on landscape potential to support wide-ranging terrestrial species across the Peace Break. Terrestrial species addressed are associated with a range of ecological conditions that are broadly represented within the larger region. There are two parallel and related aspects to this assessment:

1. understanding current and potential-future changes to the ability of specific landscapes to support focal species, and
2. understanding spatial patterns of population connectivity that is of importance in the long-term stability and resilience of these species and the ecological communities they represent.

In addition to evaluating and characterizing impacts, I interpret results of this assessment with respect to options and opportunities to potentially mitigate the cumulative effect of historic and future development on landscape connectivity and associated biodiversity values.

PEACE BREAK ASSESSMENT AREAS

In a world dominated by human activity, the Rocky Mountain cordillera of North America, from Yellowstone to Yukon (Y2Y), is composed largely of wild lands that are relatively intact to various degrees. One key zone in the Y2Y ecoregion is that which straddles the Peace River watershed of northeastern British Columbia, with the Peace River providing a natural east-west break in the Rocky Mountain ranges. This area is ecologically diverse with a long history of First Nations use and later European settlement. In contrast to most other Rocky Mountain regions, the Peace River Break has little protected area representation and a substantial existing human development footprint. This, combined with natural constraints results in a critical "pinch-point" in the continuity of ecologically intact and functioning landscapes along the north-south extent of the Canadian Rocky Mountains. The tenuous continuity and unique ecological values of the Peace Break are potentially threatened by the "cumulative" impact of industrial expansion and acceleration including several major developments currently proposed. The assessment area addressed in this report is an integral part of the much larger Y2Y region (Figure 1).

Within the general region of the Peace Break, I have defined specific "regional" and "local" assessment areas for this analysis (Figure 2). A regional assessment area of 74,325 km^2 is defined in terms of dominant climatic and physiographic zones (see Biophysical Description, below). Embedded within this, a smaller local assessment area of 13,416 km^2 is defined by a 25 km buffer surrounding the original course of the Peace River.

Biophysical Description

The Peace Break region is centered on drainages of the Peace River which has the distinction of being the only river to flow eastward through the Rocky Mountains. From its source in the Rocky Mountain Trench, the Peace River runs east through a break in the Continental Divide. The Finlay and the Parsnip Rivers are the major sources of the Peace, the confluences with which were flooded in 1968 by the Williston Reservoir. The "break" in the Rockies through which the Peace River flows channels relatively warm, moist Pacific air east of the Rockies where Arctic air typically dominates. The result is a moderated climate and relatively unique ecological conditions.

Ecologically, the Peace Break assessment region is tremendously diverse and is represented by the merging of six physiographically distinct ecoregions each with unique ecosystems (Demarchi 2011). These ecoregions include the Central Canadian Rocky Mountains, the Fraser Basin, the

Omineca Mountains, the Southern Alberta Upland, the Peace River Basin, and the Central Alberta Uplands (Figure 3).

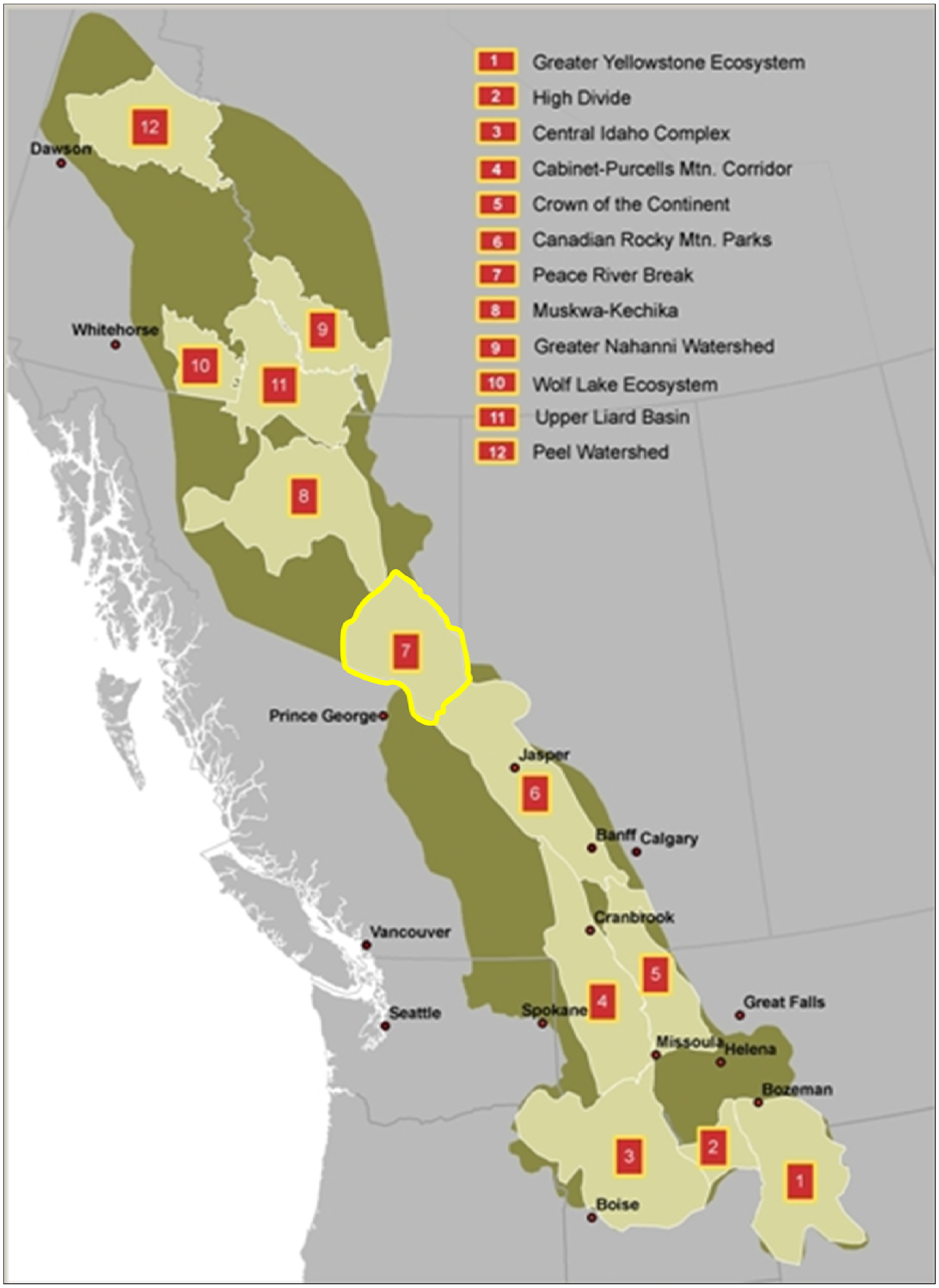

Figure 1. The Peace River Break priority area (#7, highlighted yellow) of northeastern British Columbia within the Yellowstone to Yukon (Y2Y) ecoregion.

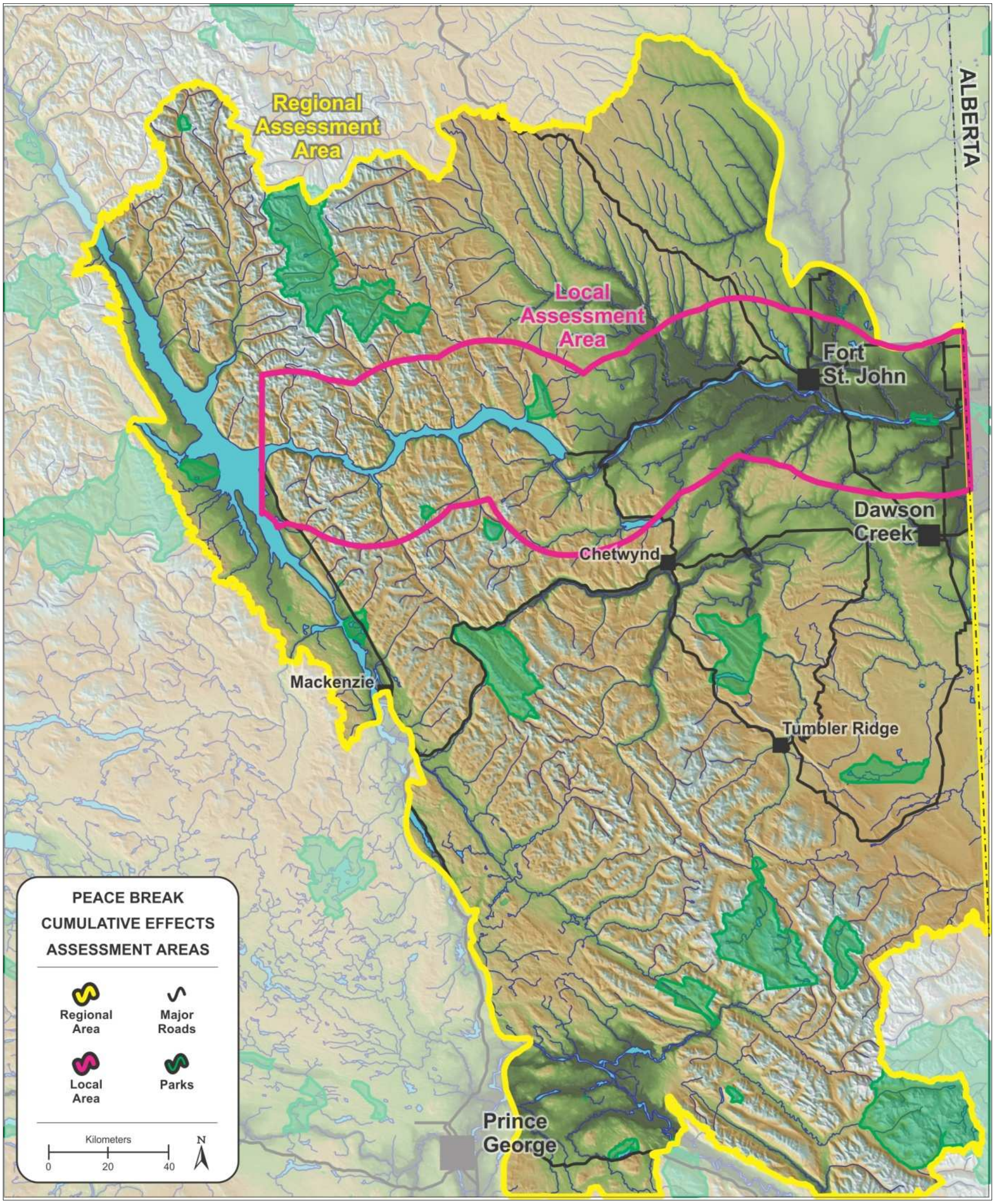

Figure 2. The "Peace Break" region of northeastern British Columbia and both the regional and local areas defined for evaluating the cumulative impact of human activity on select wide-ranging focal species. The regional area is defined by dominant climatic and physiographic zones within British Columbia (see text for details) and does not precisely correspond with the Peace Break region delineated by Y2Y.

The *Central Canadian Rocky Mountains Ecoregion* consists of steep-sided, but round-topped mountains and foothills that are lower than ranges of the Rockies to either the south or the north. There are four Ecosections contained within. The driest is the *Hart Foothills Ecosection*, an area of low, rounded mountains and wide valleys on the east side of the Rocky Mountains. Here, cold Arctic air often stalls along the eastern margin or in the valleys. Within the *Hart Ranges Ecosection*, mountains build in height from north to south and form a low barrier to the eastward moving Pacific air or south-westward moving Arctic air. The rugged *Misinchinka Ranges Ecosection* is a highly mountainous area with deep narrow valleys over which moist Pacific air typically stalls bringing high summer and winter precipitation. The *Peace Foothills Ecosection* is a blocky mountain area on the east side of the Rockies, and is associated with strong rain shadows.

The *Fraser Basin Ecoregion* consists of broad, flat lowlands and rolling uplands, located in the central plateau area of the interior of British Columbia. Two of its three Ecosections occur in the Peace Break assessment area. The *Babine Upland Ecosection* is a rolling upland with low ridges and several large lakes in the depressions. The *McGregor Plateau Ecosection* is rolling upland adjacent to the Hart Ranges, and is associated with a cool moist climate.

The *Omineca Mountains Ecoregion* consists of several groups of rounded mountains that are more prominent in the north than the south. The *Manson Plateau Ecosection* is a rolling upland, that lies south of the higher Omineca Mountains and receives a flow of moist, warm air from the southwest. The *Parsnip Trench Ecosection* is a wide intermountain plain that lies between the Omineca Mountains to the west and the Rocky Mountains to the east. Here, warm, moist air flows in from the south and cold Arctic air moves south down the Northern Rocky Mountain Trench.

Within the *Boreal Plains Ecoprovince*, the *Southern Alberta Upland Ecoregion* is a rolling upland that rises from the Peace River Basin to the north and culminates in the Rocky Mountain Foothills to the south. This Ecoregion is represented by only one Ecosection within the assessment area. The *Kiskatinaw Plateau Ecosection* is a flat upland incised by the Murray, Kiskatinaw and Wapiti rivers, and with numerous wetlands in upper drainages

The *Peace River Basin Ecoregion* is a wide, low elevation plain that lies between rolling uplands to the north and south, bisected by the Peace River and its tributaries. This ecoregion extends eastward from the Rocky Mountain Foothills above the Peace River into Alberta where it turns northward to the base of the Caribou Mountains. Within the assessment area, the *Peace Lowland Ecosection* is a large lowland of deep sedimentary bedrock deeply incised by the Peace River and its main tributaries. In addition to the Peace River, drainages include the Moberly, Pine, Kiskatinaw, Halfway and Beatton rivers in British Columbia, and the Pouce Coupe, Clear and Smoky rivers in Alberta. Included is the large Moberly Lake as well as many smaller lakes, wetlands and muskeg. The relatively low elevation Peace Lowland Ecosection has the mildest climate and lowest snowfall in the Boreal Plains Ecoprovince.

Rising to the north of the Peace River is a rolling plateau defined as the *Central Alberta Uplands Ecoregion*. It extends east from the Rocky Mountain foothills, and is often associated with cold Arctic air. Within, the *Clear Hills Ecosection* is a smooth rolling upland that gradually rises in elevation toward the north and east into Alberta. The *Halfway Plateau Ecosection* is a rolling upland with some higher ridges. Valleys are wide and bisected by small, southward flowing streams.

The typical pattern of overstorey vegetation within the assessment area as a function of climate, soils and topography is defined by the provincial biogeoclimatic ecosystem classification (BEC; Meidinger and Pojar 1991). The foothills and plains east of the Rocky Mountains represent the southern extent of the boreal forest. They are dominated by the Boreal White and Black Spruce (BWBS) BEC zone with a moist warm variant that extends from near where the Rocky Mountains cross the Alberta border, north to near the Beatton River. Aspen poplar is the dominant overstorey across most of this BWBS variant due to fire history and other human disturbance, while balsam poplar (*P. balsamifera*) occurs on wetter seepage sites. Where disturbance has been limited, white spruce is present on moist to wetter sites. Lodgepole pine is a seral species typically associated with dry and less productive sites. Black spruce interspersed with tamarack are often associated with organic soils.

Within the assessment area, overstorey conditions within the Rocky Mountains are generally defined by the Englemann Spruce/Subalpine Fir (ESSF) BEC zone, with a Boreal Altai Fescue Alpine (BAFA) Zone at higher elevations. Lower elevation slopes and valleys fall within the Sub-boreal Spruce (SBS) zone. The SBS also occurs in the landscape around the Williston Reservoir, and plateau country to the west of the Rocky Mountains. The assessment area also includes a small part of the northernmost reaches of the comparatively wet Interior Cedar-Hemlock (ICH) Zone in the south-west end of the region in the Rocky Mountain Trench.

Reflecting the considerable variation in ecosystem conditions described above, the Peace Break assessment area supports tremendous diversity of native wildlife and fish species, although abundance and distribution has been reduced for many. Carnivores include black (*Ursus americanus*) and grizzly (*U. arctos*) bears, grey wolf (*Canis lupus*), Canada lynx (*Lynx canadensis*), wolverine (*Gulo gulo*), fisher (*Martes pennati*), and American marten (*M. americanus*). Ungulates include bighorn (*Ovis canadensis*) and Stone (*O. dalli stonei*) sheep, mountain goats (*Oreamnos americanus*), elk (*Cervus elaphus*), white-tailed (*Odocoileus virginianus*) and mule (*O. hemionus*) deer, moose (*Alces alces*) and woodland caribou (*Rangifer tarandus caribou*). Common raptors include bald eagles (*Haliaeetus leucocephalus*) and great horned (*Bubo virgineanus*) owls. Fish include bull trout (*Salvelinus alpinus malma*) and arctic grayling (*Thymallus signifer*). Many other avian, terrestrial and aquatic species also occur in the region and in association with the Peace River, including at least 20 Threatened (blue-listed) species (KWRL 2009).

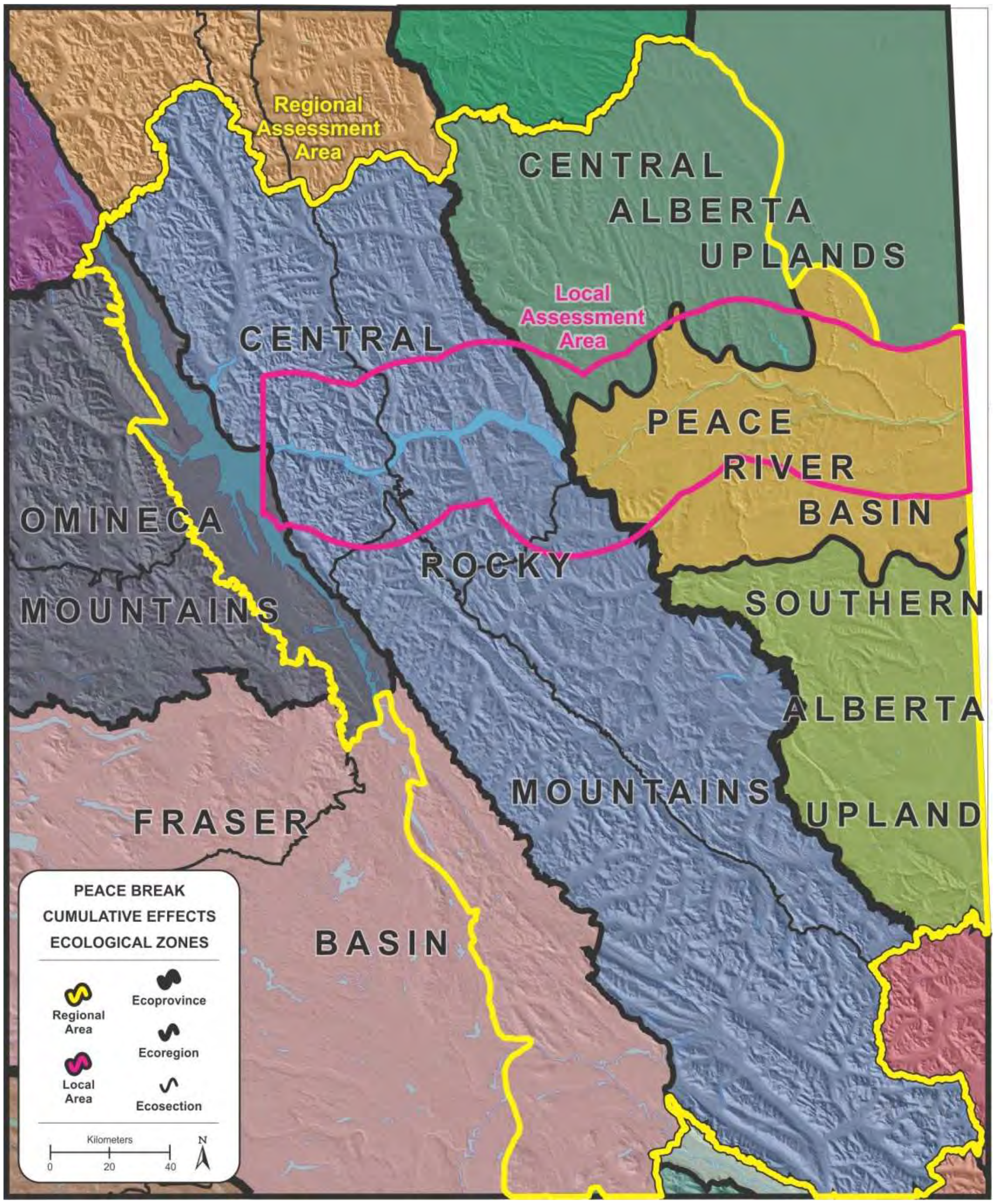

Figure 3. Broad physiographic and climatic zones defining the "Peace Break" region of northeastern British Columbia and the regional and local assessment areas addressed herein.

Human Use - Historic, Present, and Future Trend

As a reflection of the ecological diversity, the Peace Break region and the Peace River Valley in particular has a long history of human use. First Nations peoples have lived in and used the area for at least 10,000 years, with the two main language groups in the Peace River area being the Athapaskan and the Algonquian. The Dunne-za people traditionally occupied the eastern part of the assessment area, while the Sekani people were located in the west that included the upper reaches of the Peace River and what is now Williston Lake (BC Ministry of Education 2012). European influence began with the fur trade in the late 1700s (Clare 2004). However, the British Columbia portion of the Peace did not attract significant permanent European settlement until about 1912 when the land was first opened up and extensively sold off by the federal government for homesteading, which was highly successful given the rich soils. This was the last great wave of agricultural settlement in Canada, as the Peace River Valley's value for agriculture was largely unknown until this time given its isolation from the prairies. The Alaska Highway was built in 1942/43 beginning in Dawson Creek and running along the east flank of the Rockies, and travel to and through the area was further improved after 1945 and World War II. Oil and gas exploration and development began shortly after, further increasing road development. This included the 1952 John Hart Highway linking Dawson Creek to Prince George. The huge WAC Bennett Dam at Hudson Hope was constructed in the mid 1960s (completed 1968) creating the Williston Lake/Reservoir on the upper Peace River and flooding confluences with the Finlay and Parsnip rivers. Downstream 23 km from this dam, the Peace Canyon Dam was completed in 1980. In addition to the massive impact of these structures and their impoundments to aquatic communities upstream, reduced downstream flows of the Peace River has had severe consequences that involve impacts to migratory birds, furbearers, fish, and aboriginal lifestyles (Green 1992).

At present, the Peace Break region supports a significant human population mostly distributed in and around several major centres. These include Fort St. John and Dawson Creek with populations between 10 and 20 thousand, Mackenzie and Fort Nelson at around five thousand people, Chetwynd and Tumbler Ridge at two to three thousand, as well as Taylor, Hudson's Hope and Pouce Coupe at around one thousand people. In addition to several other smaller communities, there are five First Nations Communities within the assessment area. Part of the Treaty 8 Tribal Council are the West Moberly Nation at the west end of Moberly Lake, the Saulteau at the east end of Moberly Lake, the Halfway River north of the Peace River, and the Tsekani at McLeod Lake. The Kelly Lake Cree Nation is in the eastern part of the assessment area near Kelly Lake south of Dawson Creek. Within the Peace River Regional District, the resident human population grew 6.7% between 2007 and 2011, from 60,220 to 64,280 (BC Stats 2012). To the year 2036, this growth rate is expected to decline somewhat under current demographic trends but increasing a further 23.5% to 79,384 (AMEC 2010) (Figure 4).

Human communities throughout the assessment area are presently supported by several primary industries. The area is a prominent producer of oil, natural gas, coal, and hydro-electricity. The forest industry has expanded to produce pulp, lumber and particle board with mills in Chetwynd, Dawson Creek, Taylor and Fort Nelson. The agricultural industry has also continued to be an economic mainstay, producing oil seeds, grains, cattle, bison and other livestock. In most recent years, oil and gas exploration is at an all time high and the human population is increasing significantly. Other major developments with potential for significant individual and/or cumulative impact include the Site C hydro-electric dam and impoundment, the Northeast Transmission Line, the Northern Gateway Pipeline, coal and coalbed methane development, mineral mining, and wind-energy development. Tourism has also become an important aspect of the economy, especially along the Alaska Highway. Relative to most other regions of British Columbia, there is relatively little protected area representation within the assessment area (MOE 2007) with most current protection situated in the Rockies well north and south of Williston Lake (Figure 2). Road access is extensive, especially in the east, but the Hart Highway and two railroads also bisect the region east-west.

