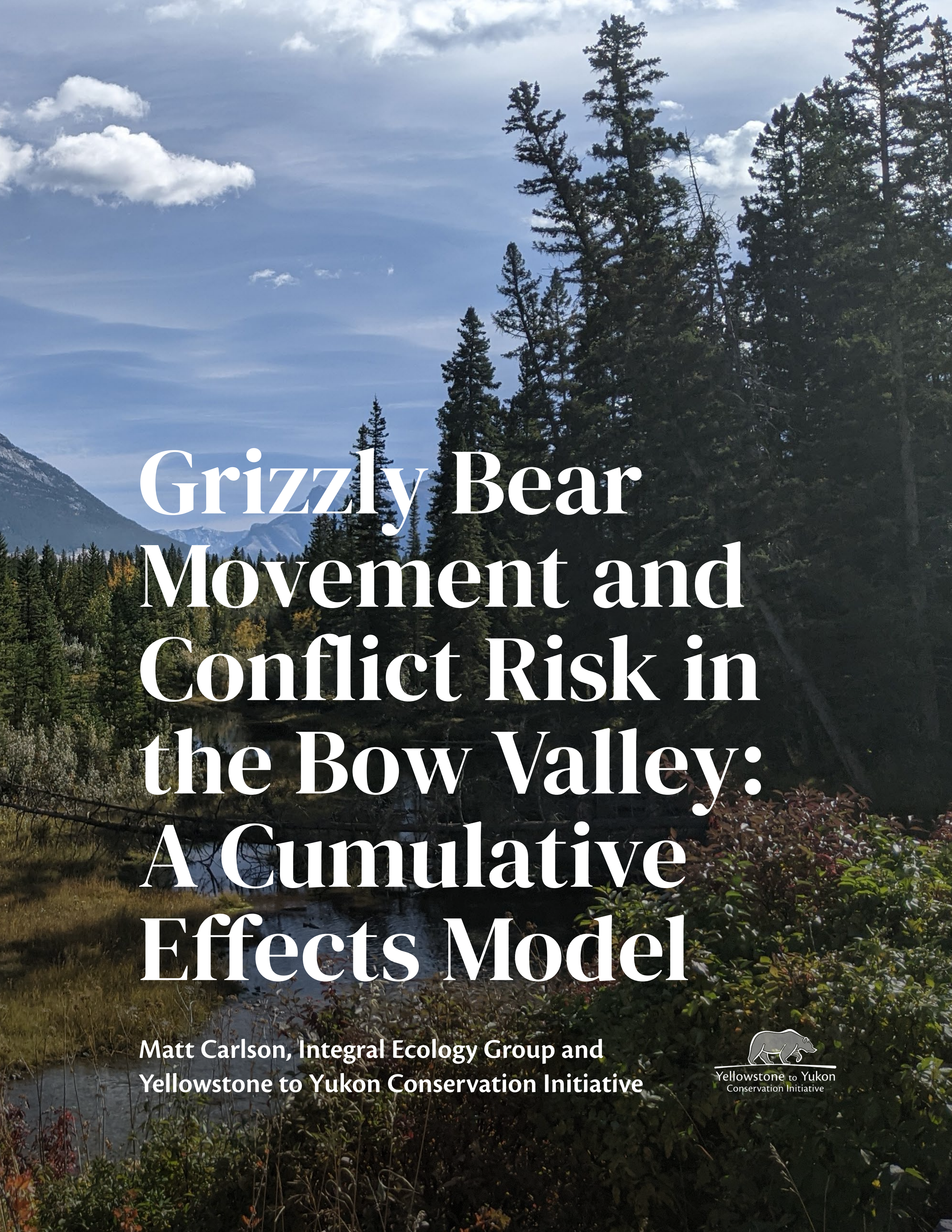

Grizzly Bear Movement and Conflict Risk in the Bow Valley: A Cumulative Effects Model

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Conservation Initiative

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Summary

Using the ALCES Online cumulative effects assessment tool, this project models how human development and recreational use have changed, and are likely to change, in Alberta's Bow Valley, with the aim of understanding how these changes impact likely grizzly bear movement paths and risk of conflict between grizzly bears and people. Results from the modeling suggest:

1. Since the 1970s, human development and recreation have significantly altered likely grizzly bear movement paths, pushing those routes upslope onto less desirable terrain, and this trend is likely to continue;
2. The Trans-Canada Highway, with the significant exception of wildlife crossing structures, directs likely grizzly bear paths onto less desirable terrain by keeping bears on one side of the highway or the other for long stretches of the valley; and
3. The risk of conflict between people and grizzly bears has increased over recent decades and is likely to continue to do so, especially around Canmore, as we advance toward 2050.

The modeling also evaluates how common mitigation approaches could impact human-wildlife conflict risk. Regarding conflict risk, and relative to a "business as usual" approach to future planning and management:

1. A modeled future in which urban expansion is severely limited reduced the proportion of land classified as having moderate or high conflict risk by 35%
2. A modeled future in which all informal (non-designated) trails are deactivated reduced the proportion of land classified as having moderate or high conflict risk by 41%
3. A modeled future in which the intensity of nature-based recreation declines by 50% reduced the proportion of land classified as having moderate or high conflict risk by 23%.

While not proposing specific actions by decision-makers, this study suggests that mitigation strategies have potential to considerably reduce the risk of conflict between grizzly bears and people in the Bow Valley, thereby supporting grizzly bear movement and connectivity.

Introduction

Located in the Eastern Slopes of Alberta's Rocky Mountains, the Bow Valley is one of the most important valleys for wildlife movement in the entire Yellowstone to Yukon region. It offers a rare, low-elevation connection between protected habitats in Kananaskis Country and Banff National Park and is used by a wide variety of large wild animal species. Even so, the Bow Valley has long been described as "one of the most developed landscapes in the world where grizzly bears (*Ursus arctos*) still survive" (Chruszcz et al. 2003).

The Bow Valley's natural beauty and world-class recreational opportunities have driven steady growth in the region's human population and visitation over recent decades. One negative outcome of the expansion of settlements and tourism has been wildlife displacement and mortality. Human impacts on Bow Valley wildlife threaten the region's role as one of the most important valleys in the Rocky Mountains for the movement of large mammals such as grizzly bears. The accumulation of wildlife risk in the valley is an example of the tyranny of small decisions, whereby environmental degradation occurs not by design but through the unintended consequence of numerous small decisions made in isolation from one another.

DEFINITION

Human-wildlife conflict refers to events in which wildlife exhibit stress-related or curious behavior, causing a reasonable person to take extreme evasive action, make physical contact with a person or exhibit clear predatory behavior, or are intentionally harmed or killed by a person (excluding legal harvest). Unintentional wildlife mortality incidents like road or rail mortality are likewise considered conflicts.

(Adapted from Bow Valley Human-Wildlife Coexistence Roundtable 2018)

DEFINITION

Human-wildlife coexistence refers to successfully balancing the needs of wildlife and humans, which includes managing human use in designated wildlife habitat, excluding wildlife from developed areas, and mitigating negative human-wildlife interactions.

(Adapted from Bow Valley Human-Wildlife Coexistence Roundtable 2018)

Valley bottoms that provide good habitat for wildlife, like the Bow Valley, are also attractive to humans, as they provide access to water and associated resources, relatively flat terrain that supports the development of roads, buildings, and other infrastructure, easy travel, and proximity to established transportation paths. The population of the Bow Valley has been steadily increasing since the early 1980s, as have tourism, recreation and visitation pressures.

This work follows on the heels of the Human-Wildlife Coexistence Roundtable process and fits with the Roundtable report's recommendations about needing to 'think big' and increase inter-jurisdictional communication, as well as the need to fill research gaps (Bow Valley Human-Wildlife Coexistence Roundtable 2018). Addressing human-wildlife conflict in the valley requires a strategic perspective whereby land-use decisions consider cumulative effects of the full suite of human activities occurring across the region. Strategic planning in support of human-wildlife coexistence can be informed by scenario analysis that explores changes in landscapes over large spatial and temporal scales to evaluate the potential capacity of management options to mitigate threats to wildlife in the valley.

