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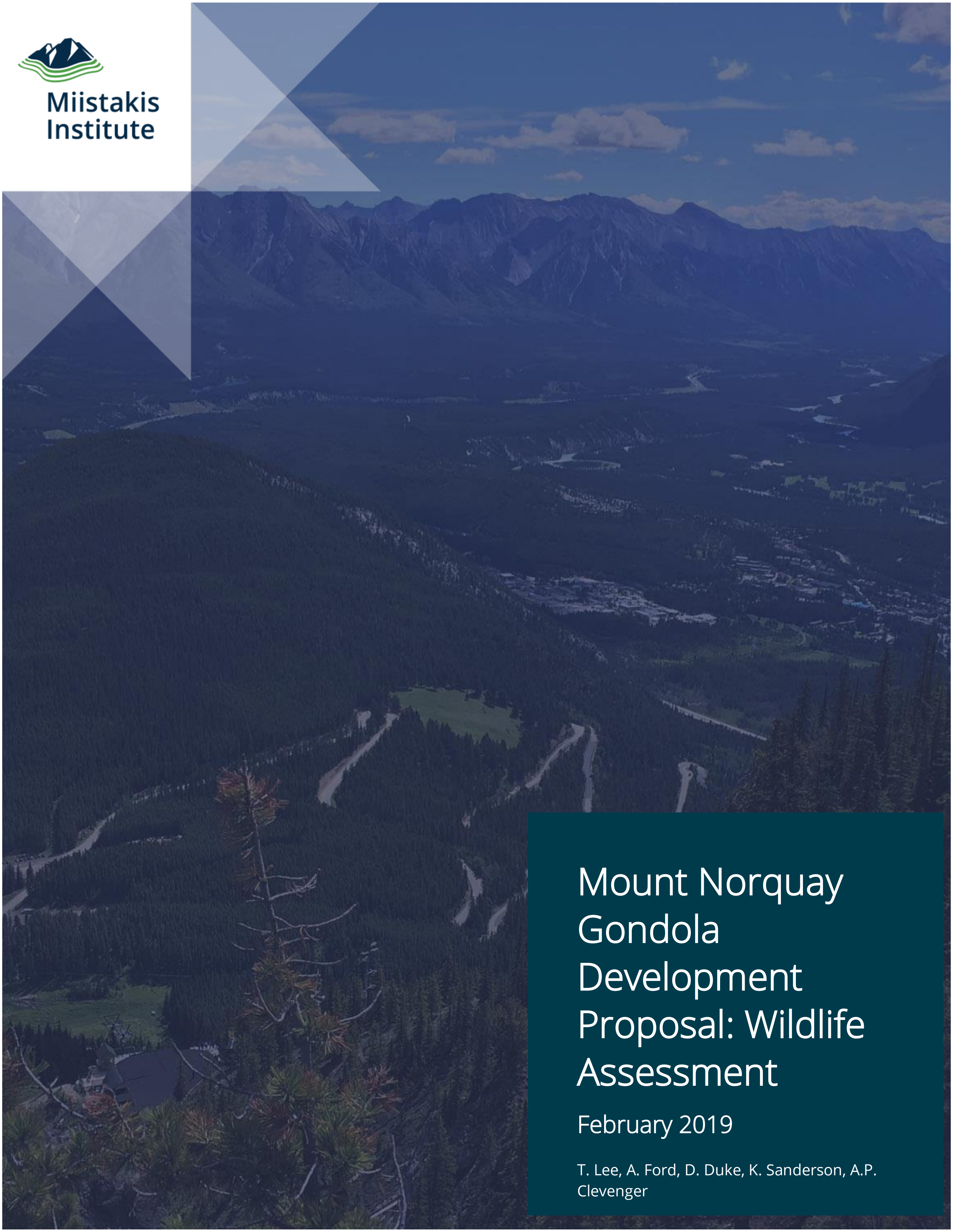

Mount Norquay Gondola Development Proposal: Wildlife Assessment

February 2019

T. Lee, A. Ford, D. Duke, K. Sanderson, A.P. Clevenger

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Prepared by T. Lee, A. Ford, D. Duke, K. Sanderson, A.P. Clevenger
February 2019

Miistakis Institute
Rm U271, Mount Royal University
4825 Mount Royal Gate SW
Calgary, Alberta T3E 6K6

Phone: (403) 440-8444
Email: institute@rockies.ca
Web: www.rockies.ca

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Acknowledgements

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Executive Summary

The Mount Norquay Lease Site and Access Road is located on the east slopes of Mount Norquay in the Bow Valley, AB, approximately 2 km north of the Town of Banff in the west end of the Cascade Wildlife Corridor. The Norquay Lease Site includes high quality habitat for a variety of wildlife species including grizzly bear, black bear, cougar, wolf, lynx, elk, bighorn sheep, mule deer, and white-tailed deer.

The Bow Valley in Banff National Park has been identified as a critical area for supporting healthy populations of large mammal species across the region. The co-occurrence of people and wildlife in the Bow Valley is especially problematic for wolves, cougars, and grizzly bears. These wide-ranging species are sensitive to human activity and occupy large areas to meet their needs for forage, shelter, and mates. Currently, animals move around the Banff townsite via several small-scale wildlife corridors that are constrained between infrastructure and the slopes of steep mountains. One of these corridors, the Cascade Wildlife Corridor, is located on the north side of the Trans-Canada Highway, and links wildlife habitat to the east and west of the Banff townsite. Parks Canada has invested in restoration in this corridor, resulting in improved connectivity for large mammals. The Norquay Access Road, a two-lane paved road that switchbacks up the southerly aspects of Mount Norquay from the Trans-Canada Highway, bisects 68 hectares of habitat. Use on the road by people may compromise the effectiveness of the Cascade Wildlife Corridor and undermine broader objectives to maintain or restore ecological integrity.

The Mount Norquay Ski Area Site Guidelines for Development and Use, completed in 2011, propose several mitigations to improve wildlife habitat use and connectivity. The site guidelines also consider a gondola from the Town of Banff to the ski area. The guidelines state that a gondola has "*the potential to enhance visitor experience, contribute to ecological integrity by significantly reducing human use in the Cascade Wildlife Corridor, and contribute to the community's and park efforts to explore alternative mass transportation systems*" (Banff National Park, 2011).

The guidelines allow for changing of the Norquay Lease Site necessary for the gondola project as currently proposed, provided there is a "substantial environmental gain." Parks Canada's Site Management Guidelines for ski areas define an environmental gain "as a positive change in key ecological conditions (wildlife movement and habitat, wildlife mortality, sensitive species/areas and aquatic ecosystems) that leads to the restoration or the long-term certainty of maintaining ecological integrity."

Norquay proposes to develop an all-season, high-alpine destination through the construction of a 4-Station gondola from the Banff Train Station to the summit of Mount Norquay. The gondola development proposal also includes the following initiatives:

- re-configuring the Norquay Lease Site by removing a portion of the lease at lower elevation, while expanding the lease at higher elevation;
- reducing on-mountain vehicle parking and buildings within sensitive subalpine habitat, including restoring upper parking lots to natural land cover;
- reducing traffic volume on the Norquay Access Road;
- adding 2,000 new parking stalls at the Banff Train Station adjacent to the Town of Banff; and
- restricting human use in the alpine to a fenced boardwalk system.

The Miistakis Institute, in partnership with Drs. Adam T. Ford and Tony Clevenger examined the potential for an environmental gain from the gondola development proposal using a combination of an expert workshop, a literature review, empirical modeling, and Analytical Hierarchy Process (AHP).

Methods

An expert workshop identified three conservation challenges to be addressed with modeling approaches:

1. Grizzly bear habitat use and movement;
2. Wolf and cougar movement; and
3. Bighorn sheep lambing habitat.

For empirical modeling, Resource Selection Function (RSF) models were developed to determine the seasonal distribution of three large carnivore species common in Banff National Park; grizzly bear, cougar, and wolf. The RSF models were used to create resistance surfaces to predict animal connectivity and to test impact treatments (10%, 50%, 90% adjustments, both positive and negative to resistance values) on movement in and around the Norquay Lease Site and Norquay Access Road. Resistance surfaces and focal nodes (eight nodes were placed around the edge of the study area in wildlife corridors and on either sides of road) were created using Circuitscape to determine how carnivores move around the landscape.

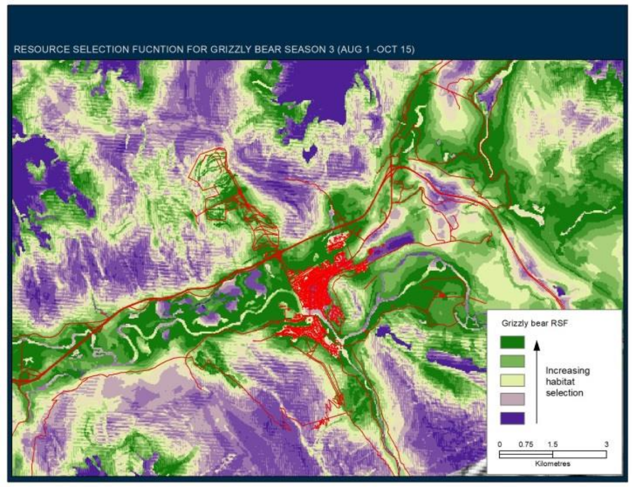
Bighorn sheep lambing habitat was modeled using variables identified in a literature review validated with existing known lambing sites from the Kananaskis Area.

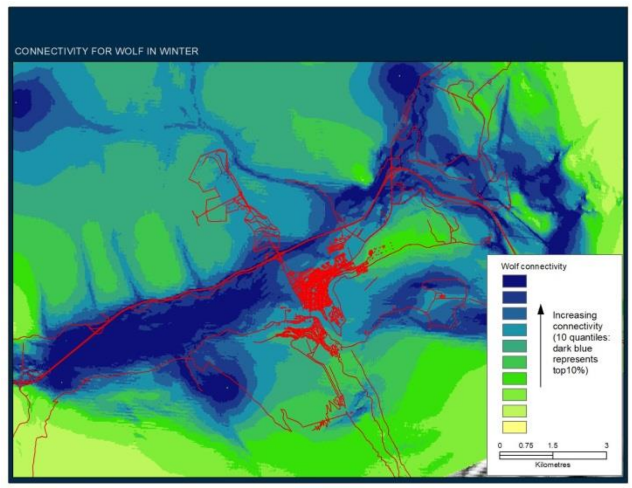
An AHP was developed that included impacts, sources of impact and mitigations for grizzly bear, cougars, and wolves using information from the expert workshop and The Mount Norquay Ski Area Site Guidelines.

Results

Modeling results for grizzly bear habitat use and movement for grizzly bear, wolf, and cougar demonstrate:

- Norquay Lease Site and Norquay Access Road represent important habitat for grizzly bears in the Bow Valley during the summer and cougar in the winter (see example grizzly bear season 3 RSF on right).
- Cascade Wildlife Corridor provides important east west movement opportunities for wolf, cougar, and grizzly bear (see example connectivity for wolves in winter on right).
- Model treatment results indicate improving connectivity on the Norquay Lease Site did not show a strong impact for grizzly bear, cougar, and wolf movement around the broader Bow Valley landscape.
- Model treatment results demonstrate there is some opportunity for change to connectivity for grizzly bear, wolf, and cougar within the immediate Norquay Lease Site and Access Road if improvements greater than 50% can be achieved.





The modeling results did not demonstrate how to enhance habitat to achieve improvements to habitat use and connectivity. Instead experts prioritized mitigations relating to the proposed gondola development using the AHP process and found:

- Priority mitigation for grizzly bear is to restrict use on the Norquay Ski Hill during summer, followed by some type of treatment to the Norquay Access Road. Decommissioning of the Norquay Access Road had more significant benefits, but temporal closure to recreation and vehicles also rated high as a mitigation priority.
- Priority mitigation for improving wolf and cougar movement consists of implementing some type of treatment to the Norquay Access Road. Decommissioning of the Norquay Access Road had significant impacts, but temporal closure to recreation and vehicles also rated high as a mitigation priority. In addition, consideration of physical corridor improvements, such as an additional underpass at the base of the Norquay Access Road and Trans-Canada Highway along with restricting summer use of the Norquay Ski Hill also will contribute to improved wolf and cougar connectivity.

Bighorn sheep lambing habitat was considered in relation to new infrastructure (gondola and fenced boardwalk) and human activity in the alpine region. Lambs and ewes have been reported within the Norquay Via Ferrata area during monitoring by Mount Norquay staff and there is a historical record of lambing on Mount Norquay. Our modeling of key habitat features associated with lambing habitat suggests Mount Norquay has suitable conditions for lambing and that potential lambing habitat does not occur within a 150 m buffer of the gondola and boardwalk; however, it could occur within a 500m buffer of the development.

Summary of findings

Our modeling results indicate the potential for an environmental gain from the gondola development proposal for:

- ***Grizzly bear and cougar habitat use on the Norquay Lease Site and Norquay Access Road***, if summer use on the Norquay Ski Hill is restricted and the Norquay Access Road is decommissioned or human activity (vehicles and recreation) is restricted temporally to the extent feasible for public safety.
- ***North/south connectivity for carnivore species***, if greater than 50% improvement can be achieved though habitat enhancements.
- ***Carnivore east/west connectivity in the Cascade Wildlife Corridor***, if the Norquay Access Road is decommissioned or human activity (vehicle and recreation) is restricted temporally to the extent feasible for public safety.

Our modeling results indicate there is potential for a negative impact from the gondola development proposal if bighorn sheep lamb in close proximity to the gondola terminus and fenced boardwalk. The location of bighorn sheep lambing sites is currently unknown; although there is strong evidence that lambing does occur on Mount Norquay.

As to the importance of the environmental gains, our results indicate:

- The Norquay Lease Site does not play an important role in broader landscape connectivity around the Bow Valley.
- The Cascade Wildlife Corridor does play an important role in broader east/west regional landscape connectivity around the Bow Valley and includes a portion of the Norquay Access Road.
- Grizzly bear habitat use on the Norquay Lease Site is an important localized benefit (localized because the Norquay Lease Site represents only a fraction of a female grizzly bear home range).
- Improved north/south movement opportunities for cougar, wolf, and grizzly bear to access habitat to the north of Mount Norquay is a potential localized benefit but requires habitat enhancements.
- There is more potential for the gondola development proposal to improve ecological conditions for carnivores than for the project to affect them negatively, i.e., the gondola development proposal provides better opportunities for carnivores than no change.

Recognizing movement opportunities are limited throughout the Bow Valley any opportunities for an environmental gain for sensitive carnivore species should be considered.

Lastly, due to lack of local information on how wildlife responds to alterations of their environment, we recommend Norquay create a long-term multi-species, wildlife monitoring program that will provide evidence-based data to inform management and adaptively manage measures used to mitigate potential impacts on Mt. Norquay.

1.0 Project Purpose

Norquay has proposed the development of a new gondola as part of a mass transit system to carry passengers from the Banff townsite to the Norquay Lease Site and to future facilities at higher elevations on Mount Norquay. The Mount Norquay Gondola proposes to improve ecological integrity by transforming Norquay into an all-season, high-alpine adventure and learning eco-tourist destination through the construction of a 4-Station gondola from the Banff Train Station to the summit of Mount Norquay (Harley & Associates, 2018).

The "gondola development proposal" could impact the overall ecological condition of the area. The gondola development proposal includes:

- Introducing a mass transit system through the development of a gondola that initiates at the Banff Train Station and terminates at the summit of Mount Norquay , and includes stops at the base of the Norquay Lease Site and base of the Norquay Via Ferrata;
- Reconfiguring Norquay's overall footprint by reducing the Norquay Lease Site by 18.5 acres (10%) in lower elevation habitat near the base of the Norquay Lease Site while expanding the lease at higher elevation;
- Reducing on-mountain vehicle parking and buildings within sensitive sub-alpine habitat, including restoring upper parking lot to natural land cover;
- Reducing traffic volume on the access road;
- Developing 2000 new parking stalls at the Banff Train Station adjacent to the Town of Banff; and
- Restricting human use in the alpine to a boardwalk system.

Many of these elements have the potential to result in an environmental gain. The Miistakis Institute, in partnership with Drs. Adam T. Ford and Tony Clevenger, was asked to examine the potential environmental gain the gondola development and associate changes to infrastructure could have on large mammals (i.e. ensuring healthy populations are able to move around the landscape to access resources and mates) in and around Mount Norquay in Banff National Park, and specifically to address the question:

> ***Can the gondola development proposal result in an environmental gain to large mammals in Banff National Park?***

Historically, recreation and tourism development in the Bow Valley corridor has resulted in a negative impact on wildlife habitat and movement. It is conceivable that a reorientation of development (i.e. reducing traffic in lower-elevation vital habitat, and increasing traffic at higher-elevation, lower-value habitat) could result in a net positive effect on wildlife. The opportunity to create an environmental gain on wildlife in Banff by redesigning infrastructure is rare and requires careful study to ensure both negative and positive impacts are understood and monitored.

1.1 Background

The importance of wildlife corridors has been well documented for their role in improving landscape connectivity and facilitating animal movement between otherwise separate but potentially suitable habitats (Gilbert-Norton, Wilson, Stevens, & Beard, 2010; Rosenberg, Noon, & Meslow, 1997). Wildlife corridors are critical for maintaining ecological processes including allowing for the movement of animals, predator-prey interactions, reducing human-wildlife conflict, and the continuation of viable populations. In mountainous environments like Banff National Park, valley bottoms provide critical habitat and movement opportunities for wildlife through otherwise inhospitable terrain. Valley bottoms are also where human activity is concentrated, further reducing areas available for wildlife movement. The co-occurrence of people and wildlife in valley bottoms becomes especially problematic for wolves, cougars, and grizzly bears. These wide-ranging species are sensitive to human activity and occupy large areas to meet life requirements.

In Banff National Park, the low elevation Bow Valley has been identified as a critical component of the Central Rockies Ecosystem, which supports healthy populations of large mammal species (Green, Cornwell, & S. Bayley (eds), 1996). The Bow Valley supports a diversity of wildlife species and serves as a vital wildlife corridor for large mammals between the Kananaskis Valley, Banff National Park and areas to the north (Paquet, Gibeau, Herrero, Jorgenson, & Green, 1994). The extent to which the Bow Valley supports viable, persistent wildlife populations depends on habitat loss and fragmentation from human development and activity.

Currently, animals move around the Banff townsite via several small-scale wildlife corridors that circumnavigate the town. These wildlife corridors have no legal or regulatory basis and constitute 'what is left' on the landscape (i.e., areas that are not modified by houses, commercial developments, roads and railways; Figure 1).

Figure 1: BNP wildlife corridors displayed in grey (not official boundaries), roads in red, and Norquay Lease Site and Norquay Access Road with hash-marks.

The Cascade Wildlife Corridor, which is located on the north side of the Trans-Canada Highway, has the greatest potential for use by large carnivores, compared to the other available corridors (Banff National Park, 2011; Duke, Hebblewhite, Paquet, Callaghan, & Percy, 2001). It is one of three travel routes linking wildlife habitat to the east and west of the Banff townsite. The other wildlife corridors are within areas of high human use and contain subdivisions, commercial developments and a golf course. Recognizing the importance of the Cascade Wildlife Corridor to facilitate wildlife movement, Parks Canada restored portions of the corridor in 1997. This restoration included the removal of a buffalo paddock, barns and horse corrals and the closure of an airstrip to all but emergency use in the east end of the corridor. Subsequent research examining the use of wolves before and after restoration found significant increase in use by wolves following restoration (Duke et al., 2001) and demonstrated that a reduction in human structures and human activity can promote wolf use of a wildlife corridor.

1.2 The Norquay Lease Site

The Norquay Lease Site, includes parking lots, ski hill and via ferrata, is located on the east slopes of Mount Norquay, approximately 2 km north of the Town of Banff in the west end of the Cascade Wildlife Corridor. The Norquay Lease Site includes good quality habitat for a variety of wildlife species including grizzly bear, cougar, wolf, lynx, elk, bighorn sheep, mule deer, and white-tailed deer (Banff National Park, 2011). Ungulate species including elk and bighorn sheep have been documented to use the Norquay Lease Site (Norquay, 2014) with the ski area and adjacent landscapes supporting some of the highest concentrations of ungulates in the Bow Valley (Banff National Park, 2011). Elk calving and big horn sheep lambing have also been documented on the Norquay Lease Site (Banff National Park, 2011) with ewes with lambs observed from the location of the Norquay Via Ferrata (Norquay, 2014).

Parks Canada data for grizzly bear, wolf and cougar indicate use of the Norquay Lease Site, high prey availability and high vegetation quality for bears (Banff National Park, 2011). Figure 2 demonstrates density of six grizzly bears from 2016 and 2017 indicating the relative importance of the Norquay Lease Site as habitat for grizzly bears. Snow tracking data for cougar and wolf from 2008 to 2017 highlight movement through the Cascade Wildlife Corridor (see Figure 1) across the Norquay Access Road (Figure 3).

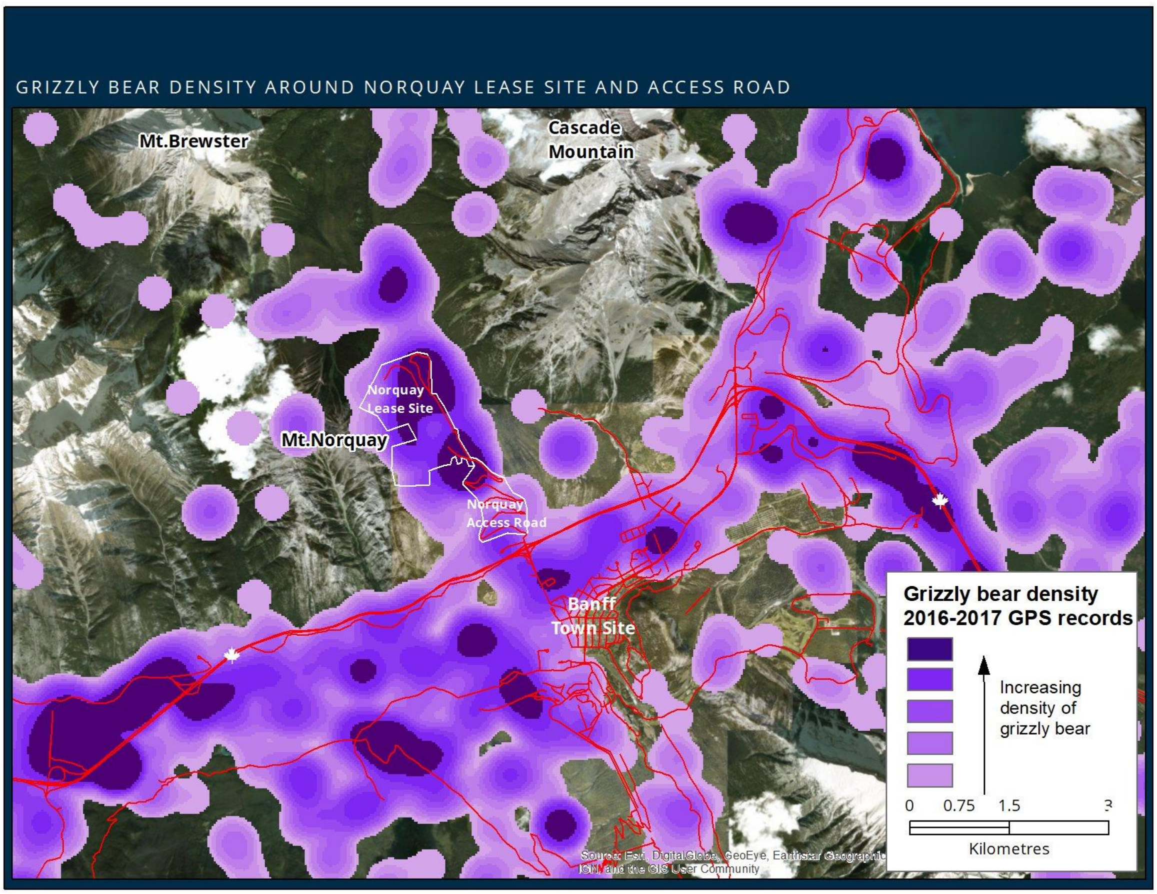


Figure 2: Grizzly bear density of GPS records (2016-2017) created using a kernel density estimator (data provided by BNP)

However, Norquay Lease Site, Norquay Access Road and associated human use of Mount Norquay all impact wildlife use of the area. The Norquay Access Road, a two-lane paved road that switchbacks up the southerly aspects of the mountain from the Trans-Canada Highway, bisects 68 hectares of prime wildlife habitat and use on the road compromises the effectiveness of the Cascade Wildlife Corridor (Banff National Park, 2011).