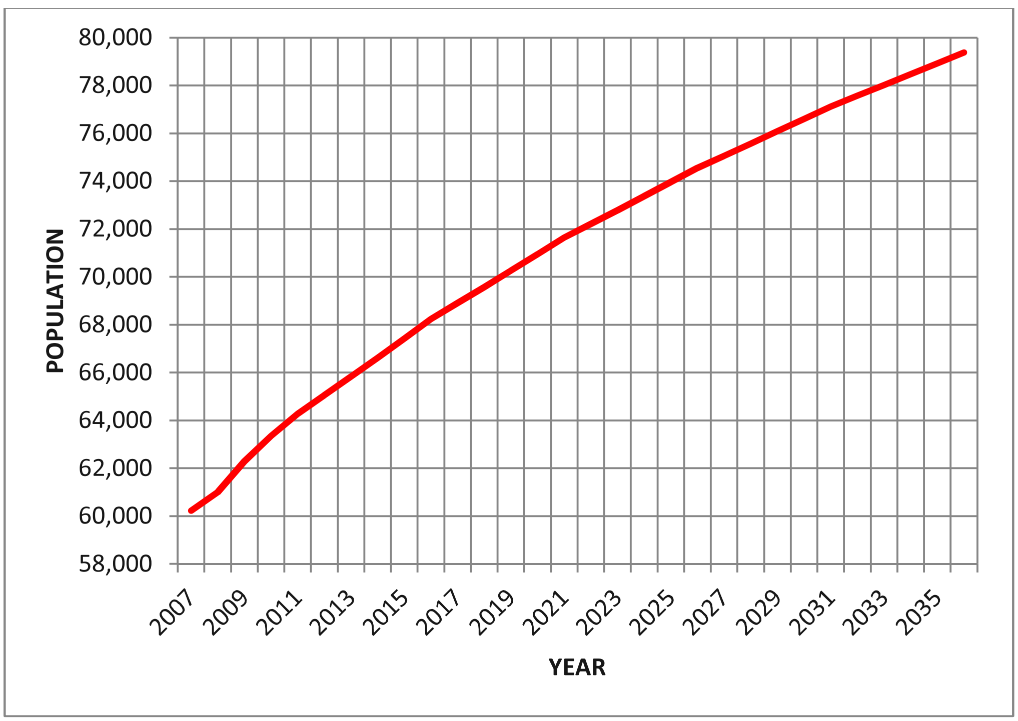

Figure 4. Human population growth projections within the Peace River Regional District. Years 2007 - 2011 are based on census data (BC Stats 2012) and 2012 to 2037 are based on growth rate projections that vary in 5-year increments (AMEC 2010).

The Proposed Site C Hydro-Electric Dam and Impoundment

In the mid-twentieth century, four major hydro-electric dams on the Peace River were proposed (Wikipedia Contributors). As described above, two of these dams presently exist. "Site A" was what is now the massive WAC Bennett Dam that began operating in 1968, flooding the upper Peace River basin to create the 1,761 km^2 Williston Reservoir, the largest lake in British Columbia. Located 23 km downstream of this dam and 6 km southwest of Hudson's Hope, "Site "B" was what is now the Peace Canyon Dam completed in 1980 to impound a 21 km reservoir called Dinosaur Lake. "Site C" was proposed 83 km further downstream beyond the confluence with the Moberly River and roughly 7 km southwest of Fort St. John. This project was rejected after a 1982 BC Utilities Commission hearing and again in 1989. The fourth proposed dam was "Site E" near the BC/Alberta border but it was also not considered for development after the 1982 hearing.

In April 2010, the British Columbia government announced the intention to move ahead with the potential development of Site C pending regulatory review including environmental assessment and consultation. The government's intention is for this dam to be producing energy by 2020, providing 1,100 megawatts of capacity and producing 5,100 gigawatt hours of electricity per year (BC Hydro 2012a). The Site C impoundment would flood 5,550 ha of land and about 83 km of the Peace River Valley and the lower portions of the Moberly and Halfway rivers (Figures 5 & 6). The controversial nature of Site C largely pertains to the potential loss of important wildlife and fish habitat, heritage/cultural sites and agricultural land in addition to families, farms and businesses. But there are other concerns about ecological impacts downstream. At the time of this report, the Site C planning and evaluation process is in the final of a three-stage joint environmental review between the Canadian Environmental Assessment Agency (CEAA) and the British Columbia Environmental Assessment Office (EAO). This involves consultation and input by the public, communities, aboriginal groups, property owners and stakeholders (BC Hydro 2012b).

Figure 5. Location of existing hydro-electric projects along the upper Peace River, and the proposed Site C dam and reservoir.

Figure 6. Computer generated rendering of the proposed Site C dam and lower portion of the impoundment of the Peace River (www.bchydro.com).

CUMULATIVE EFFECTS & CONNECTIVITY

The Concept of Cumulative Effects

The notion that human environmental and social impacts accrue cumulatively over space and time stems from the recognition that environmental degradation is largely due to the "tyranny of small decisions" (Odum 1982). In Canada, cumulative effects assessment (CEA) entered the realm of consideration in the 1980s (Peterson et al. 1987), with primary definition as "impacts on the natural and social environment which occur so frequently in time or so closely in space that they cannot be assimilated, or they combine with effects of other activities in a synergistic manner (CEARC 1988)." Cumulative effects can occur in ways that include the following (Sonntag et al. 1987, Davies 1992):

Time Crowding - perturbations that are so close in time that the effects of one are not dissipated before the next one occurs (e.g., continuous displacement from suitable habitat resulting from multiple human activities).

Space Crowding - perturbations that are so close in space that their effects overlap (e.g., resulting in habitat and population fragmentation).

Synergisms - compounding effects arising from multiple perturbations occurring in the same area (e.g., road networks and increasing human populations synergistically increasing wildlife mortality risk).

Indirect Effects - Secondary effects produced after or away from the initial perturbation often by a complex pathway (e.g., various potential mechanisms of habitat displacement or mortality risk due to the number of people in a landscape facilitated by a single development or road network).

Triggers and Thresholds - Disruption to ecological processes that ultimately change system behaviour (e.g., increased risk of regional extirpation due to localized population fracture).

Nibbling - Incremental and decremental effects often applying to each of the above categories (e.g., piecemeal development of natural areas resulting in time crowding, space crowding, compounding, and indirect effects potentially exceeding thresholds for species persistence). Because impacts are usually separated in space and time and often differ in degree, environmental degradation can be gradual and unnoticed.

Fundamental to the concept of cumulative effects is that the end degradation is greater (i.e., multiplicative) than would be expected if impacts were considered individually. Specific to wildlife, Salwasser & Samson (1985) specified that cumulative effects must consider all impacts from humans as well as natural events (negative or positive). Species extirpation (local or extensive) and other population impacts are virtually never tied to single developments and are always mediated by underlying habitat conditions and dynamics whether natural or human-influenced. Essential to managing cumulative effects is establishment of common goals and specific thresholds for acceptable impacts, coordinated among government agencies and jurisdictions (Salwasser 1990).

The consideration of cumulative effects differs in several key ways from single project-specific assessments. Project-specific environmental assessments (EAs) generally do not, cannot, or have limited ability to:

- consider additive effects of repeated developments in the same ecological system,
- deal with precedent-setting developments that stimulate other activities that would not have otherwise been viable (i.e., "spin-off" development),
- consider changes in ecological systems that result from perturbations only apparent in a cumulative context (e.g., population fragmentation), and
- develop comprehensive environmental objectives that reflect the broad social goals and values.

In contrast, consideration for cumulative effects requires:

- orientation beyond the project level to the policy-level,
- expanded spatial assessment scale,
- extended planning horizon,
- consideration of the range of relevant ecological systems and mechanisms,
- integration across boundaries of discipline, agency and jurisdiction, and
- an association with monitoring and "adaptive" management.

Importance of Regional Context

As discussed above, CEA is most relevant to comprehensive multi-scale evaluation within the context of larger population areas, current and projected human impacts, and changing environmental conditions. This regional approach is especially important for wide-ranging species given the challenge in balancing their needs against other multiple resource values. It is unrealistic to expect that meaningful assessment of impacts to grizzly bears, for example, could be achieved in highly localized project-specific assessment. Without the regional context, it is difficult to consider the relevance of localized impacts at the most important, population level. Further, CEA should ideally be carried out against regional-level thresholds of acceptable impact. Since no such standards exist in British Columbia as pertaining to any wide-ranging species, the "significance" of any cumulative impact is impossible to determine regardless of how large or small a relative change appears to be. The utility of CEA is thus in comparing among scenarios or in demonstrating the mitigations (e.g., access management) necessary to theoretically balance or offset predicted impacts (e.g., achieve "no net loss").

The Issue of Connectivity

Ecological connectivity is a fundamental principle in the conservation of wildlife, ecosystems and biodiversity (Crooks & Sanjayan 2006). In a general sense, all animal and plant populations are shaped by, and persist because of, spatial connections. Habitat connections are needed for mobile animals to move through and survive within resident home ranges. At broader scales, landscape linkages allow individuals to move among core habitat areas, providing stability to regional populations and allowing range peripheries to be occupied through periodic or continual augmentation. The resulting genetic flow across large connected populations also contributes to localized adaptability to a changing environment and helps to ensure that only genes beneficial to individual fitness are expressed. While the importance of ecological connectivity is well recognized, the concept is also somewhat nebulous and requires specific definition as pertaining to species, habitats, spatial and temporal scales, thresholds and risk. Despite uncertainties and the need for research, the notion of connectivity is nonetheless central to effective conservation planning.

For wide-ranging species, effective conservation planning revolves around concepts reflecting basic tenets of conservation biology (see Noss & Cooperrider 1994, Noss et al. 1996): (1) *productive population cores* – areas that support multiple overlapping reproductive females; (2) *peripheral areas* – surround and connect core areas and into which individuals (especially males and transient subadults) often range; (3) *linkage zones* – landscapes that are likely to allow at least ephemeral residence and movement; (4) *fracture zones* – landscapes that lack options for individuals to move and/or persist; and (5) *perpetually unoccupied areas* – broad areas that extend beyond landscapes where individuals are expected to reside and move regardless of recovery efforts.

A landscape's function in regard to this model is determined by multiple factors and is reflected in the actual density, distribution and connectivity of the larger regional population. The continual or periodic population augmentation that connectivity facilitates can support peripheral populations that may not otherwise persist, and can result in a stable and resilient metapopulation anchored by secure and productive habitat cores (Brown & Kodric-Brown 1977, Fahrig & Merriam 1994). Maintaining genetic flow among historically connected populations also contributes to localized adaptability in addition to the purging of deleterious alleles that can manifest in the reduction of individual fitness and ultimately population productivity and resilience (Schonewald-Cox et al. 1983, Frankham et al. 2002). From both perspectives (demographic and genetic), population connectivity can facilitate ecological and geographic shifts in response to a changing environment such as due to climate change (Root et al. 2003, Parmesan 2006).

The threat to ecological connectivity is greatly influenced by the spatial pattern of human development. Highways often concentrate settlement and development in a manner that can pose a significant threat to ecological connectivity (Foreman et al. 2002, Crooks & Sanjayan 2006). The ways by which major highways influence wide-ranging carnivores and their populations varies among species depending on life-history, behaviour, and human factors. Movements are influenced by highways but also by habitat quality and distribution within and around landscapes that highways bisect. To the degree to which highways coincide with landscapes of preferred habitat across scales, they are an obvious source of mortality by way of either direct vehicle collision or through facilitation of human access and presence. However, the impact of human access and development is dependent and often exacerbated by the inherent potential to support a given species across the larger regional landscape and to facilitate or restrict movement. This potential is often influenced by broad climatic and physiographic conditions but also by localized natural and human features that may include rock and ice as well as major water bodies including hydro impoundments.

Both movement restriction and mortality increase the potential for population fracture and isolation (Young & Clarke 2000, Lindenmayer & Fischer 2006). The resulting loss of gene flow and the potential for inbreeding depression is a concern, though alleviated by relatively little successful movement and breeding (Lande 1988). Of greater concern are the demographic effects of isolation including the loss of potential immigration, augmentation, and recolonization. Species that occur at low densities and/or in limited distribution may be vulnerable to such effects especially near range peripheries. Grizzly bears are particularly sensitive because they exhibit rather low dispersal potential relative to other carnivores, especially among females. Dispersal by young bears is a gradual process that can take years, with adults residing close to their natal ranges and females usually overlapping their mother (McLellan & Hovey 2001b). In North America, highways and associated human-use has had a considerable impact on grizzly bear movement and gene flow (Proctor et al. 2012). Hence, maintaining and enhancing connectivity across regional landscapes requires consideration for specific movement options as well as landscape management for habitat effectiveness and security.

2.
FOCAL SPECIES PROFILES & REVIEW

FOCAL SPECIES SELECTION

By necessity, biodiversity conservation must rely on partial measures or surrogates (Gaston et al. 2002, Sarkar & Margules 2002). In managing for intact ecosystems that balance multiple values it is helpful to consider select focal species sensitive to predominant human influences on natural processes (Lambeck 1997). In many if not most regions, broad-scale habitat and population fragmentation is a primary conservation issue (Crooks & Sanjayan 2006). Species most vulnerable to such landscape fragmentation tend to be wide-ranging with large individual area requirements and typically occur at densities that are low and with inherent spatial variability depending on resource distribution and limiting factors. The dispersal potential of such species also tends to be low or otherwise limited given landscape conditions. These species, which include most large and mid-sized carnivores, are appropriate candidates on which to focus broad-scale conservation planning and in assessing and mitigating cumulative human impacts (Noss & Cooperrider 1994, Lambeck 1997, Gittleman et al. 2001). Given their position at the top of food chains, carnivores also reflect lower levels of ecosystem function and can play important "keystone" roles in maintaining the natural composition of ecosystems (Ray 2005). Finally, western North America remains one of the few parts of the world where wide-ranging species including top predators have largely persisted due to large areas with low human influence and are thus especially relevant to conservation planning here (Soule & Terborgh 1999).

For my assessment across the Peace Break regional area, I selected the following focal species: grizzly bear, Canada lynx, fisher, grey wolf, wolverine, and woodland caribou. These wide-ranging species represent the diverse array of ecosystem conditions across the greater region. They are also considered sensitive to anthropogenic impacts and have experienced substantial range retractions since European settlement (Laliberte & Ripple 2004). As earlier described, the Site C hydro-electric development may have significant implications to the aquatic ecosystem; thus I have also considered bull trout and Arctic grayling in this review. Below, I profile aspects of each species' ecology relevant to understanding and modeling landscape suitability, core areas and connectivity as well as sensitivity, vulnerability and overall resilience (*sensu* Weaver et al. 1996).

SPECIES PROFILES

Grizzly Bear

Overview

The grizzly bear is an iconic species of high public profile in North America and is often held as a focal or "flagship" species in various types of environmental planning and assessment. As a species of special concern in Canada (Ross 2002) and considered "vulnerable" in British Columbia (Conservation Data Centre 2002), grizzly bear management garners attention at local, national and international levels. The province's commitment to grizzly bear conservation is reflected in the BC Grizzly Bear Conservation Strategy (MELP 1995) which seeks to maintain in perpetuity the diversity and abundance of grizzly bears and the ecosystems on which they depend.

Relative to other species, wide-ranging carnivores tend to exhibit low fecundity and large area requirements. Populations thus occur at low densities, exhibit low resilience and require long periods for recovery (Weaver et al. 1996). Among large carnivores, the reproductive potential of grizzly bears is especially low, and grizzly bears are more limited in dispersal ability especially among females (McLellan & Hovey 2001b). Thus grizzly bears are considered particularly sensitive to the decline and depression of populations and the contraction of range due to anthropogenic impacts (Mattson & Merrill 2002, Purvis et al. 2000).

Like many other large carnivores, the primary challenge in grizzly bear conservation pertains to their incompatibility with people as evidenced by the loss of grizzly bear range in the conterminous United States to about 1% of what existed historically, with little potential for recovery (Servheen 1990, Mattson & Merrill 2002). Today, much of the southern fringe of grizzly bear range is defined by the mountains and high plateaus associated with limited human access and settlement (McLellan 1998). The persistence of many southern populations is tenuous and contingent on connectivity among increasingly fragmented core populations allowing the flow and interchange of individuals and their genes (Proctor et al. 2012). Fundamental to grizzly bear population recovery and conservation is the provision of core population areas where incompatible human activities can be controlled, as well as opportunities for bears to move, survive and interbreed among such areas (MELP 1995).

Ecology & Conservation

Grizzly bears are generalist omnivores that historically have been able to occupy a great diversity of ecosystem types, and their ecology can vary considerably among regions depending on local conditions. One study in the southern Canadian Rocky Mountains found grizzly bears to feed on (1) ungulates, especially moose and elk, as well as hedysarum (*Hedysarum sulphurescens*) roots in the early spring, (2) grasses, horsetails (*Equisetum arvense*) and cow parsnip (*Heracleum lanatum*) in early summer, (3) huckleberries (*Vaccinium* spp.) and buffaloberries (*Sheperdia canadensis*) in late summer, and (4) berries, ungulates and hedysarum roots in the fall (McLellan & Hovey 1995).

Important habitats generally include riparian zones, avalanche chutes and stands with appropriate site conditions to produce abundant berries in decades following wildfire (McLellan & Hovey 2001a, Herrero 2005).

More locally, a habitat and demographic study was carried out in the Parsnip drainage that included a rolling plateau and a mountain area where human influence was relatively high and low respectively (Ciarniello et al. 2003, Ciarniello 2006). Here, spring foods included dandelions (*Taraxacum officinale*), stinging nettle (*Urtica dioica*) and sedges as well as emergent vegetation within avalanche chutes such as corms and vetches (*Vicia* spp.). Cow parsnip was used during summer. During fall, huckleberries were important and were concentrated within forest openings and burns, but bears also foraged for ants in dead wood and under rocks and logs. Prior to denning, Parsnip bears may also seek out roots of various plants as well as glacier lily (*Erythronium grandiflorum*) bulbs. Habitats selected by Parsnip grizzly bears in mountainous areas were characterized as non-forested land cover types including mid- to upper-elevation grasslands (e.g., alpine meadows), avalanche chutes, krummholz subalpine fir slide and alder-rhododendron communities. Younger aged forest stands (i.e., burns, cutblocks) were also selected presumably due to the availability of *Vaccinium* spp. fruits. Plateau bears occurred at one-quarter the density of mountain bears and ate more high quality food items such as meat and berries. Plateau bears also appeared to be limited by human-caused mortality in association with forestry road access while the mountain bear population may be regulated by density-dependent factors (Ciarniello et al. 2006). Dens tended to be in alpine areas at mid to upper elevations, and were most often excavations in sloping ground (Ciarniello et al. 2005). Home ranges of plateau bears ranged widely from 64 to 1,607 km^2 for females and 889 to 4,361 km^2 for males. Home ranges of mountain bears varied from 20 to 284 km^2 for females and 117 to 273 km^2 for males (Ciarniello 2006).

Anadromous salmon are not available within the assessment area and other fish species are not known to be of importance to grizzly bears. However, as elsewhere, grizzly bears within the assessment area undoubtedly rely greatly on berries during late summer and fall for the deposition of fat needed for successful hibernation and reproduction. Aside from this, it is unlikely that bear density and distribution is reliant on any single food source but, more likely, it is the diversity of potential foods that influences bear abundance and population stability.

The reproductive potential of grizzly bears is very low. Females do not reach reproductive maturity until the late age of 6 years, after which they produce small litters with long inter-birth intervals, averaging 0.5 - 0.8 cubs per year. With a resulting low intrinsic rate of increase, populations are highly sensitive to adult mortality, and low (<8%) mortality among adult females is considered essential for grizzly bears to persist (Weaver et al. 1996).

Disperal potential among grizzly bears is also relatively low and is a gradual process that can take months or years. The one grizzly bear dispersal study in the Canadian Rockies study found adult bears to reside relatively close to their natal ranges. Females ranges in particular can overlap with their mother and differ by only 10 km while males resided an average of 30 km from their natal range (McLellan & Hovey 2001b).

Grizzly bear conservation largely pertains to the potential for displacement from otherwise suitable habitats and the risk of direct or indirect mortality (LeFranc et al. 1987). Grizzly bears do, however, exhibit a reasonable level of behavioural adaptability, and displacement effects are undoubtedly confounded by habituation and inter-specific spatio-temporal partitioning (i.e., by age, sex, and reproductive status). The more important conservation consideration is mortality risk, primarily related to bear interactions with people and the lethality of those interactions (MELP 1995). Notwithstanding local grizzly bear habitat conditions and population density, mortality risk can be described simply as a function of the number of people in bear habitat (frequency of encounter), and the behaviour of those people including whether they have firearms (lethality of encounter) (Mattson et al. 1996, McLellan 1998). It follows then that human accessibility to the landscape is perhaps the most direct and relevant predictor of potential impact to grizzly bears. These effects are primarily tied to roads (McLellan & Shackelton 1988, Mace et al. 1996, Apps et al. 2004, Nielsen et al. 2004, Waller & Servheen 2005, Ciarniello et al. 2007).

<u>Understanding Cumulative Effects</u>

The provincial Grizzly Bear Conservation Strategy seeks to “maintain in perpetuity the diversity and abundance of grizzly bears and the ecosystems on which they depend throughout British Columbia for future generations” by moderating the impacts of continued development and multiple land uses on grizzly bears (MELP 1995). Grizzly bear conservation is therefore a key issue in many land-use planning and environmental assessment processes across British Columbia. And CEA is highly relevant to grizzly bear conservation planning across multiple scales of space and time. In project-specific assessments, CEA is often applied, ostensibly, in evaluating impacts to wildlife including grizzly bears within a conceptual modeling framework (Figure 7). Modeling limitations typically include:

- our ability to account for underlying grizzly bear habitat quality within and among seasons,
- our assumptions about grizzly bear behavioural response to human activity and the lethality of human activities to grizzly bears,
- our ability to accurately represent human activity types and levels in the model,
- our ability to project human use types, levels, and patterns resulting from the development in question and any other developments or trends that will influence habitat quality or human use within the analysis area, and
- scale-dependency of grizzly bear behavioural and population responses.

Many of these limitations can be addressed through investment in local research along with an accurate inventory of human features and the types and levels of use with which they are associated.

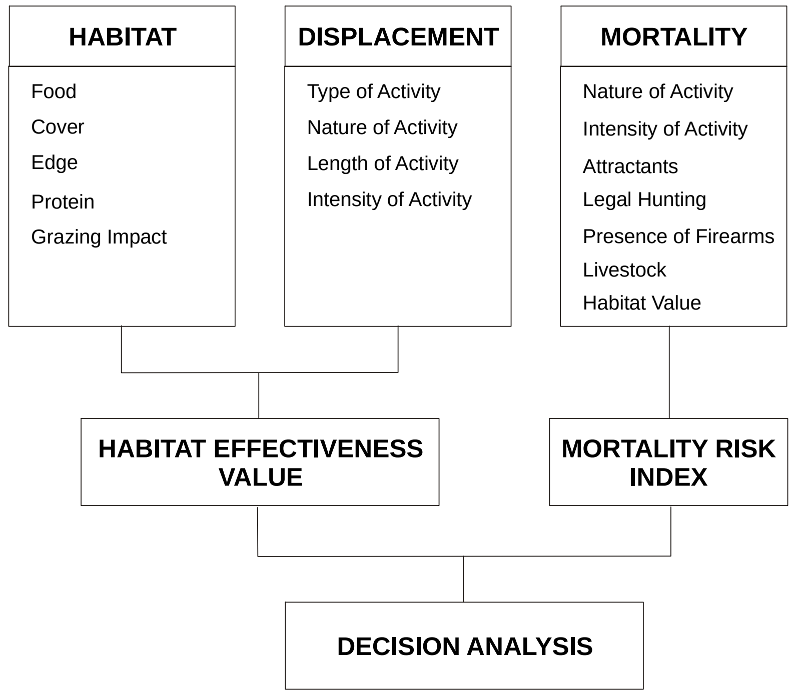

Figure 7. A framework for modeling the cumulative effects of human activity on grizzly bears (Weaver et al. 1986 and USDA Forest Service 1990).

