FINAL REPORT

Do oil and gas activities and access control measures affect the distribution, abundance and movements of grizzly bears?

Prepared for
Alberta Upstream Petroleum Research Fund

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Report Summary

To understand how oil and gas activities and access control measures, particularly gates, influences grizzly bears and their habitats in Alberta, we used multiple data sources including spatial layers representing roads with and without gates, GPS locations from collared grizzly bears, and counts of unique bears from a recent (2014) population inventory. In the first section of this report, we inventory gates within core and secondary grizzly bear conservation areas and evaluate how the presence or absence of gated and other types of roads (road removal scenarios) contributes to the amount of sink habitat for grizzly bears. In section two, we investigate the response (habitat use, movement) of grizzly bears to roads with and without access control measures by determining whether or not bears select or avoid habitats adjacent to roads as well as the frequency of crossings associated with roads. In the third and final section, we investigate relationships between the abundance of grizzly bears and the oil and gas footprint (roads, well-sites, and pipelines).

Key research findings

- The vast majority of grizzly bear mortalities documented in BMA 3 between 2000 and 2015 occurred near major access routes (primary and secondary roads) compared to decommissioned roads or roads with gates.
- Access control features (gates) were not common within the study area and reduced highway vehicle access potential for about 440 km of road. BMA 3 has about 21,650 km of road.
- Many of the gates were likely ineffective in reducing vehicle access as most were not locked (62%), some could be bypassed with a highway vehicle (10%), and others (6%) had secondary access points.
- Increases in sink habitat (high quality habitat with high bear mortality risk)for grizzly bear were largely associated with secondary type roads with no noticeable reduction in the amount of sink habitat associated with gated roads as determined by existing habitat state models.
- Grizzly bears do not respond (habitat use, road crossings) differently to roads with and without access control measures (gates) suggesting gates currently are doing little to reduce human-caused mortality risk.
- Further research is required to test the effectiveness of access control measures by installing gates in strategic locations at the landscape level.
- The problem of roads relative to grizzly bear mortality risk is not dependent on the type of road or the associated land use activity for which the roads are constructed, and that current management strategies which focus on reducing and minimizing road densities are warranted and supported by this research.
- Access control measures which would limit motorized human use of roads in grizzly bear habitat, along with education and enforcement measures, would also serve to reduce human caused grizzly bear mortality rates.

Acknowledgements

We would like to thank Alberta Upstream Petroleum Research Fund (AUPRF) and the many partners of the fRI Research Grizzly Bear Program for providing funding in support of this project. We would also like to thank our staff Brent Rutley, John Saunders, Terry Winkler and Joshua Crough for their assistance with field data collection. Thank you to fRI Research staff Julie Duval and Joshua Crough for their help with data management and GIS processing.

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1. General Introduction

One of the key strategies in the Alberta provincial grizzly bear recovery plan (2008-2013) was the development of core and secondary conservation areas where open route (road) density thresholds would be established in an effort to reduce and limit the amount of human caused grizzly bear mortality in these areas. A significant body of research has shown the common but unfortunate relationship between increasing open road densities and reductions in grizzly bear survival. Most recently Boulanger and Stenhouse (2014), using 14 years of GPS radio collaring data, showed the relationship between open road densities and population performance (lambda) in Alberta and suggested that when road densities exceed 0.75km/km^2 local grizzly bear populations would be declining.

With a provincial recovery goal of the reduction of human caused bear mortalities and an increase in population size, management actions have focused on efforts to not exceed stated road density thresholds while at the same time restricting human access to new and sometimes existing roads to reduce possible poaching events along these roadways. The management options to limit access have largely focused on the use of gates and road deactivation or removals. All these measures are directed at limiting human access and thus preventing grizzly bear poaching events. However, to date, no attention has been given to what if any impacts these access control measures may have on grizzly bear behaviour or their use of habitat in these areas. This research project set out to use new and existing data sets to determine if oil and gas activities and access control measures affect the distribution, abundance and movements of grizzly bears.