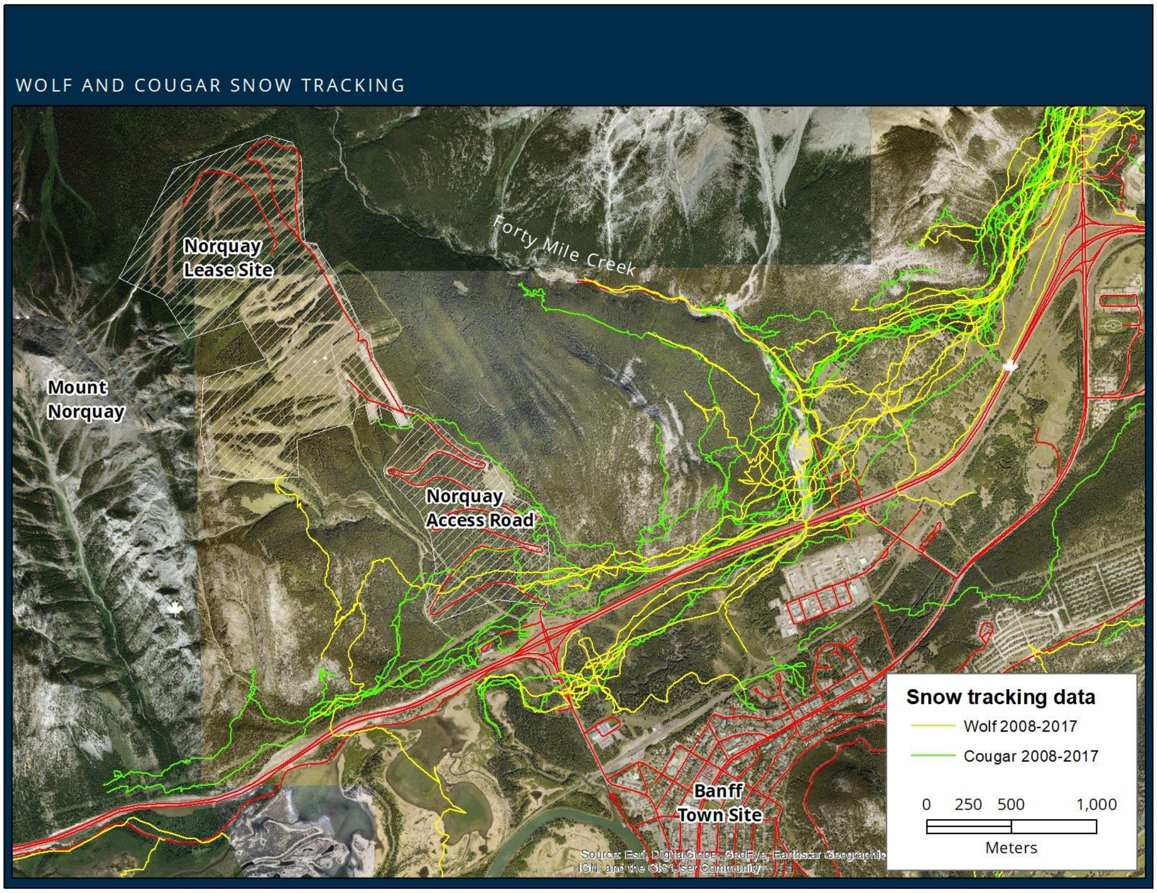


Figure 3: Cougar and wolf snow tracking data (data provided by BNP) Roads are shown in red and the Norquay Lease Site and Access Road in the gray hash-marked polygon.

Concern over impacts caused by the Norquay Access Road were addressed in the Mount Norquay Ski Area Management Guidelines (Banff National Park, 2011) where it was recommended that traffic on the Norquay Access Road be reduced during night time and crepuscular periods (vehicle use remain below 25 events per hour prior to 9am and after 6pm from June to the end of August). It was also recommended that the overall frequency of use on the road be reduced based on the baseline year of 2009. However, the recommended thresholds have been exceeded, with 36% of the 128 crepuscular hourly time periods between June and August (2009 – 2014) exceeding the threshold of 25 events per hour (Parks Canada data)[1]. Additionally, the Norquay Access Road has seen increasing vehicular traffic every year since 2009 (see Figure 4).

[1] Parks Canada Norquay Access Road data provided by Mount Norquay

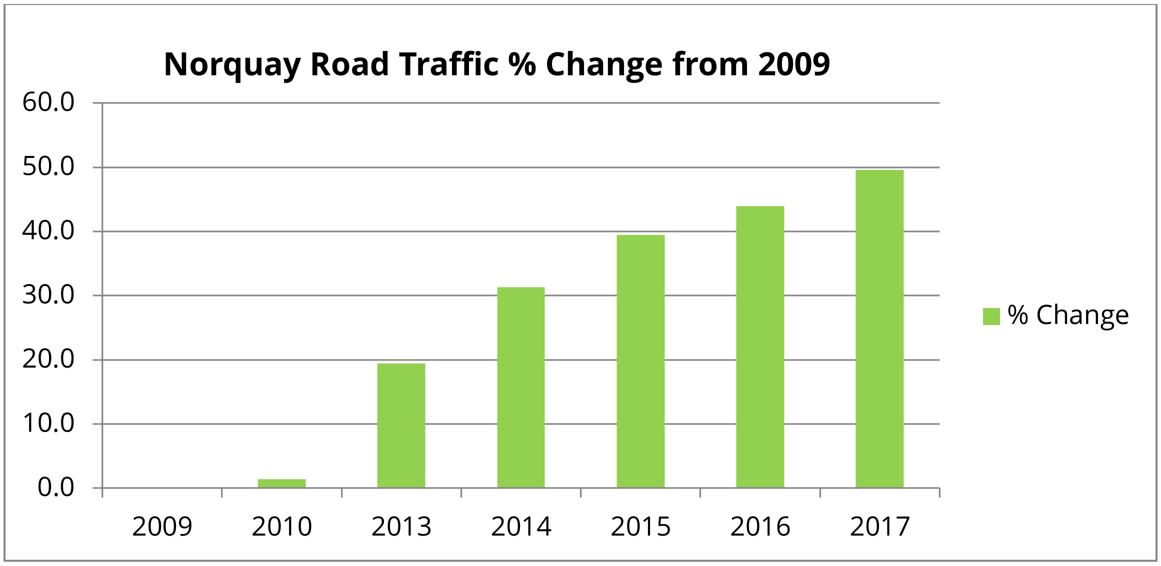


Figure 4: Norquay Access Road percent change in traffic since 2009

Human use of the Norquay Lease Site has the potential to impact wildlife, through reduced use of the habitat due to avoidance behavior and increasing risk for human-wildlife conflict. Grizzly bears may avoid areas of extremely high human use because of disturbance (Nielsen et al., 2004). Parks Canada wildlife monitoring indicates wildlife use in the Norquay area is less than expected compared to other movement areas in the Park (J. Whittington, 2018). While human-wildlife conflict that results in carnivore mortality is low in Banff National Park (8% of large carnivore mortality from 2005-2017 was a result of management destruction, compared to highways (55% of mortality) and railways (37% of mortality[2]), increasing human use in areas of high grizzly bear habitat may result in increased risk for human-wildlife conflict. The Mount Norquay Ski Area Management Guidelines stress the importance of physical separation of summer visitor use from bears and their key foraging habitats (Banff National Park, 2011).

The impact of Mount Norquay operations on wildlife and wildlife movement is an important consideration of Mount Norquay. In the past, Norquay has undertaken actions to improve security for wildlife and to improve connectivity. These include lease reductions and closure of the ski out which have enhanced the Forty Mile Creek wildlife corridor and the Cascade Wildlife Corridor (Banff National Park, 2011). The Mount Norquay Ski Area Management Guidelines outline a 44% reduction in leasehold size of which 19% was directly related to providing better protection to the wildlife corridors and Park lands.

The gondola development proposal is in direct alignment with many recommendations outlined in the Mount Norquay Ski Area Management Guidelines to enhance ecological integrity. Specifically, Parks Canada identified a gondola as part of a mass transit strategy, as having 'the potential to enhance visitor experience, contribute to ecological integrity by

[2] Open Government Licence Canada https://open.canada.ca/data/en/dataset/6aa18934-5fec-4f12-8dd7-8356555d0576

significantly reducing human use in the Cascade Wildlife Corridor, and contribute to the community's and Park's Canada's efforts to explore alternative mass transportation systems'. In addition, the Mount Norquay Ski Area Management Guidelines recommends mitigations to be considered for any future developments which have been included in the gondola development proposal.

From this point forward when we refer to the "gondola development proposal" (Figure 5) it is inclusive of a mass transit system (gondola), restricting human activity to a boardwalk in the alpine via fencing, new parking lots at train station, reduced vehicle traffic on the access road, and reconfiguration of the Norquay Lease Site (outlined in bright yellow), including restoring upper parking lots to natural land cover.

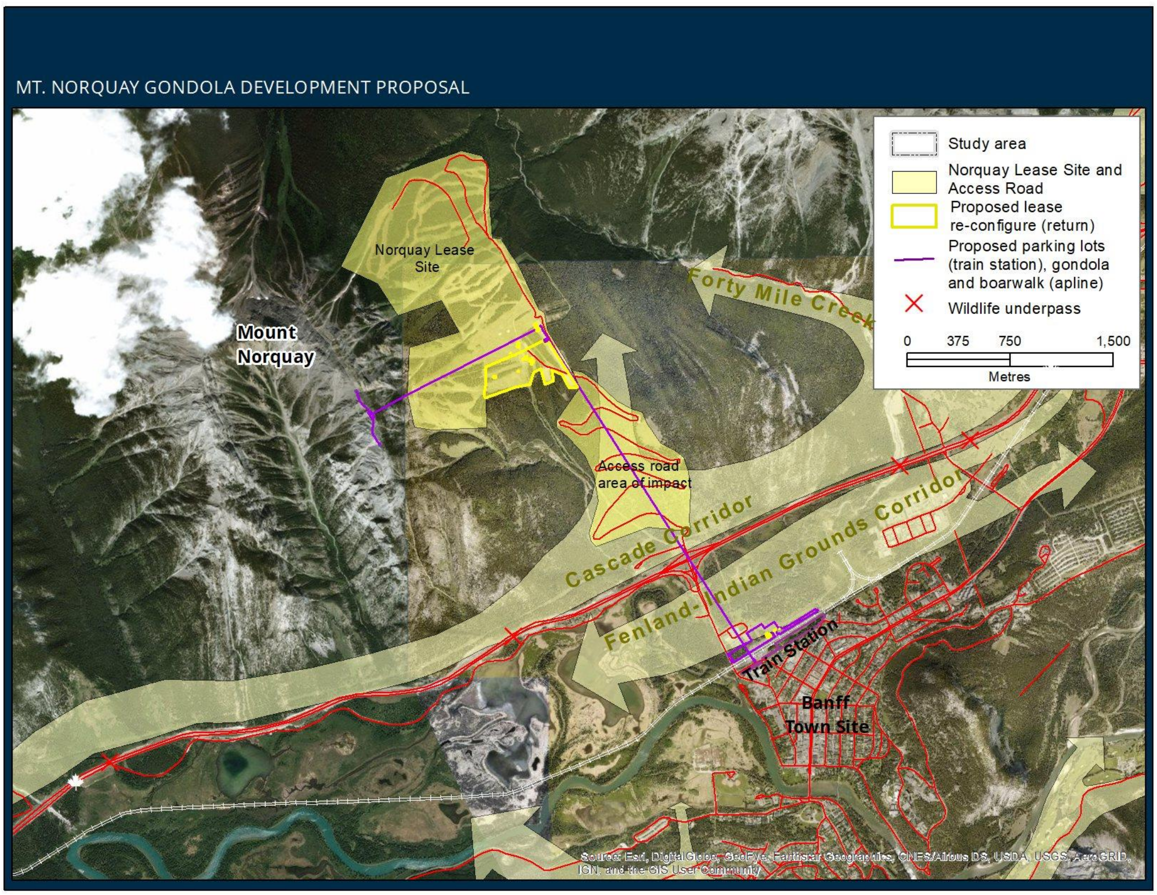


Figure 5: Mount Norquay gondola development proposal

2.0 Approach

A comparative ecological assessment was proposed to examine the impact of the gondola development proposal and various mitigations in the Mount Norquay area. The assessment endeavored to answer the question: ***Can the gondola development proposal result in an environmental gain to large mammals in Banff National Park?*** To answer this question, we undertook four research activities, including:

1. Expert Workshop: The purpose of the expert workshop was to discuss the gondola development proposal and explore the ecological viability of mitigation options that could enhance conditions for wildlife. The results of the expert workshop informed the development of conservation challenges to consider in modeling.

2. Literature Review: The purpose of the literature review was to provide background research to the mitigations identified during the expert workshop. This information was used to support the modeling and AHP process (described below).

3. Modeling: Resource Selection Function and connectivity modeling was conducted using wildlife and environmental data provided by Parks Canada. Modeling treatments were developed to test the impact of the Norquay Lease Site and Norquay Access Road on carnivore connectivity.

4. Analytical Hierarchy Process (AHP): AHP was used to rank mitigations associated with the gondola development proposal as they related to identified conservation challenges. At a second expert workshop, results from both the empirical modeling and AHP hierarchy structure were reviewed.

We report on the methods and results of the research activities below.

3.0 Expert Workshop

The purpose of the expert workshop was to bring experts together to discuss the gondola development proposal to identify and prioritize conservation challenges for consideration in modeling.

The workshop was hosted by the Miistakis Institute, Dr. Adam T. Ford and Dr. Tony Clevenger on November 2, 2018 at the Mount Norquay Ski Lodge in Banff National Park. Participants included individuals with expertise in wildlife ecology, wildlife connectivity or the area of focus (Norquay Lease Site). A participant list and agenda for the workshop are included in Appendix 1.

3.1 Workshop Objectives and Process

The intended outcomes of the workshop were to:

- Determine study area boundary;
- Determine focal species to model;
- Identify possible conservation challenge questions relating to focal species habitat; and movement impacts;
- Identify possible mitigation measures;
- Prioritize list of challenges and mitigations to inform modeling; and
- Identify species and variable datasets available for the modeling.

Facilitated discussions focused on:

- *Study area*: Participants were asked to consider the area of focus for the modeling conservation challenges and to consider focal species data availability, the extent of Norquay operations and what an appropriate modeling extent would be relative to the area of concern.
- *Focal species*: Participants were asked to brainstorm focal species and to consider the following: data availability and representativeness.
- *Impacts and Causes of Impacts*: Participants were asked to determine the impacts of concern (human use on access road).
- *Mitigations*: Participants were asked to determine what mitigations might benefit the focal species and/or what might make impacts less severe (physical modifications to the affected landscape, changes in human behaviours/practices).
- *Conservation Challenges*: The final exercise was to develop conservation challenges for consideration in modeling by selecting species, impacts and mitigations.
- *Prioritization*: Participants prioritized the conservation challenges using a dot-mocracy exercise. Each participant was given 10 stickers to rank the list of generated conservation challenges.

3.2 Workshop Outcomes

Participants felt the study area should consider regional wildlife movement in addition to the localized Mount Norquay least site and Norquay Access Road since wildlife connectivity in and around the Bow Valley was deemed regionally important.

Species of concern included sensitive carnivore species (grizzly bear, cougar, and wolves) and bighorn sheep (due to potential alterations in the alpine area impacting sensitive lambing grounds).

Participants were most concerned about potential impacts of habitat loss (due to avoidance), decreased movement/connectivity, and negative human and wildlife interactions (human-wildlife conflict).

Mitigations (strategies to reduce impacts to focal species) included:

- Alpine containment of humans – limiting human access to alpine areas with the construction of a boardwalk
- Reduction of buildings/footprint – this includes the decommissioning of parking lots and infrastructure located adjacent to the existing main lodge
- Limiting summer human use of the Norquay Lease Site – restricting human use to the immediate area surrounding the proposed Stoney Woman Lodge and Cliff House
- Decommissioning of Norquay Access Road– restricting all vehicle use of the Norquay Access Road with no on-going maintenance of the road
- Temporal restrictions on Norquay Access Road– vehicle and recreational use restricted during crepuscular time periods (defined in the Mount Norquay Ski Area Management Guidelines).
- Corridor enhancements - improve wildlife movement opportunities through the Cascade Wildlife Corridor via physical alterations or enhancing wildlife trails across Stoney Squaw
- Mitigating sound and light impacts from the gondola itself
- Habitat enhancement - restoring open habitat patches between the Trans-Canada Highway and the leasehold using prescribed burning or other wildlife habitat improvements
- Visitor education - this would not be included as a modelling parameter but included as an important consideration

Many of the identified mitigations aligned with recommendations included in the Norquay Ski Area Management Guidelines (Table 12), with the exception of decommissioning the Norquay Access Road and mitigating sound and light from the gondola.

Table 1 highlights the prioritized conservation challenges from participants.

Table 1: Prioritized conservation challenges

	Conservation challenge 1	**Conservation challenge 2**	**Conservation challenge 3**
Species	Grizzly bear	Wolf and Cougar	Bighorn sheep
Concern	Habitat use and connectivity	connectivity	Lambing habitat

Conservation challenge 1 and 2 were modeled using empirical data while mitigations were assessed by expert opinion using an AHP. Conservation challenge 3 included a literature review and expert opinion and modeling to identify possible locations of bighorn sheep lambing habitat and proximity to the gondola terminus and boardwalk in the alpine region.

4.0 Carnivores (Conservation Challenge 1 & 2)

4.1 Carnivore Modeling Methods

We developed a Resource Selection Function (RSF) model to determine the seasonal distribution of three large carnivore species common in Banff National Park: grizzly bear, cougar and wolf. A RSF is defined as a function (i.e. statistical model) that estimates the probability of use of a resource (Manly, McDonald, Thomas, McDonald, & Erickson, 2002). Resource selection functions are models used to compare the amount of used habitat with the amount of available habitat (Manly et al., 2002). A RSF quantifies the relative use of different habitat types and/or landscape features given the amount of those habitat or features available on the landscape (Koper & Manseau, 2012), thereby providing an understanding of how species use the landscape.

To develop a RSF we acquired GPS datasets from Parks Canada for all three carnivore species. Both continuous and discrete (categorical) variables of various habitat features were developed to infer how species use landscape features. Variables were selected based on a review of previous RSF modeling undertaken for grizzly bear, cougar and wolf (Chetkiewicz & Boyce, 2009; Hebblewhite & Merrill, 2008; Nielsen, 2007a).

The RSF models were used to create resistance surfaces to model animal movement and to test impact treatments that may improve movement in and around the Mount Norquay Lease Site and Norquay Access Road.

The study area includes the Norquay Lease Site and the proposed gondola mass transit system from the train station in the Banff townsite to the alpine region of Mount Norquay. To define the study area, we used a 10 km window around the proposed gondola starting site (near the Banff Train Station) (Figure 6). The analysis window was determined by expert opinion, informed by a study by Koen et al. 2004 who found that a 20% buffer around areas of interest is ideal when developing connectivity models (Koen, Bowman, Sadowski, & Walpole, 2014).

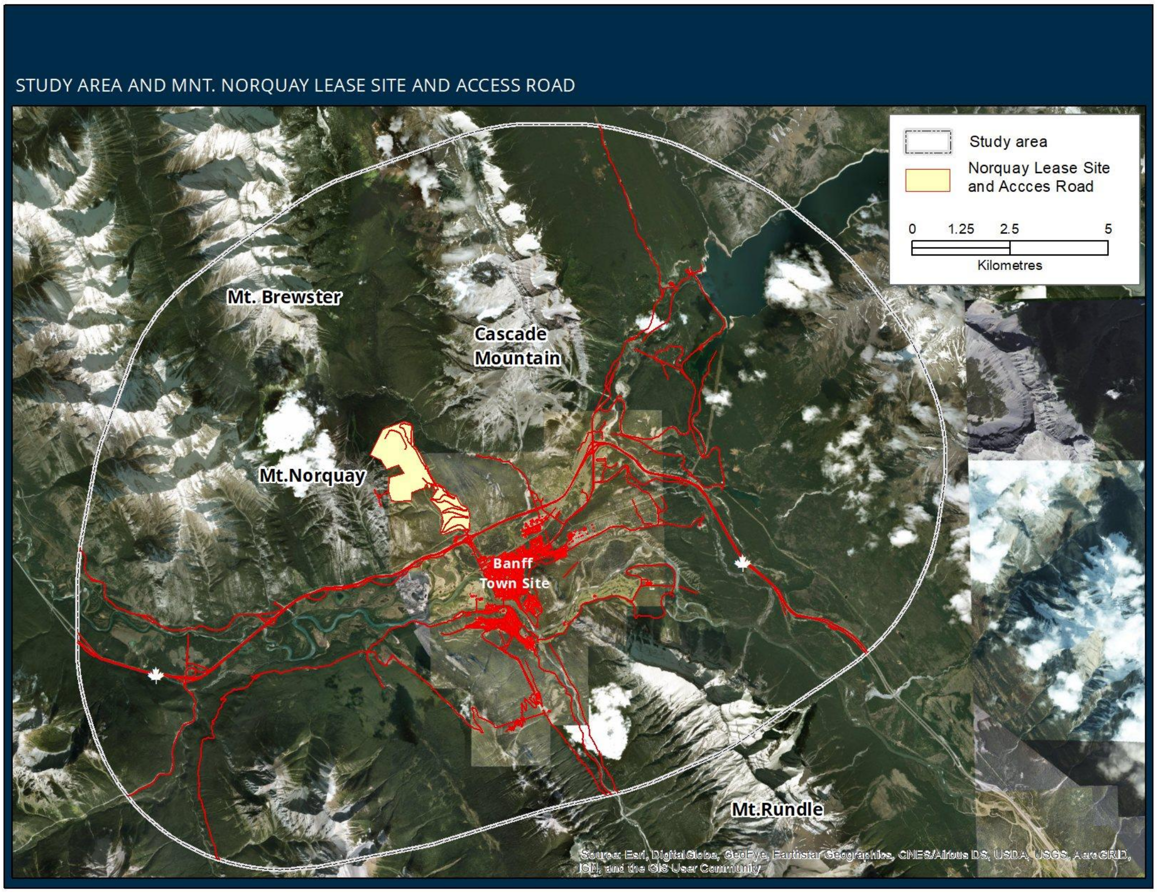


Figure 6: Modeling study area, boundary shown by the white line, major roads in red, and the Norquay Lease Site and Access Road in yellow.

Grizzly Bear Resource Selection Function Modeling

From 2000 to 2017 fifteen grizzly bears with GPS collars were recorded in the study area resulting in a total of 12,492 observations. The data was separated into three seasons (Table 2). The time between points per grizzly bear was two hours on average. Research shows that there is no time period where GPS point data from the same animal is thought to be independent of a subsequent record (Koper & Manseau, 2012), therefore for this analysis all GPS recorded points were included.

Within each season animals with less than 100 observations were removed from analysis.

Table 2: Grizzly bear GPS points per season

Season	Time period	Number of animals	Number. of GPS points
1	May 1 to June 15	13	4151
2	June 16 to July 31	15	5214
3	Aug 1 to Oct 15	9	3127

Season 1 (May 1 –June 15) represents den emergence where bears tend to consume herbaceous materials, roots, tubers and scavenge on ungulate carrion. Season 2 (June 16 – July 31) represents when bears forage on fresh vegetation and prey on young ungulate and Season 3 (Aug 1- Oct 15) represents when bears consume berries and dig roots. All GPS records outside of these time periods were removed from analysis.

Eighteen potential environmental variables for grizzly bear distribution were developed based on a review of grizzly bear variables used in other RSF models developed for grizzly bear populations in Alberta or British Columbia (Table 3) (Chetkiewicz & Boyce, 2009; Lamb et al., 2018; Nielsen, 2007a, 2007b; Stewart et al., 2013). All environmental variables were derived using GIS (30m resolution) and data layers were provided by Parks Canada. Two mask variables were developed to represent non-habitat, non-vegetated areas at high elevation and open water and/or ice. Mask variables were not included in modeling but used as an overlay at the end of the modeling process to remove non-habitat conditions.

Variables that were represented by *distance-to* metrics, including vegetation edges, various human features and stream variables were developed to emphasize greater influence of edge habitat with little relevance at larger distances using an exponential transformation of straight-line distance (values were scaled from 0 (at edge) to 1 (at some large distance from an edge). We used methodology outlined by Nielsen (2007b), specifically the formula:

$$y = 1-e^{-(d/500)}$$

where d represents the distance in meters to an edge and y the resulting distance index for forest edge or streamside habitat.

Table 3: Grizzly bear habitat variables

Model coefficients
stand_cc_treed- crown closure (0-100) inside treed habitats (upland-tree or wetland-tree)
stand_cit_avg- average compound topographic index (CTI) within a 150m radius
d500streams2- distance to stream
d500for_nove3 - distance to forest and non-vegetated edge
dforupherb - distance to forest and upland herb edge
d500opn_utre3- distance to open and upland tree edge
nonveg- non-vegetated land cover (barren, cloud, shadow, snow/ice, water) 1, otherwise 0
noveg_alpmask- non-vegetated pixels within the alpine nat. sub region (MASK variable)
shrub- shrub land cover pixels are 1, otherwise 0
upherb- upland herb land cover type is 1, otherwise 0
uptree- upland tree is 1, otherwise 0 (reference category; not required, but included)
waterice_mask- mask of water & snow/ice pixels as 0, otherwise 1 (MASK variable)
wetherb- wetland herb land cover type is 1, otherwise 0
wettree- wetland tree land cover type is 1, otherwise 0
stand-sa-slope_1 10 bins (0-10, 10-20, etc.)

Elevation -
d500roadsd - distance to major highway (scaled)
d500roadsu -distance to secondary roads (scaled)
d500trails - distance to Trails - non-used gravel roads, trails and cutline (scaled)
d500camp - distance to campgrounds (scaled)
d500town - distance to Banff Town (scaled)

To test for collinearity among potential variables we ran a correlation matrix in R, all pairwise coefficients within +-0.70 were included in the modeling process as potential variables (Jesse Whittington, St. Clair, & Mercer, 2005).

Home ranges for each grizzly bear were created using a minimum convex polygon; each polygon was buffered by 1km to represent the areas of use per grizzly bear. Random points, equivalent to the number of grizzly bear GPS points, were generated within each bear defined area of use. To create RSF models we compared seasonal grizzly bear GPS locations with random locations within individual home ranges.

We ran a generalized linear mixed model (GLMM), using the *glmer* function in R. To validate the models we used a K-fold approach (Boyce, Vernier, Nielsen, & Schmiegelow, 2002; Chetkiewicz & Boyce, 2009; Koper & Manseau, 2012).

Wolf Resource Selection Function Modeling

Wolf GPS data was collected from 2002-2005, 2009-2013 and 2015-2018 for a total of thirteen years of data collection, representing 14 wolves and a total of 8,122 GPS points in study area (Table 4). The data was separated into two seasons, summer and winter. Within each season animals with less than 100 observations were removed from analysis.

Table 4: Wolf GPS points per season

Season	Time period	Number of animals	Number of GPS points
Summer	April 15 to Oct 15	6	2651
Winter	Oct 16 to April 14	8	5471

Seventeen potential environmental variables were considered for modeling wolf resource use based on a literature review and expert opinion (Table 5) (Chetkiewicz & Boyce, 2009; Musiani, Morshed Anwar, McDermid, Hebblewhite, & Marceau, 2010; Rogala et al., 2011). All distance variables were generated using the same approach as described for grizzly bear.