To inform strategic planning aimed at mitigating risk to wildlife in the Bow Valley, we completed a scenario analysis that simulated past and potential future development and recreation, and consequences of changes to those activities. We also explored the outcomes of three mitigation scenarios on grizzly bear connectivity and the risk of human-wildlife conflict in the future. We chose grizzly bears because they are a threatened species in Alberta whose recovery is a provincial government objective (Alberta Environment and Parks 2020), whose persistence in the Bow Valley has long been a public and scientific concern (Bow Valley Human-Wildlife Coexistence Roundtable 2018), and whose occupancy of a landscape serves as a powerful indicator that other, less intensively studied species, are likewise able to persist (Steenweg 2016).

Methods

The ALCES Online computer model was applied to simulate the cumulative effects of land use to landscape connectivity and wildlife risk in the Bow Valley, with a focus on grizzly bears. ALCES Online is a web-based decision support tool for cumulative effects assessment that has been used in a variety of management contexts including regional planning, wildlife management, conservation planning, urban planning, and forest management (Carlson and Stelfox 2014, Carlson et al. 2019, Rempel et al. 2021, Leston et al. 2020).

For this project, a scenario analysis was completed to explore changes in connectivity caused by past and potential future land use footprints (roads, trails, settlements, acreages, mines etc.), and risk created by overlapping areas of high connectivity and high human activity. The project adopted the same study area used for the Bow Valley Human-Wildlife Coexistence Roundtable, a 900 km^2 portion of the Bow Valley extending from Castle Junction to Kananaskis River. To explore the implications of past and potential future land use, the time period for the analysis was the 1970s to the 2050s. The analysis involved the following components:

1. Simulation of past and potential future changes in land-use footprints and recreational activity under a base case scenario
2. Simulation of land-use footprint and recreation mitigation scenarios
3. Simulation of grizzly bear connectivity using least cost paths
4. Integration of simulated estimates of recreational activity and least cost paths to map risk of human-wildlife conflict

DEFINITION

We use “**base case**” to refer to a status quo approach to managing development and recreation without additional mitigation action.

Development and refinement of the model was guided by the input of the Bow Valley Cumulative Effects Advisory Group. This group was comprised of staff from the Town of Banff, Town of Canmore and Alberta Parks and met five times between November 2020 and September 2021. The stated key objectives under which the Advisory Group was organized were:

1. To model how foreseeable changes and developments are likely to impact grizzly bear movement and connectivity through the Bow Valley
2. To provide an opportunity for local municipalities and stakeholder organizations to inform the model and indicators reflecting their own priorities so it is useful for them to use if they choose.

Advisory Group Process

2020

NOVEMBER 18

Meeting 1

Introduction to the model capabilities and process to develop the outcomes.

2021

JANUARY 13 + 29

Meetings 2 & 3

Explored indicators and available data that could be used for modeling future scenarios.

MAY 17

Meeting 4

Reviewed and refined the indicators used to create the future scenario models.

SEPTEMBER 2

Meeting 5

Reviewed model outcomes and how the information will be presented publicly.

Simulation of Land Use Footprint

Current landscape composition was estimated from available land cover and footprint inventories, and used as the starting point for backcast (i.e., historical) and forecast (i.e., future) land-use simulations. Natural land cover was based on Earth Observation for Sustainable Development map data, and anthropogenic footprint was based on the most recent version of the Alberta Biodiversity Monitoring Institute's (ABMI) Human Footprint Inventory (2018).[1] The data layers were intersected to create a non-overlapping representation of landscape composition, with anthropogenic footprints taking precedence over natural land cover during the intersection. The resulting data set represented landscape composition as the proportion of each 100 m cell that is covered by each natural and anthropogenic cover type. An additional version of the landscape layer was created that excluded anthropogenic footprints to provide an estimate of landscape composition prior to European settlement. It was found that the Human Footprint Inventory was incomplete with respect to its representation of trails, so additional data sources were used to identify the trail network. Trails within Banff National Park were identified using data provided by Parks Canada. Trails outside of Banff National Park were identified using data provided by Alberta Environment and Parks.

A backcast simulation of the change in land use footprint from 1970 to 2018 was prepared using historical data, including Agriculture and Agri-Food Canada (AAFC) land use layers (available for 1990, 2000, and 2010), the Canada Land Inventory (available for 1970), the date of origin for major developments (Three Sisters golf course, Stewart Creek golf course, Silvertip golf course, Kananaskis Ranch golf course, Canmore Nordic Centre), and date of origin information for gravel pits from the ABMI Human Footprint Inventory.

To simulate future development over the next three decades, settlement footprint was assumed to expand at the same rate as population growth rates prepared by the Calgary Regional Partnership (2017) for the towns of Banff and Canmore and the Municipal District of Bighorn. An exception was that settlement footprint within the municipality of Canmore grew 10% slower than the population growth rate due to the target identified in the Town of Canmore's 1998 Municipal Development Plan that 10% of population growth will be accommodated within the existing settlement footprint.

When simulating future settlement footprint in the MD of Bighorn, development was assumed to grow outwards from existing footprint, with a higher likelihood of new development in proximity to larger patches of existing footprint. In Canmore, development was assumed to initially occur within the Urban Growth Boundary, with priority given to areas closer to the town centre. Once any undeveloped area was no longer available within the Urban Growth Boundary, development expanded into the Area to Be Determined (Smith Creek). Footprint expansion did not occur in the Town of Banff because the town's footprint is fixed (i.e., no expansion is allowed by Parks Canada).

FACT

The data used in this modeling exercise were obtained from many sources, including Parks Canada, Alberta Environment and Parks, Agriculture and Agri-Food Canada, the Canada Land Inventory, Calgary Regional Partnership, and the Alberta Biodiversity Monitoring Institute.

Simulation of Recreational Activity

The current intensity of recreational activity was estimated based on the publicly available Strava Global Heatmap. The heatmap, which can be viewed online, maps the intensity of public activities as recorded by Strava users over the past two years. Colours in the heatmap represent different levels of activity, scaled such that there is an equal area of each colour in the map. Based on visual inspection of the map, we created a 0 to 5 index with 0 representing no activity, 1 representing the colour associated with the lowest level of activity, and 5 representing the colour associated with the highest level of activity. We did not have access to the raw counts, i.e., the actual number of trips associated with each category. In the absence of raw counts, we assumed that the increase in activity from one level to the next is nonlinear because a small number of popular routes likely account for a large proportion of total activity. Recreational activity was assumed to increase with the Strava index according to the exponential function, i.e., index of recreational activity = $e^{\text{Strava index}}$. The implication of this approach is that the Strava index is assumed to increase at a more gradual rate than the population.[2] As a simple test of the validity of the assumed nonlinear relationship between Strava categories and intensity of use, we utilized trail use data estimated from cameras or counters in the month of August for

[1] https://abmi.ca/home/data-analytics/da-top/da-product-overview/Human-Footprint-Products/HF-inventory.html

[2] Applying the exponential function assumes that recreational activity increases by a factor of 2.71 from one Strava category to the next, such that a Strava index of 5 represents an ~55-fold increase in recreational activity compared to an index value of 1. Simulation of recreational activity used the index of recreational activity. The simulated index of recreational activity was then backtransformed to the Strava index by taking the natural log.


Photo by Adam Linnard

official trails occurring within the Banff National Park portion of the study area. The trail use data layer was imported into ALCES Online such that it was summarized at the scale of 100 m. Cells with nonzero trail use were sorted by their use value and divided into 5 categories that each had the same number of cells. The average trail use value within each category was then calculated. As expected, trail use increased nonlinearly across the 5 categories. The increase factor between categories ranged from 2.1 to 5.1 with an average value of 3.1, which is in reasonable agreement with the exponential function (i.e., an increase factor of 2.7).

Simulation of past and future change in recreational activity was based on two core assumptions:

1. Recreational activity (as opposed to the Strava index) changes at the same rate as growth in population or visitation; and
2. Settlement footprint affects the presence of recreational activity within a radius of 2 km, based on the current pattern of 84% of recreational activity occurring within 2 km of settlement footprint.

Change in recreational activity from 1970s to current was simulated by assuming that recreational activity grew at the same rate as the population, based on Canmore and Banff population data for the portions of the study area outside of and within Banff National Park, respectively. The spatial distribution of the removal of recreational activity back through time was based on the spatial pattern of footprint growth, as follows: recreational activity occurring in cells with footprint or recreational development (e.g., Canmore Nordic Centre) was removed if the footprint or recreational development was removed during the backcast; and recreational activity occurring within 2 km of current settlement footprint was removed if it no longer occurred within 2 km of settlement footprint during the backcast. Additional recreational activity was removed as needed for the index of recreational activity to exhibit the same rate of growth as the population trajectories; the spatial distribution of the removal of additional recreational activity was proportional to the spatial distribution of the index of recreational activity.