Status & Conservation

The government of British Columbia manages grizzly bears across the province on the basis of grizzly bear population units (GBPUs). These large sub-regional polygons are assumed to reflect our best present understanding of relatively cohesive and manageable populations of consistent behavioural ecotype (Figure 8). The boundaries of GBPUs correspond to geographic breaks or restrictions in population connectivity where known, although notable discontinuity is unlikely to exist among many adjacent units, particularly in the north. The degree of interchange among adjacent units is otherwise expected to vary, with some populations being largely isolated. Since GBPU boundaries are mostly defined subjectively, they may be re-defined or adjusted as new information comes available. Across the province, where mortality and/or cumulative impacts are of concern, subpopulation units defined by management units within GBPUs can be helpful in assessment, mitigation-planning and management (A. Hamilton, *pers. comm.*).

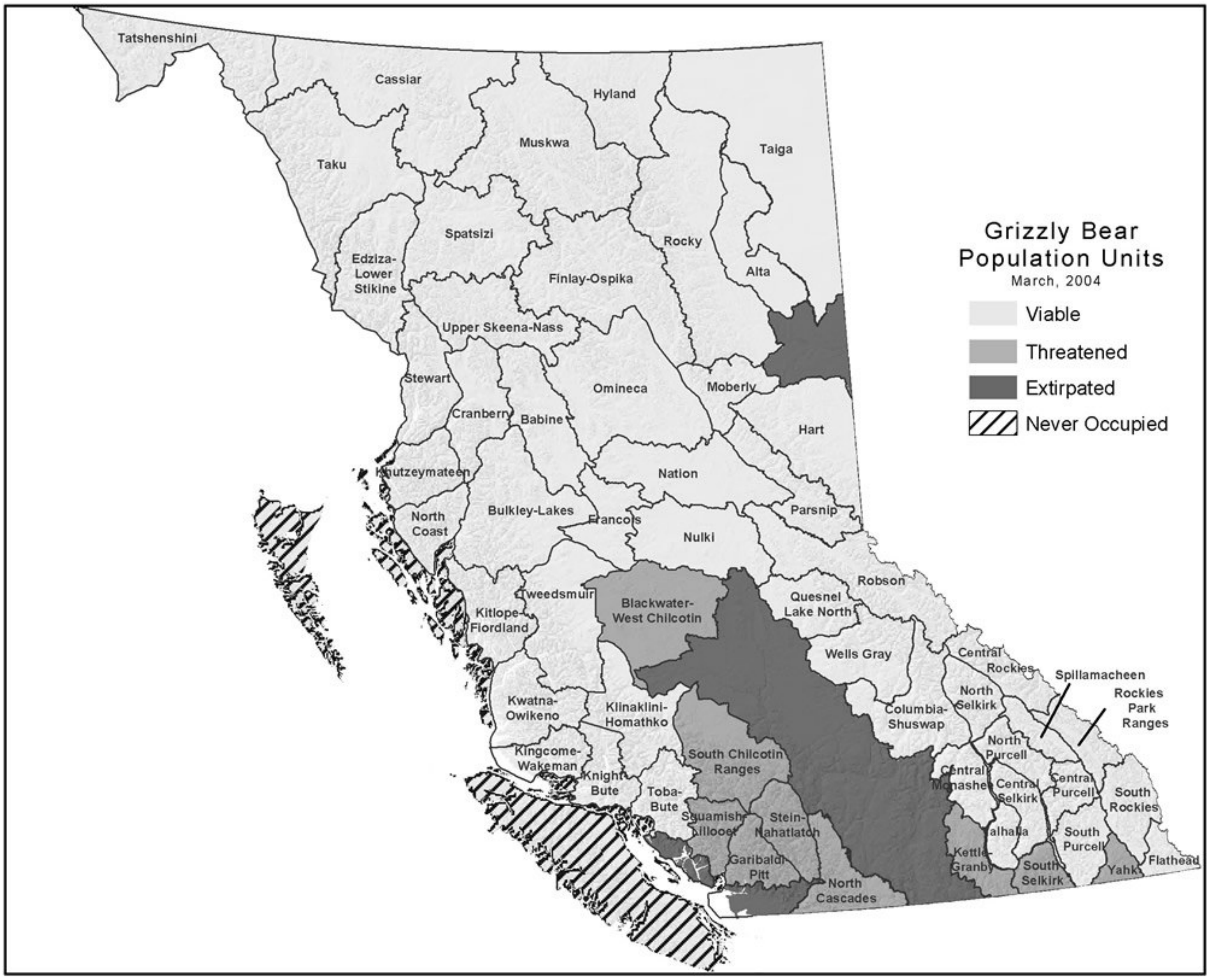

Figure 8. Defined grizzly bear population units (GBPUs), and associated status, across British Columbia (from Hamilton & Austin 2005).

Population abundance and status of grizzly bears has been assessed by GBPU across the province using either subjective or empirical techniques. The primary method to date has been qualitative evaluation of broad-scale habitat potential in the context of assumptions regarding historic human impacts, and augmented with information from sightings records where available (Hamilton & Austin 2004). Where empirical data are not available, some GBPUs have been assessed through model-based interpolation of collective survey results from across western North America (Mowat et al. 2004). In GBPUs where actual population survey/inventory has been conducted, both of the above methods are typically superseded by appropriate extrapolation of these more reliable localized estimates.

Regardless of the assessment method employed, the status of individual GBPUs is classed based on the current population estimate relative to expected potential (carrying capacity) without human impacts as follows: Viable (≥50%), Threatened (<50%), or Extirpated (no reproductive females resident). Threatened populations are mandated for recovery to Viable status, consideration for which may be reflected in land-use planning (e.g., Land and Resource Management Plans) and environmental assessment. Threatened populations are also not subject to legal harvest, but Viable populations potentially are.

The greater Peace Break regional area is comprised of parts of ten different GBPUs including the Hart, Moberly and Rocky units that surround the proposed Site C development. Across most of these, understanding of grizzly bear populations is based on expert opinion or model extrapolation. There have been few survey efforts in the region and most GBPUs are of relatively high priority for inventory of abundance, distribution and connectivity as well as trend monitoring (Apps 2010). The few DNA/hair-snag sampling efforts were well removed from landscapes considered occupied by grizzly bears near to the proposed Site C development. Roughly 110 km northeast of Prince George, the Parsnip/Herrick sampling area covered 9,452 km^2 of both mountainous and interior-plateau topography (Mowat et al. 2002). This area fell largely within the Parsnip GBPU but also extended into the eastern portion of the Nation unit. Population abundance was addressed, and the notable difference in densities between mountain and plateau landscapes was documented. A short distance to the west, ~100 km northwest of Prince George, a 7,031 km^2 area of the Nation River drainage was sampled in 2003 (Mowat & Fear 2004). This area was more centrally located within the Nation GBPU, and the low population density found is expected to have been influenced by the history of human-caused bear mortality in the area. North of the Parsnip, a limited sampling effort was conducted in the Burnt River area during 1997 (Wentworth Associates 1998).

Based on present assumptions, nine of the GBPUs across the Peace Break region are considered Viable though density estimates vary (Table 1). Within these units, grizzly bears are subject to hunting through guide-outfitter allocation and limited entry. Grizzly bears are presently considered extirpated within the lower part of the Peace River basin of the assessment area. Although this means there is no evidence for the residency of reproductive females, it does not preclude the potential for ephemeral movements from adjacent GBPUs that could be characterized as forays by resident adults or subadult dispersals.

Table 1. Assumed grizzly bear populations associated with defined grizzly bear population units (GBPUs) across the Peace Break assessment area of northeastern British Columbia (from FLNRO 2012).

GBPU	Source	Population	Bears/1000 km^2	Hunted?
Parsnip	Model	455	30.8	Yes
Hart	Model/Opinion	244	13.6	Yes
Moberley	Model	71	8.8	No
Nation	Inventory	170	11.4	Yes
Omineca	Model	402	13.4	Yes
Finlay-Ospika	Model	971	31.6	Yes
Rocky	Model/Opinion	538	14.2	Yes
Alta	Expert Opinion	132	4.7	Yes
Taiga	Expert Opinion	94	2.8	No
Lower Peace	Expert Opinion	0	0	No

Caribou

<u>Ecological Overview</u>

Caribou are well adapted to northern climates and associated winter conditions. Five subspecies of caribou are recognized in North America (Thomas & Gray 2002). Woodland caribou (*R. t. caribou*) is the subspecies inhabiting forests from British Columbia and southern Yukon to Newfoundland. Among woodland caribou, three ecotypes occur within BC (Heard & Vagt 1998, Cichowski et al. 2004). All ecotypes rely on lichens as their primary food source but are differentiated according to habitat use and foraging strategies they employ during winter.

Boreal caribou are associated with the relatively flat terrain of the boreal forest in the northeast of the province. These caribou generally inhabit open forests and muskeg where they "crater" for terrestrial (ground) lichens (*Cladina* spp. & *Cladonia* spp.) in the winter.

Northern caribou live in the mountainous part of northern and west-central BC. These caribou typically also forage on ground lichens, using low-elevation or mid-slope lodgepole pine or pine/spruce forests during early winter. During late winter, many typically move to windswept mountain ridges where they continue to crater for terrestrial lichens. Northern caribou tend to aggregate at high elevations during the mid-September to mid-October rut, and females isolate themselves to rugged, high elevation subalpine or alpine areas during calving.

Mountain caribou are associated with the "interior wet-belt" of southeastern BC and a small portion of northern Idaho and northeastern Washington. This area accumulates much deeper snow precluding the ability of caribou to access food through digging. Mountain caribou therefore employ a strategy that involves migrating to low elevations and continuing to ground-forage as snow accumulates. Then as snow deepens but firms up, they move to higher elevations where the snowpack can support them due in part to their large crescent-shaped hooves. Here, in subalpine forests, mountain caribou feed almost exclusively on arboreal (tree-growing) lichens (*Bryoria* spp. and *Alectoria sarmentosa*) through the winter. Forest stands that support an abundance of arboreal lichens and that caribou prefer tend to be of old age.

None of the woodland caribou ecotypes make significant geographic migrations among seasons but do typically make elevational shifts. The northern ecotype will shift either to lower elevations or to windswept ridges during winter, and this may involve some horizontal migration. Whereas mountain caribou typically are at high elevations during summer, shift low during early winter, move high during mid- to late-winter, then again briefly to low elevations during spring.

<u>Status & Conservation</u>

Reflecting a global trend for caribou (Vors & Boyce 2009), many if not most caribou herds in Canada have been in decline in recent decades (Sleep 2007). Populations of woodland caribou in the Southern Mountains National Ecological Area (SMNEA)[1] of western Canada are federally designated as "threatened" meaning that they could regress to a state of imminent extirpation if limiting factors are not reversed (Thomas & Gray 2002). Concerns pertain to anthropogenic impacts, with primary hypotheses related to habitat fragmentation through direct forest modification and increasing road access. Given their federal Threatened designation, the provincial government is required to prepare recovery plans for caribou populations within the SMNEA.

Woodland caribou naturally occur at low densities in small groups or herds. Typically, they are highly dispersed within potentially suitable landscapes that do not support high densities of other ungulates. This limits predation pressure allowing the persistence of relatively stable caribou populations. Widespread habitat modification within landscapes suitable for caribou can concentrate individuals and also promote abundance of, and spatial overlap with, other ungulates for which such change is favorable. This is expected to result in increased exposure of caribou to abnormal predation risk (Wittmer et al. 2007). Within the Peace Break assessment area, caribou are expected to be primarily influenced by the wolf/moose predator-prey system (Chowns & Gates 2004, Seip & Jones 2011). But broader-scale influences, including climate and habitat change, may also shape ecological changes within caribou ranges and predation levels to which caribou are exposed. Potentially, mountain caribou are additionally impacted by the direct loss of old forest stands on which they depend during winter. In addition to the potential influence on caribou predation risk, road access to

[1] The vast majority of the Peace Break assessment area is included within the SMNEA.

and within caribou ranges can increase population vulnerability through direct killing and disturbance. Across BC, unregulated snowmobile activity is also of particular concern in the harassment and displacement of caribou from critical winter ranges that may ultimately increase mortality and hasten population decline (Powell et al. 2004, Seip et al. 2007).

Provincially, northern caribou are "blue-listed" or "of special concern" (formerly termed "vulnerable"), and boreal caribou are "red-listed" meaning they are considered "extirpated, endangered or threatened" (BCCDC 2012). Mountain caribou have suffered severe range reduction and fragmentation of habitat and populations (Apps & McLellan 2006) and are also red-listed within BC. Given their status, woodland caribou are not subject to legal harvest .

The Peace Break assessment area encompasses all or parts of 12 woodland caribou herds of the northern ecotype, and one herd (Hart Ranges) that is considered of the mountain ecotype (Table 2, Figures 9 & 10). The very northeast corner of the assessment area also does catch the southern tip of the Chinchaga herd which are considered boreal caribou. Most northern caribou in the assessment area exhibit the typical winter habitat selection strategies, but some of the small mountain-bound herds (Finlay, Scott, Moberly, Narraway, and Quintette) are thought to occasionally forage on arboreal lichens (Johnson et al. 2004, Jones et al. 2007). South Peace caribou herds are considered especially vulnerable to increasing industrial development within core high elevation summer and winter ranges and within low elevation winter range that is of importance to the Narraway herd. Collectively, these seven herds are included within the *recovery and augmentation plan for woodland caribou in the central Rocky Mountains of British Columbia* (Knowledge Team 2010). All of these herds and the Narraway herd are considered to be in decline (Seip & Jones 2011, ASRD & ACA 2010). The Graham herd has experienced a major decline since the 1980’s, but may have been stable over the past decade (Culling & Culling 2009). The Hart Ranges herd has been stable over recent years (Heard et al. 2010) (Table 2).

Cumulative impacts to woodland caribou across the assessment area can be characterized in terms of loss and displacement from key foraging habitats and associated ranges, increased mortality risk, and reduction in movement options within and among core seasonal landscapes. Conservation strategies include complete protection from industrial development to habitat restoration through forestry-related activities (McNay 2011). Legal (Forest and Range Practices Act) habitat protection is through regulated General Wildlife Measures (GWMs) that apply to Ungulate Winter Ranges (UWRs), and Wildlife Habitat Areas (WHAs).

Table 2. Status and trend of defined woodland caribou herds (populations) partly or fully included within the Peace Break assessment area of northeastern British Columbia.

Herd	Ecotype	Last Survey	Popn Estimate	Range (km^2)	Density per 1000 km^2	Trend	Source
Hart Ranges	Mountain	2010	560	12,466	45	stable	Heard et al. 2010
Narraway	Northern	2008	100	6,372	16	declining	ASRD & ACA 2010
Quintette	Northern	2011	173	6,978	25	unknown	Seip & Jones 2011
Kennedy - Siding	Northern	2011	44	2,962	15	major decline	Seip & Jones 2011
Scott	Northern	2006	60	4,149	14	likely declining	Seip & Jones 2011
Burnt Pine	Northern	2011	13	710	18	declining	Seip & Jones 2011
Moberly	Northern	2011	35	3,291	11	major decline	Seip & Jones 2011
Graham	Northern	2009	311	9,921	31	stable[a]	Culling & Culling 2009
Chase	Northern	2009	475	12,465	38	stable	McNay 2011
Wolverine	Northern	2008	378	10,541	36	stable	McNay 2011
Finlay	Northern	2002	26	8,175	3	unknown	McNay 2011
Pink Mountain	Northern	2000	850	9,583	89	unknown	McNay 2011
Bearhole-Redwillow	Northern	2008	49			likely declining	Seip & Jones 2011
Chinchaga	Boreal	2006	250	13,985	18		

[a] But this herd has declined considerably since the 1980s.

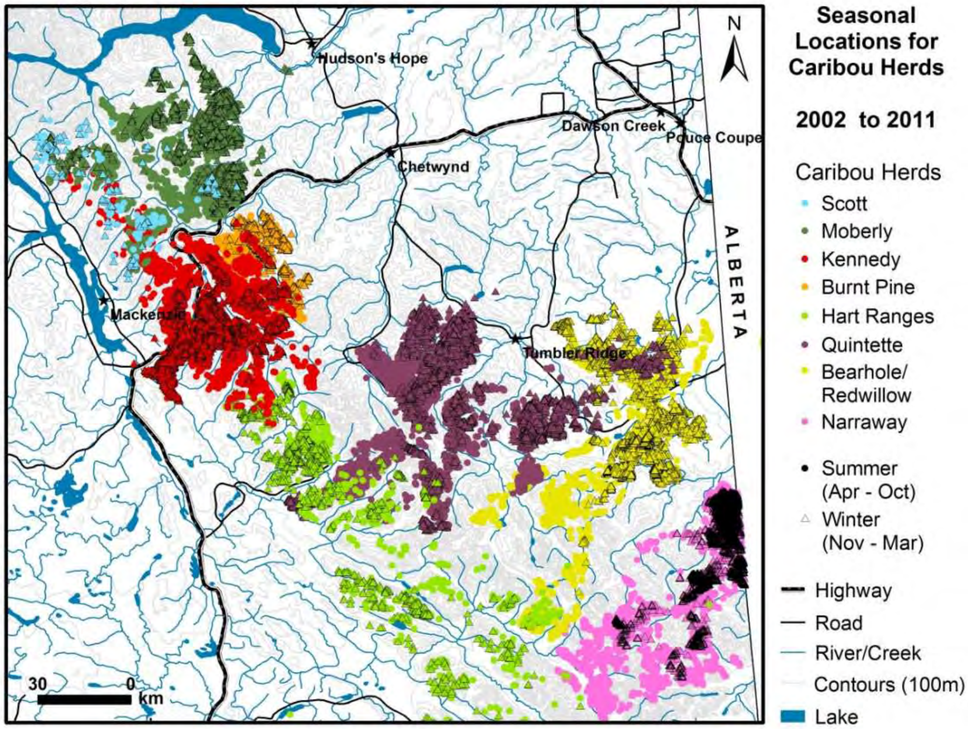

Figure 9. Distribution of woodland caribou of the northern ecotype addressed by the Central Rockies Recovery Implementation Group (RIG) (from RICBC 2012).

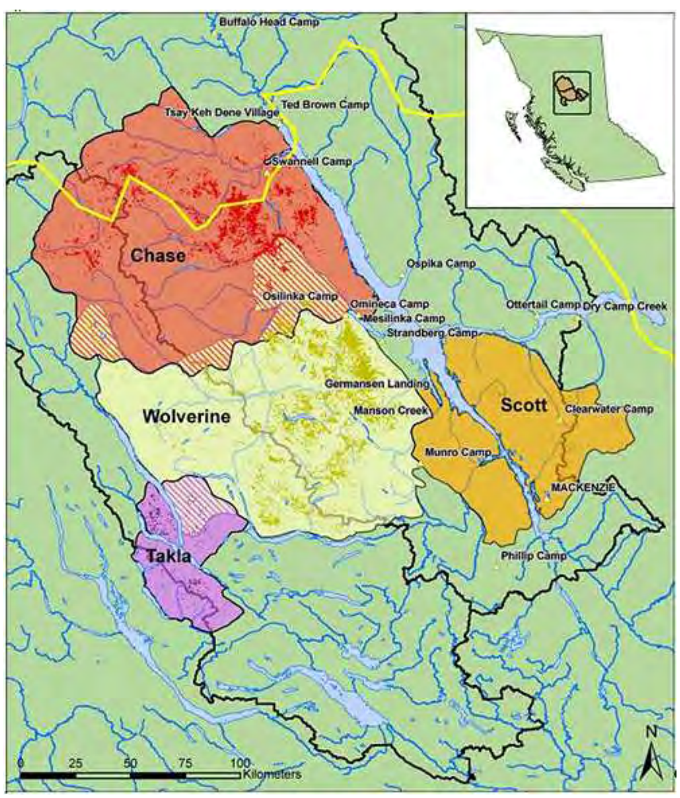

Figure 10. Herds and distribution of woodland caribou of the northern ecotype addressed by the North-Central Recovery Implementation Group (RIG) (from RICBC 2012).

Fisher

<u>Ecological Overview</u>

The fisher is a mid-sized mustelid (weasel family) carnivore that is an uncommon resident of temperate and boreal forests of North America. Much of what is known about fishers has been based on studies done in the largely deciduous forests of the eastern United States and the boreal forest of central Canada (Powell 1993, Powell & Zielinski 1994), but research has been conducted in British Columbia in more recent years (Weir 2003).

Fishers rely largely on snowshoe hares (*Lepus americanus*) but are generalist predators that make use of a variety of prey including shrews (*Sorex* spp.), microtine rodents, tree squirrels (*Tamiasciurus hudsonicus* & *Glaucomys* spp.), passerine and galliform birds, and deer as carrion. The fisher is also one of the few species to prey significantly on porcupines (*Erethizon dorsatum*). Adult fishers are not often preyed upon but compete with canids, felids, and raptors for prey and carrion. Due to their generalist food habits, fisher populations are not expected to be as sensitive to cyclic variations in some prey species as is the case for more specialized predators such as the lynx.

Fishers inhabit both coniferous and deciduous forests and most often occur in older, closed-canopy stands. However, fishers will occupy other forest types including regenerating stands where and when prey is available especially if older structural components remain such as large-diameter residual trees or snags. Unlike the closely related marten (*M. americana*), fishers forage above the snow layer and snow conditions likely influence foraging efficiency and energetics. Fisher distribution is thus limited by deep snowfall and fishers and marten are typically segregated by elevation where sympatric (overlapping). In general, fishers can occur at relatively low elevations, in flat or rolling terrain and in association with mature to old closed-canopy forests, ideally with a component of large deciduous trees. These conditions are often associated with riparian habitats, especially where upland forests are extensively managed for timber values. While there is little known of fishers' response to habitat alteration, they generally avoid forest stands of early succession and/or which lack overstorey cover. Reflecting habitat of potential prey, fisher habitat is often associated with coarse woody debris (CWD) and understorey shrub cover, but CWD can also provide thermal cover to fishers during harsh winter conditions.

Fishers have been extirpated across a significant portion of their historic range, especially within the United States (Powell & Zielinski 1994). Their decline has likely been the result of habitat loss coupled with population overexploitation and predator poisoning programs. Where they persist, western fishers also apparently occur at considerably lower densities, have lower reproductive output, and maintain much larger home ranges than what is known in eastern North America (e.g., M = 219 km^2, F = 49 km^2; mostly intrasexually exclusive; Weir et al. 2008) likely due to greater dispersion of habitat and resources. Within the Peace Break region, fisher density is low, estimated at 8.8 - 11.2

per 1,000 km^2 within the SBS BEC zone (Weir & Corbould 2006) and 11.4 - 23.1 per 1,000 km^2 in the BWBS zone (Weir et al. 2010).

Fishers appear to have relatively low dispersal potential. Juvenile fishers dispersed < 11 km from their natal range in one eastern study, but fishers in the Peace Break area dispersed up to 41 km (Weir et al. 2008). Large, open areas are expected to hinder dispersal and the connectivity, recovery and resilience of fisher populations (Powell & Zielinski 1994). These effects are apparent in the genetic structuring among fisher populations across North America (Kyle et al. 2001).

Fisher populations in British Columbia are thought to have declined in recent decades and fishers may have become locally extirpated in most southern areas where they were historically known, such as the East Kootenay (Apps 1995). Extant fisher populations are generally found within low elevation forests of the central interior as well as the Peace River and Fort Nelson Lowland areas east of the Rocky Mountains (Weir 2003). Habitats are generally associated with the SBS, SWB and BWBS biogeoclimatic zones. Research that has been done suggests that fisher diet is more diverse here than elsewhere and that attributes typical of late-successional forests are required for foraging, resting and whelping and for snow interception (Weir & Corbould 2008). Large, old and degenerating black cottonwood (*P. trichocarpa*), balsam poplar or aspen poplar trees as well as large black or white spruce with rust brooms appear especially important for reproduction and resting and at least partially explain the importance of riparian and spruce-forested floodplains to fishers (Weir et al. 2008, Weir et al. 2011).

<u>Impacts and Threats</u>

Since fisher habitat is generally synonymous with low elevation forests of late succession, including riparian stands, much fisher habitat has been considerably modified and outright lost in BC over the past 100 years (Badry 2004). Impacts have been primarily through forest harvesting, hydro-electric development and land clearing.