Table 5: Wolf habitat variables

Model coefficients
alpine1: if in natural region 1, otherwise 0
subalpine: if in natural region 1, otherwise 0
opn_conifer1: conifer land cover type with percent cover >=20% 1, otherwise 0
upherb1: upland herb land cover type is 1, otherwise 0
shrub1: shrub land cover type is 1, otherwise 0
stand_sa_slope_1; 10 bins created (0-10%, 10-20….)
d500for_nove3: distance to forest and non-vegetated edge (scaled 0 to 1)
d500opn_utre3
d500streams2: distance to stream (scales 0 to 1)
d500roadsd: distance to major highway (scaled 0 to 1)
d500roadsu: distance to secondary roads (scaled 0 to 1)
d500town: distance to Banff town site (scaled 0 to 1)
d500camp: distance to camp grounds (scaled 0 to 1)
d500trails: distance to trails (scaled 0 to 1)
stand_aspect_bins
stand_elevation: m above seas level
TRI: Terrain Ruggedness Index

To test for collinearity among potential variables we ran a correlation matrix in R, all pairwise coefficients within +-0.70 were included in the modeling process as potential variables (Jesse Whittington et al., 2005).

Home ranges for each wolf were created using a minimum convex polygon; each polygon was buffered by 1km to represent the areas of use per wolf. Random points, equivalent to the number of wolf GPS points, were generated within each wolf defined area of use. To create RSF models we compared seasonal wolf GPS locations with random locations within individual home ranges.

We ran a generalized linear mixed model (GLMM), using the *glmer* function in R. To validate the models we used a K-fold approach (Boyce et al., 2002; Chetkiewicz & Boyce, 2009; Koper & Manseau, 2012).

Cougar Resource Selection Function Modeling

Cougar GPS data was collected from 2000-2003 representing 4 cougars and a total of 1,373 GPS points in study area. There was only enough data for the winter season, and data only represented the months from January to May. Within each season animals with less than 100 observations were removed from the analysis. For cougar the same potential environmental variables as wolf were considered (Table 5).

The potential variables were tested for collinearity using a correlation matrix in R, all pairwise coefficients within +-0.70 were included in the modeling process as potential variables (Jesse Whittington et al., 2005).

Home ranges for each cougar were created using a minimum convex polygon; each polygon was buffered by 1km to represent the areas of use per cougar. Random points, equivalent to the number of cougar GPS points, were generated within each cougar defined area of use. To create RSF models we compared seasonal cougar GPS locations with random locations within individual home ranges.

To generate RSF model we ran a generalized linear mixed model (GLMM), using the *glmer* function in R. To validate the models we used a K-fold approach (Boyce et al., 2002; Chetkiewicz & Boyce, 2009; Koper & Manseau, 2012).

Connectivity Modeling

We considered both least cost path (LCP) (least cost distance between focal nodes- one pathway) and Circuitscape (probability of movement between focal nodes based on random walks – multiple pathways) for this analysis. A key limitation of these models is that LCP assumes the animal is all-knowing and will always take the most optimal route or least costly path to move around the landscape while Circuitscape assumes the animal doesn't know the landscape and assess the probability of movement based on each pixel score. Neither of these assumptions is likely a true reflection on how animals choose to move around the landscape.

LCP measures the least cost distance between focal nodes, while Circuitscape measures the resistance distance between focal nodes. If there is a single pathway between two focal nodes then the LCP and resistance distance will be equal. Where there are multiple independent pathways between nodes, the average least-cost distance of these pathways is equivalent to the resistance distance (Marrott and Bowman 2015). For this assessment we assumed there may be multiple pathways between focal nodes and felt this better represented the intended purpose of the research – to understand how changes in the resistance values impact movement around the landscape.

Higher resistance distances among locations are assumed to correspond to a higher degree or likelihood of isolation among habitat areas or locations. Circuitscape requires development of two key layers, a resistance surface to represent the relative effort for an animal moving across each pixel on the landscape, and focal nodes to represent areas where the animal is moving to and from.

RESISTANCE LAYER DEVELOPMENT

A resistance surface has an assigned resistance value per pixel based upon land cover type or habitat features. The resistance value represents the relative effort required for an animal to travel across a pixel on the landscape, and the map of resistance values is used to derive all the possible pathways for modeled electrical current to traverse the landscape from one focal point or region to another. The resistance surface was derived using the RSF for each species and applying a negative exponential using the following function:

$$f = 100 - 99\frac{1 - \exp(-ch)}{1 - \exp(-c)}$$

where f is the friction value ranging from 1-100 and the function C=4 and h is the RSF score from 0 to 1 (Trainor, Walters, Morris, Sexton, & Moody, 2013). Recently there has been some scrutiny on the use of habitat modeling representing how animal moves around a landscape. Mateo-Sanchez et al. (2015) found that resistance surfaces based on habitat models may tend to overestimate landscape resistance in areas with low habitat suitability (Mateo-Sanchez et al 2015). The negative exponential was used enable a gradual change in friction values with suitability when suitability values are relatively high; if the function is not applied there is a drastic increase in friction values as habitat suitability declines beyond the mid-range (Trainor et al., 2013).

FOCAL NODES

Banff National Park is fairly restrictive in terms of movement opportunities, which are limited to the mid to lower valley bottoms. A review of the density of grizzly bear GPS points indicated use hotspots, and identified movement corridors where grizzly bears were present; resulting in eight focal nodes placed within expected movement corridors at the edge of the study area. For the major valley that runs parallel to the Trans-Canada Highway, nodes were placed on both sides of the highway (Figure 7). Koen et al (2014) found placement of focal nodes around the edge of the study area is least likely to bias results from node placement. The same focal nodes were used for wolf and cougar.

Focal nodes were labeled 1 through eight, and an accompanying text file instructed Circuitscape to avoid neighboring focal nodes during modeling.

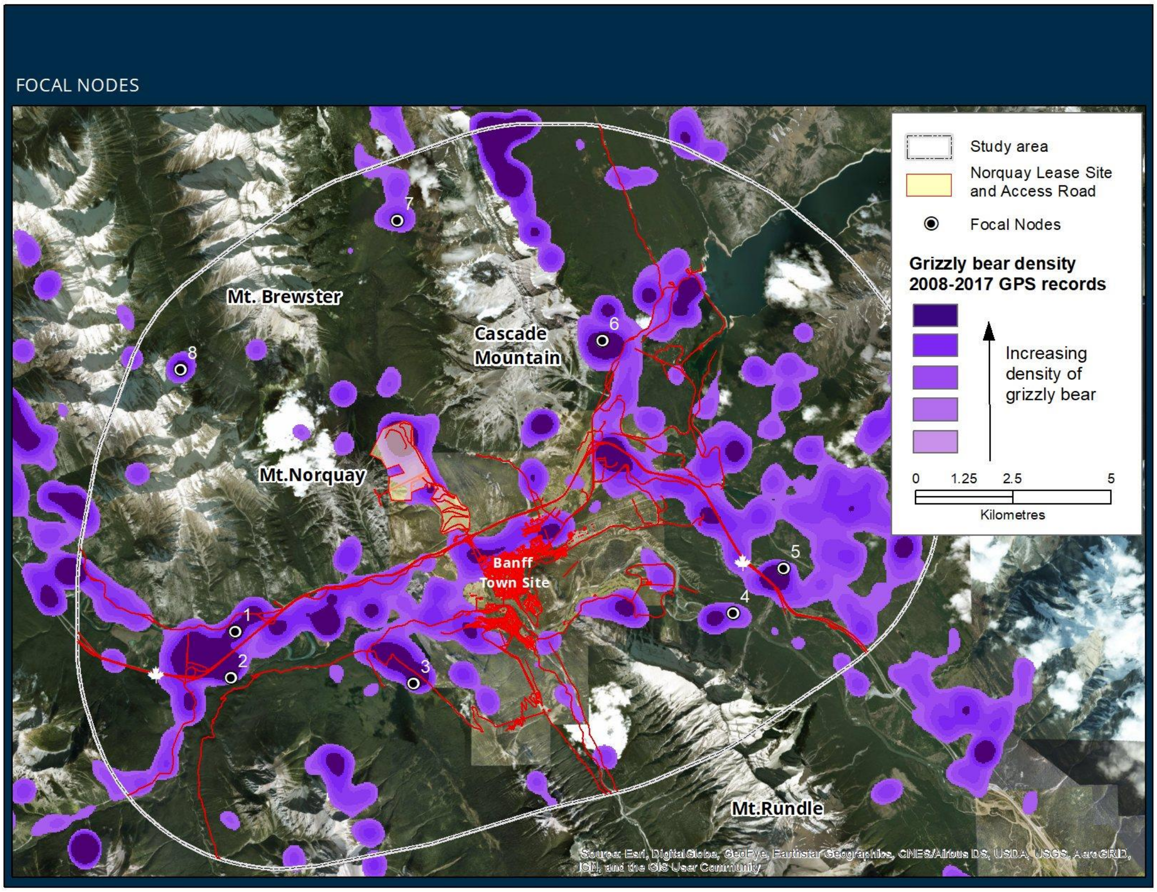


Figure 7: Focal Node sites used for Circuitscape modeling

MODELING TREATEMENTS

Our modeling treatments included both the Norquay Lease Site and Norquay Access Road to determine if improvement or impediments in resistance values would alter the ability of large carnivores to move around the landscape (Figure 7).

Within the area of interest we developed six modeling treatments by adjusting resistance values by 10% lower friction per pixel, 50% lower, and 90% lower and 10% friction increase per pixel, 50% increase, and 90% increase. A reduced friction indicates improved movement opportunity while increase in friction represents reduced movement opportunity. As such, the “90% Lower” and the “90% Higher” modeling treatments represent the endpoints for the most optimistic and pessimistic outcomes, respectively, that we tested. This methodology does not determine the method of accomplishing the connectivity improvement or reduction. Mitigations to improve connectivity were assessed using an AHP and expert opinion.

For all treatments we re-ran Circuitscape using the same focal nodes. We generated 10,000 random points and reported on the change in the connectivity value at each point as function of 1) distance from the edge of the area of interest and 2) within Norquay Lease Site.

Figure 8 outlines the modeling process in a flow chart and indicates products found in in the results section.

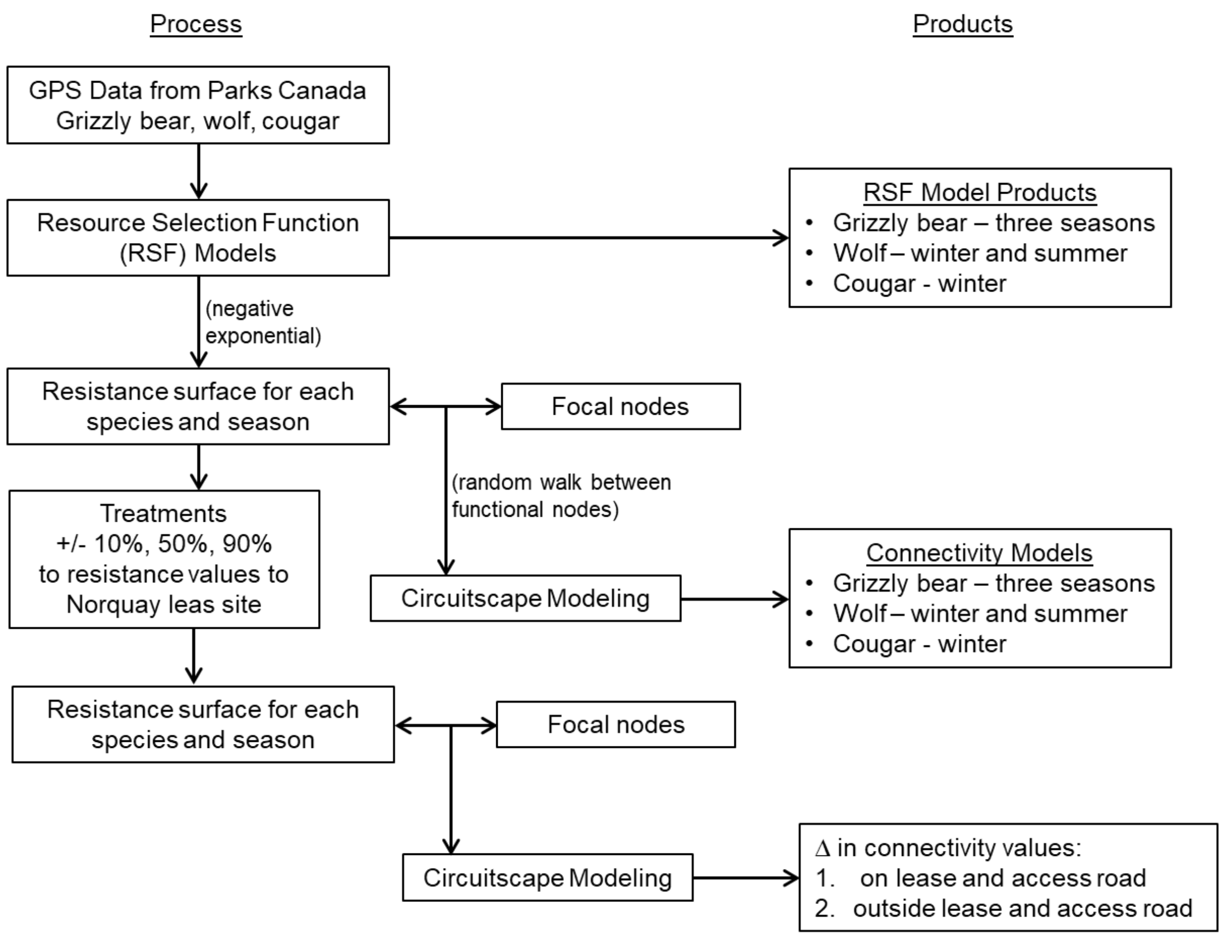


Figure 8: Modeling process flow chart

4.2 Carnivore Modeling Results

Grizzly Bear Resource Selection Function Models

RSF models were developed for grizzly bear for three seasons using coefficients derived from general linear regression using global model produced in R (Table 6, Table 7, Table 8). Correlations between uptree and stand_cc-treed, stand_sa_slope_1and elevation and between d500opn_utre3 and d500for_uher3 with values r >+-0.70 resulted in dropping uptree, elevation and d500for_uher3 from the model analysis.

Kfold plots for each season indicate a good model fit, since on all three plots the number of observations was near 1, mean and standard deviation of spearman rank values for random points was near 0 (Appendix 2).

Table 6: Grizzly Bear season 1 model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.497	0.280	-1.772	7.645E-02	
nonveg	-2.647	0.167	-15.876	9.224E-57	*
wetherb	0.276	0.311	0.887	3.753E-01	
upherb	-0.241	0.116	-2.073	3.818E-02	*
shrub	0.154	0.148	1.037	2.997E-01	
stand_sa_slope_1	-0.255	0.037	-6.868	6.491E-12	*
d500for_nove3	0.049	0.103	0.473	6.363E-01	
d500opn_utre3	-0.751	0.103	-7.279	3.361E-13	*
d500streams2	-0.044	0.116	-0.379	7.050E-01	*
d500roadsd	-1.040	0.125	-8.323	8.560E-17	*
d500roadsu	-1.412	0.106	-13.328	1.587E-40	*
d500town	1.077	0.167	6.455	1.085E-10	*
d500camp	1.448	0.224	6.468	9.956E-11	*
d500trails	0.604	0.101	5.960	2.518E-09	*
stand_cti_avg	0.252	0.039	6.446	1.151E-10	*
stand_cc_treed	-0.224	0.037	-6.129	8.853E-10	*

*statistically significant variables

Table 7: Grizzly Bear season 2 model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.528	0.259	-2.035	4.184E-02	*
nonveg1	-2.368	0.129	-18.359	2.797E-75	*
wetherb1	0.459	0.313	1.466	1.426E-01	
upherb1	-0.173	0.100	-1.734	8.300E-02	*
shrub1	0.657	0.140	4.691	2.721E-06	*
stand_sa_slope_1	-0.345	0.032	-10.733	7.096E-27	*
d500for_nove3	-1.046	0.087	-12.048	1.985E-33	*
d500opn_utre3	-0.218	0.085	-2.552	1.071E-02	*
d500streams2	0.437	0.096	4.542	5.560E-06	*
d500roadsd	-0.412	0.102	-4.024	5.716E-05	*
d500roadsu	-0.532	0.095	-5.601	2.129E-08	*
d500town	-0.045	0.158	-0.283	7.773E-01	
d500camp	1.980	0.207	9.550	1.297E-21	*
d500trails	-0.163	0.088	-1.855	6.354E-02	*
stand_cti_avg	0.263	0.033	7.884	3.176E-15	*

stand_cc_treed	-0.180	0.032	-5.611	2.013E-08	*

*statistically significant variables

Table 8: Grizzly Bear season 3 model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.131	0.312	0.419	6.754E-01	
nonveg1	-1.702	0.137	-12.447	1.448E-35	*
wetherb1	-1.559	0.452	-3.445	5.703E-04	*
upherb1	-0.045	0.140	-0.318	7.503E-01	
shrub1	0.176	0.154	1.142	2.536E-01	
stand_sa_slope_1	-0.255	0.039	-6.478	9.316E-11	*
d500for_nove3	-1.027	0.102	-10.107	5.161E-24	*
d500opn_utre3	-1.059	0.101	-10.442	1.593E-25	*
d500streams2	0.467	0.120	3.895	9.827E-05	*
d500roadsd	0.774	0.146	5.291	1.215E-07	*
d500roadsu	-0.365	0.121	-3.020	2.527E-03	*
d500town	-0.287	0.194	-1.478	1.393E-01	
d500camp	0.704	0.257	2.740	6.146E-03	*
d500trails	0.158	0.101	1.562	1.182E-01	
stand_cti_avg	0.124	0.043	2.912	3.592E-03	*
stand_cc_treed	-0.217	0.041	-5.325	1.008E-07	*

*statistically significant variables

We used the global model (includes all variables) to generate resource selection function models. The resulting grizzly bear RSF models for each season are displayed in Figure 9, Figure 10, and Figure 11. The models highlight the importance of lower elevation valleys as habitat for grizzly bears as well as the Norquay Lease Site and area around the Norquay Access Road for all three grizzly bear seasons.

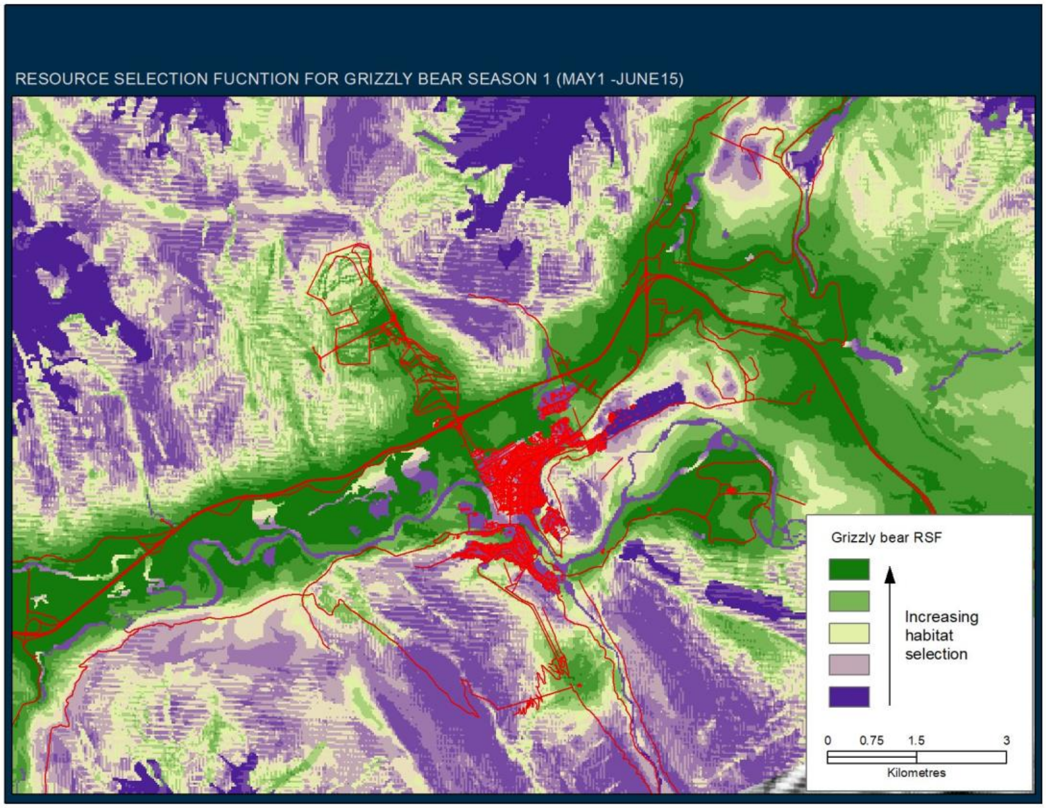


Figure 9: RSF for Grizzly bear season 1

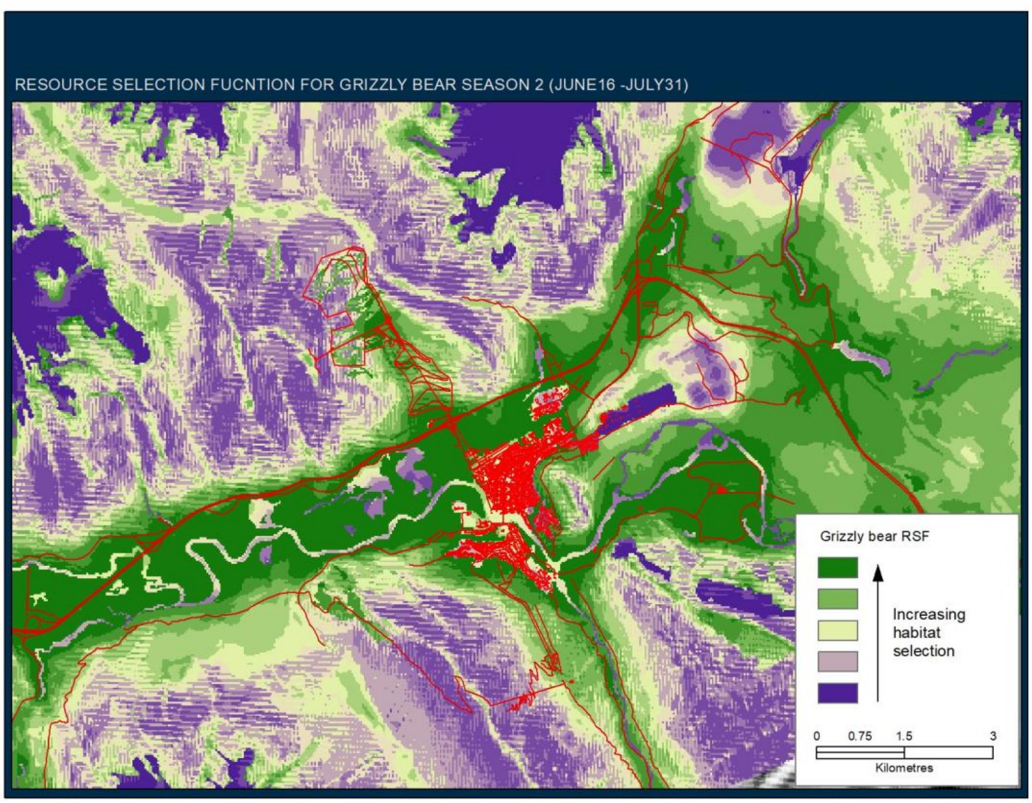


Figure 10: RSF Grizzly Bear Season 2

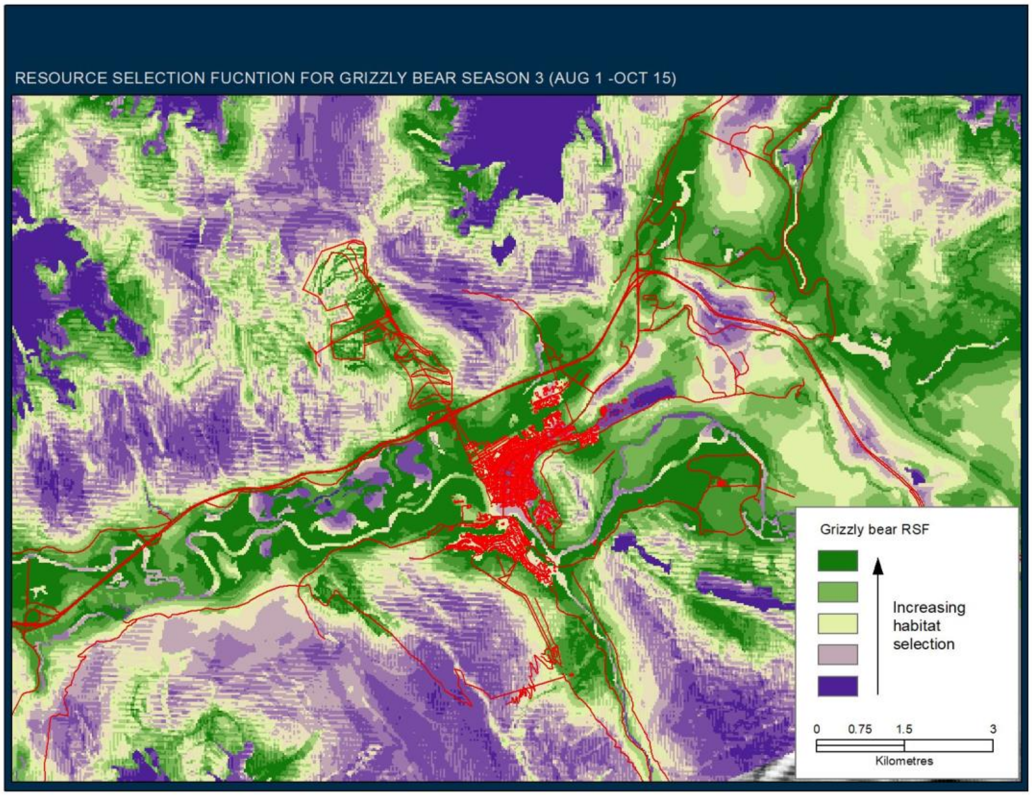


Figure 11: RSF Grizzly Bear Season 3

Wolf Resource Selection Function Models

RSF models were developed for wolf for two seasons (summer: April 15 - October 15 and winter October 16 – April 14) using coefficients derived from general linear regression using global model produced in R (Table 8,Table 9) Grizzly Bear season 1 model coefficients). Correlations occurred between Terrain Ruggedness Index (TRI) and both stand_sa_slope_1and elevation with values r >+-0.70 resulting in removal of TRI from the model analysis.