Simulation of future change in the index of recreational activity over the next three decades focused on Strava activity occurring away from settlement footprint and highways, which we interpreted as representing nature-based recreation (e.g., hiking, mountain biking, trail running). Winter recreational activities were not considered because grizzly bears are not active during this season. Growth in nature-based recreation was assumed to increase linearly with population growth in both Canmore (including the Nordic Centre) and the MD of Bighorn. In Banff National Park, the rate of growth in nature-based recreation was assumed to equal 25% per decade, which is about half the rate of growth in visitation between 2011/12 and 2017/18. During that period, visitation in Banff National Park increased 29.6%, or around 5% per year which extrapolates to 50% per decade.[3]

In Canmore and the MD of Bighorn, half of the simulated future growth in nature-based recreation was assumed to be accommodated through increased intensity of use in areas that already have Strava activity, with the spatial pattern of the growth based on the current spatial distribution of the index of recreational activity. The remaining half of the growth in nature-based recreation activity in Canmore and the MD of Bighorn was assumed to occur in cells that do not currently have Strava activity or settlement footprint (in other words, new trails).[4] The assumption that new nature-based recreation was accommodated equally by intensification of existing trails and creation of new trails was made in the absence of more detailed information. The new areas of nature-based recreation occurred within 2 km of new settlement footprint, with the relative likelihood of new recreational activity equal to a 2 km radius moving window average of the density of new settlement footprint. The model treats growth of recreational activity within and outside of designated wildlife corridors the same, as is the case in the present day. The initial level of recreational activity for new areas of nature-based recreation in the simulation equaled the current average Strava index value across cells, excluding settlement, highways, and areas without recreational activity. This average value was 2.24 for the MD of Bighorn and 3.92 for Canmore. In addition to growth in nature-based recreation (i.e., recreational activity away from settlement footprint), cells receiving new settlement footprint during the forecast are assigned an index of recreational activity equal to the current average Strava index value across cells with settlement footprint (3.11 for the MD of Bighorn and 4.29 for Canmore).

[3] Additional visitation data, obtained from Parks Canada after the scenario analysis was completed, exhibited a similar rate of growth prior to the Covid pandemic. According to those data, independent visitor attendance to Banff National Park increased from 1,115,951 in 2013/2014 to 1,412,372 in 2019/20 for an increase of 26.6% over the 6 year period or 4.4% per year.

[4] Two exceptions to the assumption of new trails accounting for half of new recreational activity is the Nordic Centre and Banff National Park. These areas do not receive new settlement footprint during the simulation and, as a result, all growth in recreational activity is assumed to occur in areas with existing Strava activity.

Grizzly Bear Least Cost Path Analysis

Connectivity was assessed through least cost path analysis (e.g., Singleton et al. 2002). Least cost path analysis is based on the concept that permeability (and, inversely, resistance) varies across a landscape in response to habitat, barriers, and human activity. The cost of moving between locations is calculated as the cumulative resistance encountered along a path between the locations. Least cost paths (LCPs) between start and end points are identified as those that have the lowest cumulative resistance. By identifying LCPs for numerous start and end points, the analysis maps a cell's relative importance to connectivity based on the assumption that cells occurring more frequently in LCPs are more important to connectivity.

DEFINITION

Least Cost Paths, or LCPs, are routes that offer the easiest way from point A to point B for the species being considered. This study considers LCPs for grizzly bears.

Least cost path analysis requires a permeability layer that conveys the relative cost of moving through the landscape, represented here as 100 m cells. A cell with lower permeability indicates lower quality habitat and/or greater displacement from human activity. Permeability was calculated by applying a summer grizzly bear resource selection function (RSF) prepared using grizzly bear GPS collar data from the Bow Valley (Table 1; Whittington pers comm). As per the Whittington RSF, settlement footprint as well as barren land cover with a slope greater than 35° were excluded (i.e., considered impermeable). Prior to application in the permeability layer, the RSF was transformed from the log scale using exp(RSF)/(1+exp(RSF)), creating an index that ranged from 0 to 1. Permeability was also reduced within 500 m of highways to incorporate the tendency for grizzly bears in southwestern Alberta to avoid roads with greater than 100 vehicles per day (Northrup et al. 2012). A review of historical traffic count data for Highways 1 and 1A indicated that the highways exceeded 100 vehicles per day throughout the simulation period (i.e., 1970 onwards). To reflect the finding that grizzly bear habitat selection declined towards zero as proximity to road approached zero (Northrup et al. 2012), permeability was modified by a factor that declined linearly from 1 to 0 as proximity to highways declined from 500 m to 0 m. With the exception of wildlife crossing structures, the Trans-Canada Highway was considered a barrier during simulations, given that much of it is fenced and because the Trans-Canada Highway was found to be a barrier for grizzly bear movement in the region (Gibeau 2000). The number of wildlife crossing structures increased from the beginning of the backcast to current, based on their construction dates, and two planned future crossing structures were added during the first decade of the forecast (Lac des Arc underpass and Bow Valley Gap overpass). Given that fencing along the Trans-Canada Highway did not begin until the 1990s, the Trans-Canada Highway did not act as a complete barrier prior to the 1990s in simulations but still presented resistance to least cost paths due to reduced permeability within 500 m of highways.

LCPs were generated for all pairwise combinations among 100 start points and 100 end points randomly selected from cells with two or more grizzly bear locations according to grizzly bear collar data with coverage across the study area that was provided by Parks Canada. When generating LCPs, a Monte Carlo method was applied whereby stochasticity, or randomness, was added to the cost layer and 10 paths simulated for each pairwise combination. The stochasticity was incorporated to reflect the expectation that grizzly bear movement is not optimal with respect to permeability but rather has a higher likelihood of selecting higher permeability options. Stochasticity was added by having a cell's cost for a given iteration equal to a random number selected from a normal distribution with mean equal to its calculated cost (i.e., 1 – permeability) and standard deviation equal to the standard deviation in cost across cells in the study area. Ten iterations of each of 10,000 pairwise combinations resulted in 100,000 LCPs for a landscape. The output from the analysis was summarized as the proportion of the 100,000 LCPs that crossed each cell.

Mapping Human-Wildlife Risk

To map human-wildlife risk, simulated values of the Strava index (i.e., recreational activity) and the LCP proportions (i.e., grizzly bear connectivity) were combined. Like recreational activity, the distribution of LCP proportions was highly skewed with a small number of cells having high values relative to other cells. For consistency with the Strava index and to avoid having a small number of cells dominate the value of the human-wildlife risk index, the LCP proportions were divided into six bins with LCP proportion increasing nonlinearly between bins by a factor of 2.718 (i.e., exponential function).[5]

> *"The index identifies areas with both high grizzly bear connectivity and high recreational activity as presenting high risk of interaction between grizzly bears and humans."*

Prior to combining the Strava and LCP indices, moving window averages of each index were calculated using a diameter of 400 m such that proximate recreational activity and grizzly bear connectivity contributed risk. The approach was informed by previous research from the region that applied a 400 m buffer to non-motorized human activity when assessing risk to grizzly bears (Gibeau 1998). After calculating the moving window average values, the Strava and LCP indices were multiplied by each other to calculate a human-wildlife risk index. The resulting index identifies areas with both high grizzly bear connectivity and high recreational activity as presenting high risk of interaction between grizzly bears and humans. The maximum possible value of the index is 25, although the current realized maximum value was less than 20 due to the effect of averaging within a diameter of 400 m. A human-wildlife risk index value greater than 9 was interpreted as high because it suggests a situation where, on average, Strava and LCP indices exceed moderate values (i.e., 3). A human-wildlife risk index value greater than 4 but less than or equal to 9 was interpreted as moderate because it suggests a situation where, on average, Strava and LCP indices exceed low values (i.e., 2). A human-wildlife risk index value greater than 1 but less than or equal to 4 was interpreted as low because it suggests a situation where, on average, Strava and LCP indices exceed very low values (i.e., 1). A human-wildlife risk index value greater than 0 but less than or equal to 1 was interpreted as very low. The risk index value for a particular trail or area represents the relative risk of intersection of the paths of a grizzly bear and a recreating human in comparison to other parts of the study area.