Development of valley bottoms for urban and semi-rural settlement has undoubtedly impacted fisher habitat and persistence in some areas. Agricultural development along major river systems resulting in the loss of forest overstorey and important structural attributes must have also had a significant impact. This history of extensive forest harvesting in the province has also certainly been detrimental to fishers through the transformation of late-successional stands to early-seral conditions. In the Peace Break area, the proportion of forest openings as characterized by wetlands and recent logging, were shown to notably decrease the potential for landscape occupancy by fishers (Weir & Corbould 2010). Hence the rate of forest harvesting can have profound effects of the stability and persistence of fisher populations. It is likely that such impacts will continue to accrue especially due to mountain pine beetle (*Dendroctonus ponderosae*) outbreaks affecting much of interior BC, and associated salvage and sanitation logging.

Hydro-electric impoundments have eliminated fisher habitat in several areas of the province. For example, in the Peace region, some of the most productive habitat has been lost due to 1,773 km^2 of flooding to create the Williston Reservoir in 1968. The Ootsa Reservoir also destroyed 700 km^2 of moderately high capability fisher habitat associated with the Nechako River, and about 700 km^2 of potential fisher habitat has been similarly lost through flooding of the Columbia River in the Kootenay Region (Badry 2004).

The proposed Site C development can be expected to result in the direct loss of high quality fisher habitat that supports what may be a core population of resident fishers. A recent DNA/hair-snag survey for fishers was conducted recently along the Peace River Valley within the potential flood zone between Hudson's Hope and the proposed dam site (KWRL 2009). Nine fishers were detected including seven males likely to be resident and one for which sex could not be determined. No individuals were detected on both sides of the Peace River consistent with its alignment with home range boundaries. However dispersing fishers can cross major rivers (Weir et al. 2008) and the Peace River is unlikely to represent a population "barrier" (R. Weir, pers. comm.). Given the detection of males, it is suggested there may be 28 to 35 female fishers in and around the sampling area (KWRL 2009).

<u>Status and Conservation</u>

Fishers are sensitive to human activities, especially habitat modification due to forestry practices, and they are also vulnerable to over-harvest by trapping. Fishers are therefore "blue-listed" in British Columbia meaning they are of special concern and potentially vulnerable to extirpation (BCCDC 2012), although fishers have not been evaluated by COSEWIC federally. Fishers have been an important furbearer in trapping harvest historically and are significant to First Nations, and they continue to be subject to a regulated trapping harvest through much of the central interior of the province. However, the resilience of fishers to trapping harvest is likely to be lower in British Columbia than elsewhere given their ecology and both current and projected habitat impacts. The potential impact of trapping on fisher populations is also likely exacerbated by increased road access associated with resource development.

Wolverine

<u>Ecological Overview</u>

The wolverine is a mid-sized carnivore that is the largest member of the Mustelidae (weasel family) and is holarctic in distribution. Wolverines are associated with tundra, taiga and subalpine environments that include the western mountains of North America where wolverines occur at very low densities (Aubry et al. 2007). Wolverines are well adapted to northern winter conditions and are likely to benefit from deep and persistent snow cover. In British Columbia, wolverines are widely distributed within cool montane to alpine ecosystems but generally do not occur within arid and semi-arid, grassland-dominated and some coastal ecosystems (Lofroth & Krebs 2007). Wolverines likely are extirpated from Vancouver Island, the lower Fraser Valley, the Okanagan Basin and the Thompson Basin. Although there has been relatively little research on wolverines, one study was completed within the Peace Break assessment area (Lofroth 2001). The study area encompassed 8,900 km^2 area of the Omineca, Manson, Mesilinka, and Osilinka drainages directly west of the Williston Reservoir, hereafter referred to as the Omineca study area.

The wolverine is a generalist, making use of a variety of foods potentially available. Ungulates are very important to wolverines and include moose, elk, caribou, deer, and mountain goats. Ungulates are primarily obtained as carrion, especially during winter, though wolverines have been known to attack and kill caribou. Wolverines also opportunistically prey on smaller animals including snowshoe hares, porcupines, ground squirrels (*Spermophilus* spp.), tree squirrels, mice, voles, ground-nesting birds and fish (Banci 1994). Where they occur, hoary marmots (*Marmota caligata*) appear to be a particularly important prey item. Within the Omineca study area, moose were a very important food across age and sex classes, but adult females with kits made extensive use of hoary marmots during summer (Lofroth 2001). The distribution of marmots as well as caribou may influence natal den site selection by female wolverines.

Wolverines breed during spring and summer and exhibit delayed implantation, with litters of 1 - 5 born between late February and mid-April. Reproductive potential is low, with 0.5 - 0.7 kits/year produced per female on average (Weaver et al. 1996). Females initially use a natal den but subsequently move among several maternal dens. Dens are generally located within high, upper subalpine forests and cirque basins with woody debris and large talus. Deep snow cover that persists to the end of the mid-May reproductive denning period appears very important (Magoun & Copeland 1998, Aubry et al. 2007). Dens are typically located within snow-tunnels leading to masses of fallen trees or rocky colluvium (Krebs & Lewis 2000, Lofroth 2001, Magoun & Copeland 1998). Suitable denning habitat may partially limit wolverine distribution (Banci 1994). Kits travel with their mother for one year before dispersing.

Wolverines are well known to move extensively. Within the Omineca study area, males ranged over 1,366 km^2 on average, while females maintained reasonably exclusive home ranges of 405 km^2 (Lofroth 2001). Subadults (particularly males) are typically transient over greater areas than resident adults. Daily movements can be up to 65 km and females can easily move 20 km per day while maintaining a natal den (Banci 1994). Upon dispersal, subadult females tend to remain near to their natal range but males typically disperse more widely with distances of 170 to 378 km reported (Inman et al. 2012). Subadults can remain transient for roughly a year, moving extensively among small temporary home ranges prior to establishing residency (Lofroth 2001).

Core wolverine populations are generally associated with large, remote areas of low human activity and presence. In mountainous regions of BC, females tend to use ESSF biogeoclimatic zones during winter and AT during summer, whereas males will often use lower elevations during winter and ESSF during summer (Krebs & Lewis 2000, Lofroth 2001). Wolverines may benefit from the habitat and food diversity associated with mountainous and ecologically complex landscapes. Wolverines are not otherwise associated with distinct habitat conditions and habitat relationships are undoubtedly influenced by the requirements of species that constitute potential food for wolverines. Habitat use patterns may reflect the availability of carrion in ungulate wintering areas, fossorial rodents in alpine habitats during summer, energetic requirements, and/or human avoidance (Krebs et al. 2007). Recent studies have indicated that wolverine distribution is largely defined by the areal extent of persistent spring snow cover (Aubry et al. 2007, Copeland et al. 2010).

In moving through the landscape, wolverines often use forests with mature to old structural attributes, follow watercourses, and make extensive use of low elevation passes between valleys (Krebs & Lewis 2000, Lofroth 2001). But human features also appear to influence wolverine movement. Industrial activity such as mining, logging and associated transportation may displace or alter movement paths (Lofroth 2001) and landscapes of extensive clearcutting are avoided especially by females (Krebs et al. 2007). Transportation corridors may interrupt wolverine movements (Austin et al. 2000), and can be a mortality source (Krebs et al. 2004). Hydro-electric impoundments can also hinder dispersal movements (Krebs & Lewis 2000, Lofroth 2001). Across their southern range, wolverine populations exhibit genetic structure indicative of a fragmented metapopulation that depends on the functioning of what today is likely tenuous landscape connections to facilitate dispersal among core populations (Kyle & Strobeck 2002). Population connectivity is likely to be hindered by habitat loss, overharvest, major transportation corridors and other anthropogenic factors that limit successful dispersal. Wolverine populations especially vulnerable to population fracture and/or decline are those subject to at least moderate levels of human development and access associated with industrial and motorized recreational activities (e.g., snowmobiling, heli-skiing) (Krebs et al. 2007). Climate change is likely to exacerbate current population fragmentation and isolation by limiting snow persistence to the mid-May end of reproductive denning (McKelvey et al. 2011).

Status and Conservation

Wolverines are "blue-listed" in British Columbia meaning they are of special concern and potentially vulnerable to extirpation (BCCDC 2012)[2]. Federally, wolverines are Endangered in eastern Canada and are considered "of special concern" where they occur from Ontario west (COSEWIC 2012). Wolverines are subject to legal trapping harvest in much of BC where they are recognized as Class 2 furbearers in that they move among trapline areas, cannot be managed within single trapline areas, and are vulnerable to overharvest (Hatler 1989).

[2] with the exception of Vancouver Island where wolverines are "red-listed" or endangered.

Wolverine populations are highly sensitive to adult mortality, and most is due to trapping which is not compensatory to natural mortality (Krebs et al. 2004). Given their low demographic resilience and high degree of apparent population fragmentation, wolverine conservation is best facilitated through *de facto* refugia. Such areas constitute extensive and relatively productive landscapes where populations are afforded protection from harvest such that a source of immigration to the larger regional population is provided. Wolverine refugia also need protection from disturbance and habitat degradation, and planning should consider the importance of landscape connectivity allowing wolverines to move among core areas. Hence, protected areas likely play a significant role in the conservation of wolverines, especially where connected at a regional scale.

Gray Wolf

Ecological Overview

The gray wolf (hereafter wolf) is a generalist predator that was once widely distributed across North America and the rest of the northern hemisphere but their range has been reduced dramatically due to habitat and prey loss, human encroachment and direct killing (trapping, shooting, poisoning). In Canada, wolves are extirpated from most southern, settled and agricultural areas but remain across 85% of their historic range (Hayes & Gunson 1995). Wolves were successfully reintroduced into parts of the northwestern United States twice in the 1990s. Across British Columbia, wolves are wide-spread, with the most continuous distribution and highest densities in the central and northern portions of the province. The species is, however, rare to non-existent in highly developed areas such as the lower mainland and Okanagan valley.

Wolves are highly social and most individuals belong to packs of 5 - 12 that travel, hunt and den together, though they have been known to coalesce into groups of 20 - 30 (Paquet & Carbyn 2003). The size of pack territories varies depending on prey density, pack size, as well as habitat/topographic constraints. Wolves packs have ranged across 1,058 to 3,374 km^2 in the Rocky Mountains, and 583 to 794 km^2 in the Yukon (Paquet & Carbyn 2003). In daily movements within territories, wolves often travel >20 km per day. Wolf population densities are generally low relative to some other carnivores such as bears. Densities almost never exceed 41 per 1,000 km^2, and are usually far lower (Paquet & Carbyn 2003). In the central Canadian Rockies, reported wolf densities of 3 to 4 per 1,000 km^2 are the lowest among stable populations across North America (Paquet et al. 1996, Callaghan 2002).

Wolf abundance and population stability depends on an ungulate prey base, and wolves are highly flexible in their use of available prey and associated habitats. Wolves have potential for extensive distribution throughout Rocky Mountain regions given ungulate diversity and abundance. Studies in the Rocky Mountains, both southern (Boyd-Heger 1997, Kunkel 1997) and central (Weaver 1994, Paquet et al. 1996, Hebblewhite 2000, Callaghan 2002) as well as southeastern BC (Seip 1992) indicate primary wolf prey to be deer, elk, and moose. Among large prey (elk and moose), wolves are more likely to prey on vulnerable individuals, and packs can be highly opportunistic in switching among prey species. Although wolf populations are generally supported by aforementioned ungulate prey, wolves can also be significant predators of woodland caribou where sympatric. Factors influencing wolf predation on caribou, including the abundance and distribution of their primary ungulate prey, is an important issue in woodland caribou conservation (Wittmer et al. 2007; see Caribou section herein). Wolves rely on ungulates as primary prey but will opportunistically make use of smaller species such as beavers (*Castor canadensis*). They also compete with other top predators and may displace and/or kill felids, ursids, mustelids, and other canids (particularly coyotes; *Canis latrans*). But these species may also benefit from carrion made available by wolves (Paquet & Carbyn 2003).

Where human-caused mortality is minimized, wolves are more likely to occur in association with lower elevations and subdued terrain where their ungulate prey tend to be concentrated especially during winter. In the central and southern Rockies, primary wolf distribution and habitat selection have been explained as relatively low elevation, flat terrain, and proximity to both water and roads. Security cover provided by closed coniferous forests may also be important (Boyd-Heger 1997, Callaghan 2002). Wolf distribution is, however, greatly influenced by human access and activity as pertaining to hunting, trapping and predator control (Paquet et al. 1996, Callaghan 2002).

Among large carnivores, wolves are relatively resilient to population impacts. Females can become reproductive as early as two years of age and can then produce litters of 4 - 7 pups annually. With this high reproductive potential, populations can sustain annual mortality rates of 30%. Wolves also have tremendous dispersal ability, with mean distance of 148 km in one study but movements of up to 732 - 917 km documented (Weaver et al. 1996, Boyd & Pletscher 1999).

<u>Impacts and Threats</u>

While wolf populations exhibit high resilience and potential for recovery relative to many other top predators, they are also more vulnerable in some ways. Wolves are more apt than other predators to depredate livestock and thus be targeted for management removal. Wolves are also more susceptible to removal than solitary animals given their social nature and large pack territories. Hence, In addition to prey availability, wolf distribution is mostly a function of human presence and associated mortality risk.

Behaviourally, wolves clearly exhibit a tendency for displacement from human activities. But like many other species, the tolerance of wolves to people depends on available food. That is, wolves are more likely to occur in proximity to people where they are not killed and where ungulate densities are high (Paquet & Carbyn 2003). An animal's response to a given human activity is otherwise likely to depend on many factors including density-dependent territoriality, its association with other conspecifics, reproductive status, its past experience, and inherited tolerance. However, landscape selection by wolves is usually associated with low densities of roads and people. In the central Canadian Rockies, wolf displacement from habitats was apparent when human-use of linear features exceeded 100 people/month. Wolves were further but not completely dislocated above 1,000 people/month, while near complete alienation occurred at >10,000 people/month (Paquet et al. 1996). At a finer-scale, another study showed that wolves clearly exhibited a behavioural response to higher cumulative densities of roads and trails (Whittington et al. 2005). Again, these studies describe behavioural responses assuming that wolves are, in fact, not killed. At a local (i.e., within pack-range) scale, ungulates have been known to seek out human-induced wolf-free refugia, which can influence other species (Hebblewhite 2000).

While it is clear that roads are negatively related to wolf distribution and habitat use, the linear features themselves may in fact benefit wolves by providing travel conduits (Thurber et al. 1994, James & Stuart-Smith 2000, Callaghan 2002). However, this benefit is likely only apparent where and when human traffic and overall landscape use by people is minimal (Whittington et al. 2005). Otherwise, any advantage is likely to be outweighed by displacement and mortality risk associated with the human access and traffic. In considering results among several studies, Paquet and Carbyn (2003) conclude that landscape occupancy by wolves on public, multi-use lands is likely assured with open road densities of up to 0.6 - 0.7 km/km^2.

Clearly, the distribution of people as a function of settled and agricultural areas as well as road and highway access influences the distribution of wolves. Major transportation corridors additionally function in increasing wolf mortality through vehicle collision (Callaghan 2002). This pattern of human influence in conjunction with natural features influences wolf dispersal and regional population connectivity. Such influence is apparent in genetic relatedness, highlighting the importance of landscape connectivity that facilitates wolf movement (Thiessen 2006). Areas where wolves are protected from excessive human influence including mortality risk are obviously important in wolf conservation, though protected areas are usually not large enough to represent complete population refugia. Despite local landscapes of high wolf mortality (population "sinks"), regional wolf populations may remain healthy where *de facto* refugia exist based on a combination of natural and management restrictions and where dispersal options are maintained among core/buffer areas.

Status and Conservation

Federally, the gray wolf is considered "not at risk" (COSEWIC 2012). In British Columbia, wolves are "yellow-listed" or "apparently secure" (BCCDC 2012). Designated as a game animal and a furbearer, wolves are subject to regulated harvest through both hunting and trapping throughout most of the province, though trapping is regionally managed given that wolves can range among many trapline areas. Harvest regulations are liberal for wolves relative to other species reflecting low conservation concerns and the potential for conflict with ranchers.

Lynx

Ecological Overview

The Canada lynx (hereafter lynx) is adapted to boreal forest ecosystems typical of north-central Canada and Alaska, representing the majority of their geographic range. Lynx also occur in the western mountains of North America, including the Rockies, but their distribution becomes peninsular and discontinuous toward the south, especially in southern BC and the northwestern US (Apps et al. 2011). In northern regions, lynx populations can reach high densities but undergo dramatic 8- to 11-year fluctuations in delayed synchrony with their primary prey, snowshoe hares. It is here that the vast majority of lynx research has been conducted, virtually all of which has had a direct or indirect focus on the lynx-hare cycle (Mowat et al. 2000). All aspects of lynx demography are closely tied to the abundance and cyclic fluctuation of snowshoe hares. In the boreal forest, this translates to a 3- to 17-fold variation in lynx numbers throughout a hare cycle. Although research on southern lynx populations has been very limited, several aspects of their ecology may differ from northern populations, with important conservation implications (Aubry et al. 2000; Apps 2007). While there is no obvious demarcation between "northern" and "southern" lynx populations, the Peace Break assessment area is likely on the cusp as defined by Bailey's (1998) Humid Temperate and Dry ecoregions (Apps et al. 2011) and lynx locally may exhibit ecological characteristics of both.

As an obligate predator of snowshoe hares, the ecology of lynx populations studied varies temporally with hare densities, as demonstrated with respect to population characteristics, food habits and foraging behaviour, space use and movements, and dispersal (Mowat et al. 2000). However, the degree to which southern hare populations exhibit predictable, cyclic fluctuations comparable to northern regions is unclear. It was earlier surmised that hare populations of southern latitudes and mountainous regions remain at relatively low and stable densities through time, possibly a result of more patchy habitat distribution, greater competition, and a greater suite of predators (Aubry et al. 2000). Although Hodges (2000) did detect marked oscillations in southern hare populations of similar periodicity to boreal populations, they were of subdued amplitude and overall densities were lower in southern areas than in the north, with peak densities of 1-2 hares/ha compared to 4-6 hares/ha commonly reported in the north. To date, evidence suggests that the ecology of southern lynx populations resembles that of northern populations during cyclic hare lows (Apps 2007).

Because the lynx is a specialist predator of snowshoe hares, the species generally does not occur where hares are relatively scarce. However, lynx will make use of other prey, particularly during the low phase of the hare cycle or in marginal habitat conditions. Among others, this may include grouse, beaver, small rodents, ground squirrels, and ungulates, but the most common alternate prey of lynx is the red squirrel (*Tamiasciurus hudsonicus*) (Apps et al. 2011).

Lynx breed in March and early April, with parturition occurring from mid-May to early June, and kittens are dependent on their mother for about their first 10 months (Koehler & Aubry 1994, Mowat et al. 2000). Lynx have high reproductive potential, but this is realized only during the increase to high phase of the hare cycle in the boreal forest; during other years, reproduction is close to nil. As habitat quality becomes more marginal near the southwestern extent of lynx range, reproduction may be low even during peak years of hare abundance (Apps 2007). Lynx survival can also vary dramatically with hare densities, and most natural mortality is due to starvation. In northern regions, light trapping is expected to be compensatory to natural mortality of lynx during the first 1-2 winters of hare scarcity (Mowat et al. 2000). Notwithstanding human-caused mortality, lynx survival is typically high during the hare population increase to high phase, but lynx populations crash about one year after hares do. Population recruitment (defined by reproduction and kitten survival) is very high during the cyclic increase, but recruitment and juvenile survival may be low during the peak phase in unharvested populations, presumably as suitable habitats reach saturation. The ultimate cause of most natural mortality among lynx is starvation, which may or may not be preceded by home range abandonment and dispersal. Most human-caused mortality is due to trapping and, to a much lesser extent, hound-hunting.

Near southern range extents, evidence suggests that some landscapes support only ephemeral lynx populations, while others support core populations that act as sources for more marginal habitats (Apps et al. 2011). Space use by lynx varies between sexes and among regions, seasons, and the cyclic phase of hare populations. Relatively small home ranges of 20-45 and 13-21 km^2 for males and females respectively have been reported for northern regions during hare population highs but increased 2-10 times during the low phase (Mowat et al. 2000). In southern regions, lynx home ranges are large across years, with the one Canadian Rockies study reporting 389 and 239 km^2 for males and females respectively due to low prey densities and a patchy distribution of habitat and occupied landscapes (Apps 2000). Males are more likely to maintain exclusive home ranges but extensive overlap between sexes or among females can occur. Adult lynx display a tremendous ability to disperse long distances, likely an adaptation to dramatically fluctuating prey populations. Dispersals >500 km not uncommon but are usually precipitated by periodic hare population declines (Mowat et al. 2000). However, known dispersals of juveniles in the Canadian Rockies were relatively short (17-74 km) and mostly unsuccessful, which may relate in part to the tremendous variation in lynx habitat quality in the study region (Apps 2007). Successful long-distance dispersal may explain the relatively low genetic structuring among lynx across their range (Schwartz et al. 2002).

Lynx generally occur within upland conifer and mixed forests with a relatively cool climate; in southern regions, appropriate conditions are more likely at relatively high elevations (Apps et al. 2011). At finer scales, lynx prefer landscapes that support relatively abundant snowshoe hare populations. Hare densities and survival are positively correlated with understory vegetation density, particularly of conifers that provide forage, winter thermal cover, and security cover. Such attributes are common in stands regenerating several decades post-fire. However, lynx are also known to persist in landscapes dominated by mature forests that are structurally diverse. Many forestry activities select against stand attributes preferred by hares and red squirrels. Habitat heterogeneity may benefit lynx at several spatial scales, and there may be an optimum balance between conditions that provide for high hare densities in a landscape and those that facilitate successful predation by lynx. Other factors relevant to lynx habitat include those that affect the availability of alternate prey, competition with other terrestrial predators, and energetic requirements. Maternal den sites of lynx tend to be associated with dense thickets, tangles of trees, moderate to heavy deadfall and uprooted trees. Most den sites in southern populations have also been in old (>250 year) forests (Aubry et al. 2000).

Impacts and Threats

Particularly in the southern extent of lynx range, lynx habitat effectiveness may be diminished by the existence of several other sympatric predators via food competition for snowshoe hares and a heightened risk of interspecific conflict (Apps et al. 2011). It has been surmised that human activity that leads to plowed or snow-compacted pathways, networks, or areas can minimize the energetic cost of movement by competitors, allowing them to persist in landscapes where they would otherwise be at least seasonally excluded. Aside from the possibility of elevated competition, lynx appear tolerant of moderate levels of human activity and may use habitats close to humans if they are not otherwise hunted or trapped.

Potential lynx conservation issues likely vary between northern and southern regions but are described by Apps et al. (2011) as pertaining to: (1) historic and potential population overharvest; (2) forest management resulting in widespread fire suppression and/or intensive stand management for maximum timber production (or to minimize wildfire risk); (3) interspecific competition, to which human access and associated snow compaction may contribute; (4) the effect that global warming may have in reducing and fragmenting landscapes that can support lynx; (5) the potential impacts of increasing road access on lynx vulnerability to harvest and/or in facilitating competition; (6) the potential effect of major highways on lynx movements and population connectivity; and (7) the effects of agriculture and human settlement on lynx habitat quality and availability.

Current Status Within and Adjacent to British Columbia

Federally, lynx are deemed to be “not at risk” though population distribution is expected to have declined in southern BC (Poole 2001). Provincially, the lynx is "yellow-listed" or “apparently secure but may have a restricted distribution or there may be perceived future threats” (BCCDC 2012). The lynx is a managed furbearer in BC and has historically sustained trapping including culturally-significant harvest by aboriginal peoples. Today lynx are also designated as a game species in BC where they are also subject to hunting (typically with hounds). Lynx distribution extends into parts of the conterminous United States where the species is listed under the US Endangered Species Act. The Peace Region in general has reasonably high potential to support lynx, especially in cooler, forested ecosystems, and lynx harvest has been consistent within associated management units (Apps et al. 2011).

Lynx conservation concerns have increased in recent decades and harvest has become more regulated especially as recognized conservation threats have increased (Apps et al. 2011). Lynx are also recognized as an important focal species in regional conservation planning. Being one of the most specialized terrestrial predators in North America, landscape potential to support lynx can be highly variable and populations are likely to exhibit metapopulation and/or source-sink dynamics especially in southern regions. This highlights the importance of habitat and human-use management to ensure that productive core areas anchoring regional population are likely to persist along with peripheral and linkage landscapes through which lynx may also move and disperse (Apps 2007).