2. Study Area

The study area (~20,000 km^2) encompasses a large portion of the Yellowhead population (BMA 3) unit in west-central Alberta and is bordered by Federal (Jasper, Banff) and Provincial parks (Whitehorse Wildland, White Goat Wilderness) and protected areas to the west, highway 16 to the north, and highway 11 to the south (refer to Figure 3.1). Although the area is predominantly public lands managed by the crown for a variety of land use activities, dispersed through the area are a series of relatively small provincial parks (~180 km^2) and approximately (~12,000 km^2) has been designated as core and secondary grizzly bear conservation areas (refer to Figure 3.1). Industrial development from both the energy (open pit coal mining, oil and gas) and forestry sectors occur throughout the land base, but are concentrated in the central and eastern portion of the study area. Recreational activities such as hunting, trapping, fishing, camping, hiking, and off highway vehicle use (OHV) are also prominent on the landscape. Climate, soil, topography, and vegetation are characteristic of the Rocky Mountain and Foothills natural regions (Downing and Pettapiece 2006).

3. Roads and access management: evaluating the state of grizzly bear habitat in west-central Alberta

3.1 Introduction

Access management (gates, bridge or road removal) is increasingly being used as a strategy to mitigate the ecological consequences of roads and their use to wildlife and their habitats. Although the consequences of roads are diverse and influence many ecological processes, increased mortality is arguably the single greatest threat facing wildlife populations. Grizzly bears are a species that are particularly sensitive to human activity and access, given that roads often lead to a decrease in survival potential both from direct (vehicle collisions) or indirect (legal or illegal harvest, self defense) effects. For this reason, access management strategies are often recommended within recovery plans, which may include limiting road development, establishing seasonal road closures, creating barriers to impede vehicle traffic on roads, or reclaiming the roads completely. In Alberta, reducing human-caused grizzly bear mortality risk is an essential step in the recovery and long-term conservation of the provincial population. Although grizzly bear mortalities occur for many reasons, research in Alberta suggests that there is a strong link between the number and density of roads, particularly associated with industrial development from the energy (mining, oil and gas) and forestry sectors, and reduced grizzly bear survival associated with elevated levels of mortality risk(Nielsen et al. 2004a; Boulanger and Stenhouse 2014) . Because controlling access and use is critical to grizzly bear recovery (Festa-Bianchet 2010), strategies to date have largely focused on limiting road densities within habitats (core and secondary conservation areas) viewed as important to maintaining self-sustaining grizzly bear (Nielsen et al. 2009) . Access management is a contentious issue not easily resolved within a multiple use landscape with many stakeholder groups. Perhaps this is the reason why access control measures are applied in different ways across provincial bear management units in the province. Despite this challenge, there are access control features (gates) and other strategies (road decommissioning) that are being used in some grizzly bear conservation areas in west-central Alberta. Understanding how access management might influence grizzly bear habitat use is an important step towards developing mitigation strategies as well as determining how bears respond to this suggested management action.

In this section, we use a planning tool developed by the fRI Research Grizzly Bear Program (GB Tools) to assess changes in grizzly bear habitat condition associated with access management (gates, road decommissioning). More specifically, we evaluate how certain road types associated with industrial land use activities and measures of road mitigation through access management affect the amount of sink habitat (high quality habitat with high mortality risk) for grizzly bears. Our specific research objectives were to: 1) inventory gates along major (primary and secondary roads) access routes, primarily within core and secondary conservation areas; 2) calculate the proportion of sink habitat at three scales and following six road removal scenarios; 3) evaluate changes in the amount of sink habitat associated with road types and access management (gates, road decommissioning). We conclude by discussing the value of access management and identify areas where mitigation would be most beneficial in support of grizzly bear recovery and conservation in the Yellowhead population unit.