Simulation of Mitigation Scenarios

Three mitigation scenarios were simulated to explore sensitivity of the grizzly bear risk index to general types of strategies for mitigating risk of human-wildlife conflict.

LIMITED URBAN EXPANSION

The first scenario, referred to as **Limited Urban Expansion**, excluded future development in the eastern portion of Canmore's undeveloped lands. Development of these areas accounted for 85% of the expansion of Canmore's settlement footprint during the Base Case forecast. It was therefore assumed that growth in the human population and recreational activity in Canmore and the Nordic Centre was 15% that of the Base Case scenario.

NO INFORMAL TRAILS

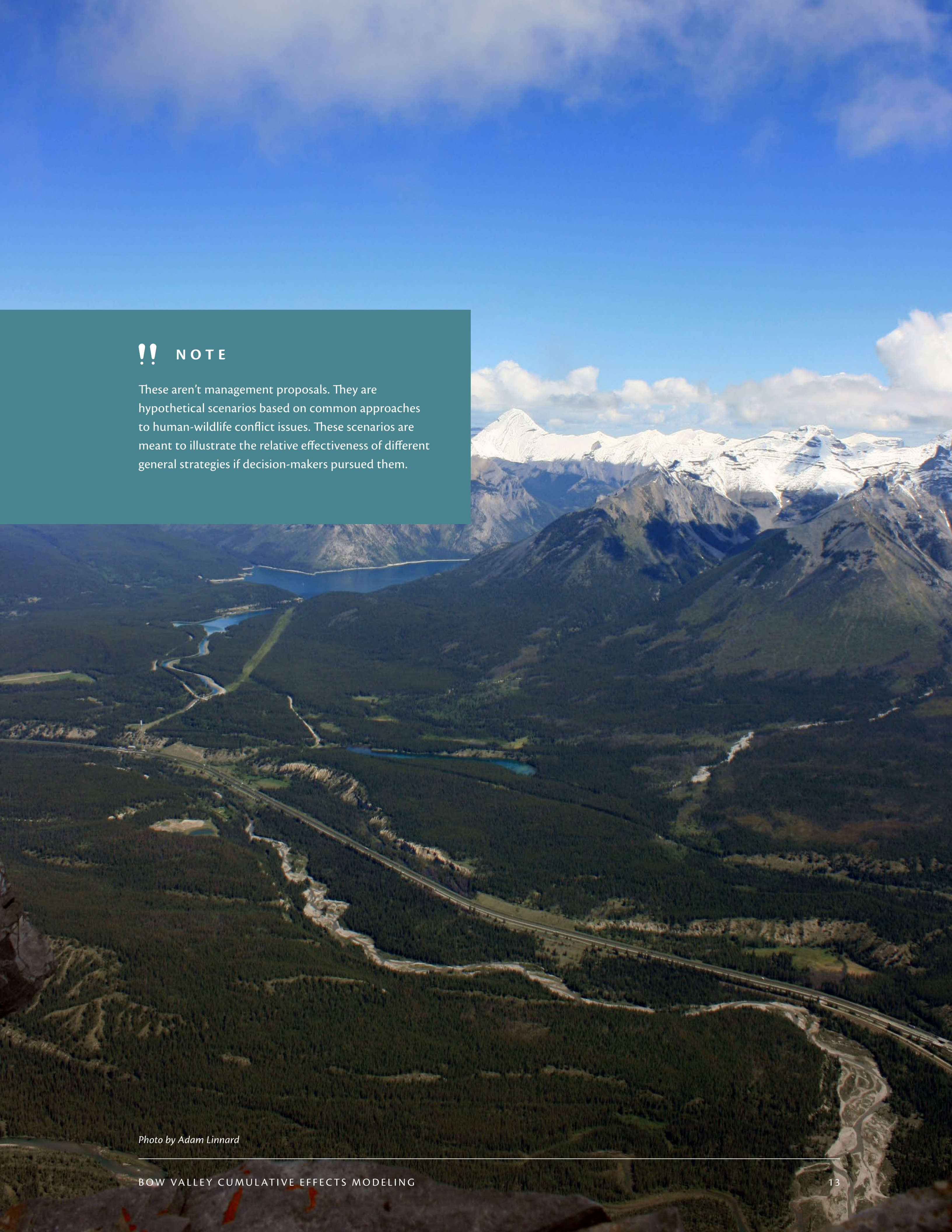
The second scenario, referred to as **No Informal Trails**, eliminated recreational activity from areas that do not overlap with legal/designated trails or with development footprint (settlements, roads, recreation facilities).

RESTRICTED RECREATION

The third scenario, referred to as **Restricted Recreation**, applied a 50% reduction to recreational activity (as compared to the Base Case scenario) in areas at least 100 m away from settlement footprint.

It was assumed that regulations limiting the volume or timing of recreational activity have the potential to achieve this level of a decline in recreational activity. The practical feasibility of the scenarios was not considered in detail. Rather, the scenarios were intended to explore the sensitivity of simulation outcomes to general types of mitigation strategies.

[5] LCP proportions associated with bin values were as follows: 0 = LCP proportion < 0.001; 1 = LCP proportion >0.001 and < 0.002718; 2 = LCP proportion >0.002718 and < 0.007389; 3 = LCP proportion >0.007389 and <0.020086; 4 = LCP proportion >0.020086 and <0.054598; and 5 = LCP proportion > 0.054598.



!! NOTE

These aren't management proposals. They are hypothetical scenarios based on common approaches to human-wildlife conflict issues. These scenarios are meant to illustrate the relative effectiveness of different general strategies if decision-makers pursued them.

Photo by Adam Linnard

Results

Human Footprint

Over the past 50 years, total development footprint is estimated to have increased from 35.1 km^2 to its current extent of 47.5 km^2. Under the Base Case scenario, footprint is projected to continue to expand to 52.0 km^2 over the next thirty years (Figure 1).

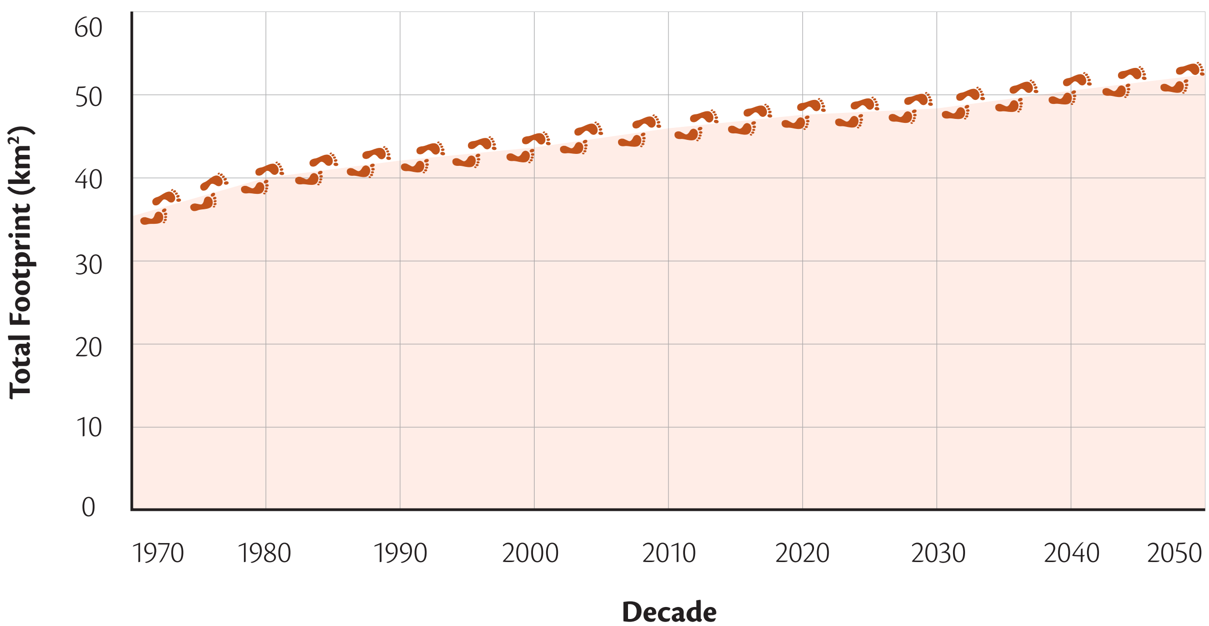


***Figure 1.** Total development footprint as simulated for the study area during backcast and base case forecast simulations.*

Footprint growth was the most prevalent in Canmore as the town expanded to house a rapidly growing population (Figure 2). In contrast, Banff experienced substantially lower footprint growth due to its fixed development boundary (Figure 2). Across the study area, footprint is focused in the centre of the valley along the Bow River where flat topography has attracted the development of settlements and infrastructure such as the Trans Canada Highway (Figure 2).