Fish Species

In addressing fisheries impacts, I focus specifically on the Peace River system on which the proposed Site-C hydro-electric development is situated. Within the main stem of the Peace River within British Columbia, 14 principal fish species have been documented. The most abundant is the mountain whitefish (*Prosopium williamsoni*; 87%), followed by long nose sucker (*Catostomus catostomus*; 7%), Arctic grayling (*Thymallus signifer*; 2%) and bull trout (*Salvelinus confluentus*; 2%) (BC Hydro 2007). Among these, bull trout and Arctic grayling are the species for which conservation concern is greatest.

<u>Bull Trout</u>

The bull trout has relatively recently (1980) been defined as a separate species from Dolly Varden (*S. malma*) and is in fact classified as a char rather than a trout. Bull trout are endemic to western Canada and the U.S. Pacific Northwest, with variable distribution across Yukon, British Columbia, western Alberta and the northwestern United States. The species is associated with cold, clean water of a variety of habitats that include small streams, large rivers, lakes and reservoirs.

Bull trout exhibit up to four life history patterns, three of which are present in the Peace drainage (the other is anadromous) (Hammond 2004 & references therein). Non-migratory stream residents are relatively small and spend their entire life in small streams, typically in headwaters above migration barriers. Larger, river (fluvial) types reside in large rivers but move to smaller tributary streams to spawn. Younger fish of this type remain in streams then move to the larger river when they are big enough to survive there. The lake type grows the largest and individuals spend most of their life in lakes or reservoirs, also using tributaries for spawning and rearing. Within the unimpounded portion of the Peace River and adjacent Halfway River mainstem, a migratory population of fluvial bull trout resides (MAL & Euchner 2009). Adults of this population make annual movements to critical spawning habitat, located in the upper Halfway River watershed and then overwinter in the lower Halfway and Peace rivers. The population appears to be phenotypically (of observable characteristics) unique in that they are among the largest bull trout in the region (ibid.).

Within their aquatic ecosystems, bull trout are top predators and their relatively large size allows adults to feed mostly on other fish. Growth is slow with late sexual maturity, typically at 5 - 7 years. Fecundity varies with female size and life history pattern, with about 500 eggs produced by smaller resident females and 2,000 - 5,000 produced by larger migratory fish. Spawning occurs from mid-August to late October at a water temperature threshold of about 9ºC. Eggs remain in the gravel through winter months before hatching in the spring. Adults will spawn over multiple years but may skip years. Bull trout are long lived, with a potential lifespan of 10 - 20 years.

Movements among spawning, feeding, and overwintering sites, and the home ranges that encompass these movements vary depending on life history strategy. Migratory bull trout within the Peace and Halfway systems use critical spawning habitat located in large tributaries of the upper Halfway River watershed, including the upper Halfway mainstem, Cypress Creek, Chowade River, and Needham Creek (MAL & Euchner 2009). The density of spawners is greatest in the Chowade River but much less in the upper Halfway River mainstem, Cypress Creek and Needham Creek. Monitoring has shown that fluvial bull trout within the Peace River system make long-distance migrations to and from spawning locations. Individuals of the Peace-Halfway bull trout population migrate up to 280 km from overwintering areas in the lower Halfway River and the Peace River mainstem as far downstream as the Clear River in Alberta (MAL & Euchner 2009, & references therein). Various studies suggest that about half of individuals will exhibit site fidelity between migrations.

Relative to other salmonid species, bull trout are associated with highly specific habitat conditions (Rieman & McIntyre 1993). These are generally characterized as (1) water temperatures below 13ºC, (2) stable flow rates, (3) clean gravel beds, (4) deep pools, (5) complex cover including snags and cut-banks, and (6) large systems of interconnected waterways that facilitate migrations among spawning, rearing and overwintering sites. Such attributes are typically associated with undisturbed systems. A supply of groundwater at spawning sites can apparently benefit eggs by increasing oxygen levels and reducing the likelihood of winter freezing (Baxter & McPhail 1999).

Bull trout populations are threatened by a variety of human activities. Major causes of population decline are potentially attributed to impacts resulting from dams and impoundments, logging, pipelines, oil and gas exploration, over-fishing, the introduction of non-native fish species and road-construction. Impassible dams and other structures can hinder the requirement of many bull trout to migrate throughout river systems. Activities that increase road access render bull trout vulnerable to over-fishing and poaching. Removing vegetation adjacent to water courses can degrade habitat value in several ways. Large woody debris that provides cover and moderates the impact of high flows can be reduced. The loss of shade can increase water temperatures. The availability of food falling into a stream can be reduced. Moreover, extensive vegetation removal in the landscape and adjacent to stream courses can increase sedimentation and increase water flow fluctuation among seasons.

The distribution of bull trout has been reduced considerably in association with human development and access. Much of this reduction has occurred at the southern fringe of the species' range, which has led to its Threatened listing in 1998 under the U.S. Endangered Species Act. In British Columbia, bull trout are Blue-listed or "of special concern" (BCCDC 2012), with populations considered to be stable to diminishing (Pollard & Down 2001) - stable under the implementation and enforcement of adequate protection, but diminishing if forest practices and industrial road development continue to degrade and alienate suitable bull trout habitat.

The aforementioned threats to bull trout may result in localized extirpation, but impacts may resonate at a river-system level through broader population fragmentation and the disruption of migration patterns. Obstructions to bull trout movement and population connectivity can be obvious (e.g., dams, culvert-related issues) or subtle (e.g., stream sections of degraded habitat or locally extirpated from overfishing). As with terrestrial species, loss of genetic and demographic connectivity can render larger river-system populations vulnerable and individual subpopulations more likely to extirpate.

<u>Arctic Grayling</u>

The Arctic grayling is a beautiful and popular game fish native to Arctic watersheds of mainland Canada and Alaska, from the Arctic coast to the northern extent of the western provinces (Wooding & Fairbairn 1959). The species was historically common within the upper Peace River watershed.

Arctic grayling are associated with cold streams and lakes but are particularly adapted to river environments (Scott & Crossman 1985, Nelson & Paetz 1992). Adult diet consists mostly of terrestrial and aquatic insects such as bees, wasps, grasshoppers and ants. They may secondarily include bottom organisms and plants, and rarely fish. Spawning occurs in small gravel- or rock-bottomed tributaries or in mainstem rivers in May and early June with water temperatures at about 4-7ºC. Males are highly territorial before and during spawning. The average female produces about 7000 eggs and the young hatch after 2 - 4 weeks. The fry are particularly vulnerable upon emergence and can easily be killed by high water, turbulence, starvation or stranding. Emerged fry will swim downstream and reside as groups in shallow, low-velocity areas along stream edges or side-channels. As they grow, grayling will gradually move to deeper, faster water. Maturity occurs at about 6 - 9 years, and lifespan is up to 12 years with many adults completing several spawning migrations. Adults overwinter in lakes or large mainstem pools and fry also migrate to deeper winter habitat. Individuals remain relatively sedentary within wintering areas from December to March. While grayling are highly philopatric (affinity to a site), they can move long distances between spawning, summer feeding and overwintering areas.

Arctic grayling stocks have been depleted and their distribution reduced through much of their range that is in overlap with regions of high human access and development. Grayling are easily caught and are susceptible to over-exploitation where stream reaches are accessible to people. The species is particularly sensitive to sudden environmental changes and apparently also to various forms of pollution (Scott & Crossman 1985, Nelson & Paetz 1992). Grayling are further vulnerable to human activities that disrupt migration patterns, reduce cover, or increase sedimentation and water temperature. Extensive logging and oil and gas development may result in such direct habitat degradation in addition to increasing public access, rendering local populations vulnerable to over-fishing. Despite these conservation issues, Arctic grayling are yellow-listed in British Columbia meaning they are a managed species not considered to be presently at risk (BCCDC 2012). However, populations in the watershed draining to the Williston Reservoir are red-listed, or critically imperiled (Blackman 2002, BCCDC 2012).

The red-listed status of upper Peace drainage grayling populations is probably due largely to impacts associated with flooding of the upper Peace River and its tributaries by the W.A.C. Bennett Dam constructed in 1968. Dam construction initially isolated these populations from the remainder of the Peace system in 1963. Grayling populations in the drainage apparently remained high until the early 1980s when they crashed. By 1988, the species had almost completely disappeared from the reservoir and most moderate to small tributaries (Blackman 1992). Causal factors include: (1) loss or degradation of key spawning and rearing areas; (2) changes to available foods and cover; (3) disruption of migration patterns; (4) competition with species better adapted to lake environments; and (5) overfishing. Remaining stocks are threatened by rapid resource development. Increased roading improves angler access leading to overfishing and the loss of unharvested refugia. Improper culvert installation can create barriers to fish movement. Siltation from logging activities can bury stream-bottom material, reducing spawning success as well as cover and feeding opportunities. Loss of forest overstorey can increase the pace of spring snowmelt, resulting in stream flows that are increased during spring and decreased during late summer. Many impacts are associated with poor road or pipeline construction and the release of non-native fish species that can outcompete grayling (Lashmar & Ptolemy 2002). The Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) of BC Hydro has conducted numerous Arctic grayling projects in the upper Peace River watershed since 1988 with the objective of compensating for impacts caused by the flooding of extensive riverine habitats of the upper Peace (see Blackman 2002 for citations).

Anticipated Impacts of Site-C Development

For fisheries, potential impacts of the proposed Site-C hydro-electric development have been outlined in the Completion Report for Stage 1 of the Site C Feasibility Review (BC Hydro 2007). It is acknowledged that the dam and impoundment reservoir would negatively impact fish habitat and populations. Existing river habitat would be transformed to reservoir habitat. Accompanying changes to aquatic habitat could potentially shift species composition with impacts to native populations. Spawning habitat would obviously be lost in the mainstem and lower tributaries. But the report posits that changes could improve overwintering conditions for some species, including bull trout and Arctic grayling. The report also cites a potential benefit as being due to a region of shallow water in the reservoir where light penetrates the bottom. Since no reservoir currently exists, this may not be a benefit but perhaps provides some level of impact offset.

In addition to habitat change due to impoundment, the proposed Site-C dam is also likely to have direct impacts to fish health and demographics (BC Hydro 2007). The operation of the dam would result in fish mortality from the reservoir over the spillway or through the turbines. The periods of spillway discharge could elevate levels of total dissolved gas, affecting fish downstream of Site-C. The report suggests that this impact could be mitigated through spillway design, but it is unclear to me whether fish passage facilities would in fact be incorporated into the project design. Without such mitigation, fish populations will be entirely fractured with negative consequences that are more certain to be significant for species such as bull trout that presently migrate past the dam location. Finally, it is unclear to what degree seasonal draw-downs of the impounded reservoir will occur and thereby render littoral habitat ineffective.

Aside from the proposed Site-C development, bull trout and Arctic grayling have and continue to be under pressure from a number of inter-related impacts within the Peace Break region. These include habitat loss and degradation, over-fishing facilitated by increased road access, changes in aquatic community composition resulting in increased competition and/or predation, and the subtle or direct fracturing of population connectivity. In considering the impacts of the proposed Site-C development, the incremental contribution to these existing cumulative effects should be recognized.

3.
EVALUATING LANDSCAPE EFFECTIVENESS & CONNECTIVITY FOR FOCAL SPECIES IN THE CONTEXT OF CUMULATIVE EFFECTS

INTENT & APPROACH

As stated, the intent of this assessment is to evaluate the potential influence of past, present and future cumulative human impacts on landscape-level habitat effectiveness and connectivity of wide-ranging species populations and associated ecological communities. My general approach was to apply the best available data and current understanding to inform spatial modeling for each defined focal species to predict population distribution at relevant scales across the Peace Break assessment area. This modeling approach was not conducive to fish species and potential impacts to Bull trout and Arctic grayling are addressed qualitatively in Chapter 2. Among terrestrial species, modeling approaches varied as did the nature and scale of information on which modeling was based. Beyond species-specific modeling of landscape potential, I further describe the approach applied to model cumulative human influence relevant to these species and both quantitative and qualitative interpretation regarding impacts to species-population connectivity. For each species, an assessment scale was determined on the basis of their known spatial ecology previously described (Chapter 2). Scaling was achieved by aggregating pixel-based model predictions using a GIS moving-window routine (Bian 1997), and was intended to match female core home range size for each species.

SPATIAL HABITAT & HUMAN-USE DATABASES

Across the 132,000 km^2 Peace Break assessment area, I assembled spatial GIS databases pertaining to physiography, climate, habitat, and human-use. Assembled spatial data were rasterized for analysis at 100 m (1 ha) resolution. From these source data, I derived explanatory/predictive factors relevant to modeling and evaluation for each species.

<u>Climate & Physiography</u>

I considered ecosystem variation across the assessment area using 1:250,000 mapping of biogeoclimatic subzones and variants (BEC; Meidinger & Pojar 1991) as well as broader ecological regions (Demarchi 2011). To account for macro-climatic variation, I assigned BEC and ecological subzones one of four ordinal classes pertaining to the frequency of stand-initiating or stand-maintaining fire disturbance under natural conditions (natural disturbance type; NDT; MOF 1995). Within alpine tundra and subalpine parkland subzones, I interpolated NDT based on adjacent ecosystems.

I derived terrain variables from a 1:20,000 digital elevation model (Geographic Data BC 1996). Predictors included elevation (m) and slope (%). A terrain curvature index reflected the maximum rate of change of a curve fit through each pixel in the context of its neighbors (profile curvature; Pellegrini 1995). Using known sun azimuths and a digital elevation model, mean daily maximum solar insolation (kJ) and duration (h) was calculated for each pixel in the study area based on 1-hour increments between 1 May and 30 October (Kumar et al. 1997, Meszaros et al. 2002). I also derived a terrain complexity index that is independent of slope by measuring the standard deviation of terrain curvature values within a defined landscape radius. Hydrographic features were obtained from 1:250,000 National Topographic Survey (NTS) data and also from the land cover classifications described below.

<u>Land-Cover & Vegetation</u>

I obtained land cover and vegetation data from several sources. I derived general land-cover classes from 1:250,000 baseline thematic mapping (BTM) data that is based on a remotely sensed classification (Geographic Data BC 2001). Classes included alpine, avalanche chutes, old forests (>100 yrs), young forests (<100 yrs), disturbance due to logging, disturbance due to wildfire, "barren" surfaces, glaciers, open range, and wetlands. I also acquired a Landsat-derived classification assembled for the earth observation for sustainable forest development (EOSD) forest monitoring program (Wulder et al. 2008). This classification better differentiated among vegetated habitats. Finally, I assembled 1:250,000 broad ecosystem inventory (BEI), spatial units of which reflect an integration of vegetation, terrain (surficial material), topography and soil characteristics (RIC 2000). Since the above data sources are unlikely to reflect more recent forest disturbance, I obtained polygons pertaining to forest harvest and management, including cutblocks (ILMB 2012). Finally, based on Moderate Resolution Imaging Spectroradiometer (MODIS) remotely sensed imagery (LPDAAC 2012), I obtained normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) (Huete et al. 2002).

<u>Human Use</u>

Depiction and prediction of human use and accessibility are fundamental to this assessment. I assembled multiple inventories of human-use point, linear and area features in building a human-use database that best represents existing infrastructure expected to facilitate and influences human use across the Peace Break assessment area. This included the most recent inventory of road features of all classes as reflected in the British Columbia Digital Road Atlas (DRA; ILMB 2010). The DRA is a data management system representing a complete and updated network of all the roads in British Columbia. Responsible government agencies contribute feature inventories typically mapped at 1:20,000 or finer (e.g., Surveys and Resource Mapping Branch 1992). To ensure a complete and comprehensive inventory, I also assembled and merged with the DRA 1:50,000 National Topographic Survey (NTS) blocks of CanVec data (CTI 2010). I classified linear features following a standard weighting system reflecting expected traffic type and volume (Apps 1997), and I removed road networks to which I knew public motorized access to be closed or restricted.

Across the regional assessment area, I also assembled a cadastral database primarily from 1:50,000 NTS blocks of CanVec data (CTI 2010). From this, I extracted relevant point and polygon features of localized human use under the following themes: (1) buildings and structures, (2) energy, (3) industrial and commercial areas, and (4) places of interest. I classified features given my expectation for localized human use that is "high" or "low" (Appendix 1). Also from CanVec data, I defined areas specifically delineated as "residential". Predominant human land uses were inferred from BTM and from land-use zoning including agricultural land reserve, protected designations, land ownership, industrial tenures and municipalities (ILMB 2012).

ASSESSING CUMULATIVE HUMAN IMPACTS

Modeling Landscape Potential for Focal Species

<u>Lynx</u>

As described, lynx food habits are relatively specialized and the species is associated with a narrow range of habitat conditions. Therefore, lynx modeling parameters developed elsewhere should remain predictive in extrapolation to the Peace Break assessment area. The most relevant study of lynx-habitat relationships and factors influencing population distribution is derived from a study completed within the Rocky Mountains and southeastern BC (Apps 2007).

For lynx, I applied two stages of modeling. Initially, I applied coarse-filter modeling of landscape potential to support the species on the basis of broad ecosystem inventory (BEI) ratings developed for British Columbia (Apps 2002). I transformed this 4-point rating system to a ratio-scale continuum to reflect the maximum habitat value a given landscape can potentially provide to lynx. Based on finer-scale and site-specific data of land cover, forest structure and terrain conditions, stage-2 involved the adaptation of a lynx habitat model initially developed for regional applications across the southern Canadian Rockies (Apps et al. 2007). This model accounts for functional relationships that are expected to control lynx distribution in a compensatory or limiting manner. Submodels pertain to lynx energetics and mortality risk as influenced by climate, enduring features, small mammal prey, and security. This finer-scale model based on site-specific conditions was used to limit (i.e., "step down") the maximum BEI rating reflected within a given pixel. I scaled landscape modeling for lynx to a radius of 5.4 km, reflecting that of an assumed female core home-range within the Peace Break region.

<u>Fisher</u>

The Peace Break region is an important area for fishers and there has been some local research carried out as previously described. To evaluate potential for fisher distribution, I adapted a draft model of fisher landscape occupancy (R. Weir, MOE, pers. comm.). This model accounts for associations with watercourses, overstorey attributes potentially providing for tree dens, prey habitat quality (i.e., snowshoe hares, tree squirrels and ruffed grouse), and recent logging. I excluded an optional variable pertaining to the rate of capture of martens within a 30 km^2 home range area. Because the model was developed based on sampling within a localized area, I expected that it would not account for broader-scale factors that influence regional population distribution. Therefore, I constrained predictions according to a fisher habitat model developed for regional application and that accounts for climatic influence including winter snow accumulation (Apps 1995). I scaled landscape modeling for fishers to a radius of 2.8 km, reflecting that of an assumed female core home-range within the Peace Break region.

Caribou

Woodland caribou herds through the Peace Break region have been subject to extensive monitoring and survey by way of tracking collars. As a result, there is very good knowledge of present population abundance, distribution and trend (Chapter 2) as well as habitat potential (Jones 2008).

Most recently, seasonal habitat selection analyses and empirically-based model development has been completed for all of the Peace region caribou groups (herds) (Williamson-Ehlers 2012). I was provided with the raw raster outputs for seasonal models for each caribou group as well as the 95% isopleths of each group's distribution as defined by collar location data. These empirical models are highly specific to landscapes used by each caribou group, and predictions are less likely to hold true at distances and for conditions far removed from the area used by those animals.

To provide a continuous and seamless prediction of caribou habitat across the Peace Break regional assessment area, I combined the raw, season-specific models developed for each caribou group. However, each model reflected a unique prediction scale. That is, each reflected "relative" habitat selection probability but predictive values were not comparable among models. Therefore, I obtained the cutpoints used to classify each model into 4 qualitative classes (low, moderate, high, very-high). Because these cutpoints were based on specific percentiles of actual caribou-use locations the resulting classes were then considered comparable among models. I used the cutpoints to then transform each raw-model output to a continuous ratio-scale (0↔1) range of habitat prediction that is directly comparable among models. For both "winter" and "summer" seasons, I then averaged predictions across herd specific models, weighting the contribution of each herd-specific model based on distance from landscapes known to be occupied by those particular animals (95% isopleths of herd distribution based on collar data). I then combined the season-specific models into a single "all season" model that reflects the maximum habitat value between the seasonal models. Finally, I scaled landscape modeling for caribou to a landscape radius of 6.3 km, reflecting that of the average 50% isopleth of seasonal ranges among defined caribou groups.

Grizzly Bear

As described (Chapter 2), there has been little effort to sample grizzly bear occurrence at scales appropriate to understanding and predicting grizzly bear abundance and distribution relative to landscape factors of habitat and human influence. Hence, there is no locally-developed model of grizzly bear occurrence, distribution and/or landscape-potential applicable to the Peace Break assessment area. The most applicable modeling relationships are those developed for predicting population distribution across the west slopes of the central Canadian Rockies (Apps et al. 2004). I therefore adapted and applied this model for grizzly bears across the Peace Break. This model accounts for functional relationships that are expected to control grizzly bear distribution in a compensatory or limiting manner. Submodels pertain to grizzly bear energetics and mortality risk as influenced by climate, enduring features, ungulate prey, plant foods, as well as habitat and human factors influencing bear security. I scaled landscape modeling for grizzly bears to a radius of 5.6 km, reflecting that of an assumed female core home-range within the Peace Break region.

Wolf

Analysis or modeling efforts pertaining to wolf occurrence or distribution has not been carried out within the Peace Break assessment area. I therefore adapted and extrapolated a model of landscape-level habitat potential for wolves that was developed for the central and southern Canadian Rocky Mountains (Apps et al. 2007). This model accounts for functional relationships that are expected to control wolf distribution in a compensatory or limiting manner. Submodels pertain to wolf energetics and mortality risk as influenced by climate, enduring features, ungulate prey, as well as habitat and human factors influencing wolf security. I scaled landscape modeling for wolves to a radius of 11.3 km, reflecting that of an assumed core pack range area within the Peace Break region.

Wolverine

As described, wolverines exhibit relatively generalized food habits and are associated with a broad range of habitat conditions. Wolverines move extensively and, with the exception of reproductive denning, are likely to exhibit habitat selection only at broad, landscape scales. Wolverine distribution likely is limited by the persistence of the spring winter snowpack that is important for reproductive denning.

I applied two stages of modeling for wolverine. Initially, I applied coarse-filter modeling of landscape potential to support the species on the basis of broad ecosystem inventory (BEI) ratings developed for British Columbia (Weir 2004). I transformed this 4-point rating system to a ratio-scale continuum to reflect the maximum habitat value a given landscape can potentially provide to wolverines. Based on finer-scale and site specific data of land cover, forest structure and terrain conditions, stage-2 involved the adaptation of a wolverine habitat model initially developed for regional applications across the southern Canadian Rockies (Apps et al. 2007). This model accounts for functional relationships that are expected to control wolverine distribution in a compensatory or limiting manner. Submodels pertain to wolverine energetics and mortality risk as influenced by climate, enduring features, ungulate and small mammal prey, and security. This finer-scale model based on site-specific conditions was used to limit (i.e., "step down") the maximum BEI rating reflected within a given pixel. I scaled landscape modeling for wolverines to a radius of 9.8 km, reflecting that of an assumed female core home-range within the Peace Break region.

Modeling Human Influence

Relevance of Human Accessibility & Remoteness

Distribution patterns of species populations are largely influenced by inherent landscape potential and current habitat suitability to meet life requisites. For the wide-ranging focal species addressed in this assessment, I consider influences on distribution to be best reflected across the Peace Break region by way of modeling described above. For these species however, population fragmentation and hence resilience are also greatly affected by the influence of human activity on potential displacement from suitable habitats and the risk of direct or indirect mortality. The manifestation of displacement effects can be complex since each species does exhibit a certain level of behavioural adaptability, and individual responses are sometimes confounded by habituation and spatial/temporal partitioning among cohorts (i.e., by age, sex, and reproductive status). Generally, it is mortality risk that is the more important conservation issue. For carnivores, this risk is primarily related to the frequency of interactions with people and the lethality of those interactions. For example, grizzly bear mortality risk can be described simply as a function of the number of people in bear habitat (frequency of encounter), and both the behaviour of those people and whether they have firearms (lethality of encounter) (Mattson et al. 1996, McLellan 1998). For other carnivores and for caribou, population vulnerability is similarly a direct or indirect function of human access, though hypothetical mechanisms vary (Chapter 2). Hence, across focal species, human accessibility to the landscape is perhaps the most relevant predictor of population fragmentation in addition to landscape potential and current habitat conditions.