3.2 Methods

3.2.1 Gate inventory and road classification

During part of the 2015 field season (August-October), we surveyed primary (major access routes) and secondary (connected to major access routes and typically associated with forestry and energy sector development) access routes within the Yellowhead population unit, focusing our efforts within core and secondary grizzly bear conservation areas (Figure 3.1). Using a tablet (Samsung Galaxy Tablet 2) and the Avenza application (Avenza Systems Inc.), we mapped our survey effort and documented the location and condition of each gate encountered. A georeferenced map identifying primary, secondary, and decommissioned roads was used to navigate through the study area and conduct the inventory. We stored the track file and location coordinates within a geodatabase to manipulate spatial layers in a Geographic Information System (GIS). We coded gates as locked or unlocked and then assigned each gate a land use activity (mining, forestry, and/or oil and gas) to road segments using signage, vector data (mine boundary), and raster data (Spot imagery). We only considered roads to be 'gated' if there were no other points of access for highway vehicles. We also identified other roads not associated with land use activities (gravel pits, parks, and airfield).

3.2.2 Grizzly bear habitat states and road removal scenarios

We used GBtools (habitat states model) and the road reclamation tool via a Python (2.7.5) script (2014 fRI Research Grizzly Bear Program Deliverables) to calculate the proportion of sink habitat at three scales: A) grizzly bear conservation area (core and secondary combined); B) core and secondary conservation areas; and C) watersheds within the conservation area. The tool combines a habitat model defined by a resource selection function (RSF) and a mortality risk model to partition grizzly bear habitat into states of habitat condition (source [habitat security] and sink [good quality but high risk]) (Nielsen et al. 2004b, 2006). At each scale, roads were removed from the landscape (base scenario [0]). We then calculated changes in the amount of sink habitat for the following road removal scenarios: 1) primary roads only; 2) primary and secondary roads only; 3) main, secondary, and decommissioned roads; 4) gated roads removed; and 5) locked gated roads removed. Because they were relatively rare, we did not include scenarios that included the gate condition (i.e., passable by a vehicle). However, we only included gated roads in our analysis that could have effectively controlled vehicle access (no other vehicle access points). Finally, we excluded gated roads associated with mining because it was illegal to trespass on mine property and mine vehicle traffic continues behind locked gates on the mine.

3.3 Results

We surveyed ~1600 km of primary and secondary roads and located 84 gates (Figure 3.2). At the time of data collection, only 33 (38%) were locked and as a determination of the condition of the gate, eight (10%) could have been bypassed with a highway vehicle (Table 3.1). An assessment of the roads associated with each gate indicated that five (6%) gates were completely ineffective because there were other vehicle access points. Considering the 79 gates where access control could have been effective, most were considered secondary road types (88%) and associated with oil and gas or a combination of oil and gas and forestry land use activity (Table 1.1). These roads accounted for about 273 km of the approximately 440 km of gated road that we surveyed (Table 3.1).

An evaluation of the proportion of sink habitat associated with our road removal scenarios revealed patterns that were consistent across scales. At the largest scales (study area, core and secondary conservation areas), the proportion of sink habitat increased with the addition of secondary and decommissioned roads (Figure 3.3 and Figure 3.4). However, this increase was greater within secondary conservation areas. Removing roads with gates had no noticeable influence on the proportion of sink habitat at these scales (Figure 3.3 and Figure 3.4). At the scale of a watershed unit, these patterns were also present, but the effect of secondary (0.1-0.6%) and decommissioned (0.1-0.7%) road types on the amount of sink habitat varied. Considering our base scenario (no roads), eight watersheds were considered to have relatively low (<0.25) levels of sink habitat, five were deemed to be moderate (0.25-0.50), and three were considered high (>0.50). At this scale, only one watershed (zone 65) within the secondary conservation area transitioned from low to moderate sink habitat when secondary roads were added (scenario 2) (Figure 3.5).