Unfortunately, the low and flat valley bottom is also preferred by grizzly bear as illustrated by high permeability values in the central portion of the valley under pre-settlement landscape composition (Figure 3). This overlap results in past and potential future development fragmenting the portion of the study area that, historically, provided the best grizzly bear habitat in the region (Figure 4).

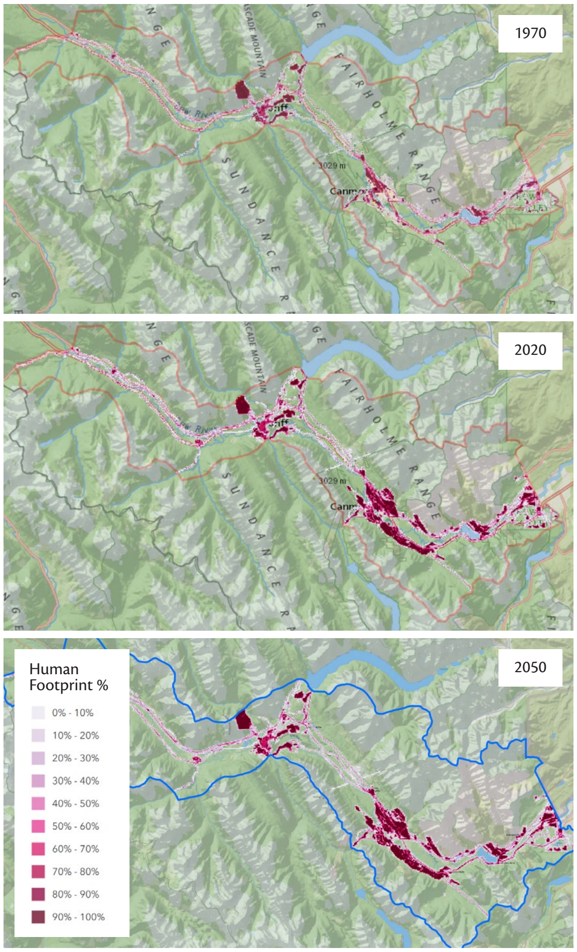


***Figure 2**. Development footprint at the start of the backcast simulation (1970s; top map), at present (middle map), and at the end of the base case forecast simulation (2050s; bottom map).*

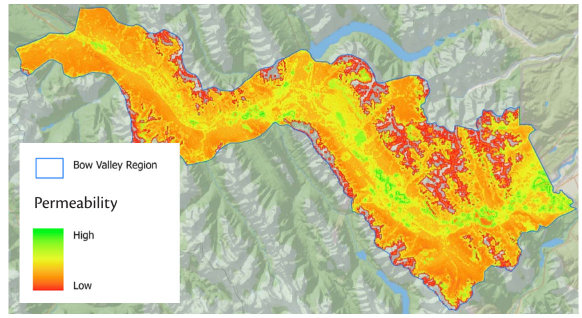


***Figure 3.** Permeability of the pre-settlement landscape to grizzly bear based on a summer resource selection function.*

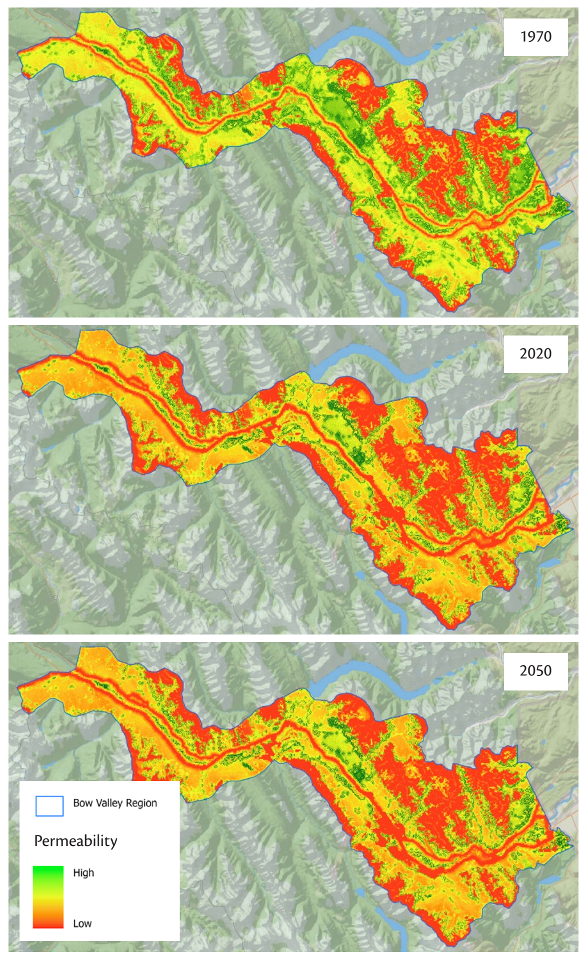


***Figure 4.** Permeability of the landscape to grizzly bear at the start of the backcast simulation (1970s; top map), at present (middle map), and at the end of the base case forecast simulation (2050s; bottom map). Permeability calculated based on a summer resource selection function and avoidance of highways.*

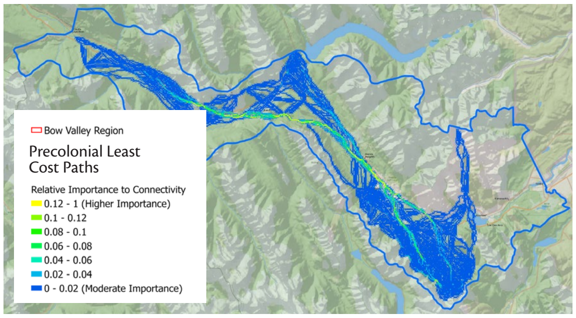


Figure 5. *Grizzly bear least cost paths for the pre-settlement landscape.*

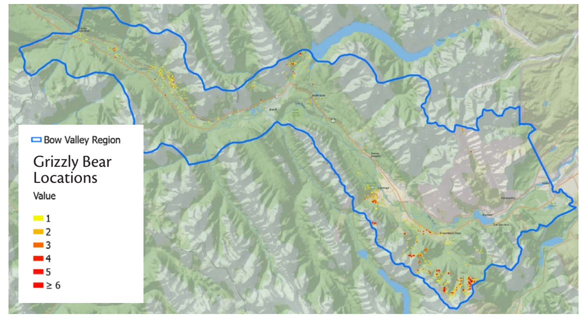


Figure 7. *Grizzly bear locations recorded from collared bears in the study area. Data provided by Parks Canada*

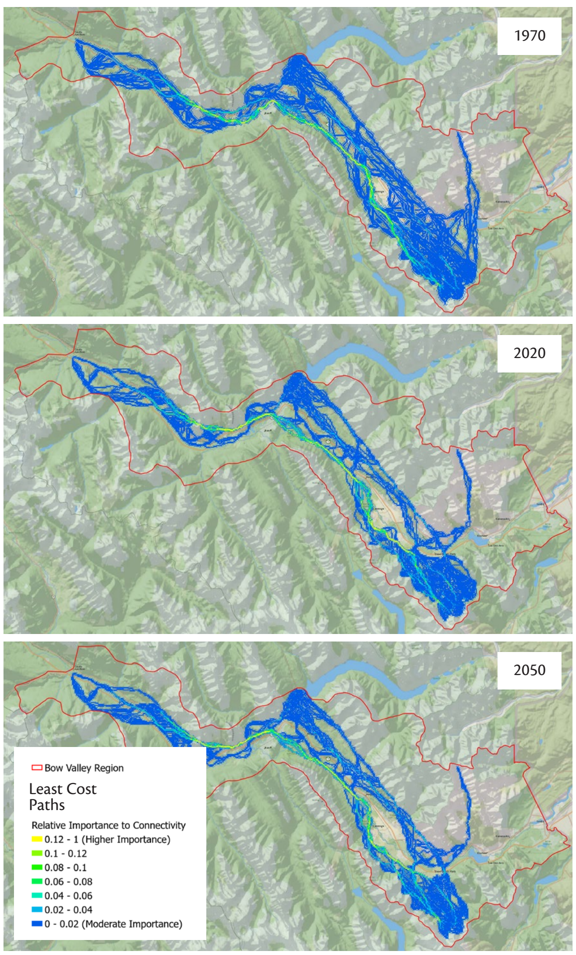


Figure 6*. Grizzly bear least cost paths at the start of the backcast simulation (1970s; top map), at present (middle map), and at the end of the base case forecast simulation (2050s; bottom map).*