The density of roads and/or other linear features has often been used as a proxy for human impacts to the landscape. However, this metric is highly scale-dependent and there are key limitations in its functional relation to human impacts. For grizzly bears in particular, human accessibility or the relative abundance of people on the landscape is far more relevant to functional hypotheses of broad-scale displacement and mortality risk. For example, Apps et al. (2004) modeled human access by way of network analysis as a function of travel time from human population centres and the size of those localized populations, demonstrating the relevance of this predictor in explaining grizzly bear occurrence and distribution. This powerful and intuitive metric was also applied in a conservation assessment across the southern Canadian Rockies (Apps et al. 2007). For the Peace Break assessment herein, I applied a more advanced and realistic iteration of this modeling approach (Apps et al. 2012), output from which can be interpreted in terms of the ease of landscape accessibility by, and remoteness from, people.

Modeling

As earlier described, I assembled a comprehensive and consistent representation of linear human features from several independent datasets. Features included everything from major divided highways to mapped trails, as well as transmission lines, railway tracks, seismic-/cut-lines, etc. There are known limitations within each dataset, so I consolidated multiple and largely redundant sources to ensure that, as best possible, all features that may facilitate any type of travel by people were represented and that their attributes and resulting classification were accurate. For each linear-feature class within each inventory, I assigned a maximum speed of travel, whether motorized or not. I then rasterized speed-class vectors, ensuring that the maximum rate through a given pixel was reflected. Motorized access closures were then applied where known, forcing the maximum rate of speed to 10 km/hr (assuming they do still facilitate non-motorized travel). Beyond linear travel features, I modeled the maximum rate of non-motorized travel-speed based on assumptions that apply to terrain and land cover (*sensu* Apps et al. 2012).

I derived points and areas of all human communities and residential areas from assembled inventories and applied corrections based on published maps, ensuring that community points were connected to the road network. I obtained current populations from recent census data and I assumed that hamlets supported local populations of 50. I also accounted for all human features and facilities that may represent either a source or target for human travel. I adjusted localized populations using an exponent to account for the observation that people living in larger population centres are less likely to venture outside the urban zone for recreation and work (Apps et al. 2012).

I derived a travel "friction" surface based on the inverse of combined motorized travel speeds along linear features and non-motorized off-road travel across the landscape. I then applied an anisotropic cost-grow algorithm (de Smith et al. 2007) to independently calculate isochrone surfaces reflecting travel time from individual communities. This process was applied in two stages to ensure that a motorized rate of movement could not be resumed after going off-road to a non-motorized rate (i.e., vehicles cannot be carried). It was also assumed that travel time to a given site would always be via the nearest road. I applied a distance-decay exponent to account for people's decreased "willingness" to travel as travel time increases (Apps et al. 2004). I then averaged all community-specific outputs, weighted by the size of respective populations. The final output represents an index of access demand (assuming no hindrance due to snow) to any site across the greater assessment area given the distribution of people and communities throughout. It can be interpreted as relative landscape accessibility, or remoteness (Figure 11). The index can be projected into the future (e.g., year 2036; Figure 12) given expected demographic trends (AMEC 2010).

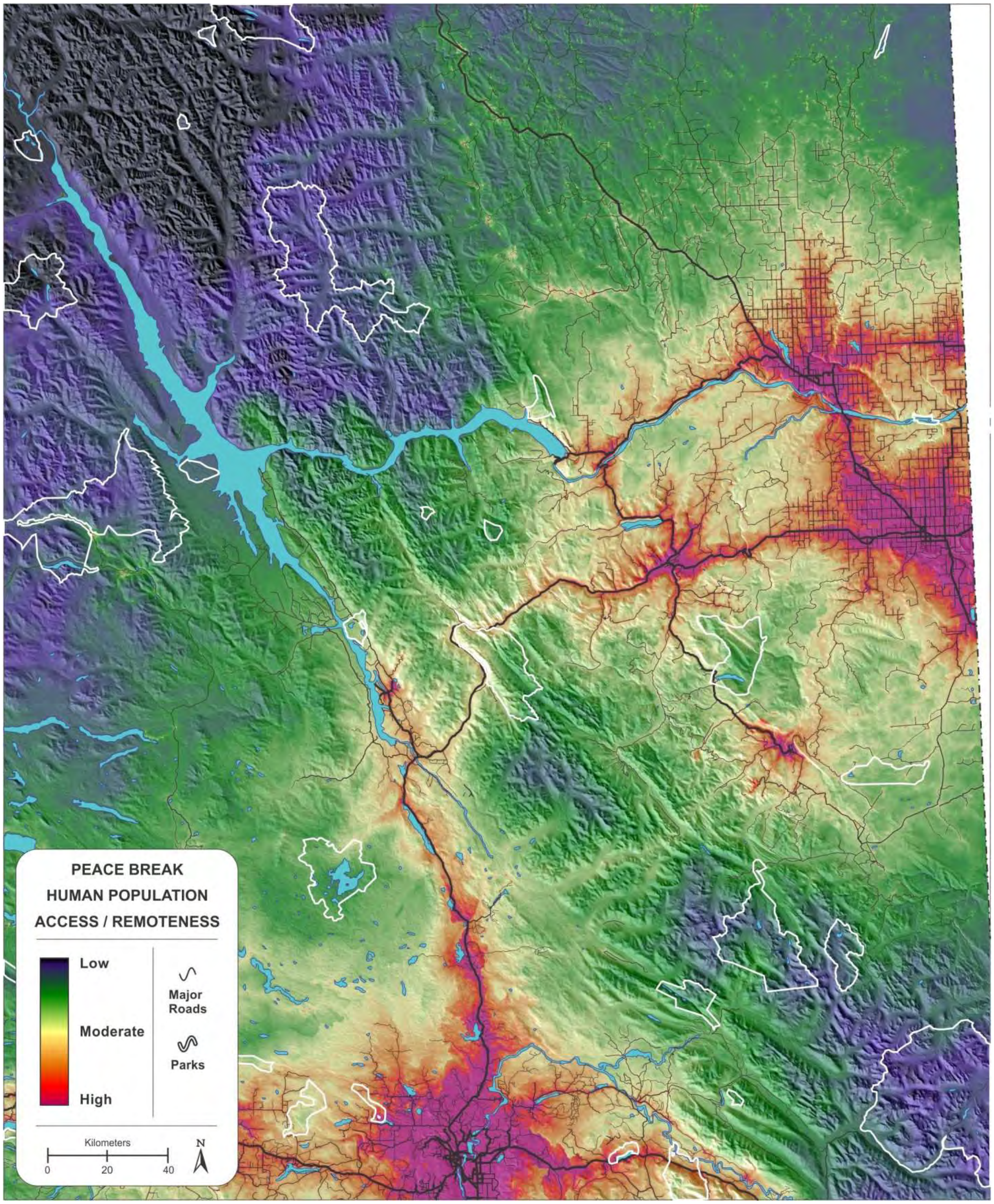

Figure 11. Index of human population access/remoteness across the Peace Break assessment area.

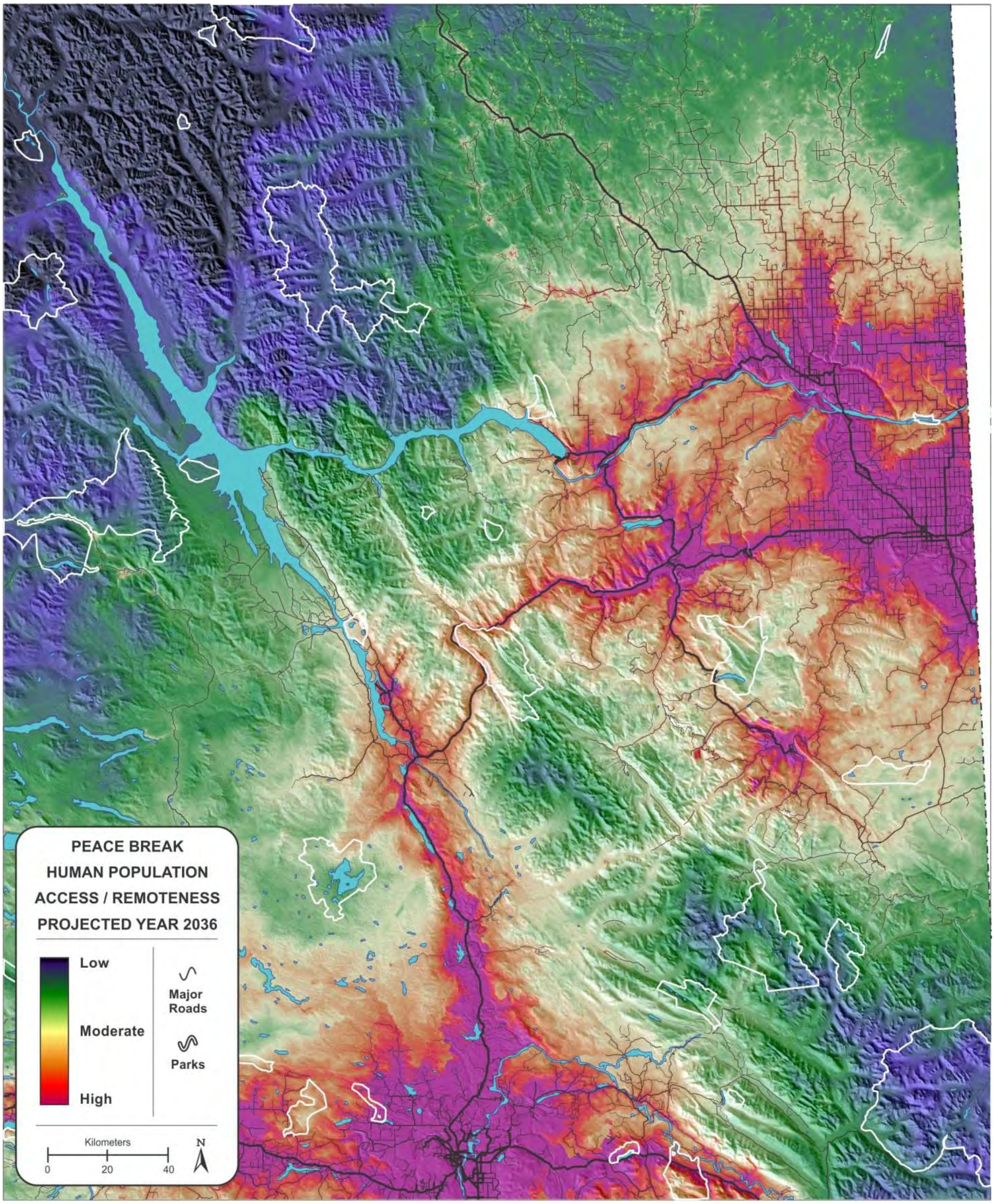

Figure 12. Index of human population access/remoteness across the Peace Break assessment area, projected to year 2036 given expected growth. This scenario is likely conservative assuming there will be a net increase in human features that positively influence accessibility and dispersion by people.

Cumulative Impacts to Landscape Effectiveness and Connectivity for Focal Species

The nature of human impacts to select focal species is described in Chapter 2. The mechanisms by which human presence and activities influence behaviour, movement, and persistence clearly varies among species. Following from this understanding, I used professional judgment to approximate the shape of the relationship between human population access and the potential that each species may persist and move either within or among occupied landscapes (Figure 13). Based on the curve for each species, I transformed the index of human population access to produce an impact factor that I applied to estimate realized landscape potential for each species.

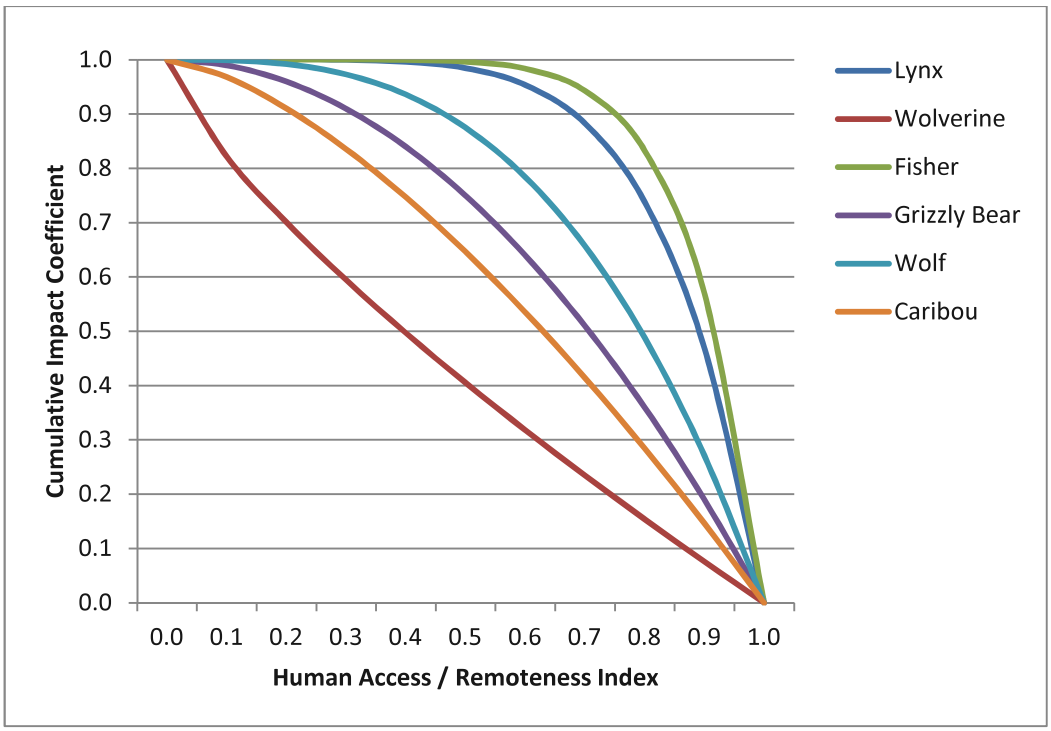

Figure 13. Theoretical coefficient curves of cumulative impact to each focal species as indicated by the human accessibility/remoteness index. Smaller coefficients reflect greater expected impact to a given species.

My assessment considered the extent of current impacts and projected trend by comparing three scenarios. The "undisturbed" scenario reflected current land cover attributes but with no human influence and prior to the development of the W.A.C. Bennett Dam and associated flooding that produced the Williston Reservoir. The "current impact" scenario considered all present human infrastructure, population and development. I then defined a "future year 2036" scenario that involves regional population growth of 23.5% over current given existing demographic trends (AMEC 2010) and the completion of the proposed Site-C hydro-electric development (Chapter 1). This future scenario is admittedly crude in that it does not (cannot) account for development of additional features of human use, residence, access or industry, or for measures that may provide additional control over the spread of human activity and disturbance. But it illustrates the likely trend.

For each of the three scenarios, I quantified and compared impacts in two ways. I measured average landscape effectiveness[3] for each species across each assessment area, comparing the relative change among scenarios. To quantify landscape connectivity, I calculated the area vs. perimeter ratio (Calabrese & Fagan 2004) at four thresholds of landscape effectiveness (0.75, 0.50, 0.25, 0). I interpreted impacts based on the change in both average landscape effectiveness and associated fragmentation.

RESULTS & DISCUSSION

Comparison Among Scenarios & Differences Among Species

As expected, the nature of cumulative impacts to the potential for landscape occupancy and population connectivity based on current and projected (+25 years) scenarios differs among focal species. Impacts are gauged in several ways and are significant. Relative to the "undisturbed" scenario, absolute reductions in regional landscape effectiveness range from 7% to 47% current loss among species, and 11% to 55% projected loss in 25 years (Figure 14). Within the local assessment area, reduction in landscape effectiveness ranges from 13% to 55% current loss, and 19% to 62% projected in 25 years (Figure 15). Also relevant is the nature of impacts to landscape connectivity, as measured by the change in the area/perimeter ratio of landscape effectiveness isopleths (Figure 16). Spatial fragmentation can be difficult to quantify in a meaningful way, and the pattern of these graphed results requires some interpretation. More serious fragmentation issues are characterized by a reduction in the area/perimeter ratio (fragmentation) of contiguous higher-quality landscapes (e.g., 75% isopleth) and an increased area/perimeter ratio (consolidation) of lower-quality conditions (e.g., 0% or 25% isopleth). Finally, both the absolute loss and the fragmentation of landscape effectiveness can be qualitatively assessed through the mapped pattern of modeled species occurrence and distribution among potential, realized and future-projected scenarios (Figures 17 - 22).

Wolf

Current impacts are greater for species whose natural distribution is more strongly linked to lower elevations and/or subdued terrain conditions. This is especially true for wolves, which range extensively, tend to conflict with certain human values and activities such as agriculture, and are

[3] The realized effectiveness of the landscape to support the species after accounting for both potential displacement effects as well as reduction in security increasing mortality risk.

afforded little protection outside of certain parks[4]. Despite these impacts, wolves have persisted due to their higher resilience than many other wide-ranging carnivores (Chapter 2). At both analysis scales, total landscape effectiveness for wolves has been markedly reduced and this is likely to continue into the future. Impacts to wolves are exacerbated by the pattern of fragmentation, whereby current and future scenarios are associated with substantial fracturing of the highest quality landscapes, with increased interspersion of marginal habitat conditions.

Fisher

Within the assessment area, the potential distribution of fisher habitat also tends to occur in association with landscapes of relatively high overall human influence. While fishers generally do not conflict with people, they are potentially vulnerable to trapping mortality and are thus impacted to some degree by human accessibility. Fisher habitat distribution and connectivity also tends to occur at a finer scale than other wider-ranging species and particularly in association with riparian areas with specific attributes of forest composition and structure. Hence, fishers are vulnerable to habitat loss and fragmentation, especially due to complete alienation such as through forest clearing and agriculture in addition to flooding for hydro-electric impoundment. Analysis results suggest that impacts to fishers are more significant at the local than the regional scale, likely as a result of the close association of fisher habitat with landscapes of current and proposed modification, including hydro impoundments within the Peace River Valley. While population connectivity is undoubtedly important in conservation planning for fishers, the more acute conservation issue appears to be the absolute loss and alienation of quality habitat.

Lynx

Like fisher, human impacts on lynx are also primarily by way of increased mortality risk through legal and illegal harvest. The majority of lynx harvest in the assessment area is through trapping. However, human accessibility potentially impacts lynx more than many other furbearers since lynx are classified as a big game species and are subject to hound hunting as well (Apps et al. 2011). Lynx can also range very widely, easily covering multiple trapline areas. They are naturally vulnerable to periodic die-offs and population fluctuations, and population persistence is greatly dependent on successful dispersal. Lynx are relatively specialized with respect to prey and habitat conditions, and the best habitat often occurs in association with extensive areas of relatively subdued terrain in association with specific climatic and forest attributes. Within ecologically diverse regions such as the Peace Break, such landscapes tend to be naturally disjunct in distribution. For lynx, population fragmentation is further exacerbated by human accessibility both within core habitat areas and within the connective landscapes through which lynx move and occupy on at least an ephemeral basis. Within the Peace Break region, the loss of landscape effectiveness for lynx is notable at both the regional and local scale. Fragmentation is also an issue, but more so at the local scale where both

[4] liberal wolf harvest regulations are due in part to conservation concerns for endangered woodland caribou.

moderate and marginal habitats are being transformed to and interspersed with highly suboptimal conditions.

Wolverine

Wolverines do not rely on a narrow range of habitat conditions as do lynx and fisher. Moreover, wolverine population distribution tends to be associated with rugged and relatively high elevation landscapes and especially where the snowpack consistently persists well into May. Hence, patterns of cumulative human influence do not impact wolverine to the degree observed for several of the other focal species. However, wolverine occur at very low densities and exhibit massive home ranges. Thus, relatively minor levels of human accessibility can put regional populations at risk without *defacto* protection from harvest. This is reflected in results that indicate a great loss in both regional and local landscape effectiveness for wolverines. With respect to fragmentation, the trend is reduced continuity of highest quality landscapes and increased interspersion of moderate and marginal conditions.

Grizzly Bear

The relationship between grizzly bear landscape occupancy/distribution and cumulative human impacts can be characterized in terms of both mortality risk and behavioural displacement from otherwise suitable habitat. Mortality risk is the more important impact and results from both intentional killing of bears as well as killing as a result of conflict situations. Such situations are particularly prevalent among ungulate hunters carrying firearms but management removals within landscapes of moderate levels of human use are also common. While underlying densities may vary, grizzly bears are potentially widespread in distribution and rarely can persist in close association with people. Hence, among the suite of focal species, grizzly bears are subject to significant impact resulting from cumulative effects of increasing landscape accessibility. At present, landscape effectiveness is reduced 25% and 36% at regional and local scales respectively, and is likely to fall to at least 42% and 44% in the future. Population fragmentation is also a major concern, with landscapes of both high and moderate quality being fractured and interspersed with marginal to highly suboptimal conditions.

Caribou

For woodland caribou, cumulative human accessibility as modeled for this assessment may function directly to limit caribou population distribution and connectivity through human-caused mortality and displacement effects. But increasing accessibility is also indicative of landscape change resulting in dominant forest conditions incompatible with caribou habitat requirements and likely contributing to increased predation risk (see Chapter 2). Current reductions of 22% and 27% landscape effectiveness at regional and local scales respectively are projected to increase to at least 31% and 37% in the future. These numbers are likely conservative since the analysis can only account for human influence and not habitat change directly. At the regional scale, the highest quality landscapes are being fractured and interspersed with marginal conditions, and this trend is projected to continue. These analysis results support the current observation that much of the Peace Break assessment area currently supports relatively small and disjunct caribou herds. Moreover, without proactive conservation measures, fragmentation among the larger regional population is likely to be exacerbated given the future trend of human activity and development.

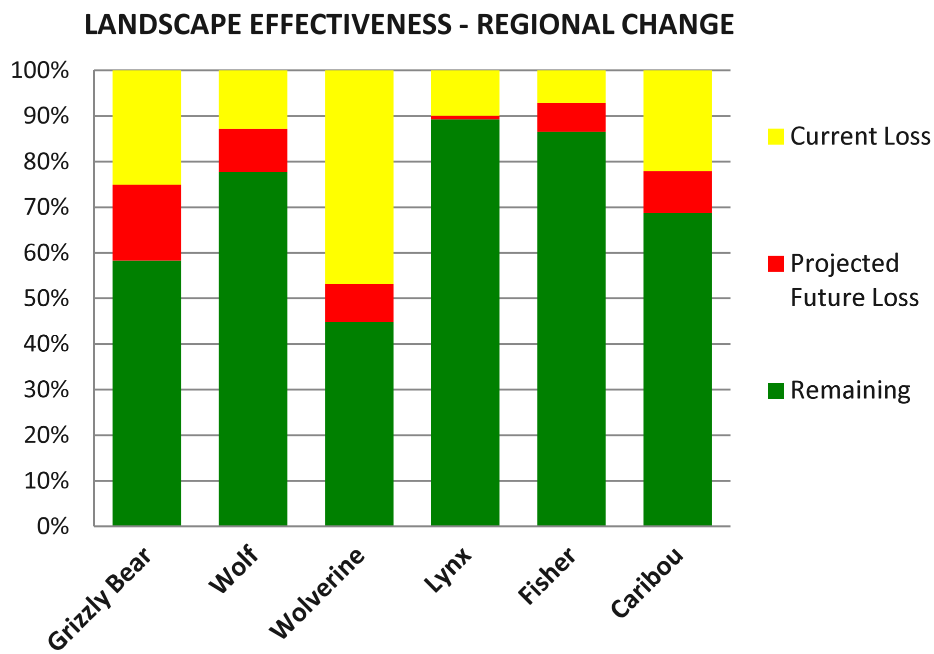

Figure 14. Minimum estimated change in REGIONAL landscape effectiveness among wide-ranging focal species given current and projected-future year 2036 scenarios.