Kfold plots for each season indicate a good model fit, as in both plots the number of observations was near 1, mean and standard deviation of spearman rank values for random points was near 0 (Appendix 2).

Table 9: Wolf summer model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.315	0.430	-7.718	1.182E-14	*
alpine1	0.603	0.231	2.609	9.078E-03	*
opn_conifer1	-0.135	0.140	-0.964	3.351E-01	
upherb1	0.211	0.140	1.507	1.318E-01	
shrub1	0.305	0.191	1.603	1.090E-01	
stand_sa_slope_1	-0.853	0.064	-13.255	4.227E-40	*

d500for_nove3	-0.528	0.146	-3.626	2.880E-04	*
d500opn_utre3	-1.951	0.147	-13.305	2.162E-40	*
d500streams2	0.296	0.156	1.898	5.769E-02	*
d500roadsd	0.500	0.177	2.820	4.805E-03	*
d500roadsu	1.113	0.164	6.767	1.316E-11	*
d500town	1.263	0.288	4.391	1.130E-05	*
d500camp	0.311	0.321	0.970	3.320E-01	
d500trails	2.576	0.148	17.354	1.857E-67	*
stand_aspect_bins	0.166	0.039	4.212	2.529E-05	*
stand_elevation	-1.235	0.094	-13.121	2.488E-39	*

*statistically significant variables

Table 10: Wolf winter model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.543	0.292	-12.148	5.878E-34	*
alpine1	0.366	0.246	1.491	1.359E-01	
opn_conifer1	-0.059	0.104	-0.569	5.694E-01	
upherb1	0.528	0.095	5.538	3.061E-08	*
shrub1	0.286	0.129	2.213	2.693E-02	*
stand_sa_slope_1	-0.355	0.044	-8.044	8.722E-16	*
d500for_nove3	0.415	0.097	4.288	1.807E-05	*
d500opn_utre3	-0.761	0.099	-7.678	1.618E-14	*
d500streams2	-0.848	0.110	-7.684	1.540E-14	*
d500roadsd	0.083	0.123	0.674	5.002E-01	
d500roadsu	0.152	0.106	1.434	1.515E-01	
d500town	1.984	0.187	10.589	3.363E-26	*
d500camp	0.892	0.206	4.341	1.416E-05	*
d500trails	1.092	0.092	11.927	8.582E-33	*
stand_aspect_bins	0.128	0.025	5.025	5.033E-07	*
stand_elevation	-1.712	0.078	-21.891	3.171E-106	*

*statistically significant variables

We used the global model to generate resource selection function models, resulting in a wolf model for both summer (Figure 12) and winter (Figure 13). The models highlight the importance of lower elevation valleys as habitat for wolves including both the Fenland Indian Corridor and Cascade Wildlife Corridor, including the southern section of the Norquay Access Road (Figure 1displays corridor locations).

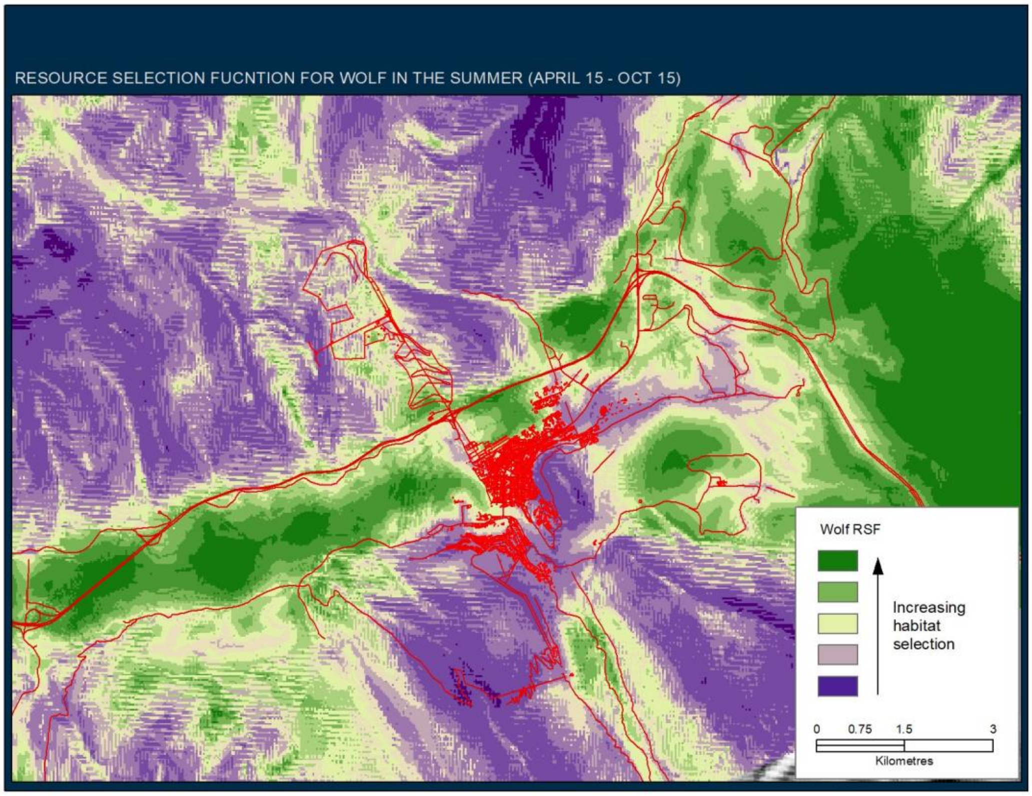


Figure 12: RSF for wolf in summer

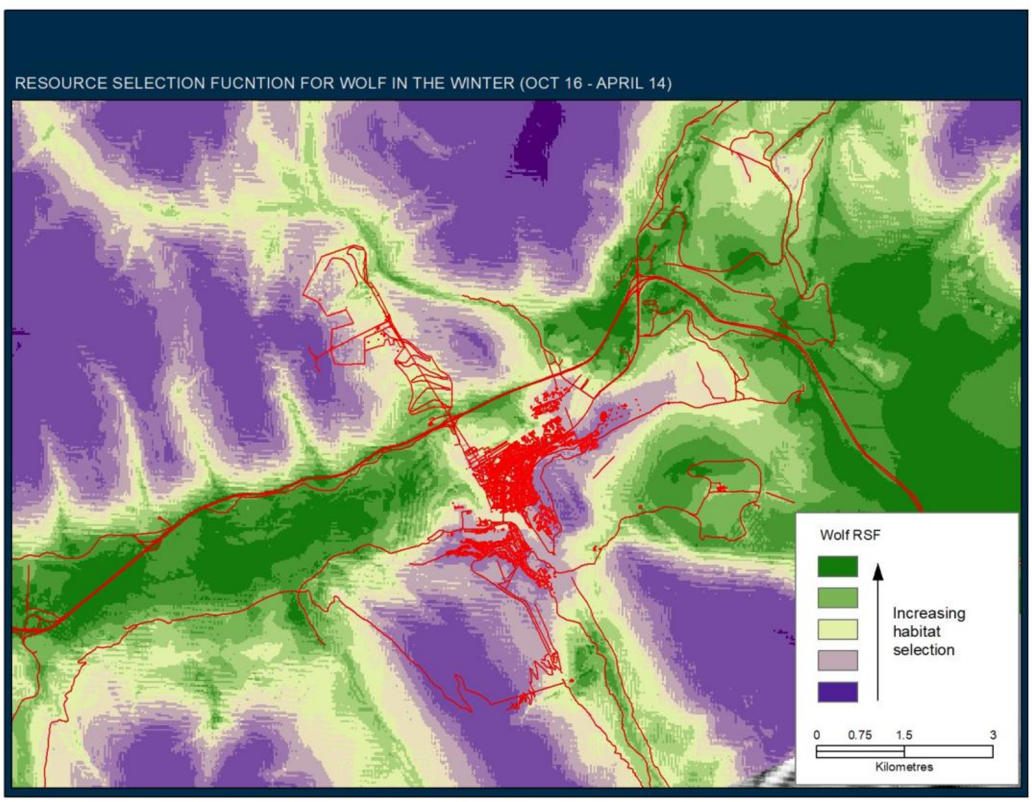


Figure 13: RSF for wolf in winter

Cougar Resource Selection Function Model

A RSF model was developed for cougar in the winter (January - May) using coefficients derived from general linear regression using the global model produced in R (Table 11). Correlations occurred between subalpine and elevation, slope and aspect, between Compound Topographic Index (CTI) and Terrain Ruggedness Index (TRI) and aspect and between elevation and TRI and slope with values r >+-0.70 resulting in removal of TRI from the model analysis. Therefore, subalpine, elevation, aspect and TRI were removed from the modelling process.

Table 11 - Cougar winter model coefficients

Variable	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.6655	0.5346	1.2449	0.213178	
alpine1	-1.7622	0.2888	-6.1018	0.000000	*
upherb1	0.3364	0.2040	1.6494	0.099069	*
shrub1	0.4083	0.2621	1.5578	0.119277	
nonveg1	-1.6035	0.2665	-6.0169	0.000000	*
stand_sa_slope_1	-0.1295	0.1089	-1.1899	0.234100	
d500for_nove3	-0.6394	0.1787	-3.5784	0.000346	*
d500opn_utre3	-1.2434	0.1777	-6.9985	0.000000	*
d500streams2	-0.7717	0.2225	-3.4687	0.000523	*
d500roadsd	-0.9687	0.2308	-4.1966	0.000027	*
d500roadsu	-1.5678	0.1918	-8.1727	0.000000	*
d500town	-1.0623	0.2813	-3.7766	0.000159	*
d500camp	2.4129	0.4636	5.2050	0.000000	*
d500trails	1.0254	0.1868	5.4902	0.000000	*
stand_cti_avg	0.0095	0.0028	3.4313	0.000601	*
stand_cctreed2	0.0902	0.0673	1.3392	0.180515	

*statistically significant variables

We used the global model to generate resource selection function models, resulting in a cougar model for winter (Figure 14). The model resulted in a fixed-effect model matrix warning of rank deficiency (not an error) suggesting some skepticism relating to this model predictability. We were therefore not able to run a Kfold cross validation.

The models highlight the importance of lower elevation valleys as habitat for cougars including both the Fenland Indian Corridor and Cascade Wildlife Corridor. The models also highlight Norquay Lease Site as important for cougar in the winter especially the area around the Norquay Access Road.

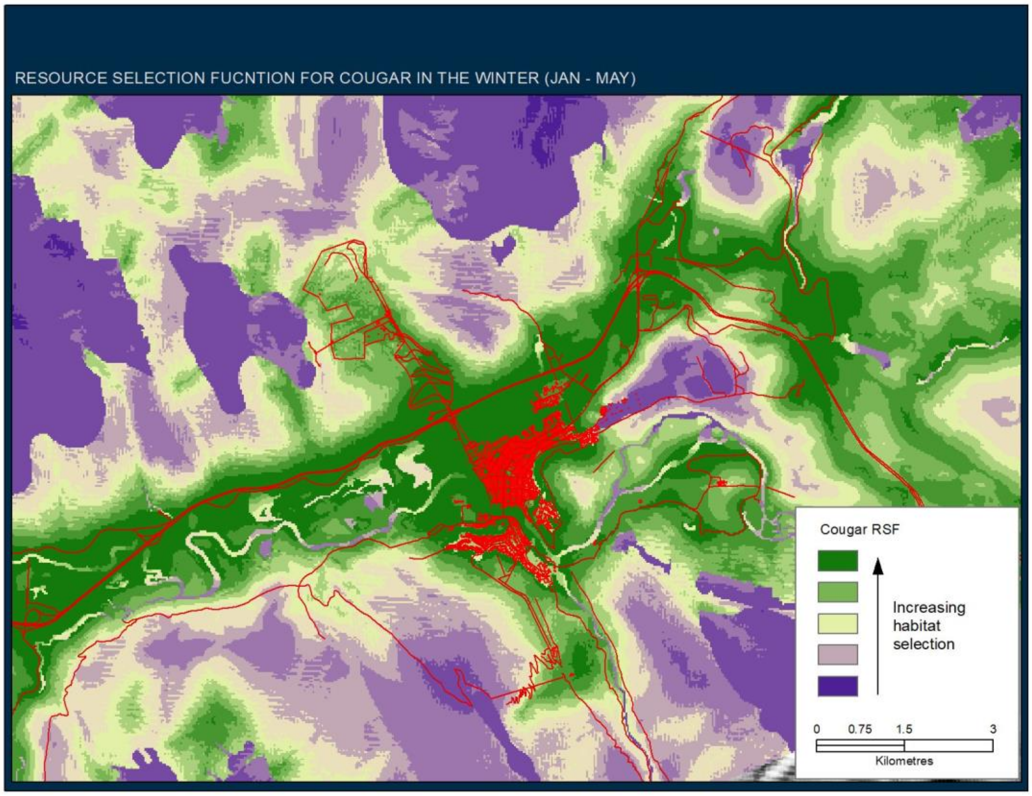


Figure 14: RSF for cougar in winter

Connectivity Modeling

Circuitscape models were run using resistance surfaces developed for species for each season from RSF models. In addition, eight focal nodes were developed to represent likely movement corridors around the edge of the study area. The model uses a random walk approach to model connectivity between focal nodes. The data is displayed as quantiles, with darkest blue representing the top 10% of movement opportunity in the region.

For grizzly bears, our results highlight the importance of the Fenland Indian Grounds Corridor (between the Banff Train Station and Trans-Canada Highway) and the Cascade Wildlife Corridor (between Trans-Canada Highway and start of the Norquay Access Road). In addition, movement to the north seems to be occurring through the Norquay Lease Site and Norquay Access Road as opposed to Forty Mile Creek in all seasons but specifically in season 2 and 3 (June 16 to Oct 15), indicating the importance of the Norquay Lease Site for grizzly bear movement to the north of the study area (Figure 15, Figure 16, Figure 17).

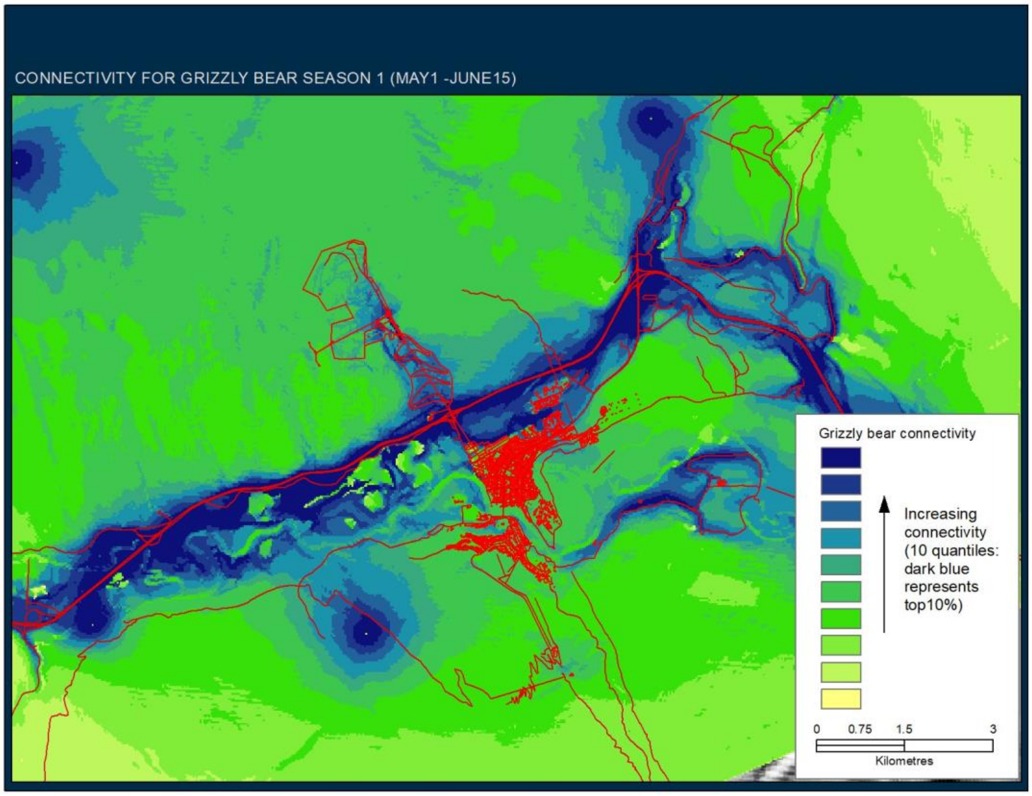


Figure 15: Connectivity for Grizzly Bear Season 1

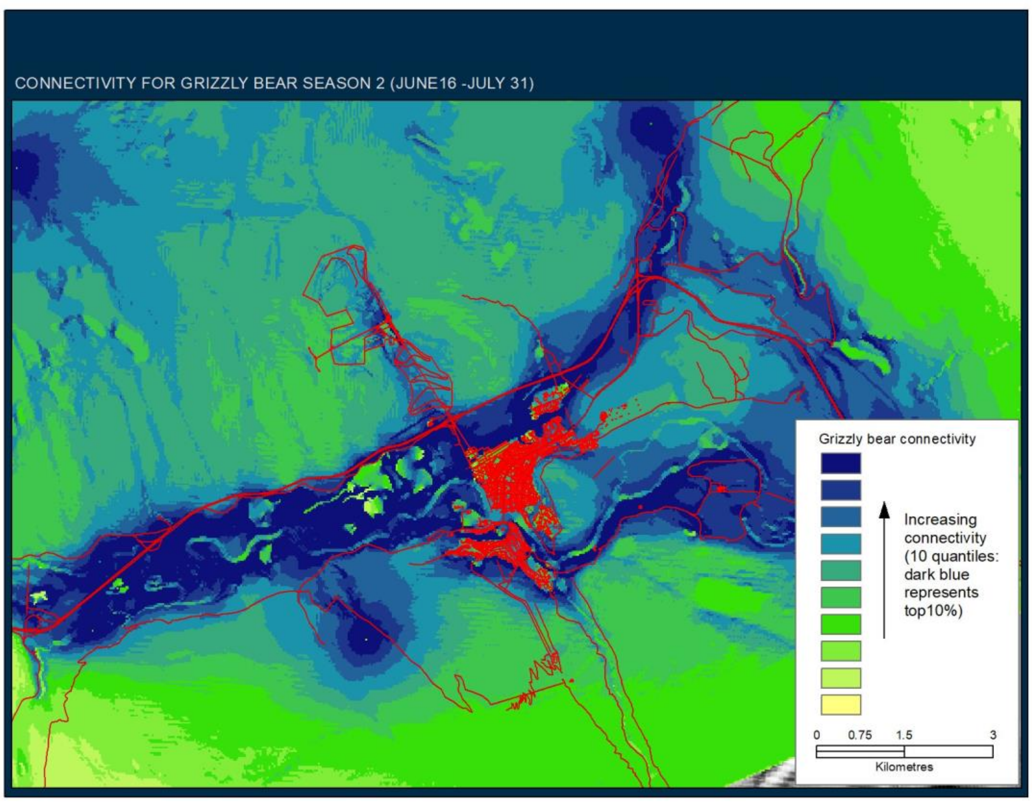


Figure 16: Connectivity for Grizzly Bear Season 2

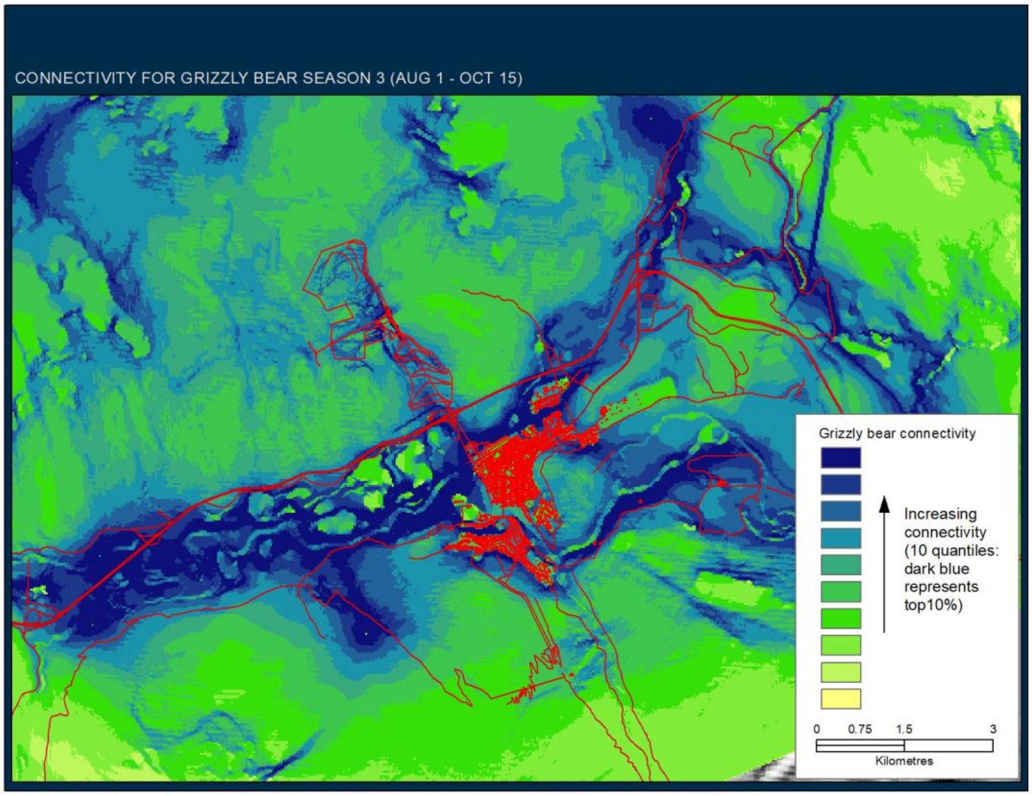


Figure 17: Connectivity for Grizzly Bear Season 3

For wolves, the results (Figure 18, Figure 18) also highlight the importance of the Fenland Indian Grounds Corridor (between the Banff Train station and the Trans-Canada Highway) and Cascade Wildlife Corridor (between Trans-Canada Highway and start of the Norquay Access Road) and Forty Mile Wildlife Corridor, especially in the winter season.

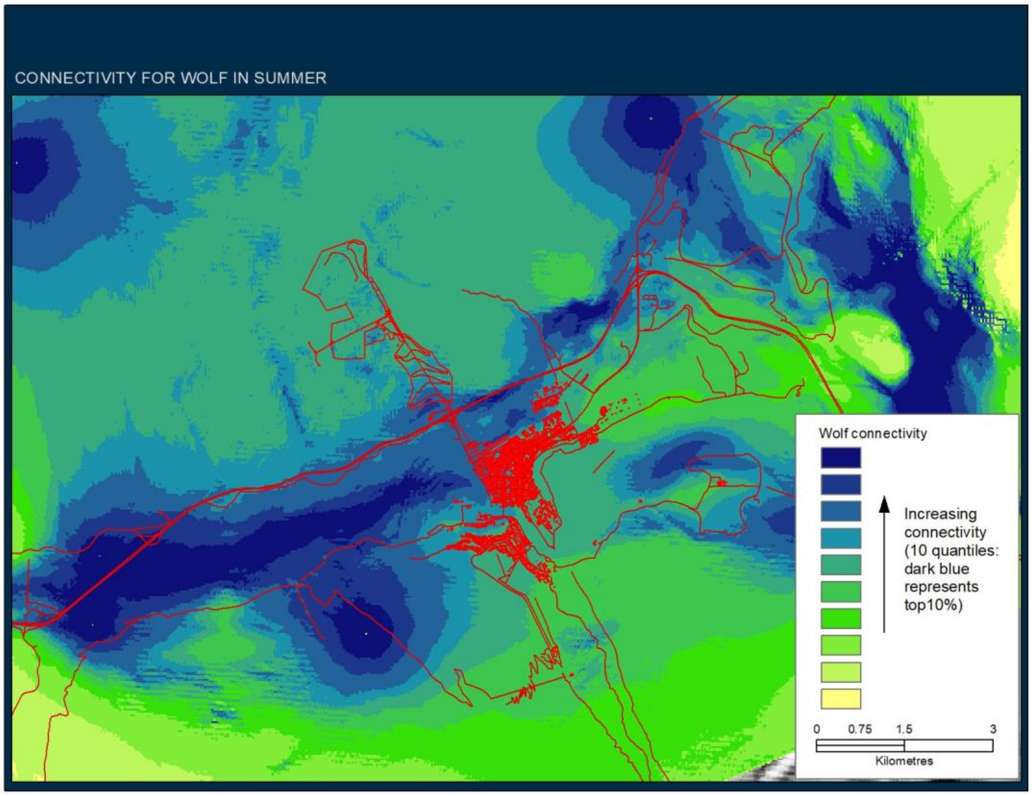


Figure 18: Connectivity for wolf in the summer

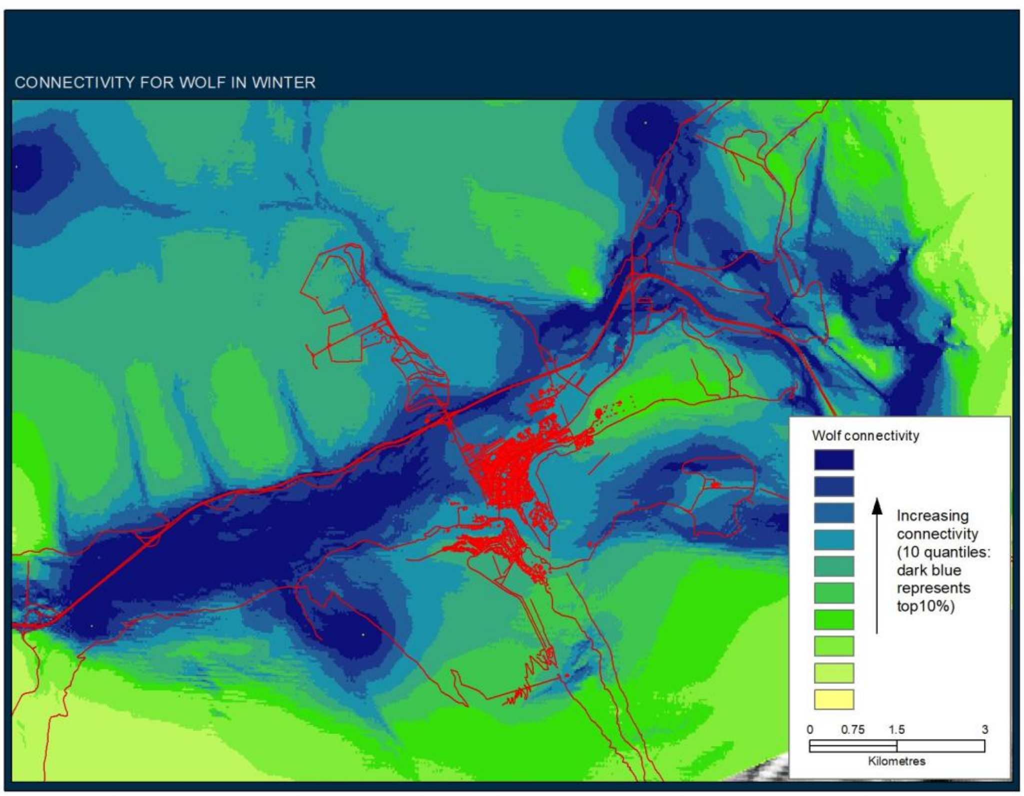


Figure 19: Connectivity for wolf in winter

For cougar, the results also highlight the importance of the Fenlands Indian Grounds Corridor (between the Banff Train Station and Trans-Canada Highway) and Cascade Wildlife Corridor (between Trans-Canada Highway and Norquay Access Road) (Figure 20).