3.4 Discussion

This component of our study showed that within important grizzly bear habitat (core and secondary conservation areas) there were relatively few roads with access control features (gates) compared to the number of roads that were present. Although the proportion of sink habitat did not increase dramatically with the addition of roads within our scenario analysis, our finding that there was no noticeable reduction in the amount of sink habitat, even at the scale of a watershed, suggests that more gates are needed in strategic locations to limit motorized vehicle access, particularly highway vehicles in order to be recognized within the evaluation tools used. Gates can effectively limit motorized vehicle use, but effectiveness can only be achieved providing that each gate is maintained to ensure functionality. We suspect that many of the gates we surveyed in our study would most likely inhibit highway vehicle access. However, most of the gates were unlocked (62%), several (10%) could have been bypassed with a highway vehicle, and in certain cases (6%), secondary ungated access points were present. Although gates may be less effective than other access management strategies that physically create a barrier or remove the road completely (Switalski and Nelson 2011), gates may be the only option where land use activities such as oil and gas require frequent access to operate. Road decommissioning has also been advocated as an effective means to limit motorized access, and depending on the method used (i.e., barriers, ripping, or bridge removal), can also be more cost effective than gates (Switalski et al. 2004). Our results showed that if decommissioned roads were removed, the amount of sink habitat could be decreased. This may be a particularly useful access management tactic for roads associated with forest harvest operations where roads are not necessary required following tree removal and silvicultural prescriptions. Arguably, any form of access control measure is likely to be beneficial and contribute to the conservation of bears (Switalski and Nelson 2011)

Planning tools offer a powerful approach to evaluate the negative effects of anthropogenic features such as roads towards wildlife populations and for the development of mitigation strategies. Our study showed that despite the relatively small change in sink habitat following road removal scenarios, we have identified watersheds where access control measures such as gates or road decommissioning can be focused to aid in population recovery efforts. This is particularly evident within core and secondary conservation areas, where there were moderate and high proportions of sink habitat. Increasingly, spatial models that represent source and sink habitats are being used to make management decisions (Aldridge and Boyce 2007; Nielsen et al. 2008), however, they must accurately portray changes in the state of habitats that reflect benefits towards the focal species resulting from the management . Although mortality risk is a fundamental component in the evaluation of grizzly bear habitat states, mortality risk is also tied to local habitat conditions such as RSF values and distance to forest edge, which tends to improve habitat quality, thus, creates potential risk. For this reason, modifying the current models that drive (RSF, mortality risk) the road reclamation tool in a way that adjusts the state of grizzly bear habitat is warranted. In doing so, the value of access control measures such as gates and road decommissioning can be more directly evaluated.

3.5 Management Recommendations

The results of our study highlights the need to manage secondary access routes given that they are prolific on the landscape and contribute to high levels of road density (fRI Research unpublished data). The effect of road density on grizzly bear demographics (population growth) are known to be deleterious due to reduced survival of sub-adult bears and females with cubs (Boulanger and Stenhouse 2014). We recommend that well maintained and managed gates be used where permanent access is required, whereas roads that are not required over long-time periods should be decommissioned. Although strategies should be used to reduce the overall amount of sink habitat accessible to motorized vehicles at the landscape level, watershed zones identified as having moderate and high proportions of sink habitat should be prioritized for further access management strategies and managers should consider the importance of both core and secondary conservation areas in their on going land management activities.

3.6 Tables

Table 3.1. The number and length (km) of roads associated with locked and unlocked gates by land use activity.

	Locked		**Unlocked**	
Land use	Number	Length	Number	Length
Mine	3	68.8	2	79.8
Oil and Gas	16	55.6	30	76.4
Forestry	2	3.6	2	50.2
Oil and Gas / Forestry	6	35.0	5	52.1
Other	3	0.7	5	3.3
Unknown	3	1.3	2	13.5
Total	33	165.0	46	275.4

Table 3.2.The length (km) of roads by gate status and type that were used to calculate grizzly bear habitat states within core and secondary conservation areas for three scales and six road removal scenarios.