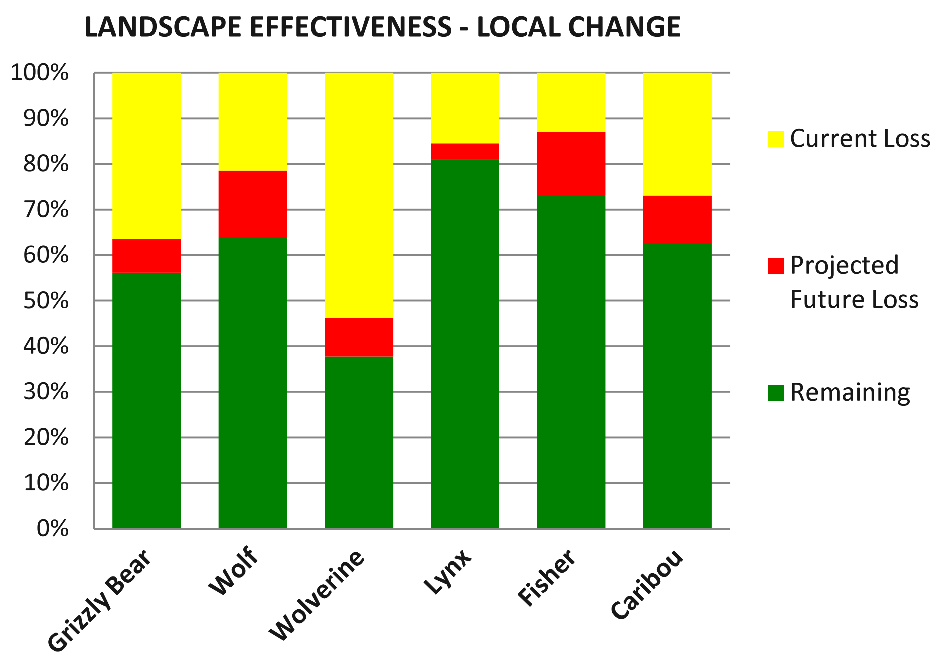

Figure 15. Minimum estimated change in LOCAL landscape effectiveness among wide-ranging focal species given current and projected-future year 2036 scenarios.

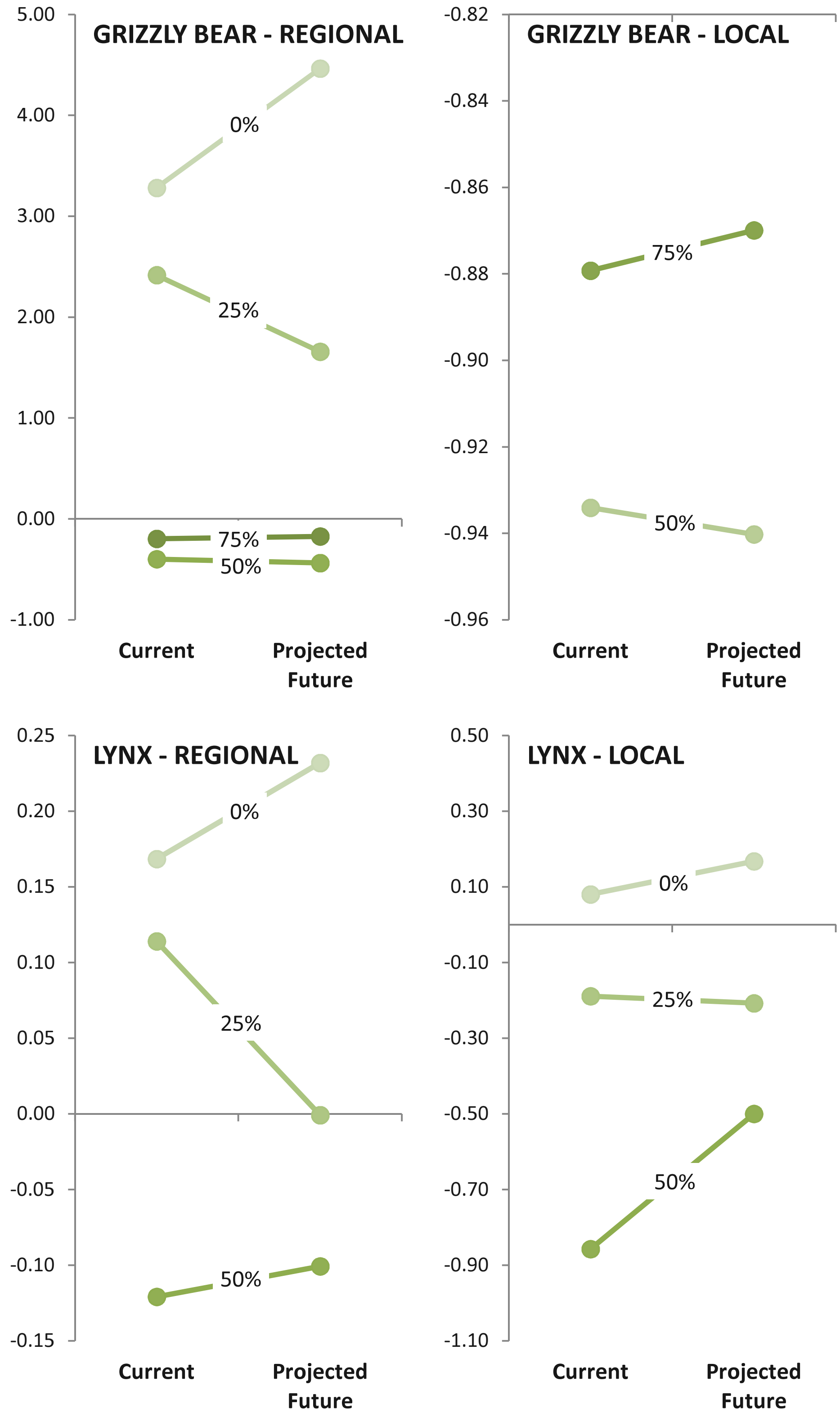

Figure 16. Proportional current and projected-future change in area/perimeter ratio relative to no-disturbance scenario for isopleths (0, 25, 50 & 75%) of landscape effectiveness. Species results are provided for both regional and local assessment areas. Note that Y-axis scale varies among graphs. Negative results indicate fragmentation while positive results indicate consolidation. Isopleth quartiles that are not shown did not exist in the no-disturbance scenario.

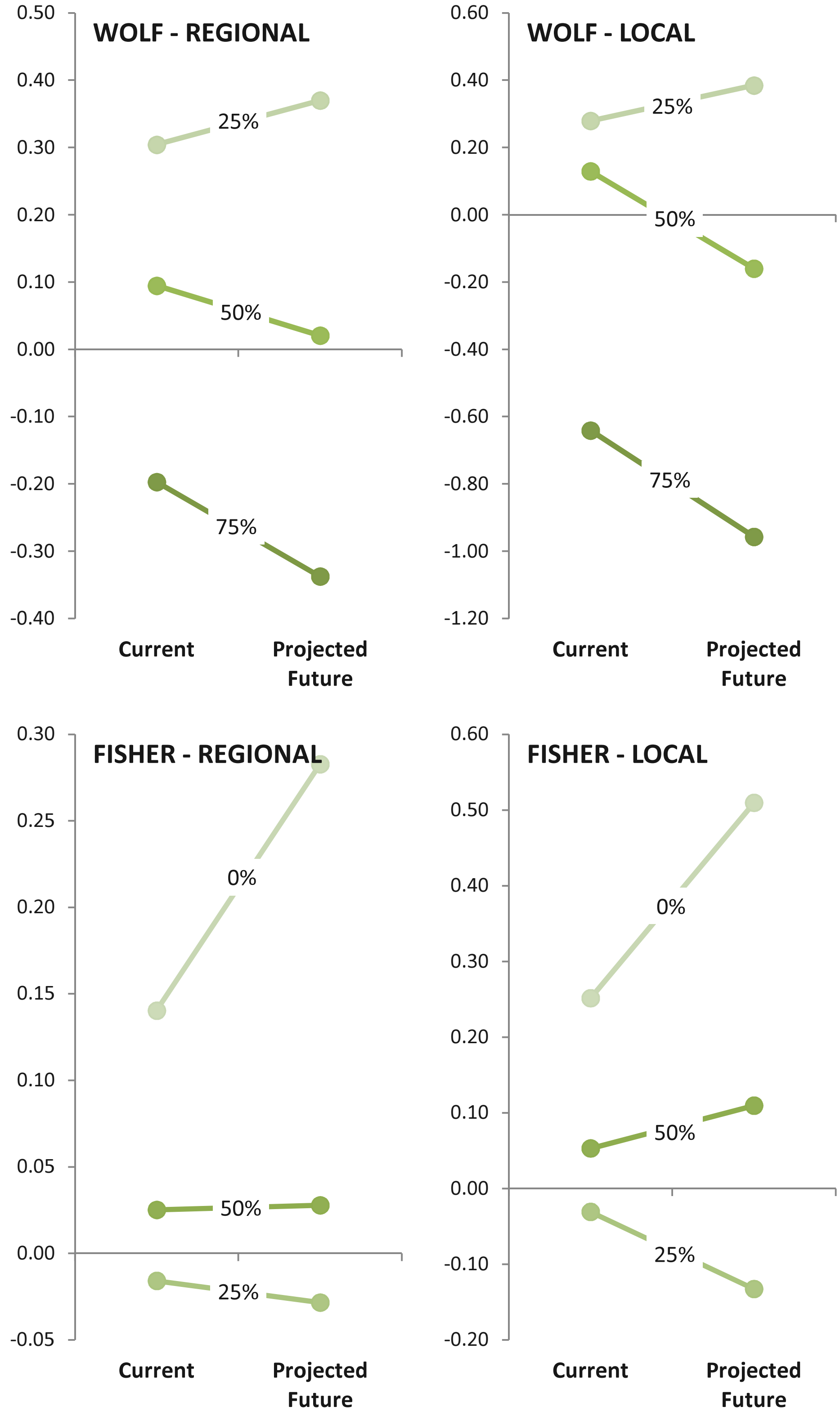

Figure 16. Continued.

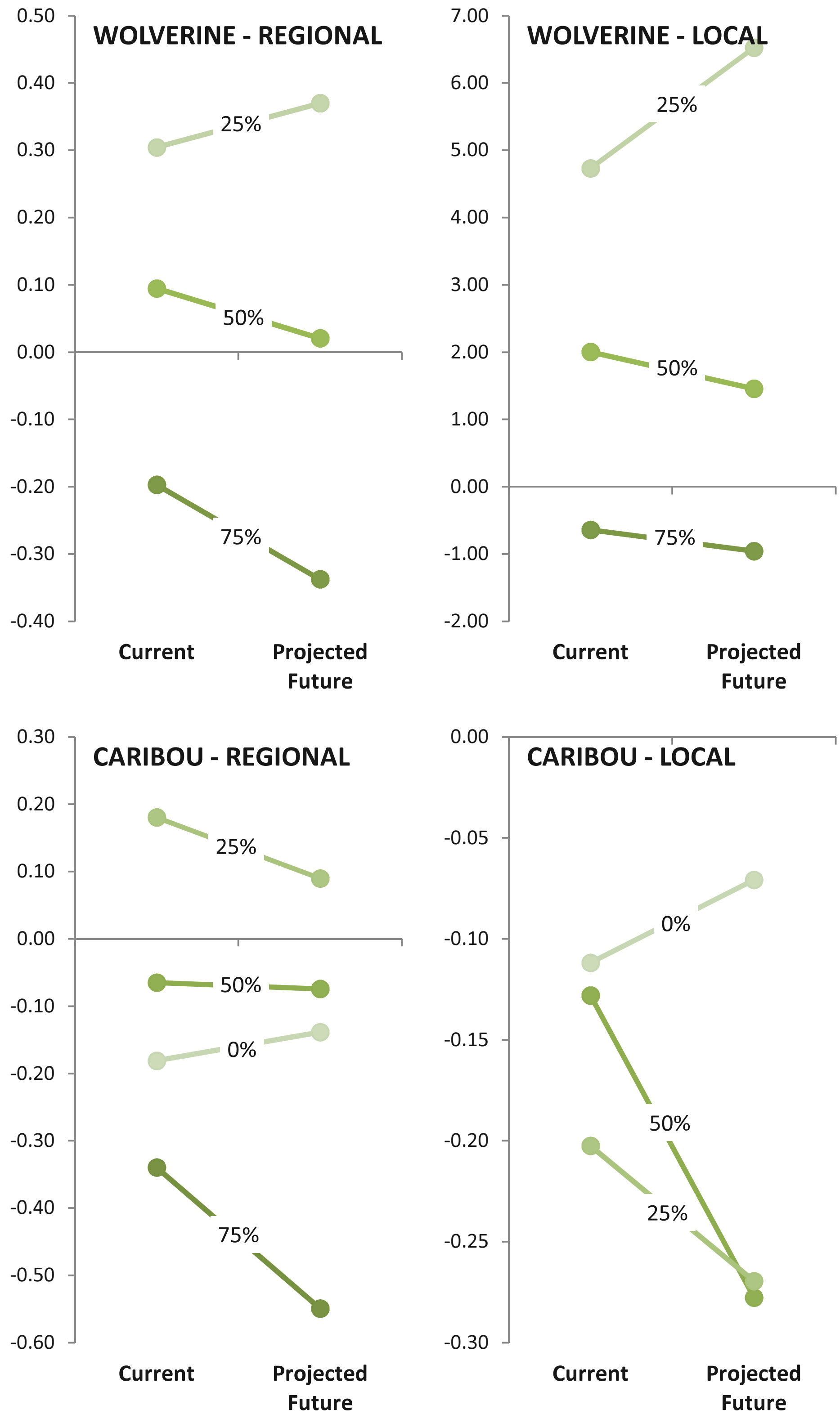

Figure 16. Continued.

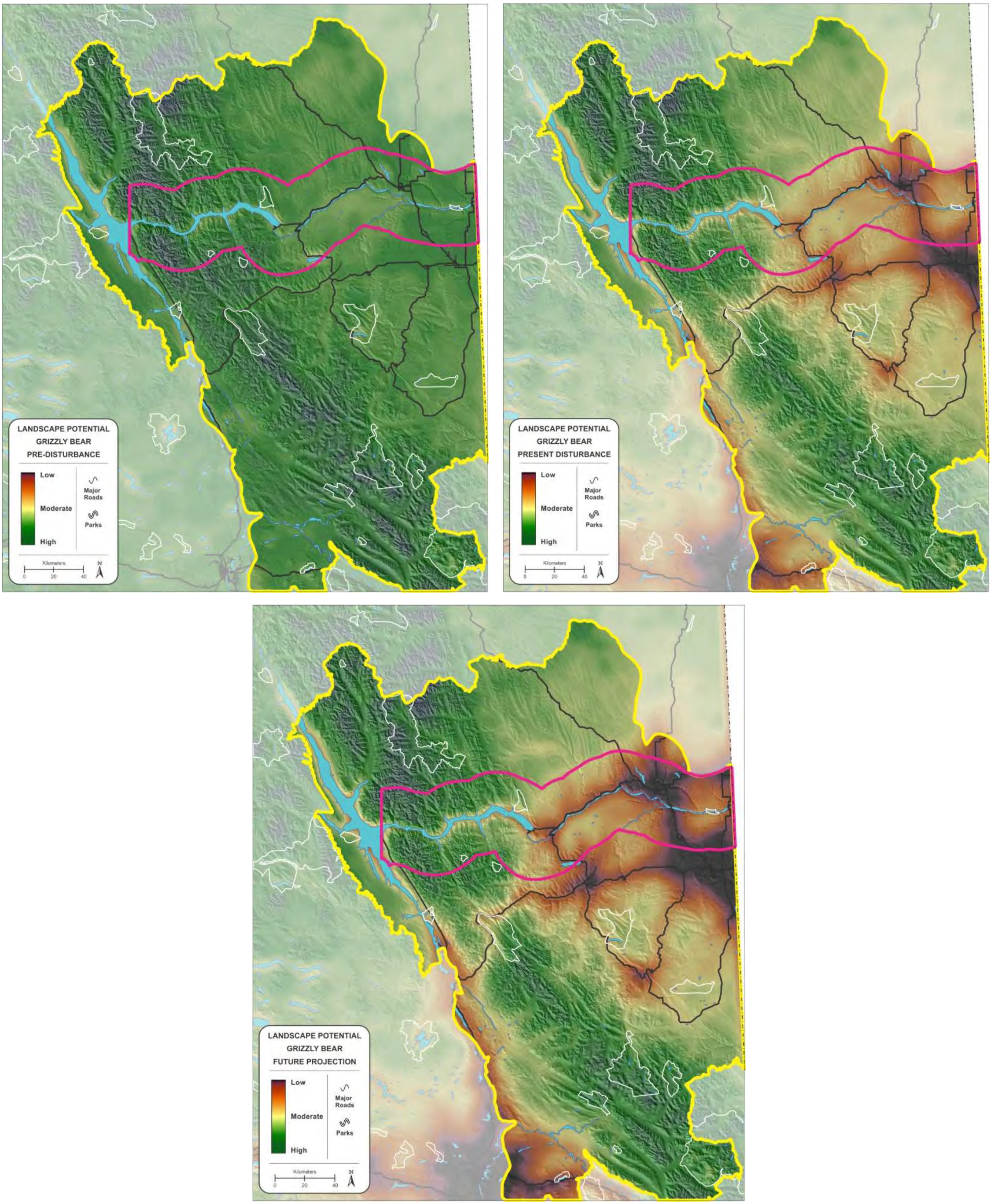

Figure 17. Landscape potential for GRIZZLY BEAR across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

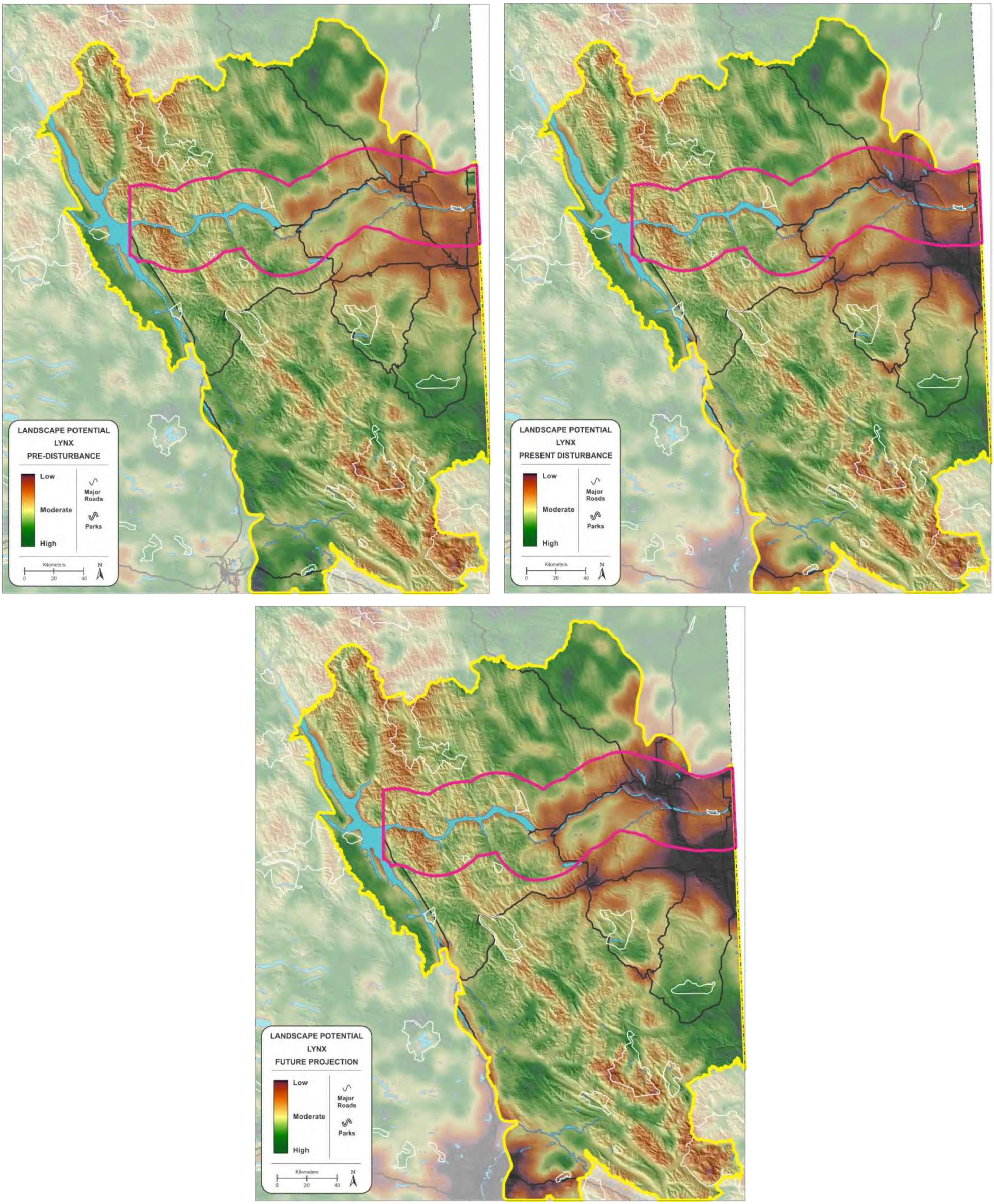

Figure 18. Landscape potential for LYNX across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

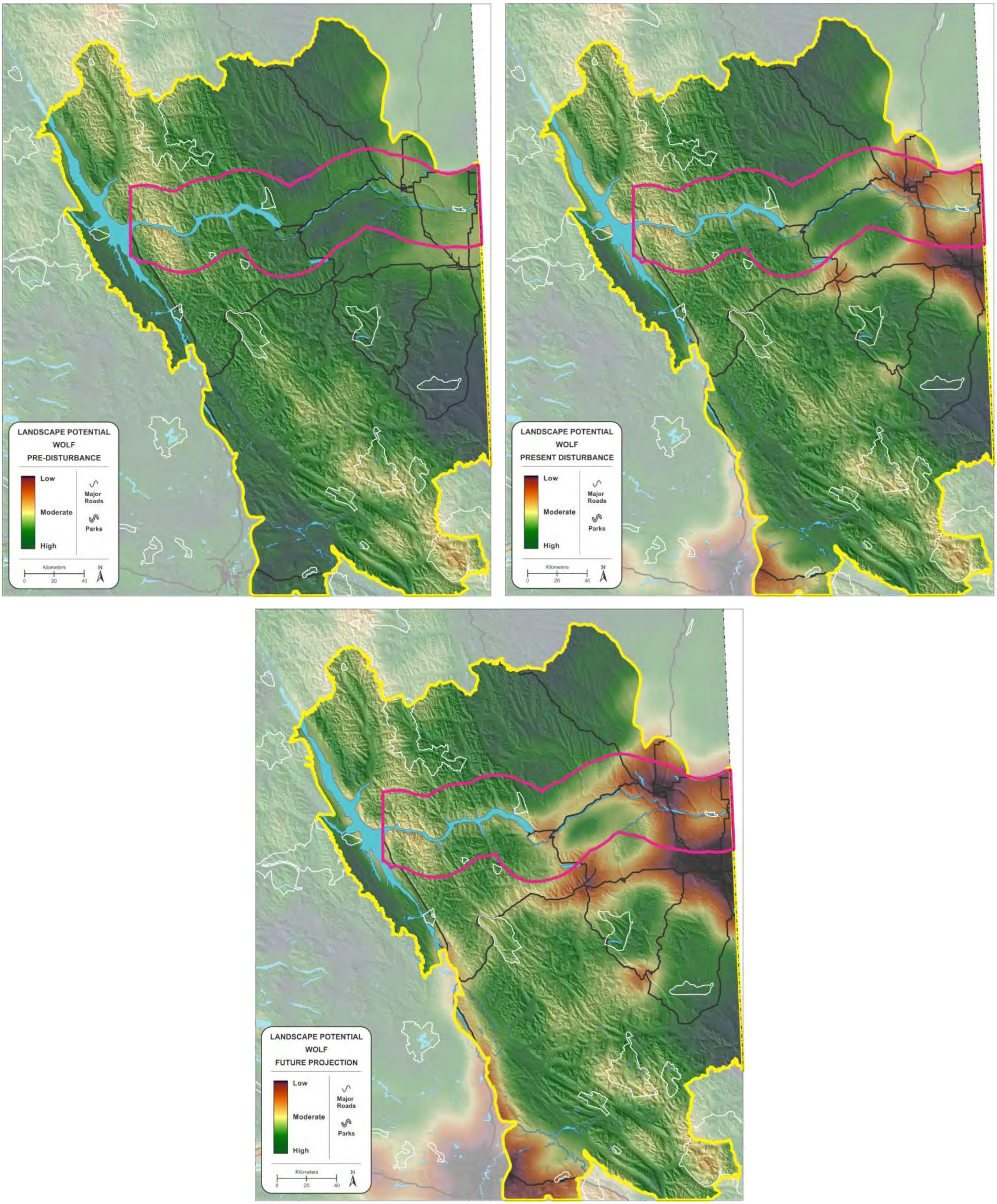

Figure 19. Landscape potential for WOLF across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