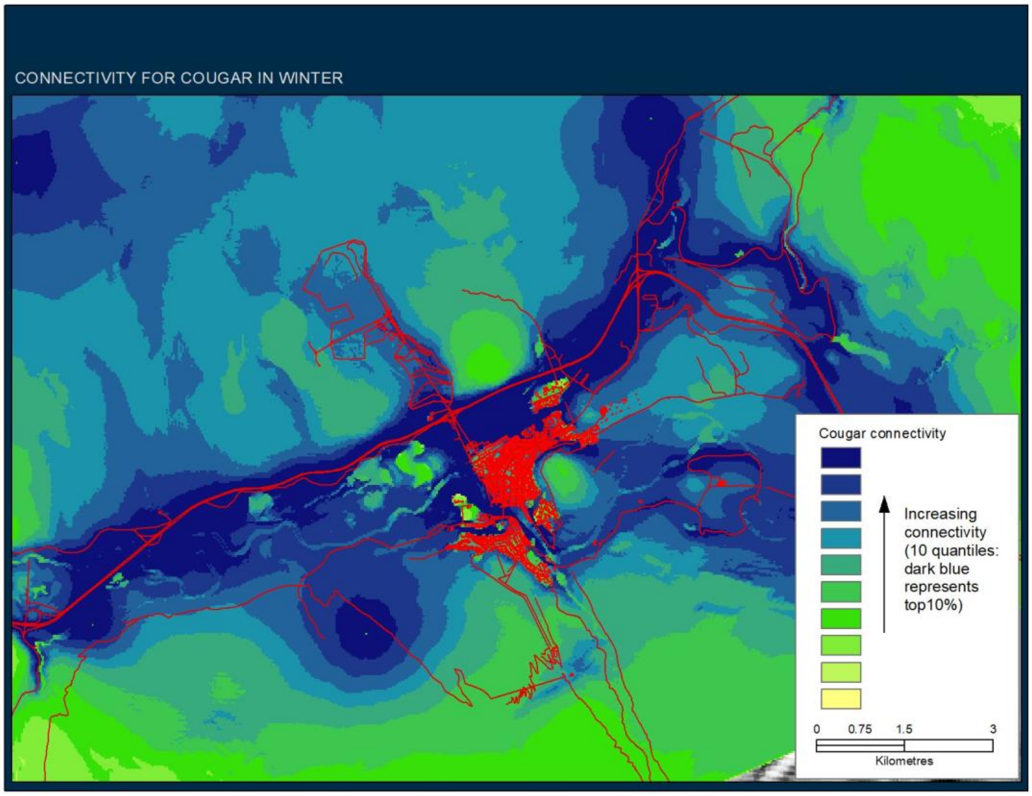


Figure 20: Connectivity for cougar in winter

Model Treatments

For the area of interest (Norquay Lease Site and Norquay Access Road) (Figure 7) we created 6 model treatments, including adjustments to resistance surfaces of 10%, 50% and 90% percent change to improve connectivity (decrease in resistance) and reduced connectivity (increase in resistance) for each species and season. Circuitscape models were run on each impact treatment using the eight identified focal nodes. To determine the effects of the impacts on connectivity in the area we generated 10,000 random points and extracted connectivity values for the base model for each species and season along with the six treatments.

To understand if there is a change in connectivity value to the broader study area, the percent change in connectivity was plotted in relation to distance from edge of the area of interest (Norquay Lease Site and Norquay Access Road) for each impact treatment. For the graphs displayed in Figure 21 the current condition is displayed as the zero value on the y axis, and impact treatments have either a positive or negative response to connectivity. The x axis represents the distance from the outside edge of the area of interest in meters. Each impact treatment has been plotted to show the influence of changing connectivity values on the broader landscape. For all species and seasons and six impact treatments there is very little change in connectivity to the broader landscape (**Figure 21**).

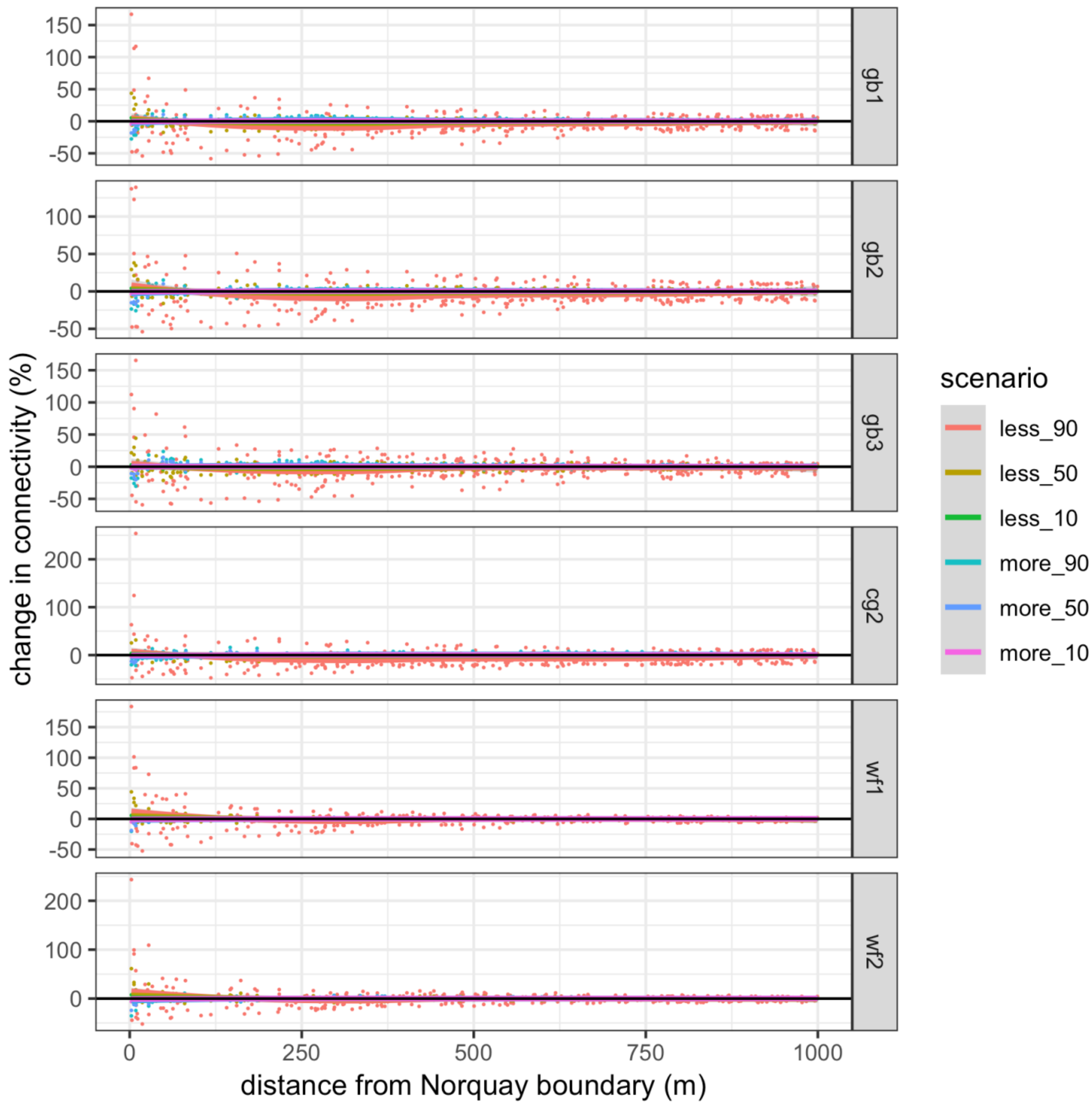


Figure 21: Plot of change in connectivity per distance from the treatment area (Norquay Lease Site and Norquay Access Road) per impact treatment (gb1: grizzly bear season 1, gb2: grizzly bear season 2, gb3: grizzly bear season 3, wf1: wolf summer, wf2: wolf summer and cg2: cougar)

Adjustments within the area of interest however show impact treatment of 10%, 50% and 90% decrease in resistance result in improved connectivity, while negative impact conservation challenges result in small reductions in connectivity (Figure 22).

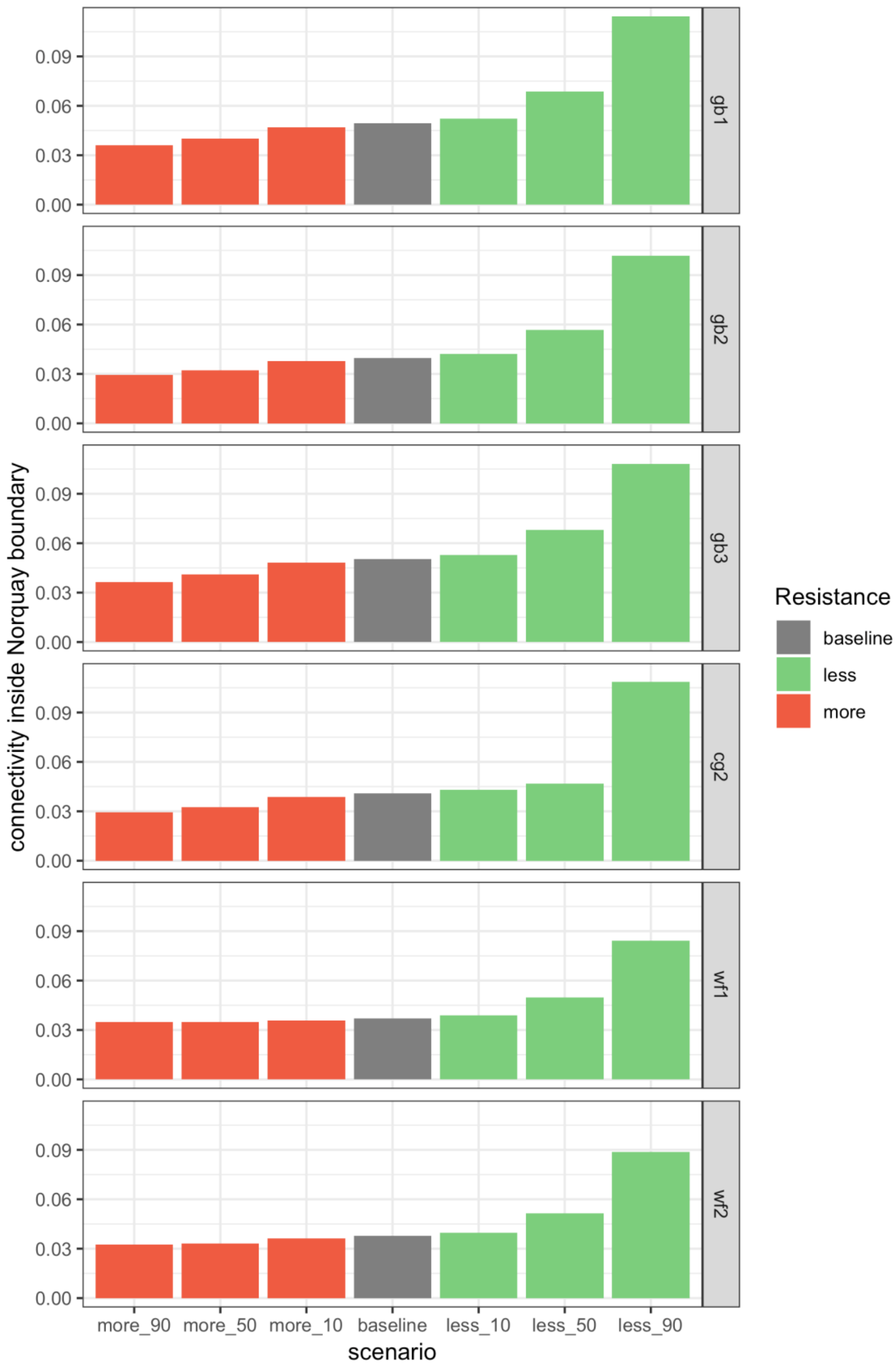


Figure 22: Changes in connectivity based on impact treatments (less resistance improves connectivity, while more resistance decreases connectivity, gb1: grizzly bear season 1, gb2: grizzly bear season 2, gb3: grizzly bear season 3, wf1: wolf summer, wf2: wolf summer and cg2: cougar in the winter)

Maps depicting results for both the area of interest and broader landscape from each species and season and impact treatments are included in Appendix 3. Figure 23 displays an example of the percent change in connectivity for two impact treatments (90%

improvement and 90% decrease in resistance values) for grizzly bears in season 3 and highlights there is almost no change in connectivity outside of the treatment footprint, both showing 0% change. For the impact treatment of 90% less resistance there is an opportunity to improve connectivity by 200-400% by reducing resistance within the Norquay Lease Site and on the access road. For the impact treatment of 90% more resistance there is a 20-40% reduction in connectivity within the Norquay Lease Site and access road.

For the impact treatment of 50% less resistance there is an opportunity to improve connectivity by 50-100% by reducing resistance within the Norquay Lease Site and on the access road. For the impact treatment of 50% more resistance there is 20-40% reduction in connectivity within the Norquay Lease Site and Norquay Access Road (Figure 23).

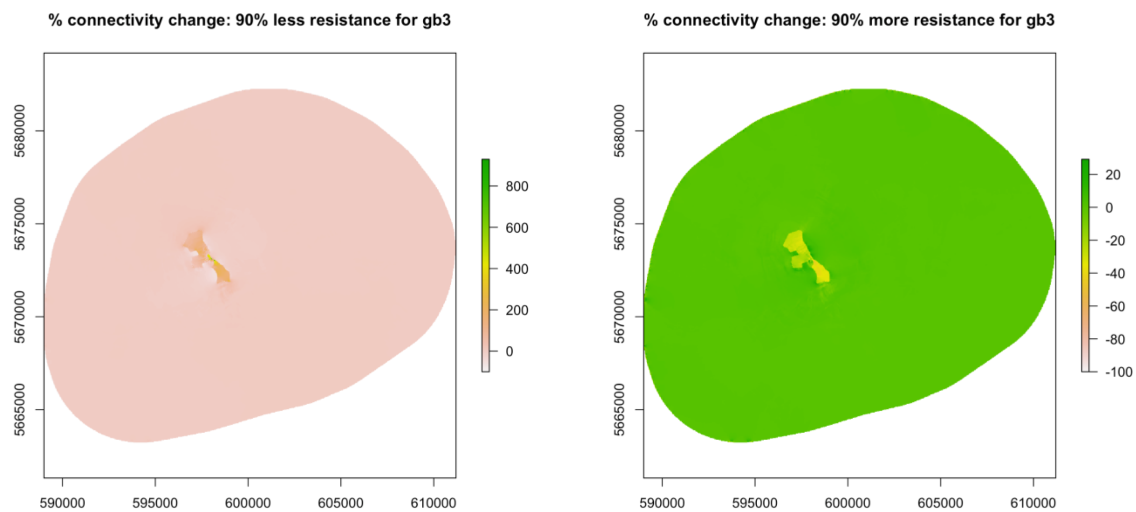


Figure 23: Change in connectivity value from 90% less and more resistance model treatments (gb3: grizzly bear season 3)

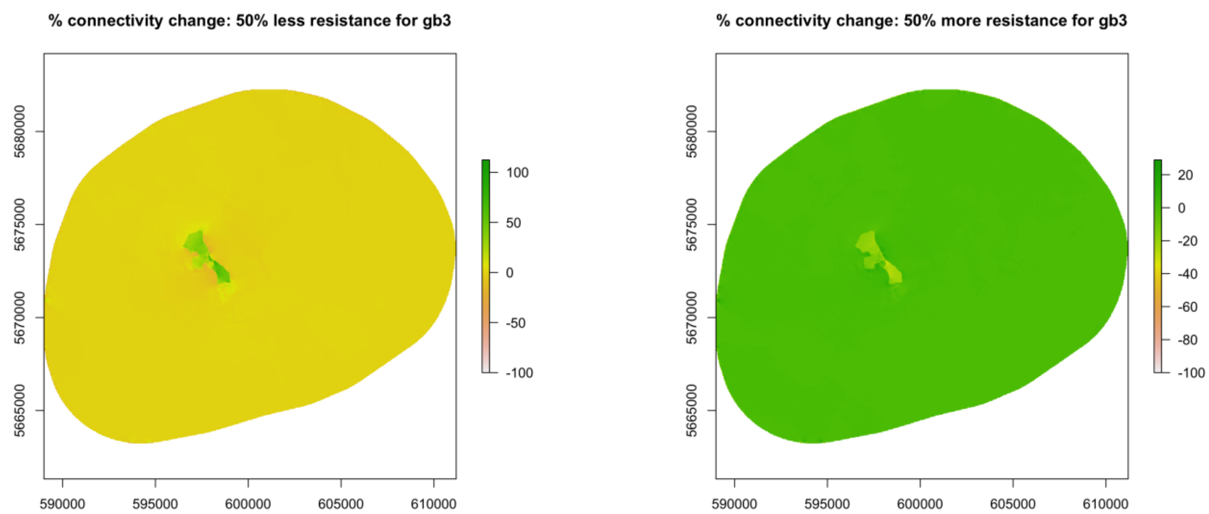


Figure 24: Change in connectivity value from 50% less and more resistance model treatments (gb3: grizzly bear season 3)

4.3 Analytical Hierarchy Process (AHP) for Carnivores

The Analytical Hierarchy Process (AHP) is a mathematical method for analyzing complex decisions using pairwise comparisons ratios. AHP enables experts to use multiple criteria to analyze complex problems. Through pairwise comparisons, it clarifies the advantages and disadvantages of management options under circumstances of risk and uncertainty.

AHP has been used in the field of natural resource management, for example Clevenger et al. (2002) used the AHP to create habitat selection maps for black bears in Banff National Park. Experts have used AHP to inform connectivity modeling, such as identifying landscape attributes that are barriers to movement or to estimate the cumulative resistance value that would result in a barrier to movement (Rabinowitz & Zeller, 2010). Alternatively, the process can be used to weigh different conservation actions to advance conservation based on multiple levels of criteria to help prioritize investments.

To understand the relative importance of different impacts and mitigations on conservation challenges 1 and 2, grizzly bear movement and habitat use and wolf and cougar movement, we applied an AHP. Using the AHP with biologists and conservation specialists, we assessed the relative importance of different impacts, sources of impacts and mitigations to improve carnivore connectivity and habitat based on the proposed Mount Norquay gondola development. RSF and connectivity modelling were used to inform the development of in the AHP structured hierarchy and ranking process.

Carnivore AHP Methods

To address the conservation challenge for grizzly bear, we developed a structural hierarchy of four levels with a goal of determining what mitigation options could best enhance wildlife connectivity, habitat use and reduce human-wildlife conflict for grizzly bears in our study area based on the proposed gondola development for Mount Norquay. The hierarchy was informed by the 1st expert workshop, empirical modeling results and a review by experts in a 2nd workshop.

In order to construct the hierarchy tree for grizzly bears, the problem was divided into different levels. The four-level hierarchy tree is shown in Figure 25. The first level defines the goal i.e., to determine best mitigation options for achieving an environmental gain (connectivity, habitat use and human wildlife conflict) of grizzly bears on Mount Norquay based on the proposed gondola development. The second level defines impacts that put stress on grizzly bears, and the third level defines sources of impact that cause the stresses on grizzly bears. The fourth level outlines a number of mitigation measures, outlined in Table 12, to achieve an environmental gain for grizzly bears in the area. The mitigations were identified at the 1st expert workshop, many of these are also outlined in the Norquay Ski Area Management Guidelines (Banff National Park, 2011).

Table 12: Mitigation recommendations from Mount Norquay Ski Area Management Guidelines

Treatments (workshop discussion)	Norquay Ski Area Management Guidelines (2011)	Scientific Support
Decommissioning of access road	Not specifically mentioned in Mount Norquay Ski Area Management Guidelines	o Decommissioning of roads creates habitat for black bears. Black bears had a significantly higher rate of detection on removed roads than open roads (increase to abundance of food, decreased line of sight). Bears detected during the day on decommissioned roads compared to open roads. Results suggest that while all types of road closure benefit sensitive wildlife, removal by recontour may be the most effective strategy for restoring habitat (Switalski, Broberg, & Holden, 2007).
Reduced use on Norquay Access Road(during Mount Norquay Ski Area Management Guidelines outlined temporal periods)	Reduction in the frequency and number of disturbances through the Cascade wildlife corridor by restricting traffic on the Norquay Access Road during night-time and crepuscular periods and reducing the existing overall frequency of disturbance during day light hours based on the baseline year of 2009. Specifically,	**(**Donelon, 2004)**:** o Found evidence that human use displaced grizzly bears during high human activity periods (i.e. roughly between 0600 hrs. and 2100 hrs., during the berry season) o There was also evidence of a threshold close to one human event per hour on roads and trails where grizzly bears used these areas less than expected o Human use in corridors should be managed to reduce disturbance during daylight hours, when bears may be more likely to be moving distances that would allow them to traverse the length of a wildlife corridor. (Percy, 2003)**:** o Results indicate that temporal closures of secondary roads, such as the BVP, will assist in restoring habitat effectiveness and connectivity for wolves, black bears and grizzly bears in the Bow River Valley. o Based on temporal road-crossing data collected during this study, I recommend that the BVP be closed to all forms of human travel between 17:00 and noon to allow bears and wolves to cross roads during daylight, crepuscular and night hours, without risk of disturbance by humans. A closure extending throughout the afternoon would benefit all three species. (Elmeligi, 2016)**:** o Found little difference in grizzly bear steps between day and night, but the threshold

	keeping vehicle disturbance events below wildlife disturbance thresholds levels (25 events per hour) prior to 9 am and after 6 pm from June to the end of August and prior to 9 am to 5 pm through September and October; and a 5% reduction in the vehicle disturbance events, averaged on a monthly basis, between 9 am and 6 pm (5 pm in September and October).	analysis did find bears were more likely to use trails before eight human events occurred that day. ○ Grizzly bears are capable of learning human use patterns and adjusting their behaviour accordingly, but this may not happen immediately. Therefore, actions such as implementing trail opening times should be monitored over several years before their effectiveness is determined. (Cuthbert, 2006) ○ Grizzly bears come to use habitat near roads when traffic is consistent and predictable. The potential influences of Whitehorn Road to grizzly bear and other wildlife movements along the Whitehorn Corridor could be reduced by gating the road during the HI period (6pm – 7am) to limit the temporal human activity on this road.
Decommission and Restoration of parking lots and Norquay Lease Site decommissioning		
Restrict use on ski slopes during summer months	Restrict hiking and other activities between tea house/top terminal	○ In LL Grizzly bears strongly select for the south facing, early seral forest stage vegetation provided by the maintained ski runs on the front side of the ski hill during the summer (Mueller, 2001). ○ Jalkotzy, Riddell, & Wierzchowski (1999**)** found that bears at LL tended to be closer to

	(base of cliffs across the upper slopes)	the ski runs than the gondola base and that the front side of the ski hill was more heavily used at night than during the day o On the Lake Louise ski hill, distribution of bear occurrence was less than expected between 6:00am and 9:00pm due to human activity. During darkness, bear use on ski hill is up to 176% higher than expected, while during daylight when visitors are present it is up to 86% below expected levels of use (Donelon, 2004). o LL summer use program will be moved from mid-mountain to top of the gondola to focus human activity out of prime GB habitat on ski slopes (Banff National Park, 2015a). o Grizzly bears in BNP are found at lower elevations and use high quality habitat close to human activities greater than random, particularly during the HI period (Cuthbert, 2006). This indicates that accessing high quality habitat is a strong attractant that can prevail over wariness of humans. o Temporal regulation of human activities at LLMR provides consistent and predictable human behaviour, which may allow grizzly bears on the leasehold to adapt to human use and adjust their patterns of movement and habitat access around periods of high human activity (Cuthbert, 2006). Need to ensure that human activities within grizzly bear habitat remain spatially and temporally consistent and predictable to allow grizzly bears to access critical habitat areas. o Electric fencing has been successful in reducing the potential for habituation of grizzly bears around the lodge (LL) and reducing random human activity within the wildlife corridor, which has led to increased habitat security and reduced potential for human-bear interactions (Jalkotzy, 2001)
Habitat enhancement: vegetation management	Prepare a run improvement and vegetation management strategy as part of a long-range plan for any proposed run	o Trail density should be minimized where possible to allow bears the opportunity to access habitats at greater distances from trails. Closure of trails and facilities, associated with high Sheperdia production, to human use during the berry season should be considered where possible. Removal of Sheperdia should be done in conjunction with the enhancement of Sheperdia in areas of low human use, to ensure that females and sub-adult bears are not negatively impacted by the loss of important habitat. (Donelon, 2004) o If human activity levels of < one human event per hour during the berry season is

	widening, new runs or glading.	not possible then enhancement of Sheperdia production to provide alternatives for bears should be considered in areas of low human use. (Donelon, 2004)
Restrict use to alpine via boardwalk system and fencing	Not specifically mentioned in Mount Norquay Ski Area Management Guidelines	○ While ewes are lactating they are particularly sensitive to human disturbance as they move frequently in search of high quality forage (Wagner & Peek, 1999) ○ Ewes abandoned sites where a recreational trail ran through known lambing sites and human activities were erratic and unpredictable. Other known lambing sites greater than 500m from human activity were unaffected and continued to use known lambing site and successfully produce young (Wiedmann & Bleich, 2014).
Corridor management: physical alterations	Improve movement opportunities through Cascade Wildlife Corridors via physical alterations or building trails – construction of one or more additional wildlife trails across Stoney Squaw.	○ Wolf use of corridor increased when physical impediments (fence) were removed. (Shepherd & Whittington, 2006). ○ Wolves avoid areas with greater than ○ 98% of grizzly bear GPS locations (14,500 observations) were located on slopes <40 degrees (Lee 2018). ○ Wide-ranging animals quickly learn how human activity changes within their home range, and that for these target species corridor restoration can improve habitat quality and reduce habitat fragmentation (Shepherd & Whittington, 2006).