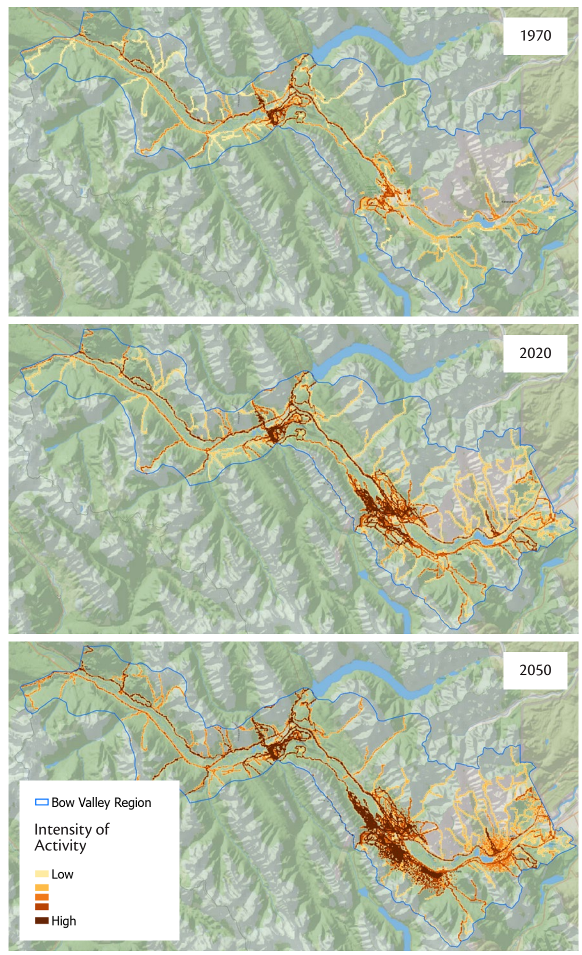


Figure 8*. Strava activity index at the start of the backcast simulation (1970s; top map), at present (middle map), and at the end of the base case forecast simulation (2050s; bottom map). The current is based on the Strava global heat map whereas the 1970s and 2050s maps are modeled.*

KEY POINT

Past development in the Bow Valley has pushed likely grizzly bear movement paths away from the river and upslope onto terrain they would be unlikely to have utilized historically. Potential future development would likely exacerbate this trend.

KEY POINT

The Trans Canada Highway is, and has been, a massive barrier to grizzly bear movement across the valley. This barrier has significantly altered grizzly bears' most likely movement paths by mostly confining bears to whichever side of the road they start out on – with the significant exception of highway underpasses and overpasses.

Fragmentation and loss of habitat caused changes to least cost paths (LCPs), suggesting that development has altered connectivity in the region. Under the pre-settlement landscape, the LCPs tended to use the valley bottom to move from one part of the study area to another, resulting in an abundance of LCPs in areas such as the Canmore and Banff townsites (Figure 5). When development footprint is incorporated, however, LCPs bypass the townsites with the diversion increasing as footprint expands over time (Figure 6). Grizzly bear location data from the region are consistent with this pattern, with few locations within major developments such as Canmore and Banff (Figure 7).

Another important driver of LCPs is the Trans Canada Highway due to its function as an impermeable barrier from the 1990s onwards. This barrier, with the exception of wildlife crossing structures, likely contributes to the aggregation of LCPs on one side of the highway or the other for long stretches of the valley (Figure 6). This pattern is also consistent with grizzly bear location data from the region, with few locations occurring north of the highway in the eastern portion of the study area (e.g., in the vicinity of Canmore) and south of the highway in the western portion of the study area (Figure 7). As such, the LCPs demonstrate two important effects of development to wildlife connectivity in the valley:

1. Displacement from the valley bottom to upslope areas away from footprint; and
2. Fragmentation by the Trans Canada Highway resulting in the isolation of habitat.

Recreational Activity

According to the Strava data, recreational activity is focused around Canmore and Banff and nearby trails such as the Nordic Centre and Tunnel Mountain (Figure 8). Indeed, over eighty percent of Strava activity occurs within 2 km of settlement footprint. Simulation of recreational activity extrapolated this pattern across the backcast (1970s to current) and forecast (current to 2050s) portions of the analysis. Recreational activity was modeled to have been less extensive around the townsites in the 1970s and to have expanded in extent and intensity as the towns grew (Figure 8). During the forecast, the extent and intensity of recreational activity continues to grow with new areas of recreational activity simulated in proximity to new developments such as eastern Canmore (Figure 8).

Risk of Human-Wildlife Conflict

Areas that are currently at higher risk of human-wildlife conflict were identified by combining the Strava layer with the LCP output for the present time period. Overlap of high recreational activity and connectivity for grizzly bear was prevalent around the Nordic Centre and other areas to the south of Canmore, and at recreational areas around Banff such Mount Norquay and Tunnel Mountain (Figure 10). Although we could not obtain a spatial layer identifying human-grizzly bear conflict locations across the region, available information is consistent with patterns shown in the human-wildlife risk layer. The location of aggressive bear incidents near the Town of Banff (Figure 8 from Bow Valley Human-Wildlife Coexistence Roundtable 2018) overlap with many of the areas identified as moderate to high risk in the human-wildlife risk layer including Tunnel Mountain, Mount Norquay, and towards Lake Minnewanka. As well, areas identified by the map as higher risk in the vicinity of Canmore correspond with locations of human-grizzly bear conflict and grizzly bear sightings such as the Nordic Centre,[6] around Three Sisters Parkway,[7] and Grassi Lakes.[8] Simulation output suggests that risk has increased over the past fifty years as recreational activity has expanded (Figure 9), with the greatest change in risk estimated to have occurred around Canmore. During the forecast, Canmore continues to exhibit the

[6] E.g., https://pressfrom.info/ca/news/canada/-155087-olympian-thwarts-grizzly-bear-attack-during-jog-in-canmore.html

[7] E.g., https://www.rmotoday.com/local-news/bear-attacks-biker-on-lowline-trail-1569248

[8] E.g., https://www.rmotoday.com/canmore/bear-spray-compliance-still-low-1780056