Gate Status	Road Type	Core	Secondary	Total
n/a	Primary	819.6	522.9	1342.5
	Secondary	2558.5	2345.9	4904.4
	Decommissioned	1197.2	804.8	2002.0
Locked Gate	Mining	4.2	75.3	79.5
	Oil and Gas / Forestry	171.8	9.4	181.3
	Other	2.4	0.9	3.3
Unlocked Gate	Mining	68.3		68.3
	Oil and Gas / Forestry	68.5	25.2	93.7
	Other	0.7		0.7

Table 3.3. The proportion of primary and secondary sink habitat by watershed and road removal scenario where the total did not exceed 0.25 according to the base scenario (0).

Watershed	Scenario	Primary Sink	Secondary sink	Total	Watershed	Scenario	Primary Sink	Secondary sink	Total
Zone103	0	0.002	0.011	0.013	Zone73	0	0.008	0.086	0.093
(611.8 Km^2)	1	0.002	0.011	0.013	(795.0 Km^2)	1	0.008	0.087	0.094

	2	0.008	0.017	0.025		2	0.013	0.121	0.134
	3	0.008	0.017	0.025		3	0.018	0.122	0.139
	4	0.008	0.017	0.025		4	0.017	0.121	0.137
	5	0.008	0.017	0.025		5	0.017	0.121	0.138
Zone46	0	0.031	0.025	0.056	Zone16	0	0.113	0.008	0.121
(675.1 Km^2)	1	0.032	0.025	0.058	(782.4 Km^2)	1	0.113	0.008	0.122
	2	0.061	0.037	0.098		2	0.114	0.009	0.123
	3	0.073	0.039	0.112		3	0.114	0.009	0.123
	4	0.073	0.039	0.112		4	0.114	0.009	0.123
	5	0.073	0.039	0.112		5	0.114	0.009	0.123
Zone71	0	0.051	0.008	0.059	Zone49	0	0.124	0.020	0.144
(160.8 Km^2)	1	0.051	0.008	0.059	(340.8 Km^2)	1	0.124	0.020	0.144
	2	0.060	0.011	0.071		2	0.129	0.020	0.149
	3	0.060	0.011	0.071		3	0.129	0.020	0.149
	4	0.060	0.010	0.070		4	0.129	0.020	0.149
	5	0.060	0.010	0.070		5	0.129	0.020	0.149
Zone48	0	0.053	0.009	0.062	Zone52	0	0.143	0.010	0.152
(164.5 Km^2)	1	0.054	0.009	0.062	(832.8 Km^2**)**	1	0.143	0.010	0.152
	2	0.100	0.019	0.119		2	0.149	0.009	0.159
	3	0.102	0.019	0.121		3	0.150	0.009	0.159
	4	0.101	0.019	0.120		4	0.149	0.009	0.159
	5	0.101	0.019	0.120		5	0.150	0.009	0.159
Zone13	0	0.068	0.008	0.076	Zone32	0	0.147	0.017	0.164
(887.4 Km^2)	1	0.068	0.008	0.076	(159.0 Km^2)	1	0.147	0.017	0.164
	2	0.068	0.008	0.076		2	0.147	0.017	0.165
	3	0.068	0.008	0.076		3	0.147	0.017	0.165
	4	0.068	0.008	0.076		4	0.147	0.017	0.165
	5	0.068	0.008	0.076		5	0.147	0.017	0.165
Zone20	0	0.049	0.032	0.081	Zone51	0	0.189	0.025	0.214
(34.0 Km^2)	1	0.049	0.032	0.081	(204.5 Km^2)	1	0.189	0.025	0.214
	2	0.051	0.031	0.081		2	0.189	0.025	0.214
	3	0.051	0.031	0.081		3	0.189	0.025	0.214
	4	0.051	0.031	0.081		4	0.189	0.025	0.214
	5	0.051	0.031	0.081		5	0.189	0.025	0.214
Zone66	0	0.044	0.043	0.087	Zone83	0	0.208	0.016	0.224
(361.6 Km^2)	1	0.045	0.044	0.089	(491.2 Km^2)	1	0.208	0.016	0.224
	2	0.079	0.056	0.135		2	0.212	0.016	0.228
	3	0.092	0.062	0.154		3	0.215	0.017	0.231
	4	0.089	0.062	0.151		4	0.215	0.017	0.231
	5	0.091	0.062	0.153		5	0.215	0.017	0.231
Zone37	0	0.084	0.007	0.091	Zone65	0	0.089	0.145	0.234
(402.4 Km^2)	1	0.084	0.007	0.091	(618.8 Km^2)	1	0.089	0.147	0.236
	2	0.084	0.007	0.091		2	0.108	0.177	0.285
	3	0.084	0.007	0.091		3	0.113	0.183	0.296
	4	0.084	0.007	0.091		4	0.113	0.183	0.296
	5	0.084	0.007	0.091		5	0.113	0.183	0.296