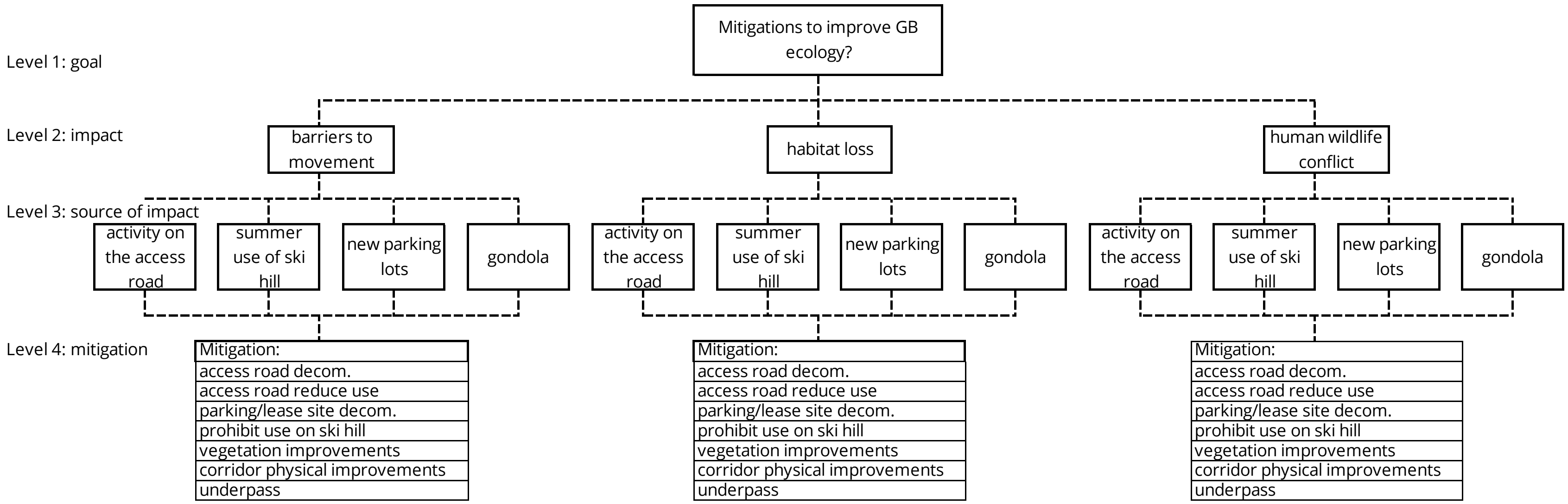


Figure 25: Structural hierarchy for grizzly bear AHP

To address the conservation challenge for wolf and cougar, we developed a structural hierarchy of three levels with a goal of determining what mitigation options could best enhance wildlife connectivity for wolves and cougars in our study area based on the proposed gondola development for Mount Norquay. The hierarchy was informed by the 1st expert workshop, empirical modeling results and a review by experts in a 2nd workshop.

The three-level hierarchy tree for wolf and cougar is shown in Figure 26. The first level defines the goal, i.e. to determine best mitigation options for improving connectivity for wolf and cougar based on the gondola development proposal. The second level defines sources of impact that cause the stresses on wolf and cougar movement. The third level outlines a number of mitigation measures to improve wolf and cougar movement in the area.

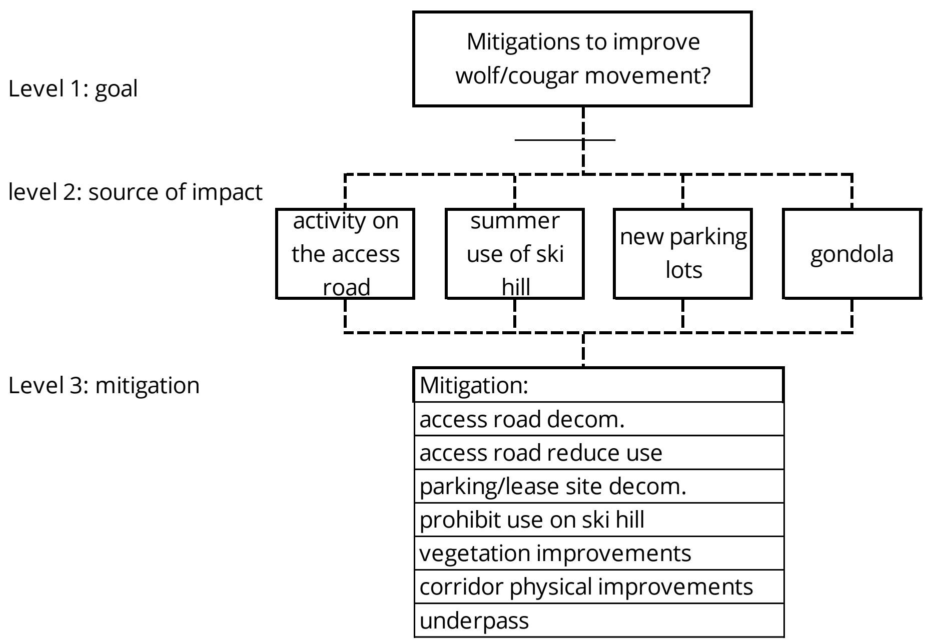


Figure 26: Structural hierarchy for wolf and cougar

For both the grizzly bear and the wolf/cougar AHP, a pairwise comparison was undertaken between criteria on each level and then for each sub-criterion in relation to each criterion outlined in the previous level. By weighting the relative importance of the impacts, sources of impacts and mitigation against each other and summing a weighted average of mitigation scores, we identify the most effective options for achieving an environmental gain for grizzly bear and wolf/cougar. To develop the weights a group of subject matter experts compared every possible pairing and entered a Saaty rating into a pairwise comparison matrix (Figure 27). For example, experts were asked if grizzly bear movement is more or less important than human-wildlife conflict followed by providing a rating of how much more or less important. For example, a rating of 1/9 means grizzly bear movement is extremely less important than human-wildlife conflict, and 9 means grizzly bear movement is extremely more important than human-wildlife conflict.

1/9	1/7	1/5	1/3	**1**	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very strongly	Extremely

LESS IMPORTANT **MORE IMPORTANT**

Figure 27: Pairwise comparison matrix

We used the AHP software online output (http://panel.onlineoutput.com/) to run pairwise comparisons and to generate weighted average of mitigation alternatives. The grizzly bear AHP was scored by a number of experts at a workshop, where each participant provided a score and if there was disagreement the group discussed the pairwise comparison until a consensus was reached. The wolf AHP was scored by experts independently, added to the online software where average between experts was calculated.

The AHP process produces an index of consistency to address discrepancy between experts or in scores entered by experts. If consistency score for each matrix table was below 0.1, then the responses among experts were deemed consistent; whereas, if they were above 0.1, then re-assessment took place to reduce variability. After a secondary review and adjustments, we accepted scores of 0.16. All consistency ratings for grizzly bear were under the 0.1 score while wolf had two matrix tables greater than 0.1 but below 0.16 (Saaty, 1977).

Carnivore AHP Results

WEIGHTS FOR GRIZZLY BEAR AHP

Experts prioritized the impacts (level 2) to grizzly bear with human-wildlife conflict (0.652), habitat loss (0.277) and barriers to movement (0.07) indicating experts are most concerned about increases in human and wildlife conflict, followed by habitat loss with minor concern of barriers to movement from the gondola development proposal. All levels scores will weight to 1.

Within human-wildlife conflict, the priority sources of impact (level 3) were summer use on the Norquay Ski Hill (0.582), followed by activity on the Norquay Access Road (0.311), with equal and less concern in regard to the new parking lots (0.038) and gondola (0.038). Within habitat loss, the priority sources of impact were summer use on the Norquay Skill Hill (0.702), followed by activity on the Norquay Access Road (0.173), with less concern in regard to gondola (0.06) and new parking lots (0.055). Lastly, within barriers to movement impact, the priority source impact was activity on the Norquay Access Road (0.616), summer use on the Norquay Ski Hill (0.241), gondola (0.104) and new parking lots (0.038).

A summed weighted average was calculated for mitigations based on scores generated from each source of impact and pairwise ratios between mitigations. Figure 28 indicates that the priority mitigation for achieving an environmental gain for grizzly bear in the area is to restrict use on the Norquay Ski Hill in the summer, followed by some type of treatment to the access road. Decommissioning of the Norquay Access Road was more significant in terms of impact, but temporal closure to recreation and vehicles also rated highly as a mitigation priority.

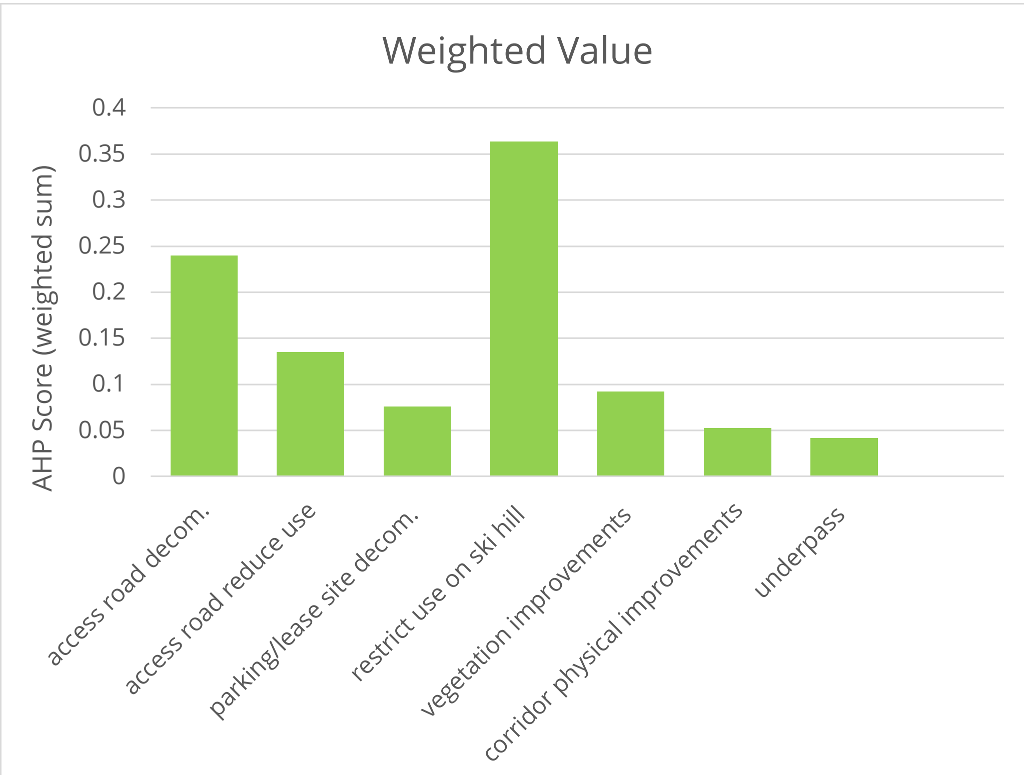


Figure 28: AHP mitigation priorities for grizzly bear

WEIGHTS FOR WOLF/COUGAR AHP

Experts prioritized the sources of impact to wolf and cougar movement as activity on the Norquay Access Road (0.644), summer use of the Norquay Ski Hill (0.190), new parking lots (0.107) and gondola (0.059), indicating experts are most concerned about activity on access road, followed by summer use of Norquay Ski Hill with minor concerns in regard to the new parking lots and gondola in terms of the gondola development proposal impact on wolf and cougar.

A summed weighted average was calculated for mitigation options for wolf and cougar based on scores generated from each source of impact and pairwise ratios between mitigations. Figure 29 indicates that the priority mitigation for improving wolf and cougar movement in the area is to implement some type of treatment to the access road.

Decommissioning of the Norquay Access Road was more significant in terms of impact, but temporal closure to recreation and vehicles also rated highly as a mitigation priority. In addition, consideration of physical corridor improvements, an additional underpass at the base of the Norquay Access Road and Trans-Canada Highway and restricting summer use of the ski slopes also will contribute to improved wolf and cougar connectivity.

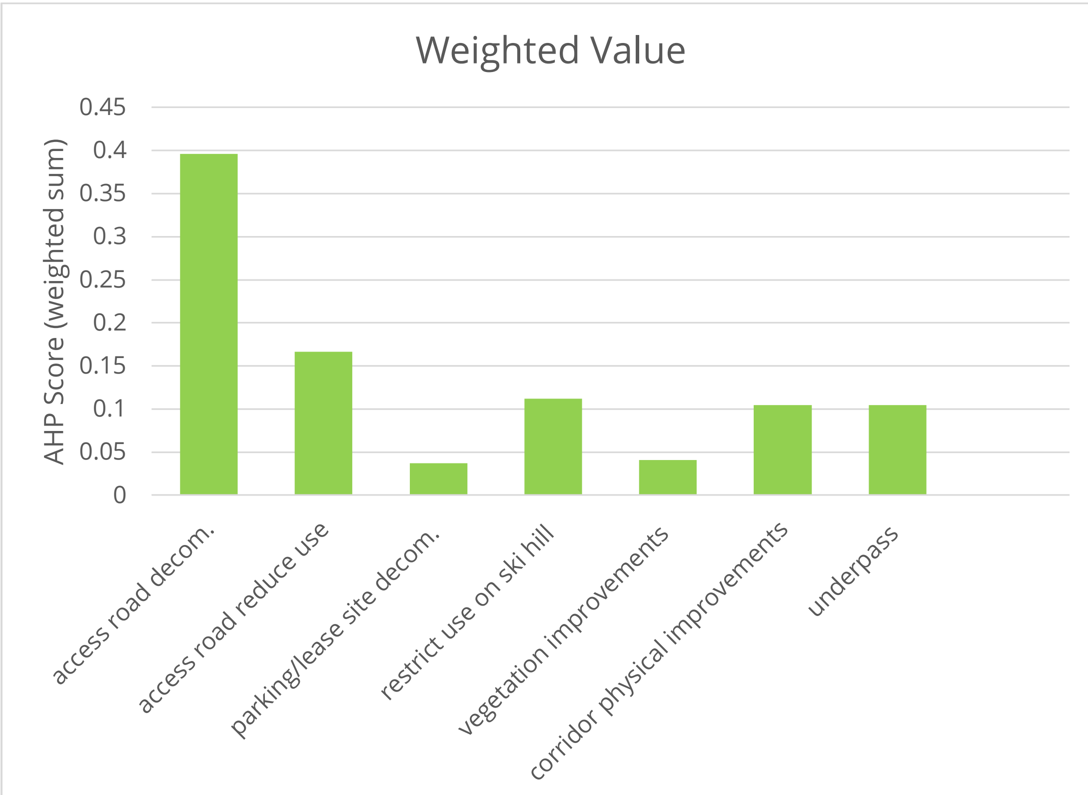


Figure 29: AHP mitigation priorities for wolf and cougar

5.0 Bighorn Sheep (Conservation Challenge 3)

Workshop 1 participants expressed concern about human activity associated with the gondola terminus and boardwalk occurring in the alpine region of Mount Norquay and possible impact to bighorn sheep lambing. There is very little documentation on lambing sites in Banff National Park (Skjonsberg, 1993). Therefore, to address this concern we modeled "potential bighorn sheep lambing habitat" based on important habitat features outlined in the literature and refined the model using existing known bighorn sheep lambing sites in the Kananaskis Mount Allan region. Possible impact was measured by comparing potential lambing habitat within a 150m and 500m zone of influence around the gondola and boardwalk in the alpine region of Mount Norquay.

Although very little known about lambing site locations in Banff National Park, Skjonsberg (1993) noted lambing historically occurred on the North side of Mount Norquay . Bighorn sheep show a high level of site fidelity with Geist (1971) reporting ewes returning to the same range 90% of the time. Therefore, maintaining the integrity of lambing sites is important to the persistence of bighorn sheep populations (Beecham, Collins, & Reynolds, 2007). In addition, Norquay staff noted bighorn sheep ewes with lambs during annual monitoring on the Norquay Via Ferrata.

A literature search identified three important habitat features in lambing site selection, southerly facing scree slopes where steep rugged terrain is interspersed by rock cliffs (Demarchi, 2004). Although forage should be closely accessible, lambing site selection is driven by protection for predators more so than forage habitat.

Typically, lambing occurs from May to June or, infrequently, at the beginning of July each year (Demarchi, 2004). A home range for sheep usually includes part of a mountain, or a whole mountain. The size of lambing areas ranged from 0.03 to 1.5 km^2 in Idaho while ewes and lambs in Montana used from 6.4 to 32.9 km^2 (Demarchi, 2004).

An important consideration is human activity and influence on potential lambing sites. While ewes are lactating they are particularly sensitive to human disturbance as they move frequently in search of high quality forage (Wagner & Peek, 1999). A study in North Dakota from 2001 to 2012 investigated the impacts of recreational activity on lambing sites, and found that ewes abandoned a lambing site where a recreational trail ran through a known lambing site and human activities were erratic and unpredictable. Five other known lambing sites greater than 500 m from human activity were unaffected (Wiedmann & Bleich, 2014).

Sheep are generally not susceptible to human activity as they easily habituate. MacArthur, Geist, & Johnston (1982) undertook a number of studies to determine the influence of human activity on bighorn sheep (not specifically ewes during lambing) by studying a heart rate response (indicating stress), and determined the following zone of influence:

- 0-50 m (human activity elicited ewe heart rate response once within 50 m);
- 50-100 m (ewes were more sensitive if the human came from above (45.9+/-11.67 m); and
- 100-150 m (humans rarely produced significant heart rate increases when more than 150 m from sheep).

Sheep were more sensitive to humans than they were to dogs, increasing heart response rate at distances 65.2+/-18.14 m or 118+/-38 m (MacArthur et al., 1982).

5.1 Bighorn Sheep Modeling Methods

To derive potential lambing habitat on Mount Norquay we considered three key habitat layers:

- Steep slopes, defined as areas >40° and <85° (Allen, Parrott, & Kyle, 2016; Demarchi, 2004);
- Surface roughness (>11.5);
- Aspect south, southwest and southeast (Demarchi, 2004); and
- Scree slopes (Demarchi, 2004).

The slopes and aspect were derived from a digital elevation model (18m resolution) and the scree slopes were derived from Vegetation Resource Index (2014 dataset, 1:20,000 scale) using the talus slopes code. Only larger talus slopes will be identified using this method, an important limitation of this analysis. Surface roughness was derived as a standard deviation of elevation.

We compared our model to known sites at Kananaskis Mount Allan and refined the model based on this comparison. For example, we used surface roughness greater than 11.5 over slope to identify escape terrain, and all southern aspects were considered, including southeast, south and southwest aspects as these overlapped well with all four lambing sites. We were not able to include scree slopes due to lack of information in our model validation. It is important to note that the model also showed other areas nearby with potential but where no lambing has been known to occur. It is therefore challenging to predict accurately where bighorn sheep will lamb within potential habitats identified. The model was further refined on Mount Allan region when forage was within 300m from a lambing site.

Since the limiting factor is protection from predators, high surface roughness was characterized as the most important variable, followed by both aspect and scree slopes. Zones of human influence, 150m and 500m were applied around the gondola line from the Bistro to the gondola terminus, and the boardwalk.

Lastly, although protection from predators is considered the driving factor for selection of lambing sites, proximity to forage is important. We therefore identified forage areas within 300m of escape terrain (defined as slopes between 40-85%) (Allen et al., 2016; Demarchi, 2004; Smith, Flinders, & Winn, 2014) as most likely to be used during lambing. Forage was identified using the vegetation resource index (VRI) land cover classes of herbaceous graminoids, herb, herb forage and low shrubs, and treed areas with less than 40% cover.

5.2 Bighorn Sheep Modeling Results

Figure 30 identifies surface roughness appropriate for lambing where overlap occurs with either one of aspect or talus slopes (light blue) as well as where all three variables overlap (dark blue).

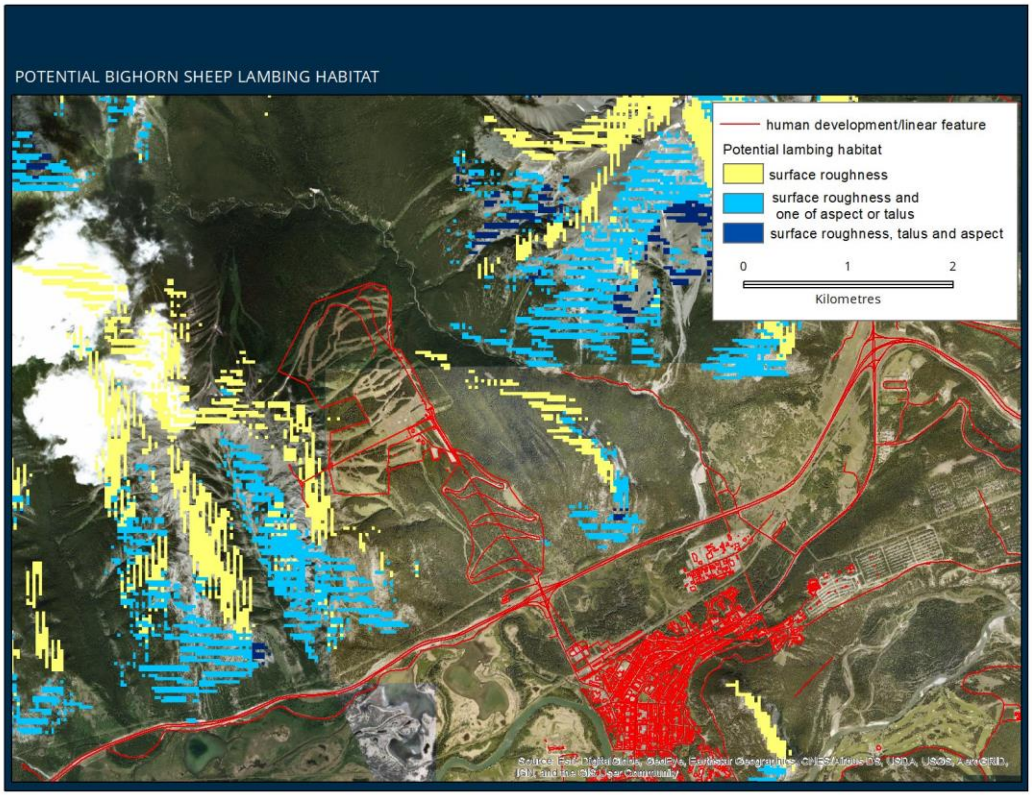


Figure 30: Potential bighorn sheep lambing habitat

There were no locations on Mount Norquay with an overlap of all three variables but a number of sites meet two of the habitat considerations. The areas on Mount Norquay (north slopes of Mount Norquay) where bighorn sheep lambing had been identified historically has talus slopes (used to represent scree) and steep terrain but these variables do not overlap and it is not on south and southwesterly aspects. This result highlights limitations of the scree dataset which only documents large areas. We therefore considered areas as “potential lambing habitat” where there were appropriate surface roughness and one of aspect or talus habitat features overlapped. A zone of human influence of 500m was applied around the gondola line from the Bistro to the gondola terminus, and including the boardwalk (Figure 31). To consider access to forage during lambing, forage within 300m of escape terrain was considered (Figure 32).