GRIZZLY BEAR RISK — BASECASE

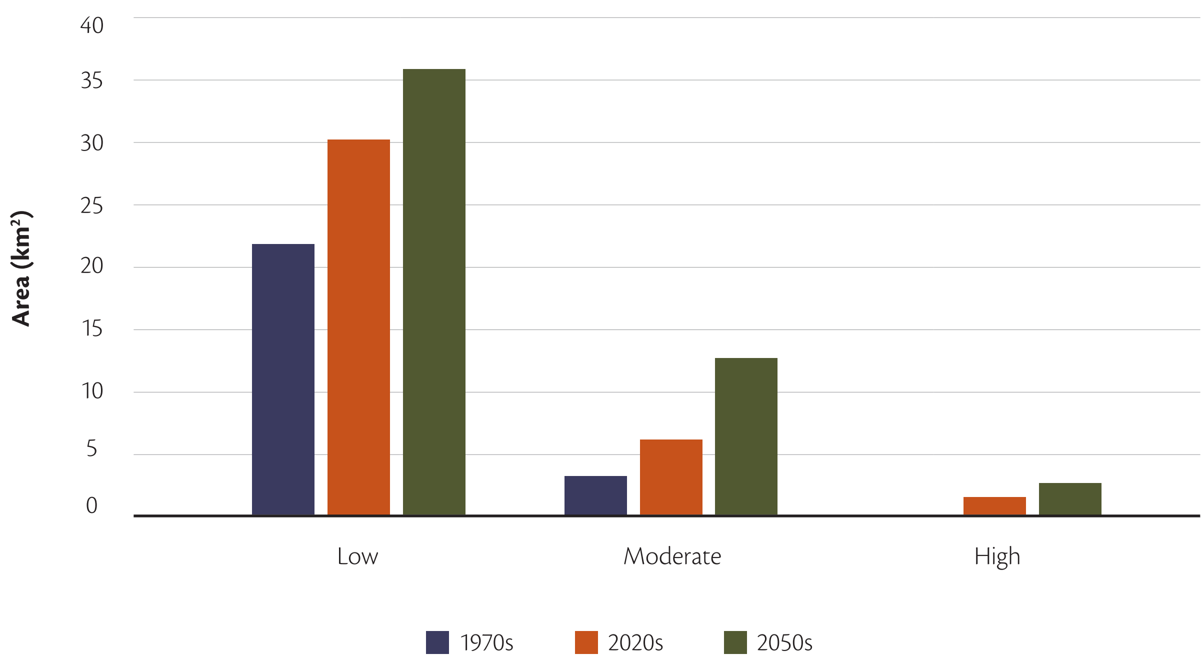


Figure 9. *The spatial extent of low (1 to 4), moderate (5 to 9), and high (> 9) values of human-wildlife risk at the start of the backcast simulation, at present, and at the end of the base case forecast simulation.*

most growth in risk of human-wildlife conflict, with risk expanding eastwards in response to the simulated expansion of Canmore and associated recreational activity (Figure 10).

The mitigation scenarios achieved substantial reductions in risk of human-wildlife conflict (Figure 11). Compared to the Base Case, the Limited Urban Expansion scenario reduced instances of moderate or high risk by 35% by excluding urban expansion and associated growth in recreational activity in the undeveloped eastern portion of Canmore (Figure 12). By eliminating recreational activity from informal (i.e. undesignated) trails, the No Informal Trails scenario reduced instances of moderate or high risk by 41% compared to the Base Case scenario. Reduction in risk was the most prevalent in the vicinity of Canmore where substantial recreational activity exists, or is projected, in areas where formal (i.e. designated) trails are absent (Figure 11). The Restricted Recreation scenario reduced instances of moderate or high risk by 23% compared to the Base Case scenario by applying a 50% decline in recreational activity across the study area (Figure 11). These scenarios are coarse explorations of the sensitivity of the human-wildlife risk index to different types of mitigation, as opposed to detailed representations of realistic management options. However, the substantial reductions in risk achieved by the mitigation strategies illustrate that options likely exist to reduce risk of human-wildlife conflict that can result from overlapping grizzly bear and human activity. Simulations suggest that limiting recreational activity to the existing legal trail network is perhaps the most promising management option, and that limiting development in areas close to probable grizzly bear movement paths is also an important strategy.

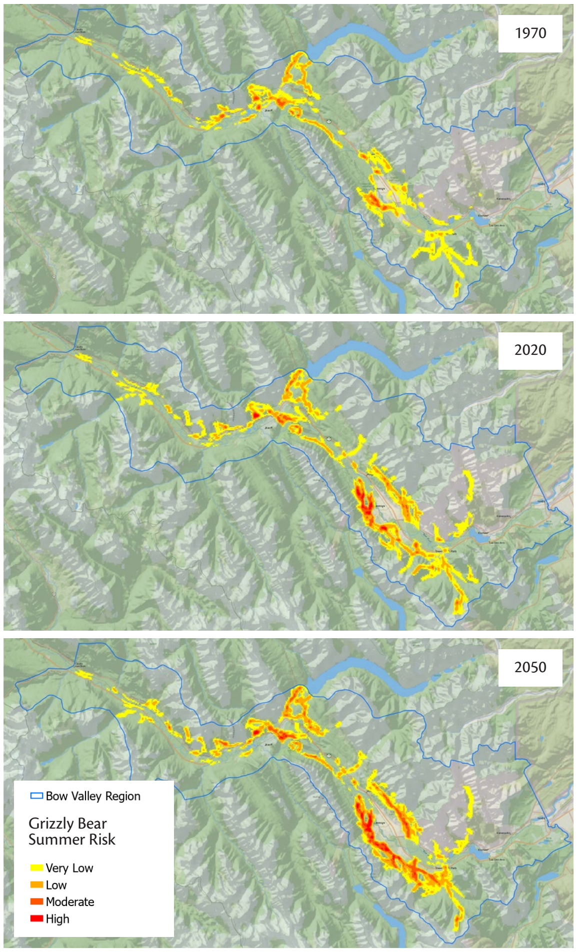


Figure 10*. Human-wildlife risk index at the start of the backcast simulation, at present, and at the end of the base case forecast simulation. Red, orange, yellow, and green indicate high, moderate, low, and very low risk, respectively.*

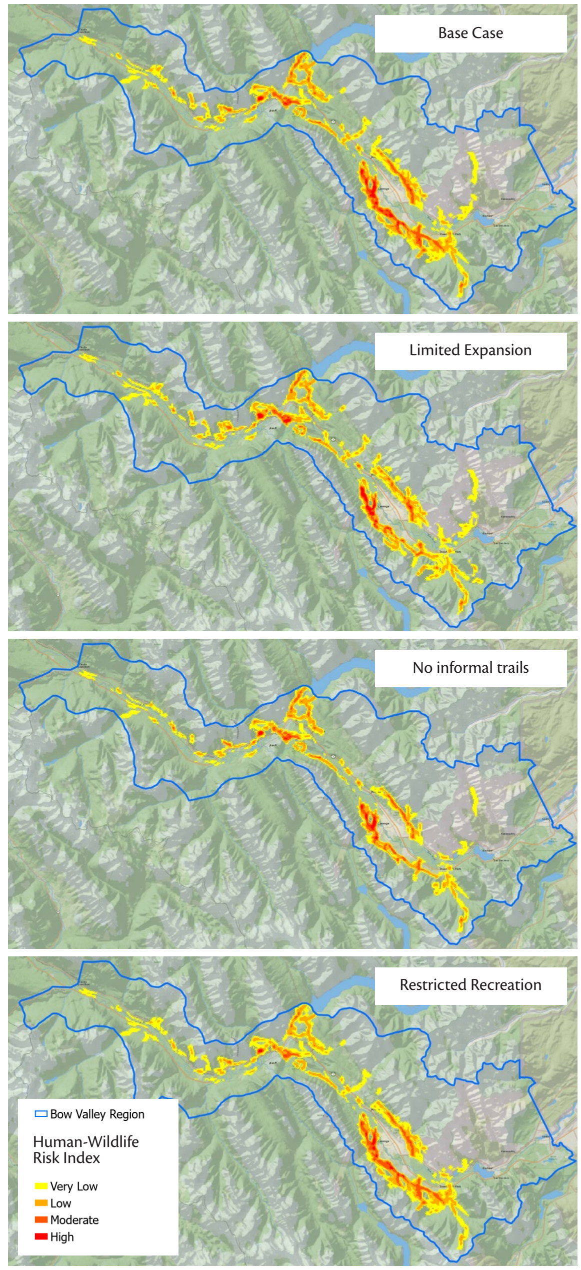


Figure 12*. Human-wildlife risk index at the end (year 2050) of forecast simulations of the base case and three mitigation scenarios. Red, orange, yellow, and green indicate high, moderate, low, and very low risk, respectively.*