Table 3.4. The proportion of primary and secondary sink habitat by watershed and road removal scenario where the total was between 0.25 and 0.5 for the base scenario (0).

Watershed	Scenario	Primary Sink	Secondary sink	Total
Zone104	0	0.206	0.065	0.271
(523.8 Km^2)	1	0.206	0.065	0.271

	2	0.218	0.067	0.285
	3	0.232	0.069	0.301
	4	0.232	0.069	0.301
	5	0.232	0.069	0.301
Zone105	0	0.156	0.142	0.298
(432.6 Km^2)	1	0.156	0.143	0.299
	2	0.176	0.160	0.335
	3	0.195	0.167	0.362
	4	0.195	0.167	0.362
	5	0.195	0.167	0.362
Zone107	0	0.249	0.138	0.387
(365.9 Km^2)	1	0.249	0.138	0.388
	2	0.264	0.146	0.411
	3	0.280	0.150	0.430
	4	0.280	0.150	0.430
	5	0.280	0.150	0.430
Zone60	0	0.175	0.213	0.388
(281.8 Km^2)	1	0.176	0.213	0.389
	2	0.183	0.215	0.398
	3	0.194	0.220	0.414
	4	0.194	0.220	0.414
	5	0.194	0.220	0.414
Zone80	0	0.152	0.254	0.406
(710.3 Km^2)	1	0.152	0.256	0.408
	2	0.157	0.265	0.422
	3	0.166	0.283	0.449
	4	0.166	0.283	0.449
	5	0.166	0.283	0.449

Table 3.5. The proportion of primary and secondary sink habitat by watershed and road removal scenario where the total exceeded 0.5 for the base scenario (0).

Watershed	Scenario	Primary Sink	Secondary sink	Total
Zone82	0	0.367	0.161	0.528
(648.5 Km^2)	1	0.369	0.161	0.530
	2	0.379	0.160	0.540
	3	0.409	0.164	0.573
	4	0.408	0.164	0.572
	5	0.409	0.164	0.573
Zone81	0	0.394	0.179	0.573
(858.2 Km^2)	1	0.395	0.178	0.573
	2	0.410	0.179	0.588
	3	0.437	0.179	0.617
	4	0.437	0.180	0.617
	5	0.437	0.179	0.617
Zone111	0	0.334	0.326	0.660
(570.8 Km^2)	1	0.335	0.325	0.660
	2	0.343	0.328	0.671
	3	0.355	0.324	0.679
	4	0.355	0.324	0.679
	5	0.355	0.324	0.679