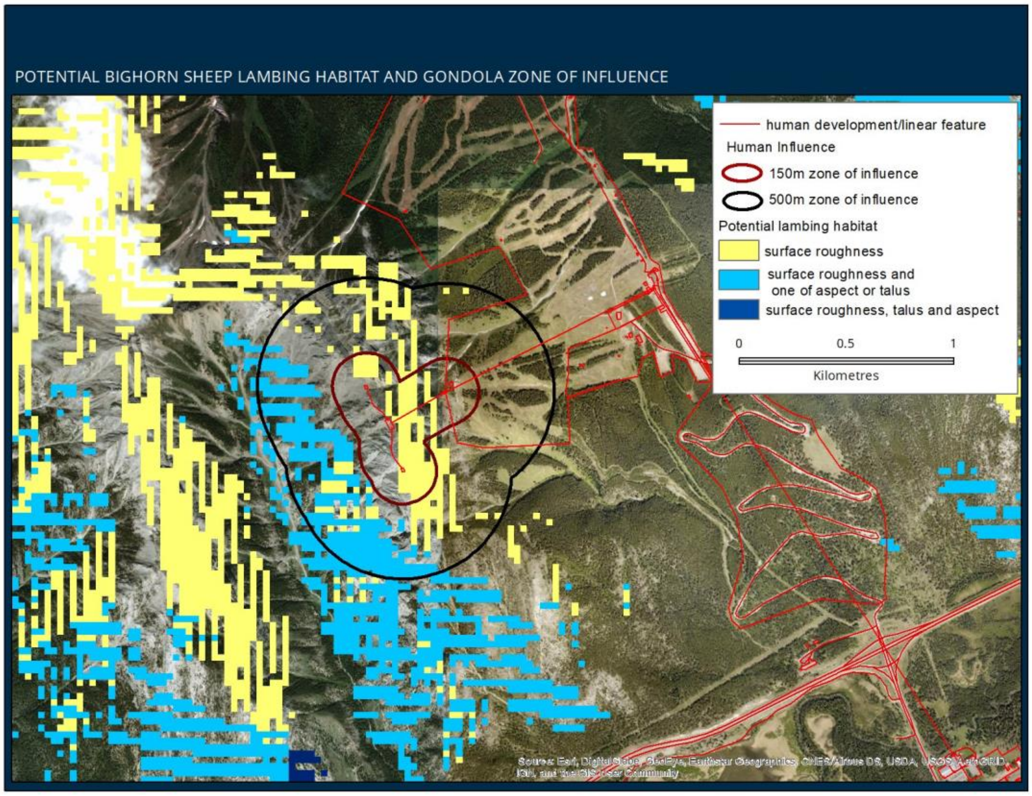


Figure 31: Zone of human influence on potential lambing habitat

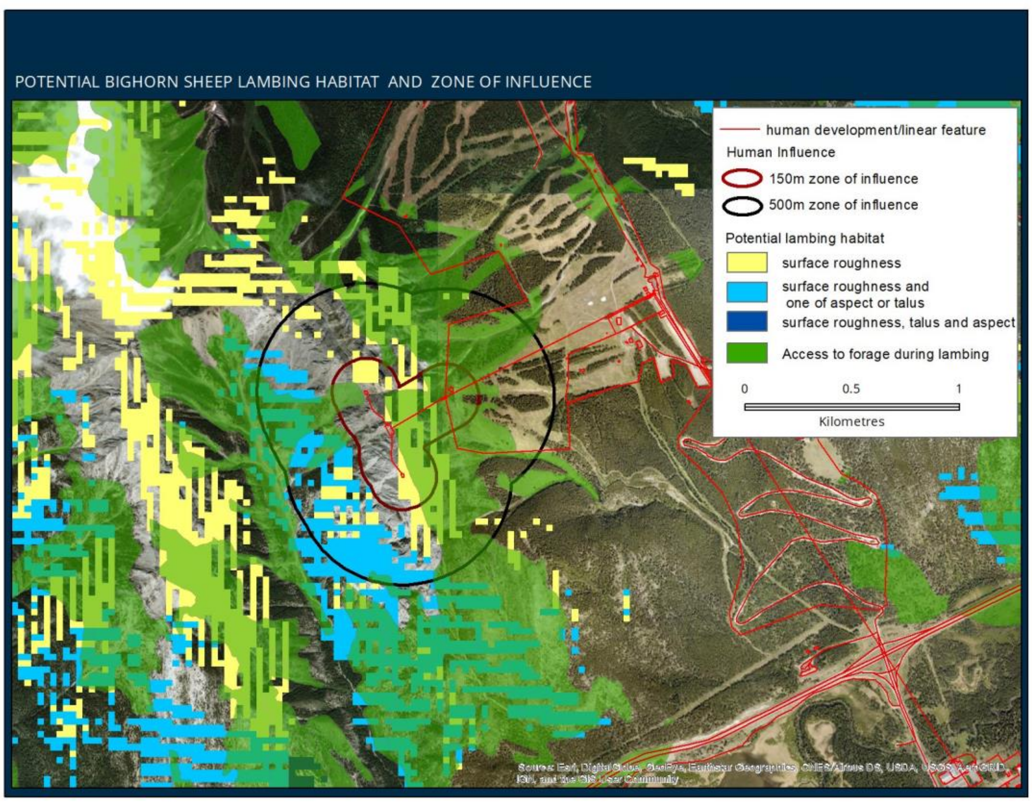


Figure 32: Forage within 300m of escape terrain

Limitations

This analysis is based on identification of "potential" lambing habitat because lambing locations in the Park are not well documented (Skjonsberg, 1993). In addition, the habitat features generated to identify potential lambing habitat were based on bighorn sheep populations occurring in other regions (British Columbia, Idaho, and North Dakota). We do not know if lambing actually occurs on Mount Norquay or if the North side of Mount Norquay is still an active lambing site.

To identify potential lambing habitat, we used habitat variables to approximate opportunity areas for lambing, while other studies have used telemetry/GPS data and location of ewes from May to July to identify lambing sites. There is no empirical data on bighorn sheep for this area of Banff National Park. Lambing habitat features were derived from the literature, again based on other regions. The resolution of the data likely limits our ability to pick up smaller areas of scree, and thus we are not confident in our ability to map this variable, reducing our ability to accurately identify potential lambing areas.

Movement to and from lambing areas is an important consideration which our assessment did not include.

6.0 Discussion

We considered three ecological conservation challenges to determine if the gondola development proposal has the potential for achieving an environmental gain to wildlife movement and habitat on Mount Norquay. The Mount Norquay Ski Area Management Guidelines define an environmental gain "as a positive change in key ecological conditions (wildlife movement and habitat, wildlife mortality, sensitive species/areas and aquatic ecosystems) that leads to the restoration or the long-term certainty of maintaining ecological integrity." An ecological gain is considered against the criteria of:

- ➢ magnitude (major as opposed to minor);
- ➢ geographic context (broad scale as opposed to localized scale); and
- ➢ ecological context (improved protection or positive impacts to high value, rare or sensitive species/ or multiple species (Banff National Park, 2015b).

The criteria outlined for demonstrating an environmental gain are challenging to interpret, even more so is the use of the term substantial environmental gain which is subjective in nature. In past decisions Parks Canada has deemed the following actions as to be a substantial environmental gain:

- ➢ Reconfigurations of the Norquay leasehold in 2011; a proportion of the Norquay Lease Site was given up in exchange for development of summer uses (Banff National Park 2011). The total lease reduction was 44% of the leasehold of which 19% was directly related to providing better protection for wildlife. The substantial environmental gain was predicated on additional management guidelines and mitigations including public transportation to minimize vehicle traffic on the Norquay Access Road during summer, temporal restrictions on human use and the use of fencing to separate human use from areas critical for wildlife.

- In 2008 Marmot Basin in Jasper National Park proposed a leasehold reconfiguration representing an 18% reduction in leasehold which was considered as a major reduction in size, that established long-term certainty and improved protection for caribou and hence contributed to a substantial environmental gain (Office of the Auditor General of Canada 2008).

For this analysis we focused on understanding if there is an environmental gain for large mammal species based on the gondola development proposal.

The expert workshop identified three conservation challenges to consider in terms of impacts of the gondola development proposal:

- Conservation challenge 1: grizzly bear habitat and movement
- Conservation challenge 2: wolf and cougar movement
- Conservation challenge 3: bighorn sheep lambing habitat

Here we discuss the results from each conservation challenge in terms of potential impact or ability of the proposed gondola to provide opportunity for an environmental gain.

6.1 Conservation Challenge 1: Grizzly Bear Habitat and Movement

Grizzly bears are an at-risk species in Alberta (Alberta Environment and Parks, 2017) and listed federally as a species of special concern (Government of Canada, 2011) and therefore represent a species of concern ecologically for Banff National Park.

Resource selection function (RSF) models were developed for grizzly bears for three seasons (representing spring, summer and fall feeding periods). All three seasons highlight the importance of the Norquay Lease Site and Norquay Access Road as habitat for grizzly bears. We did not assess the significance of this habitat in terms of population viability for grizzly bears in the Canadian Rocky Mountains, but the Norquay Lease Site itself (1.8 km^2) represents a small portion of a female grizzly bear home range which is on average around 520 km^2 (Stevens & Gibeau, 2005). However, the Norquay Lease Site and Access Road plays an important role at a localized geographic scale for grizzly bear habitat in the Bow Valley, a landscape dominated by human activity and limited habitat for grizzly bears. In addition, the proposed area (representing 0.134 km^2) is shown on the RSF to be of high value for grizzly bears.

Connectivity modeling shows the importance of the Cascade Wildlife Corridor (i.e. includes a portion of the Norquay Access Road near the Trans-Canada Highway) for east/west movement of grizzly bears. Specifically, movement parallel to the Trans-Canada Highway is most important for grizzly bears in the early spring (season 1). In the summer (season 2) and fall (season 3), the highest connectivity values occurred in the Fenland Indian Grounds Corridor and the Cascade Wildlife Corridor. However, recognizing the Fenland Indian Grounds corridor is located directly adjacent to the Town of Banff, and has high levels of human use, this movement may increase risk of human-wildlife conflict. Therefore, improving movement opportunities for grizzly bear through the Cascade Wildlife Corridor could result in an environmental gain to a sensitive species.

North/south grizzly bear connectivity occurs through the Norquay Lease Site and Norquay Access Road; modeling results indicate that bears use this route more than Forty Mile Creek for accessing lower elevation valleys to the north of Mount Norquay. This result demonstrated the importance of maintaining localized movement opportunities through the Norquay Lease Site and Access Road.

To determine the role of the Norquay Lease Site and Access Road (impact area) in providing grizzly bear connectivity, we developed six model treatments by increasing and decreasing model resistance values by 10%, 50% and 90%. The treatment results indicate improving connectivity on the Norquay Lease Site and Access Road (impact area) had a negligible impact for grizzly bear movement around the study area (10 km radius from Norquay). This implies that the Norquay Lease Site and a portion of the Norquay Access Road (impact area) does not play a significant role in broader landscape movement around the Bow Valley.

Although the Cascade Wildlife Corridor and Fenland Indian Grounds Corridor had high connectivity value, these areas were 1) trivially affected by changes in connectivity at the Norquay Lease Site and Access Road; 2) not included in the model treatments, which were applied solely to the Norquay Lease Site and Norquay Access Road impact area. While the Norquay Lease Site does not appear to play a significant role for grizzly bear movement, a portion of the Norquay Access Road (near the Trans-Canada Highway that is not included in the Norquay Access Road impact area) and the Fenland Indian Grounds Corridor are important for grizzly bear movement. Improving connectivity in the confined Bow Valley could be considered an environmental gain of broad geographic benefit.

The model treatments demonstrate that there is limited opportunity for changing connectivity, either positively or negatively, within the Norquay Lease Site and Access Road unless improvements approaching 50% can be achieved. Connectivity improvements on the Norquay Lease Site and Access Road impact area could provide additional localized movement opportunity for grizzly bears.

A key consideration in determining if the gondola development proposal has the potential to provide an environmental gain for grizzly bears is the effectiveness of mitigations identified at the expert workshop and outlined in the Mount Norquay Ski Area Management Guidelines. From a management perspective, it is important to provide insight into the best ways to achieve an environmental gain as costs, and social license may limit implementation of the full suite of mitigations. In addition, while the model treatments demonstrated some benefit to connectivity could be achieved within the Norquay Lease Site and Access Road impact area, the analysis did not determine which of the proposed mitigations would achieve a >50% improvement in connectivity. We therefore assessed the gondola development proposal and associated mitigations outlined in the Norquay Site Management Guidelines using expert opinion and an AHP process.

For grizzly bears the highest ranking impact related to the gondola development proposal was human-wildlife conflict associated with projected increases in human activity on the Norquay Ski Hill in the summer and, to a lesser extent, to activity on the Norquay Access Road. Although human-wildlife conflict is not currently an issue on the Norquay Ski Hill (based on human conflict data from Parks), increasing human activity increases the risk of bears interacting with people. Mitigations that reduce interaction of humans with grizzly bears are important for consideration. Currently, grizzly bears are using the Norquay Ski Hill, but an increase in human activity could result in avoidance behavior, reducing localized habitat use. Mitigations that align with these results have also been recommended at Lake Louise Lease Site to minimize interactions between visitors, staff, and bears during the summer. These include using exclusion fencing to restricting human use in certain areas and relocating summer sightseeing and hiking to upper elevations away from prime mid-summer grizzly bear habitat (Banff National Park, 2015b). There were also minor concerns related to the new parking lots and gondola, although any increase in human-wildlife conflict with grizzly bears should be addressed.

The second ranked impact was habitat loss caused primarily by summer use of the Norquay Ski Hill and activity on the Norquay Access Road. Ranked last, barriers to movement were considered to be impacted primarily by activity on the Norquay Access Road and summer use of the Norquay Ski Hill.

Based on the AHP, a weighted summary of all mitigations indicates that the most important mitigation for achieving an environmental gain to grizzly bears is to restrict use of the Norquay Ski Hill in the summer followed decommissioning the Norquay Access Road as the preferred mitigation, but we also assessed temporal restrictions to both vehicle and recreational activity as an option.

Additional mitigations to enhance grizzly bear habitat use in order of importance from the AHP process included parking lot/Norquay Lease Site decommissioning, physical corridor improvements, and underpass and vegetation management.

While the assessment identified the mitigations that would address the concerns identified for grizzly bears, we do not outline the methods for accomplishing these mitigations. For example, restricting use of the Norquay Ski Hill in summer would require a combination of physical barriers, enforcement, and education. Reducing human use on the Norquay

Access Road could include decommissioning of the road, or temporal closure (seasonal or time of day) of the road to vehicles and recreational activity.

Conservation Opportunity 1: Grizzly Bear Habitat and Movement

The gondola development proposal has the potential for an environmental gain to grizzly bears through improved habitat use and movement opportunities if summer use on the Norquay Ski Hill is restricted and if the Norquay Access Road is decommissioned or human use (motor vehicles and recreational use) on the Norquay Access Road is restricted to the extent feasible for safety.

6.2 Conservation Challenge 2: Wolf and Cougar Movement

Resource selection function models were developed for wolf in summer and winter and cougar in the winter. For wolf, the RSF models indicate the Norquay Lease Site and most of the Norquay Access Road are not important habitat in either season for wolves, with the exception of the Norquay Access Road portion within the Cascade Wildlife Corridor (narrow band parallel to the Trans-Canada Highway) which is important for wolf in both seasons and cougar in winter. The Norquay Access Road area also represents important localized habitat for cougar in the winter. In addition, higher RSF values occur on the proposed give back area (0.134 km^2) on the Norquay Lease Site.

Connectivity modeling showed the broad importance of the Cascade Wildlife Corridor for east/west movement, specifically a narrow band parallel to the Trans-Canada Highway. North/south localized movement for wolves in both seasons is associated with Forty Mile Creek, while for cougars the Norquay Access Road and Norquay Lease Site connects north and south low elevation valleys.

To determine the role of the Norquay Lease Site in connectivity for wolves and cougars, we developed six model treatments by increasing and decreasing model resistance values by 10%, 50% and 90%. The treatment results indicate improving connectivity on the Norquay Lease Site and Norquay Access Road (impact area) did not show a strong impact for wolf and cougar movement around the broader landscape. This implies that the Norquay Lease Site does not play a significant role in broader landscape movement around the Bow Valley. However, an important consideration is east/west wolf and cougar movement in the Cascade Wildlife Corridor as highlighted in the connectivity modeling and was not included in the model treatments. Improving connectivity in the confined Bow Valley could be considered an ecological gain change of broad geographic benefit.

The model treatments demonstrate there is limited opportunity for change to connectivity for wolves or cougars in a positive or negative direction within the immediate Norquay Lease Site and Access Road unless improvements greater than 50% can be achieved. This could potentially provide additional localized movement options for wolves to access lower elevation valleys to the north in addition to the Forty Mile Creek.

A key consideration in determining if the gondola development proposal has the potential to improve wolf and cougar movement is the effectiveness of mitigations identified at the expert workshop and outlined in the Mount Norquay Ski Area Management Guidelines. From a management perspective it is important to provide insight into the best ways to achieve an environmental gain, as costs and social license may limit implementation of the full suite of mitigations. In addition, while the model treatments demonstrated some benefit to connectivity could be achieved within the Norquay Lease Site and Access Road, the analysis did not determine which of the proposed mitigations would achieve a greater than 50% improvement in connectivity. To address this, we assessed the gondola development proposal and associated mitigations outlined in the Mount Norquay Ski Area Management Guidelines using expert opinion and an AHP process.

For wolf and cougar the biggest concern related to the gondola development proposal is reduced movement opportunities in relation to increased use on the Norquay Access Road (vehicle and recreation), and to a lesser extent use on the Norquay Ski Hill in the summer, new parking lots and gondola itself.

A weighted summary of all mitigations indicates that the most important mitigation for achieving an environmental gain relating to wolf and cougar connectivity is to address human activity on the Norquay Access Road. The AHP indicates that decommissioning the Norquay Access Road is the superior mitigation, but we also assessed temporal restrictions to both vehicle and recreational activity as an option.

Additional mitigations important for improving connectivity that are outlined in the site guidelines include restricting human activity on the Norquay Ski Hill, physical corridor improvements and vegetation management.

Conservation Opportunity 2: Wolf and Cougar Movement

The gondola development proposal has the potential for an environmental gain to wolf and cougar movement opportunities in the Cascade Wildlife Corridor if the Norquay Access Road is decommissioned or human use (motor vehicles and recreational use) on the Norquay Access Road is restricted to the extent feasible for safety.

6.3 Conservation Challenge 3: Bighorn Sheep Lambing Habitat

Human activity associated with the gondola development proposal and boardwalk could have a negative ecological impact on bighorn sheep lambing if bighorn sheep are confirmed to lamb on Mount Norquay and specifically if lambing occurs within the 500 m zone of influence of the gondola and fenced boardwalk. Lambs and ewes have been reported within the Norquay Via Ferrata area during monitoring by Mount Norquay staff in 2015. There is also historical documentation of lambing occurring on Mount Norquay and our modeling of habitat features indicates there are conditions to support lambing on

Mount Norquay. Modeling indicates potential habitat does not occur within the 150 m buffer of the gondola and boardwalk but could occur within 500 m of the gondola and fenced boardwalk.

Norquay should therefore support the development of a multi-year systematic monitoring program to determine if, and where, on Mount Norquay bighorn sheep are lambing. The monitoring program should be developed by an independent biologist and could include a series of transects running perpendicular to the Trans-Canada Highway with monitoring for ewes and lambs via drones (pending Parks approval) or helicopters during lambing season (May-July).

If bighorn sheep lambing is found to be occurring anywhere on Mount Norquay, the proximity to the gondola terminus and fenced boardwalk is an important consideration. If lambing sites are found on Mount Norquay we recommend Norquay maintain the monitoring program until after construction of the gondola to enable assessment of the impacts of human activity on lambing and improve the ability of Parks Canada and Norquay to adaptively manage human activity on the boardwalk. For example, mitigations could include the need for temporal closures or reduced access to parts of the boardwalk to ensure access to lambing sites or forage.

Conservation Opportunity 3: Bighorn Sheep lambing habitat

The gondola development proposal has the potential to negatively impact bighorn sheep if lambing occurs on Mount Norquay within the 500 m zone of influence of the alpine development. There is a high probability that bighorn sheep lambing does occur on Mount Norquay due to past records and recent observations of lambs with ewes. A monitoring program is needed to assess potential impacts of gondola development and fenced boardwalk on bighorn sheep lambing.

7.0 Summary of Findings

We considered three conservation challenges to determine if the gondola development proposal could result in an environmental gain to mammals in Banff National Park:

- Grizzly bear habitat use and movement,
- Wolf and cougar movement, and
- Bighorn sheep potential lambing habitat.

The Site Management Guidelines define an environmental gain "as a positive change in key ecological conditions (wildlife movement and habitat, wildlife mortality, sensitive species/areas and aquatic ecosystems) that leads to the restoration or the long-term certainty of maintaining ecological integrity" (Banff National Park 2011).

Our modeling results indicate the gondola development proposal can provide environmental gains for:

- ***Grizzly bear and cougar habitat use on the Norquay Lease Site and Norquay Access Road***, if summer use on the Norquay Ski Hill is restricted and the Norquay Access Road is decommissioned or human activity (vehicles and recreation) is restricted temporally to the extent feasible for public safety;
- ***North/south connectivity for carnivore species,*** if greater than 50% improvement can be achieved though habitat enhancements. This would provide additional options for movement to northern portions of the park in conjunction with Forty Mile Creek; and
- ***Carnivore east/west connectivity in the Cascade Wildlife Corridor,*** if the Norquay Access Road is decommissioned or human activity (vehicle and recreation) is restricted temporally to the extent feasible for public safety.

Our modeling results suggest there is potential for negative ecological impacts from the gondola development proposal if bighorn sheep are lambing within close proximity to the gondola terminus and fenced boardwalk. The location of bighorn sheep lambing sites is currently unknown; however there is strong evidence that lambing does occur on Mount Norquay.

As to the importance of the nature of the environmental gains, our results indicate:

- The Norquay Lease Site does not play an important role in broader landscape connectivity around the Bow Valley.
- The Cascade Wildlife Corridor does play an important role in broader east/west regional landscape connectivity around the Bow Valley and includes a portion of the Norquay Access Road.
- Grizzly bear habitat use on the Norquay Lease Site is an important localized benefit (based on the Norquay Lease Site representing a fraction of a female grizzly bear home range).
- Improved north/south movement opportunities for cougar, wolf, and grizzly bear to access habitat north of Norquay is a potential localized benefit, however it requires habitat enhancements.
- There is more potential for the gondola development proposal to improve ecological conditions for carnivores than for the project to affect them negatively, i.e., the gondola development proposal represents a better opportunity for carnivores than no change.

Recognizing movement opportunities are limited throughout the Bow Valley any opportunities for an environmental gain for sensitive carnivore species should be considered.

Potential environmental gains from the gondola development proposal are dependent on implementation of mitigations outlined in the AHP results and/or Mount Norquay Ski Area Site Guidelines including:

- Addressing concerns related to human-wildlife conflict and habitat loss for grizzly bears by restricting human use on the Norquay Ski Hill and effective physical separation between visitors and bears and other sensitive wildlife; and
- Improving effectiveness of the Cascade and Forty Mile Wildlife Corridors by decommissioning the Norquay Access Road or reducing human use (vehicle and recreation) on the Norquay Access Road temporally, by minimizing the disturbance of wildlife during crepuscular (twilight) hours and by reducing traffic on the Norquay Access Road (keeping vehicle use below 25 events per hour prior to 9 am and after 6 pm from June through August).

Additional mitigations that support environmental gains include;

- Proposed return of Norquay Lease Site and restoration of parking lots to natural habitat representing a 10% return of high value habitat for grizzly bears and cougar;
- Vegetation management by thinning of forest to provide more desirable habitat for grizzly bears; and
- Physical alternations to improve wildlife movement in the Cascade Wildlife Corridor and/or the addition of a wildlife underpass that would open up movement at a current bottleneck between the Cascade Wildlife Corridor and the Fenland Indian Ground Corridor.

Lastly, we encountered limited information on how grizzly bears, cougars, wolves, sheep, and other species respond to the types of human activities and infrastructure that might occur on the Norquay Lease Site and Norquay Access Road. For example, it is not known the extent or time it may take for animals to habituate to summer gondola operations, or thresholds for bike traffic, or where sheep lambing habitat is located This information does not occur anywhere in the scientific literature, much less Banff National Park. While our analyses were infused with empirical data on regional animal movements, we are unable to precisely determine how animals would respond to changes in levels of human activity or infrastructure at the Norquay Lease Site and Access Road.

As changes occur to Mount Norquay and the greater area, it is vital that leaseholders, park managers, and the public have the best science available to make informed decisions. Evidence-based decision making will provide confidence and credibility to estimates of impacts and ensure mitigation measures are effectively designed to protect ecological values. Data are needed to create this evidence, which is why we recommend Norquay create a long-term multi-species, wildlife monitoring program that will provide evidence-based data to inform management an adaptively manage measures used to mitigate potential impacts on the Norquay Lease Site . This is an excellent opportunity to create a legacy project that will have a lasting and positive impact for wildlife conservation and management at Mount Norquay.

The lessons learned from the Mount Norquay project and resulting land management can help inform similar projects in mountain environments faced with resolving human-wildlife conservation conflicts. This approach will collect important baseline information on species occurrence, measure how wildlife respond to changes in human activity or infrastructure, create data-informed management actions to mitigate negative impacts, and measure the performance of measures implemented. A monitoring-based approach of this type is needed to be able to accurately assess how management actions change baseline conditions and ecological responses in the Mount Norquay Lease site and Banff National Park in general.