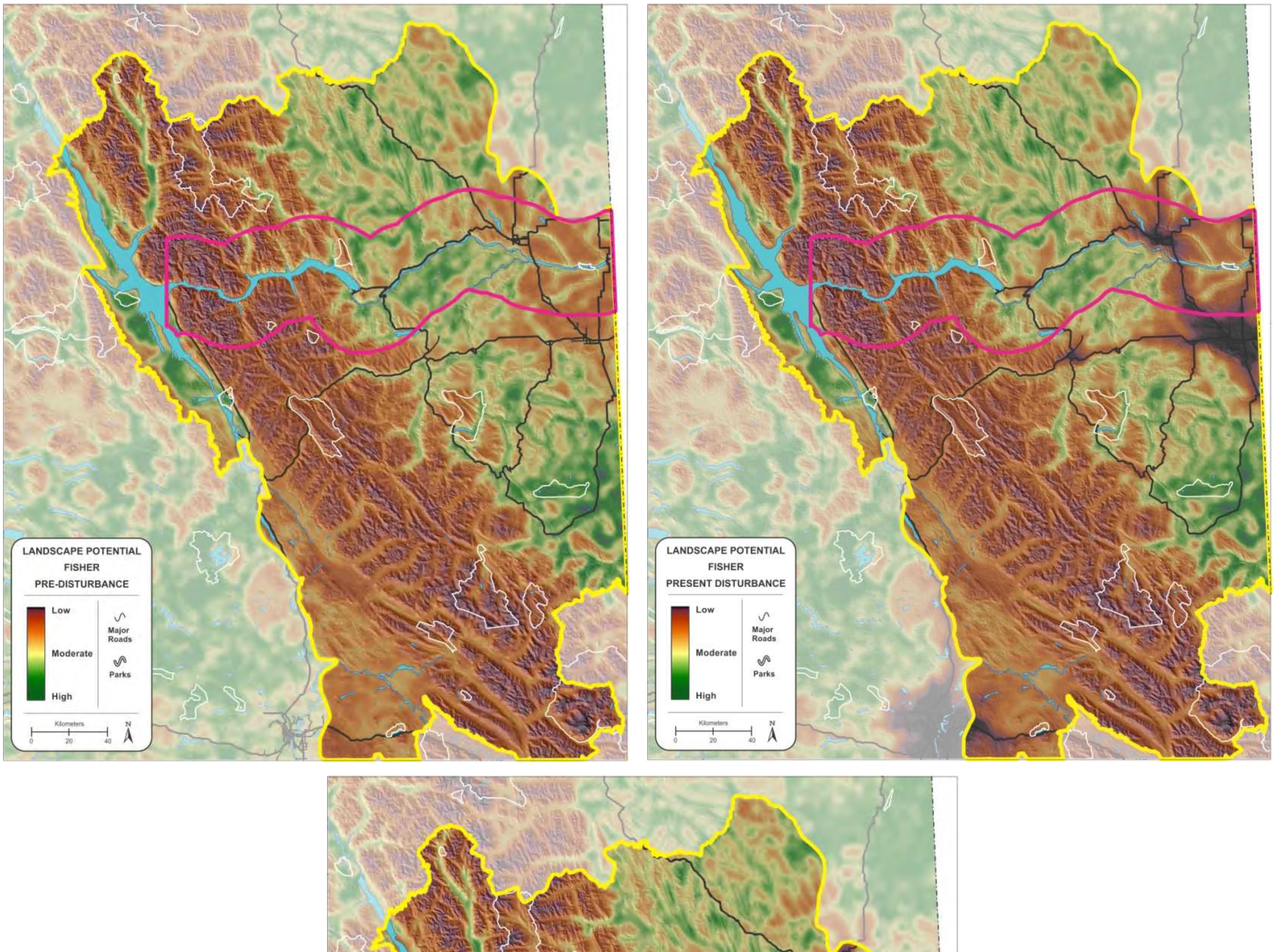

Figure 20. Landscape potential for FISHER across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

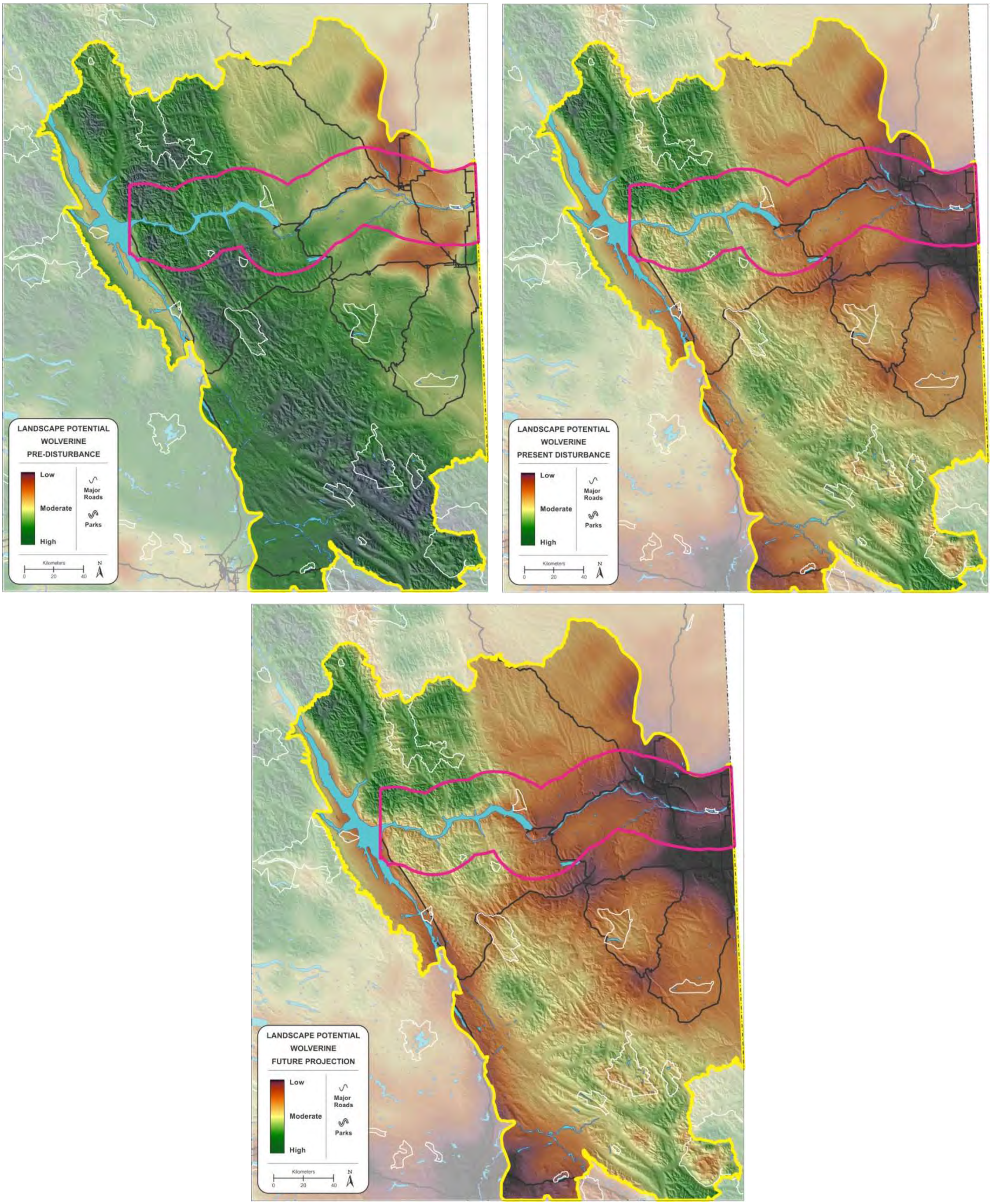

Figure 21. Landscape potential for WOLVERINE across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

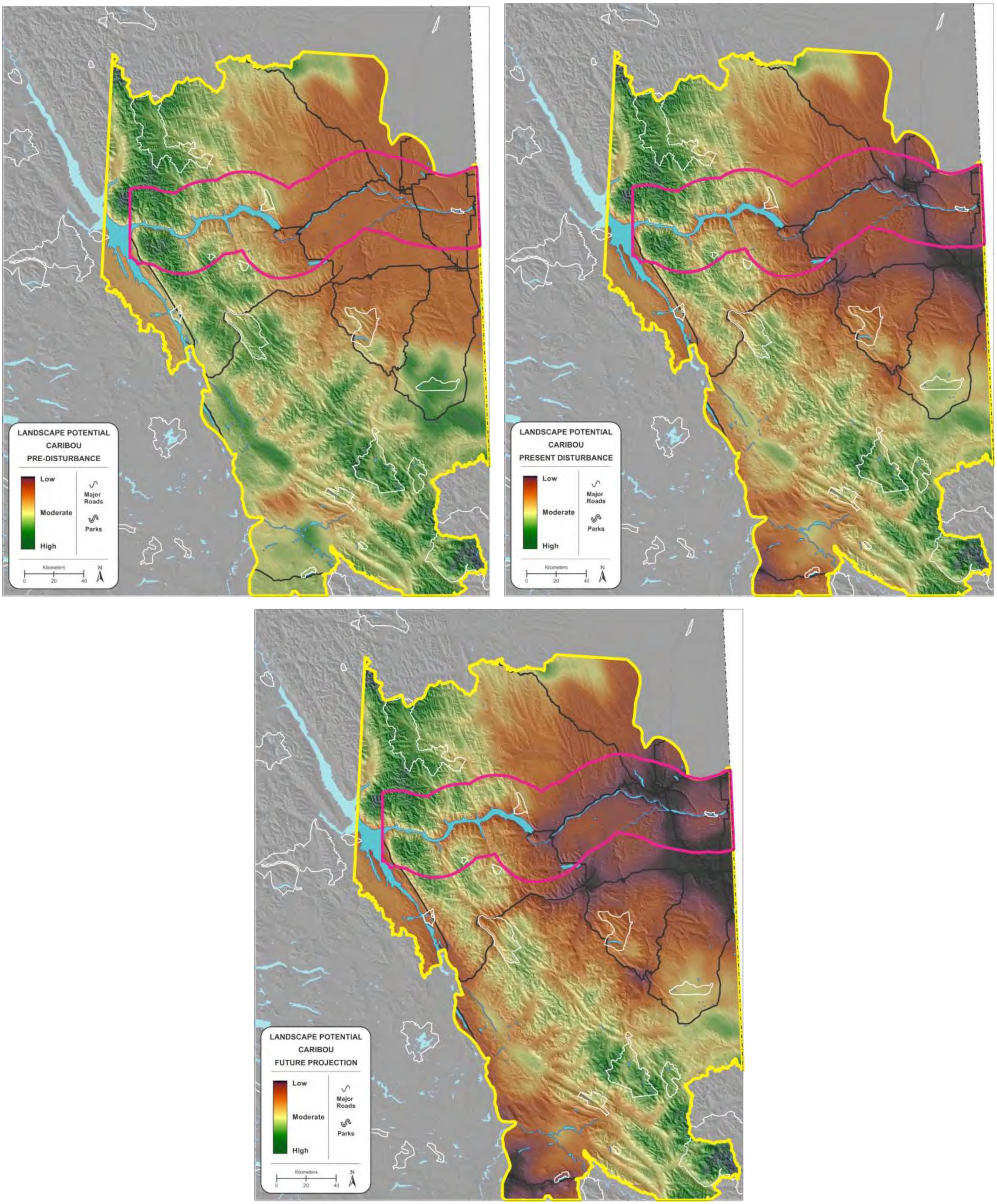

Figure 22. Landscape potential for CARIBOU across the Peace Break regional (yellow) and local (pink) assessment areas. Scenarios are "undisturbed" (upper left), present (upper right) and projected-future (bottom).

Relevance of Hydro-Electric Impoundments

Among the wide-ranging focal species considered in this assessment, fishers have the greatest potential to suffer major loss of occupied landscapes entirely due to landscape flooding for hydro-electric impoundment. The loss of biologically productive and seasonally important riparian and floodplain habitats is also undoubtedly significant for other focal species. But it is the effect of such landscape flooding on the movements of individuals and hence the connectivity of the larger population that is of particular concern.

For all focal species considered, major reservoirs will obviously reduce landscape permeability dramatically. Such large water bodies can be expected to contribute to measureable breaks in demographic and possibly genetic connectivity. However, these features are unlikely to constitute absolute barriers. All of the wide-ranging focal species considered in this assessment have known potential to move across water bodies (swim or traverse ice) similar to the existing and proposed impoundments of the Peace River. For example, male grizzly bears swim Carpenter Lake Reservoir in southwestern BC in moving within annual home ranges and likely also in dispersal (Apps et al. 2009). Reproductive females are less likely to make such movements, but the dispersal of subadult females is still quite possible depending on population density relative to carrying capacity of adjacent landscapes. Wolverines are known to be powerful swimmers and also move across large expanses of unforested habitats. Across Williston Lake, male wolverines have swum during summer and traversed the ice during winter, and wolverine movement is unlikely to be prevented by Peace River impoundments (E. Lofroth, pers. comm.). Similarly, lynx are adapted for long-distance dispersal that often span unforested habitats and waterbodies, and lynx have been observed swimming lakes and major rivers (C. Apps, unpubl. data). While wolf pack territories may be bounded by major water bodies, forays and dispersal of individuals can easily span lakes and reservoirs such as those of the Peace River. Coastal wolves, for example, will swim among islands isolated by considerably greater distance (Darimont et al. 2004). Wolves do move across frozen lakes, though they are highly vulnerable to being shot where there are people. Among the focal species, fishers are the least likely to traverse a reservoir, frozen or not. However, males are known to swim rivers and are likely to continue to make at least periodic movements across the Site C reservoir (R. Weir, pers. comm.). With respect to woodland caribou, open water is likely to deter movements and individuals will be highly vulnerable to predation and human-caused mortality on frozen lakes. That said, caribou have also been known to swim water bodies such as Kootenay Lake in southeastern BC (T. Kinley, pers. comm.).

Understanding the above-described potential for each species to move across major water bodies is relevant to recommendations to mitigate existing and any future reservoir. In particular, the potential for individuals to traverse such impoundments likely depends on the proximity and effectiveness of core habitat areas. Hence, mitigation strategies should seriously consider the potential for enhancements to habitat productivity and security in landscapes that have high inherent potential for given species and are adjacent to existing or proposed impoundments.

4.
CONCLUSIONS & RECOMMENDATIONS

The intent of this assessment has been to evaluate cumulative human influence on landscape effectiveness and connectivity for a select suite of wide-ranging species. For each species, the magnitude of impacts has been described in a context that compares past, present and potential-future scenarios. Current and projected impacts for each species are a function of (1) inherent habitat requirements, (2) different sensitivities to human activities, and (3) resulting potential for population distribution and connectivity. Although the nature of impacts does vary among species, I judge the net cumulative impacts at both the regional and local assessment scales to be highly significant for all species. While it is not possible to know the specific threshold of population persistence for a given species at either assessment scale, that point is undoubtedly exceeded in many landscapes and resulting population fragmentation is an obvious threat.

At the regional level, populations of the focal species I considered are compromised, fragmented and likely to continue to trend toward reduced stability and viability. But there does also appear to exist for each species at least some secure and effective habitat areas that are likely to sustain productive individuals and connected population cores. The protection and enhancement/recovery of such known or potential core areas and connections is central to conservation planning for these species. This end is most likely to be achieved through the flexible application of available conservation mechanisms that may involve partnerships among government, non-government, industry and private organizations and individuals.

While the distribution of private land is extensive in the Peace Break region, the majority of lands with reasonable value to the wide-ranging focal species considered in this report is under public ownership and therefore available for protective management. Here, the conservation of healthy and naturally distributed wildlife populations is an important mandate of British Columbia environment and natural resource ministries. Thus, halting and potentially reversing the recent trend of cumulative human impacts within the Peace Break region is, I believe, a realistic goal. However, the direct and indirect impacts of Site C hydro-electric development and impoundment will further erode the potential for local and regional landscapes to support the wide-ranging species considered herein. Effective conservation is, therefore, a far less likely outcome if Site C is to proceed.

Regardless of the decision on Site C, offsetting and moving toward reversal of existing and potential-future cumulative human impacts within the Peace Break region will require focused mitigation and conservation planning at local to regional scales. The species considered in this assessment are effective indicators for conservation of complete terrestrial communities, especially at broad scales. And the modeling and analytical outputs provided in this report can assist in the planning process, particularly in defining landscapes where specific mitigations and/or conservation zoning are likely to be most effective. Planning efforts should focus on the protection and enhancement of landscape conditions that facilitate core population areas appropriately buffered from negative human impacts. These core areas will most effectively anchor a resilient regional population where connecting linkage zones are also protected, enhanced and/or restored. Central to such efforts will be the management and reduction of human access, especially motorized. But habitat management that is appropriate to the local ecosystems and their regime of natural disturbance is also important. Planning for such enhancements with species-specific or biodiversity objectives should be carried out in concert with human-use management to avoid the promotion of attractive population "sinks" with high levels of mortality risk.

In managing and conserving broad-scale population connectivity for wide-ranging species, conservation strategies to address major fracture zones are of great importance. Such fractures are often associated with highways and the linear pattern of human development along them especially where associated with private land. This highway-fracture association is apparent within the Peace Break region, but it is also important to note that the course of the Peace River and its hydro-electric impoundments, including the Peace Reach of the Williston Reservoir, do also represent a present or emerging population fracture for most of the species considered in this report. Here, connectivity may be best conserved and/or enhanced through increased protection of adjacent landscapes from further human access and impacts. Many human impacts, including impoundments do not necessarily constitute absolute barriers to movement. And such movements, however infrequent, will be much more likely if adjacent landscapes are attractive, secure and productive for a given species. Moreover, any opportunities that exist to secure and potentially enhance movement opportunities through non-flooded landscapes spanning the Peace Valley should be of high conservation priority. This should include a potential linkage zone between the W.A.C. Bennett Dam and the Dinosaur Reservoir, southeast to northeast of the Peace Arm of the Williston Reservoir. It should be noted that much work toward the promotion of an ecological connectivity network for the Peace Lowlands Ecosection is completed and available (PHACET 2002).

Finally, as noted in Chapter 2, there is an obvious paucity of information derived from local research or inventory for most species considered in this report. Such local understanding and/or survey or monitoring data would greatly contribute to the modeling of species occurrence, distribution and connectivity and in evaluating current impacts and trends. For example, despite the availability of highly effective survey methods, there is virtually no information on grizzly bear abundance and distribution within the Peace Break relative to many other regions of the province. In the absence of such information to reliably inform modeling and population viability analyses, I recommend that the precautionary principle be applied in the consideration of the Site-C project and other developments that are likely to exacerbate the adverse cumulative impacts that presently pervade the region. Maintaining viable and naturally distributed populations of native wildlife is consistent with public policy in British Columbia (MELP 1994), and it is appropriate that development proponents themselves shoulder the responsibility for demonstrating that the cumulative impact to long-term persistence and viability of the wide-ranging focal species addressed herein is not significant.

The Rocky Mountains and associated ranges of western North America (the Y2Y ecoregion) are globally significant in their large component of wild lands and the relatively continuous and connected populations of most native large mammals that are supported. Without proactive conservation planning, the fracture that may eventually emerge due to current and projected levels of cumulative human impacts across the Peace Break region is consequential at a continental scale.

Below, I reiterate the primary points of consideration and conclusion discussed in this report:

- For wide-ranging species, evaluation and mitigation of cumulative human impacts is most relevant at broad scales of regional population distribution and should consider the potential for landscape occupancy, productivity and population connectivity.
- I judge the net cumulative impacts at both the regional and local assessment scales to be significant for all wide-ranging terrestrial species considered.
- A threshold of population persistence has undoubtedly been exceeded in many landscapes and resulting population fragmentation is a threat.
- The direct and indirect impacts of Site C hydro-electric development and impoundment will further erode the potential for local and regional landscapes to support the wide-ranging species considered herein.
- Bull trout and Arctic grayling fish are also under pressure from a number of inter-related impacts within the Peace Break region. The Site-C development will clearly impact these species in different ways but the net impact and the nature and extent of planned mitigation is unclear.
- Projected human population and development trends suggest that the stability and viability of focal species populations may be further compromised in the future without proactive conservation planning.
- There may be opportunities for increased protection of some landscapes, contributing to the enhancement and/or recovery of secure and effective habitat areas for multiple species. These should focus on population cores and important linkage zones.
- Management and reduction of motorized human access is central to effective conservation planning. But habitat management appropriate to local ecosystems and associated regimes of natural disturbance is also important. Habitat enhancement should be planned in concert with human-use management to avoid the potential for localized conflict with people and/or increased mortality among focal species.

- Special attention should be given to measures that can enhance habitat effectiveness and security adjacent to potential population fractures through which some movement by a given species is possible and desirable. And the landscape directly east of the W.A.C. Bennett Dam that is not subject to flooding should be of high conservation priority as a multi-species linkage zone.

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APPENDICES

Appendix 1. Classification of localized human features (NRC 2010) as "high" or "low" use.

HUMAN USE - HIGH

Theme	Feature
Buildings/Structures	Arena
Buildings/Structures	Armoury
Buildings/Structures	Burner
Buildings/Structures	City hall
Buildings/Structures	Coast guard station
Buildings/Structures	Community centre
Buildings/Structures	Courthouse
Buildings/Structures	Customs post
Buildings/Structures	Educational building
Buildings/Structures	Electric power station
Buildings/Structures	Fire station
Buildings/Structures	Flare stack
Buildings/Structures	Gas & oil facilities building
Buildings/Structures	Highway service centre
Buildings/Structures	Hospital
Buildings/Structures	Industrial
Buildings/Structures	Industrial building
Buildings/Structures	Medical centre
Buildings/Structures	Municipal hall
Buildings/Structures	Other
Buildings/Structures	Parliament building
Buildings/Structures	Penal building
Buildings/Structures	Police station
Buildings/Structures	Railway station
Buildings/Structures	Religious building
Buildings/Structures	Satellite-tracking station
Buildings/Structures	Sportsplex
Buildings/Structures	Unknown building
Buildings/Structures	Unknown chimney
Energy	Gas and oil facilities
Industrial/Commercial	Auto wrecker
Industrial/Commercial	Domestic waste
Industrial/Commercial	Industrial solid depot
Industrial/Commercial	Lumber yard
Industrial/Commercial	Mine
Industrial/Commercial	Mine, underground
Industrial/Commercial	Extraction area
Industrial/Commercial	Industrial/commercial
Places of Interest	Amusement park
Places of Interest	Botanical garden
Places of Interest	Drive-in theatre
Places of Interest	Fairground
Places of Interest	Fort
Places of Interest	Golf course
Places of Interest	Golf driving range
Places of Interest	Historic Point of interest
Places of Interest	Marina
Places of Interest	Other
Places of Interest	Park/Sports field
Places of Interest	Picnic site
Places of Interest	Ruins
Places of Interest	Shrine
Places of Interest	Ski centre
Places of Interest	Sports track/Race track
Places of Interest	Stadium
Places of Interest	Zoo

HUMAN USE - LOW

Theme	Feature
Buildings/Structures	Clearance
Buildings/Structures	Communication
Buildings/Structures	Control
Buildings/Structures	Firebreak
Buildings/Structures	Horizontal, unknown
Buildings/Structures	Lookout
Buildings/Structures	Navigation beacon
Buildings/Structures	Navigation light
Buildings/Structures	Petroleum
Buildings/Structures	Radar
Buildings/Structures	Radio telescope
Buildings/Structures	Sewage/liquid waste
Buildings/Structures	Silo
Buildings/Structures	Unk tank
Buildings/Structures	Unk horizontal tank
Buildings/Structures	Unknown well
Buildings/Structures	Vertical, other
Buildings/Structures	Vertical, unknown
Buildings/Structures	Vertical, water
Buildings/Structures	Water
Energy	Transformer station
Energy	Valve
Energy	Wind-operated device
Industrial/Commercial	Pit
Industrial/Commercial	Quarry
Places of Interest	Camp
Places of Interest	Campground
Places of Interest	Cemetery
Places of Interest	Lookout
Places of Interest	Unknown