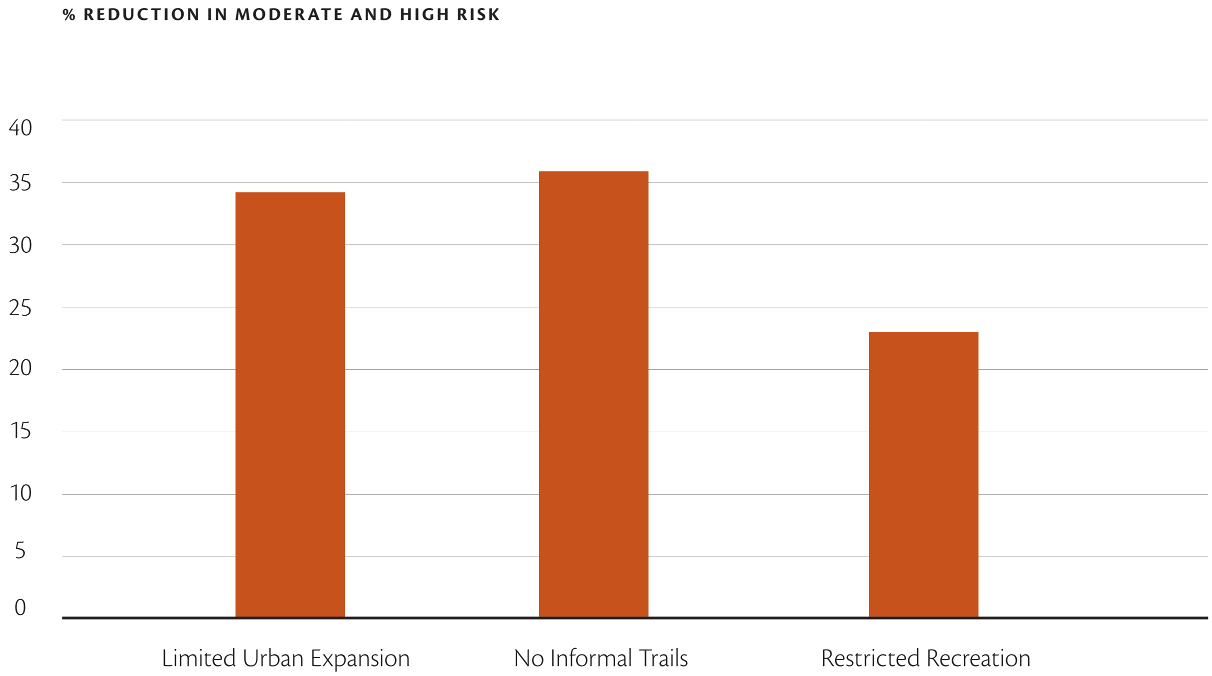


Figure 11. *Percent reduction in moderate and high risk categories of the human-wildlife risk index achieved by the mitigation scenarios. Percent reduction is based on comparison with the base case scenario at the end of the forecast period (2050).*

Discussion

The application of simulations and least cost path analysis to assess human-wildlife risk required several assumptions that need to be considered when interpreting outcomes. Simulation of past and future change in development and recreational activity is approximate, especially in the case of recreational activity for which empirical data were scarce. Indeed, the use of Strava activity data to represent human activity focuses attention on certain activities such as running and biking whose participants are more likely to use Strava. Other activities such as dog walking may not be as well represented. The use of least cost path analysis to assess connectivity and to infer areas more likely to be used by grizzly bears assumes that bears behave optimally in terms of maximizing habitat and minimizing distance as they move between locations in the study area. As a result, while least cost paths are generally consistent with the spatial pattern of grizzly bear locations, they emphasize a smaller portion of the landscape than what is actually used by bears – a limitation partly addressed by incorporating stochasticity, or randomness, into the model. In reality, factors not addressed by the least cost paths analysis also influence grizzly bears such as attractants (e.g., fruit trees, garbage, etc.), past experiences, and so on. A related caveat is that the risk index is focused on the impact of recreational activity. The analysis is not designed to assess other important sources of risk such as attractants in townsites and vehicle collisions. As well, the small size of the study area relative to the movement of grizzly bears artificially constrained the least cost paths. Grizzly bear location data indicate that bears not only move east to west through the valley, but also north and south through valleys that intersect with the study area at locations such as the Cascade River to the north of Banff and the Spray Valley to the south of Canmore. Constraining least cost paths to the study area exaggerated the importance of some areas, such as Tunnel Mountain, to connectivity when compared to grizzly bear location data.

Despite these limitations, outcomes from the analysis have important implications for conservation in the region. The analysis illustrates that development footprint has altered the region over time, and expansion of footprint is likely to continue given the area's attractiveness as a place to live and visit. How grizzly bears use the landscape has and likely will continue to be impacted by development footprint because bears and humans both prefer the flat valley bottom. Indeed, the analysis reflects that the townsites of Banff and Canmore were corridors for grizzly bear movement prior to European settlement. Development has disrupted preferred grizzly bear travel routes and their movement corridors have been diverted upslope; continued development in the valley is likely to further divert movement paths away from preferred habitat.

"With development of Banff and Canmore, corridors have been diverted upslope; continued development in the valley is likely to further divert movement corridors away from preferred habitat."

Fragmentation of habitat by development footprint is only part of the story of how humans impact grizzly bears in the region. Recreational activity is prevalent along formal and informal trails in the valley, especially around the periphery of settlements. Unfortunately, these are the same areas identified by the least cost paths analysis as being important for grizzly bear connectivity. This overlap in recreational activity and grizzly bear connectivity creates risk for both humans and bears, as demonstrated by incidents and frequent bear sightings in popular recreational areas such as the Nordic Centre and Grassi Lakes. Growth in population and visitation can be expected to intensify recreational activity and therefore risk of human-wildlife conflict in the region. As such, the impact of new development to wildlife is not limited to habitat loss, but also includes increased recreational activity and risk of human-wildlife conflict that is likely to occur in the vicinity of the development.

"The impact of new development includes increased recreational activity and risk of human-wildlife conflict that is likely to occur in the vicinity of the development."

Coexistence of grizzly bears and humans in the valley will be supported by efforts to limit both development and recreational activity in areas that are important for wildlife connectivity. The scenario analysis identified the following strategies as having the potential to contribute to this objective: limiting recreational activity to a fixed set of formal trails; limiting development within and close to high connectivity areas; and limiting the amount of trail use. Many other strategies, or a combination of multiple strategies, might also have been used to illustrate a reduction in future human-grizzly bear conflict relative to the Base Case scenario. Regardless of the strategy pursued, they all require trade-offs in terms of economic development and lifestyle. As such, use of these strategies in pursuit of coexistence with wildlife requires careful consideration and broad involvement from those who live in the region.

"Coexistence of grizzly bears and humans will be supported by efforts to limit both development and recreational activity in areas that are important for wildlife connectivity."

Questions

The Bow Valley Cumulative Effects Modeling project is not intended to resolve planning and management issues in the Bow Valley, but to provide information on the potential impacts of many combined decisions by the region's different jurisdictional bodies and some of the general, common approaches to mitigating those impacts. These mitigations include minimizing development in new areas, and more intensively planning and managing nature-based recreation on the lower slopes of the Bow Valley. To this end, modeling results raise a number of questions for decision-makers, including:

1. Given the cumulative impact of human footprint and recreational activity that grizzly bears are already experiencing in the Bow Valley, what level of displacement and conflict risk are decision-makers willing to accept for grizzlies and other large mammal species?

2. Given the regional nature of the impacts of localized decisions, how might decision-makers incorporate cumulative effects throughout the Bow Valley in future decisions for their respective communities and landscapes?

3. What types of planning and management tools exist, or could be developed, for the Bow Valley's different jurisdictions to mitigate negative impacts on wildlife movement in the present and future?

4. What kind of social license exists for mitigation options? How might social license be built for strategies decision-makers choose to pursue?

Photo by Kelly Zenkewich

Tables

Coefficients for the grizzly bear summer resource selection function used when preparing the permeability layer for the least cost path analysis.

Parameter	Coefficient
Burned since 1960[9]	0.88
Distance to campground	-0.07
Distance to forest edge	-1.46
Distance to patch > 9 km2	-1.06
Distance to town[10]	0.53
Elevation	-0.23
Barren land cover[11]	0.51
Herbaceous land cover[12]	1.03
Open conifer or deciduous land cover[13]	0.61
Shrub land cover	1.01
Railway	0.02
Slope	-0.23
Southerly Aspect	0.07
Trail	0.13
Trail Density	-0.47
Trail density[14] * log (distance to paved road)	0.04

9 To focus temporal changes on land use footprint as opposed to stochastic natural disturbance events, the present area burned since 1960 was applied through the simulation period when calculating the RSF.

10 The RSF also included a distance to town at night covariate which was excluded because day and night times were not differentiated in the analysis. The coefficient for distance to town at night was -0.04.

11 Barren land cover included the Rock Rubble and Exposed Land cover types.

12 Herbaceous land cover included the Grassland cover type.

13 The land cover data that were used did not differentiate between open and closed classes. Instead, open forest was estimated by only including forested land cover with canopy cover less than 40%.

14 As per the Whittington RSF, only legal/official as opposed to informal/unofficial trails were included.

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