8.0 References

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Appendix 1: Expert Workshop

AGENDA

Mount Norquay Wildlife Modelling Workshop

November 2, 2018; 10:00am – 4:00pm
Cascade Lodge, Mount Norquay Ski Resort, Banff

Time	Activity
9:30 - 10:00	*Arrival & coffee*
10:00 - 10:15	Welcome
10:15 - 10:30	Project overview
10:30 - 10:40	Introductions
10:40 - 11:00	Overview of the day
11:00 - 11:30	**Session 1: Focal Species** Brainstorming session to identify species of concern for the modelling
11:30 - 12:15	**Session 2: Impacts of Concern** Brainstorming session to identify the impacts of concern on focal species
12:15 - 12:45	*Lunch Break*
12:45 - 1:30	**Session 3: Treatments / Mitigations** Brainstorming session to list of potential treatments mitigation to respond to concerns
1:30 - 1:45	**Session 4: Study Area** Brainstorming session to list factors to be used to determine modelling area (extent)
1:45 - 2:45	**Session 5: Conservation Challenge Exercise** Brainstorming exercise to identify potential Conservation challenge questions based on the generated information
2:45 - 3:00	*Coffee Break*
3:00 - 3:45	**Session 6: Conservation Challenge Prioritization** Prioritization exercise to come up with Conservation challenge question list for modelling
3:45 - 4:00	*Summary and closing*

Workshop Participants

Dr. Tony Clevenger	Consultant
Dr. Adam Ford	UBC_Okanagan Campus
John Paczkowski	Alberta Parks
Jesse Whittington	Parks Canada
Hillary Young	Y2Y
Peter Zimmerman	CPAWS
Ed Whittingham	Consultant
Jon Jorgensen	Independent
Tracy Lee	Miistakis Institute
Danah Duke	Miistakis Institute
Guy Greenaway	Miistakis Institute
Andre Quenneville	Mount Norquay
Adam Waterous	Mount Norquay
Jan Waterous	Mount Norquay

Appendix 2: Kfold plots for RSF models

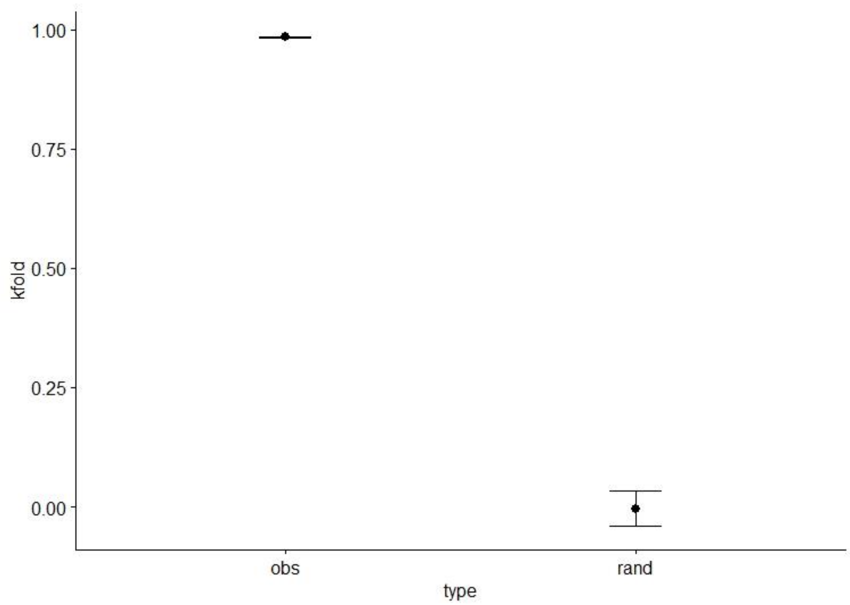


Figure 33: Grizzly bear season 1 Kfold plot

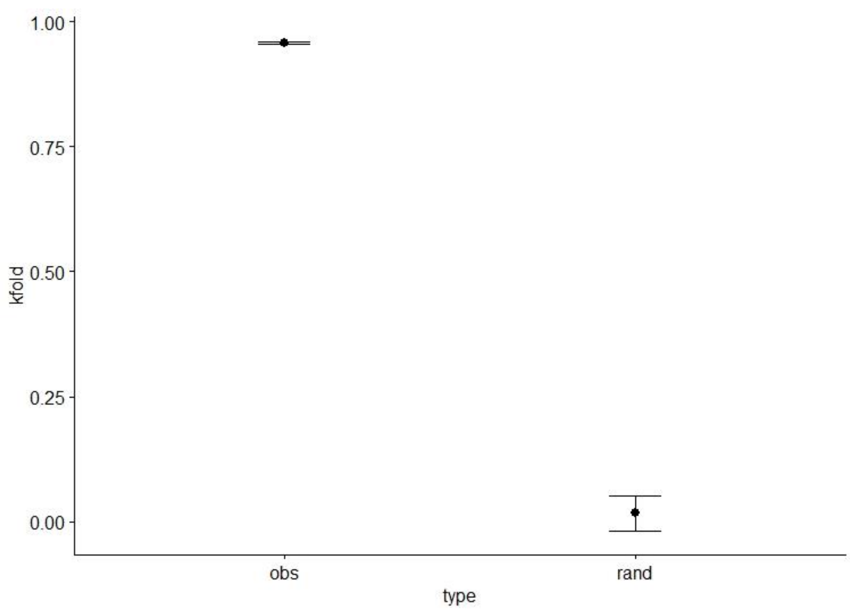


Figure 34: Grizzly bear season 2 Kfold plot

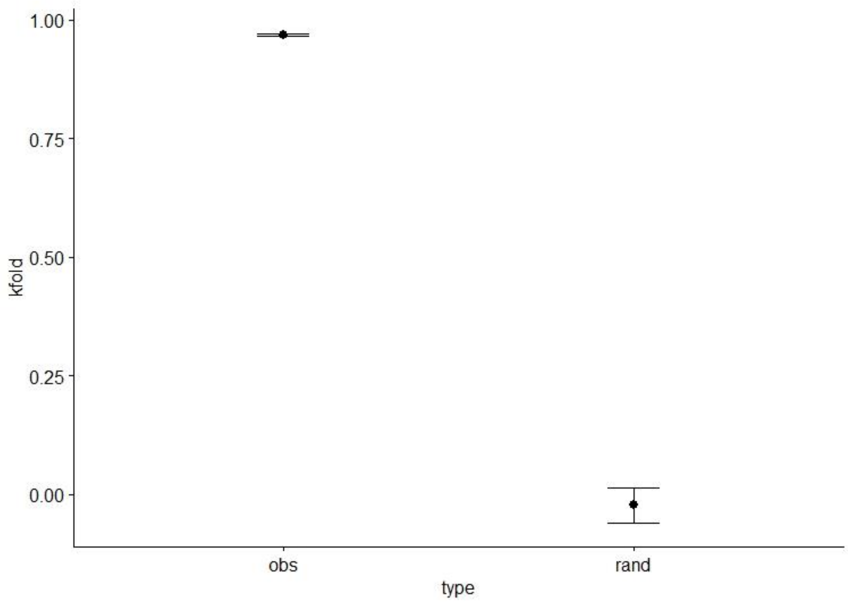


Figure 35: Grizzly bear season 3 Kfold plot

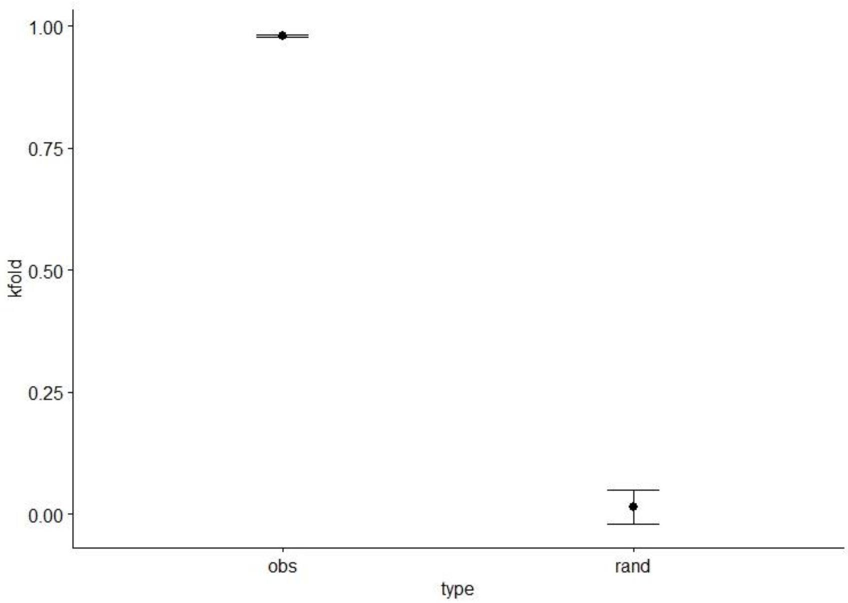
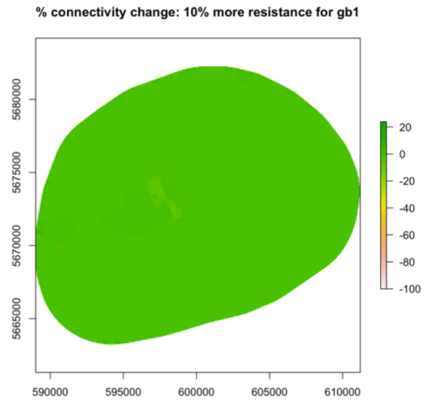
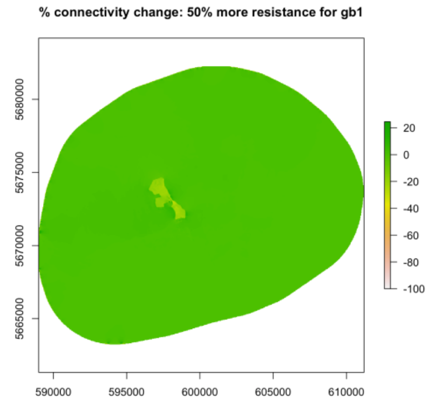


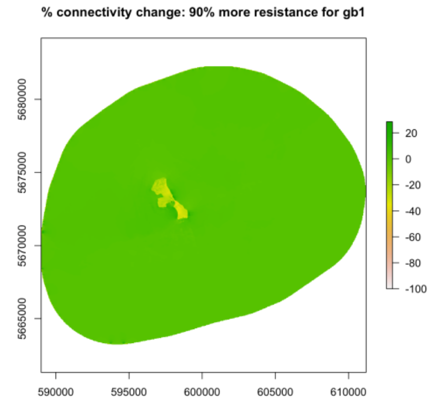
Figure 36: Wolf summer Kfold plot

Appendix 3: Modeling Treatment Results

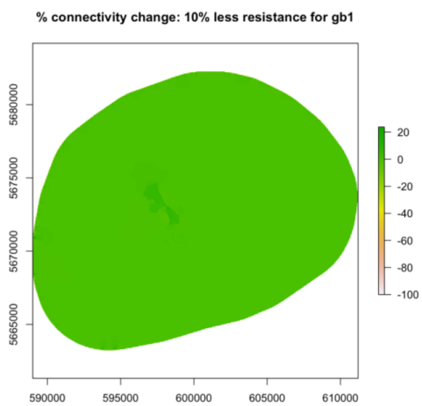
Grizzly Bear Season 1: Reduced Connectivity

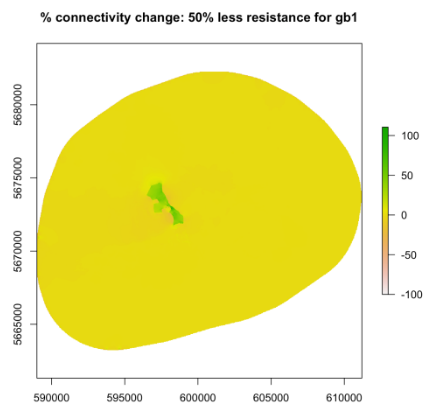


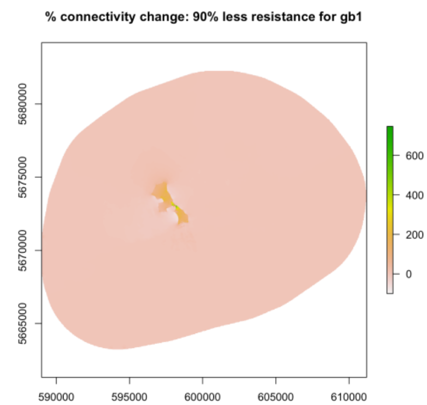




Grizzly Bear Season 1: Improved Connectivity

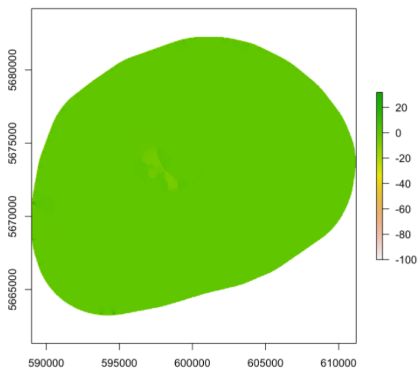




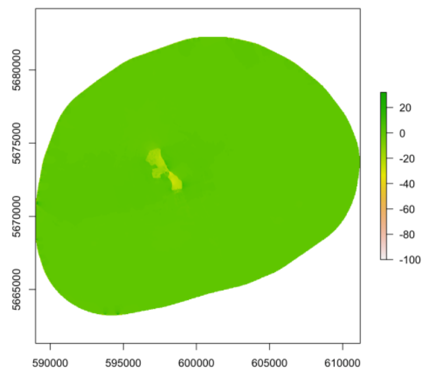


Grizzly Bear Season 2: Reduced Connectivity

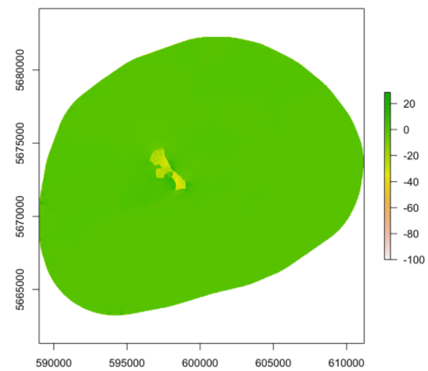
% connectivity change: 10% more resistance for gb2



% connectivity change: 50% more resistance for gb2

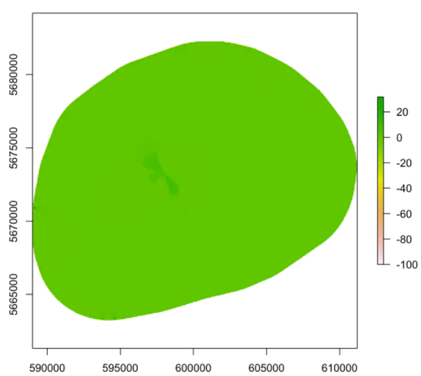


% connectivity change: 90% more resistance for gb1

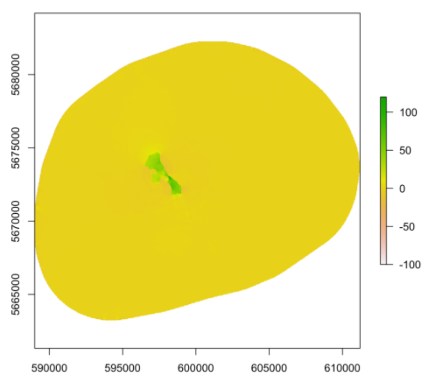


Grizzly Bear Season 2: Improved Connectivity

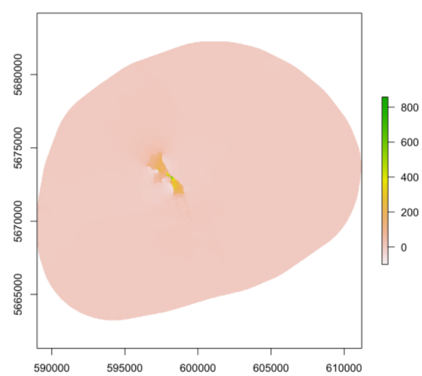
% connectivity change: 10% less resistance for gb2



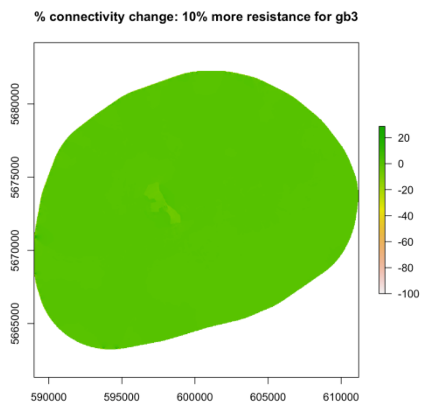
% connectivity change: 50% less resistance for gb2

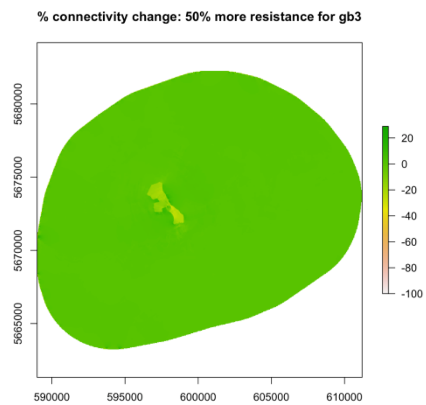


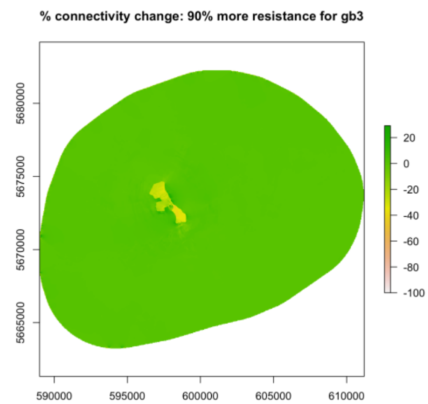
% connectivity change: 90% less resistance for gb2



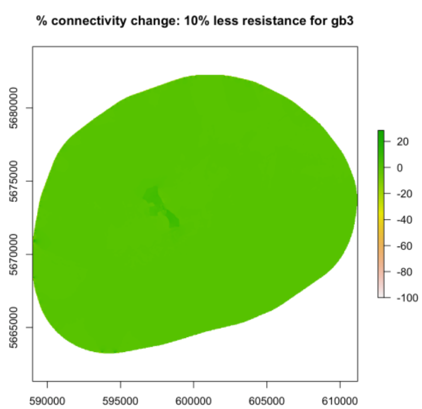
Grizzly Bear Season 3: Reduced Connectivity

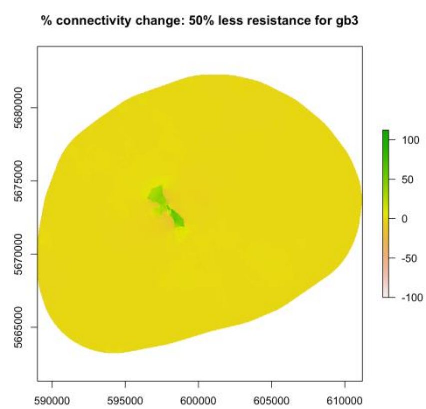


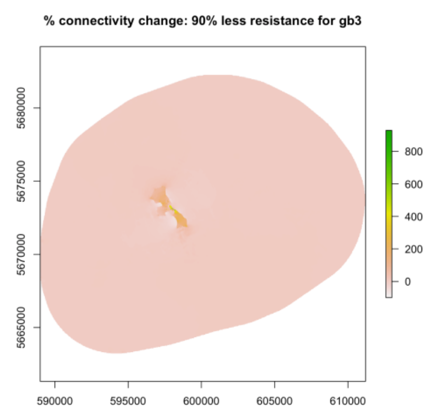




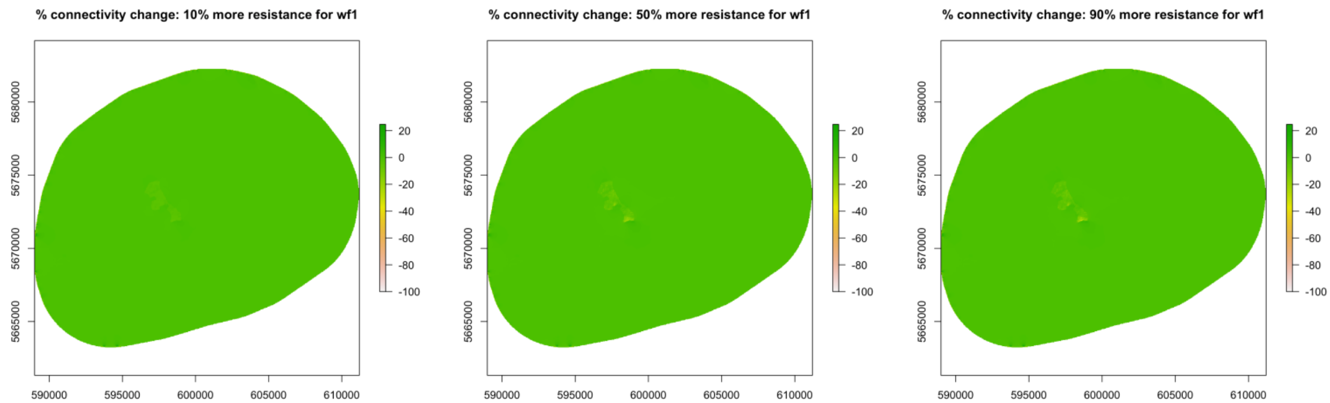
Grizzly Bear Season 3: Improved Connectivity



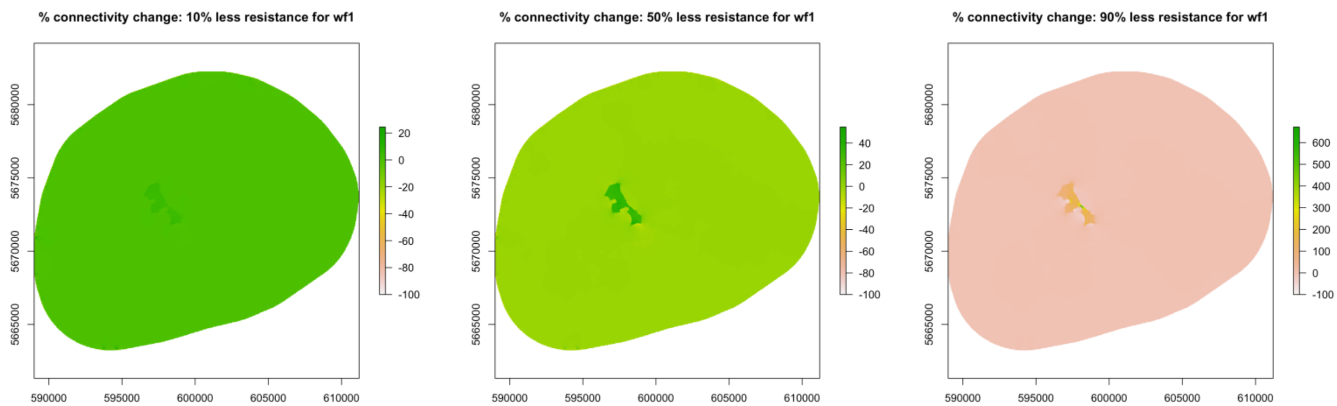




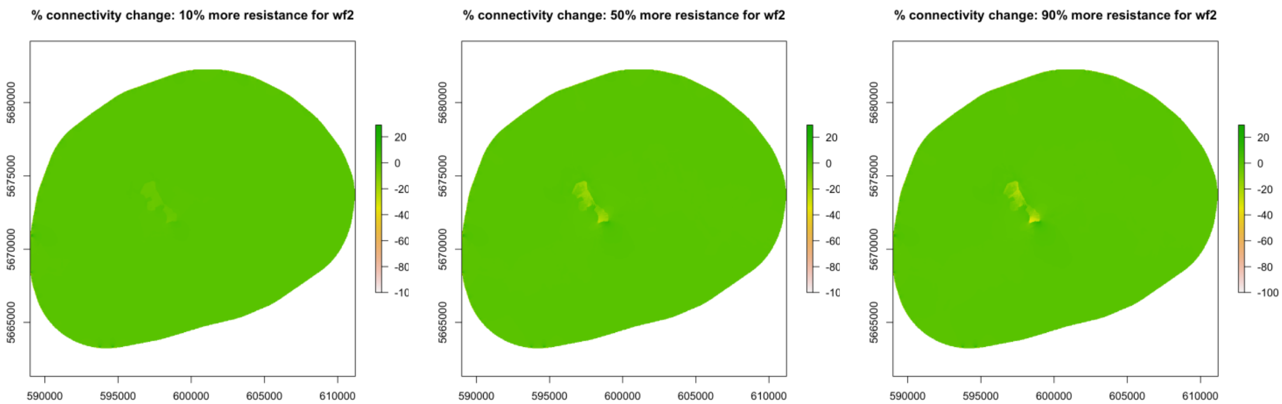
Wolf Summer: Reduced Connectivity



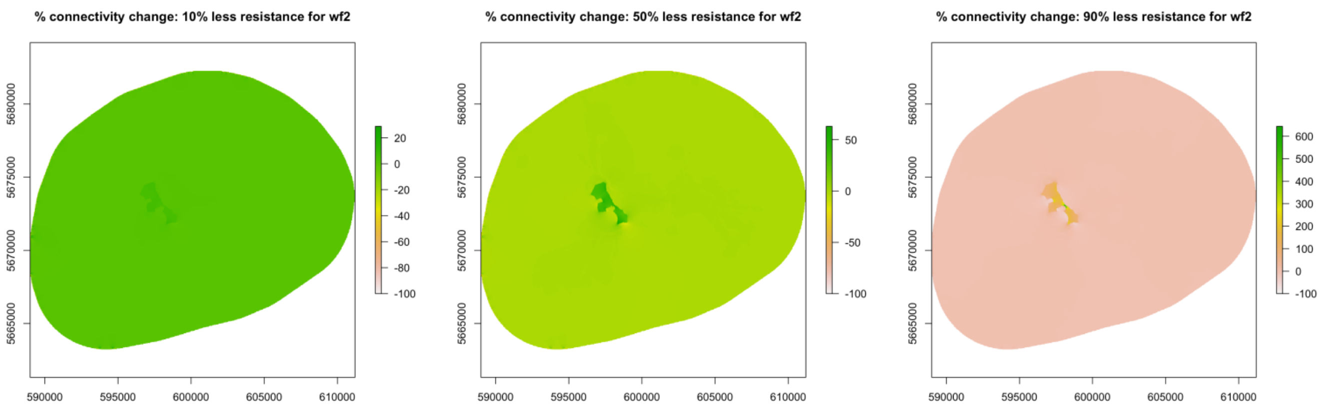
Wolf Summer: Improved Connectivity



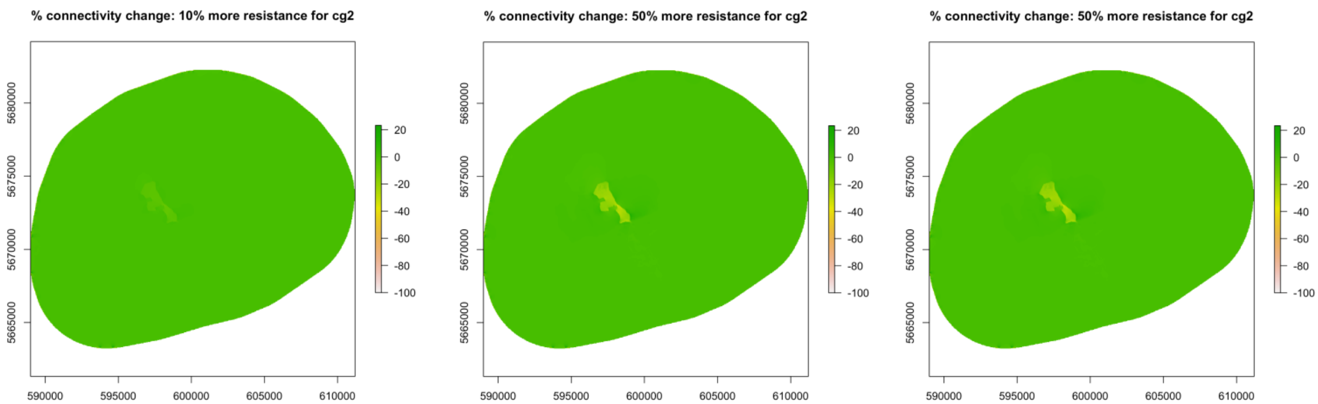
Wolf Winter: Reduced Connectivity



Wolf Winter: Improved Connectivity



Cougar Winter: Reduced Connectivity



Cougar Winter: Improved Connectivity