3.7 Figures

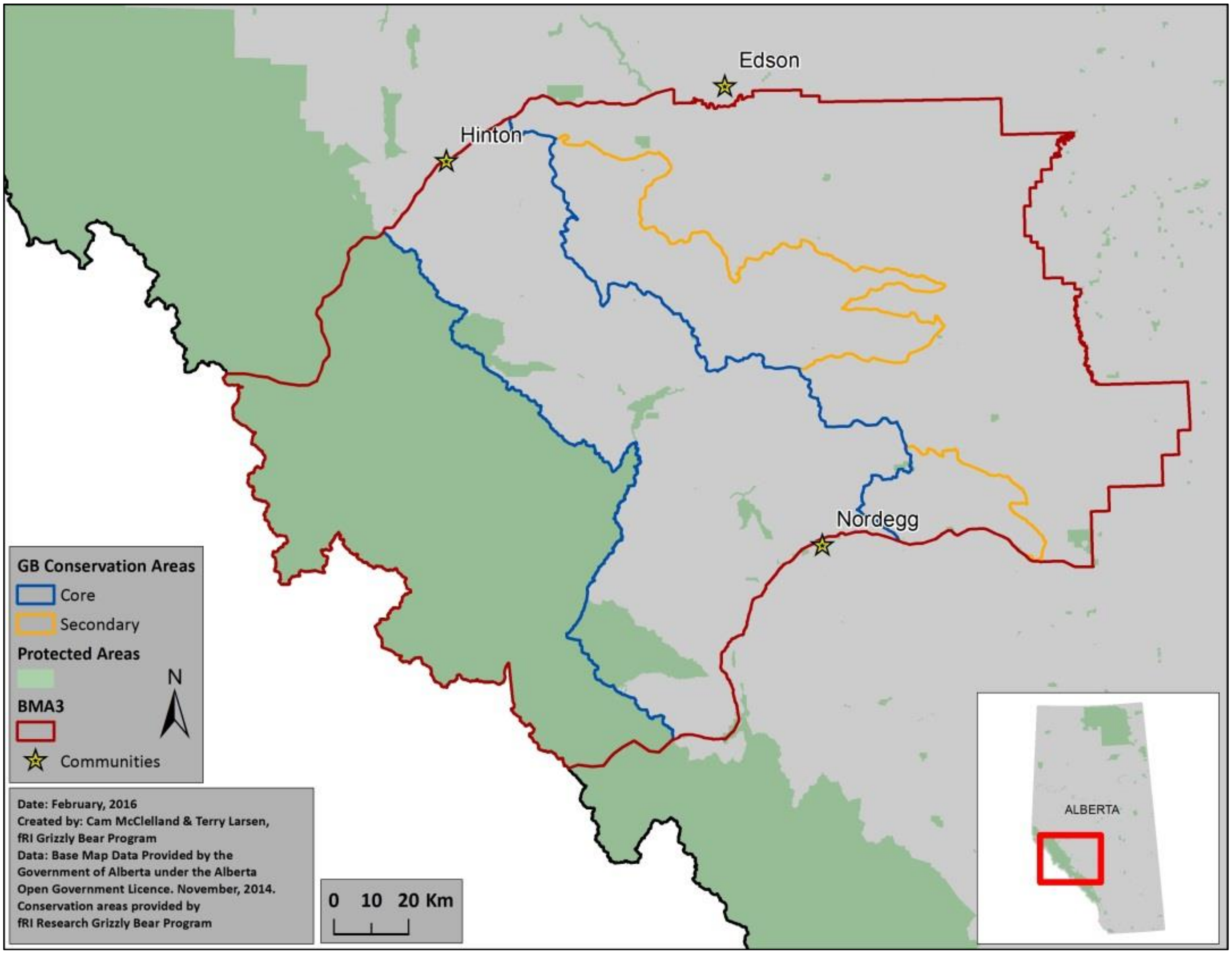

Figure 3.1. Study area map depicting the Yellowhead population unit (BMA 3), parks and protected areas, and core and secondary grizzly bear conservation areas in west-central Alberta, Canada.

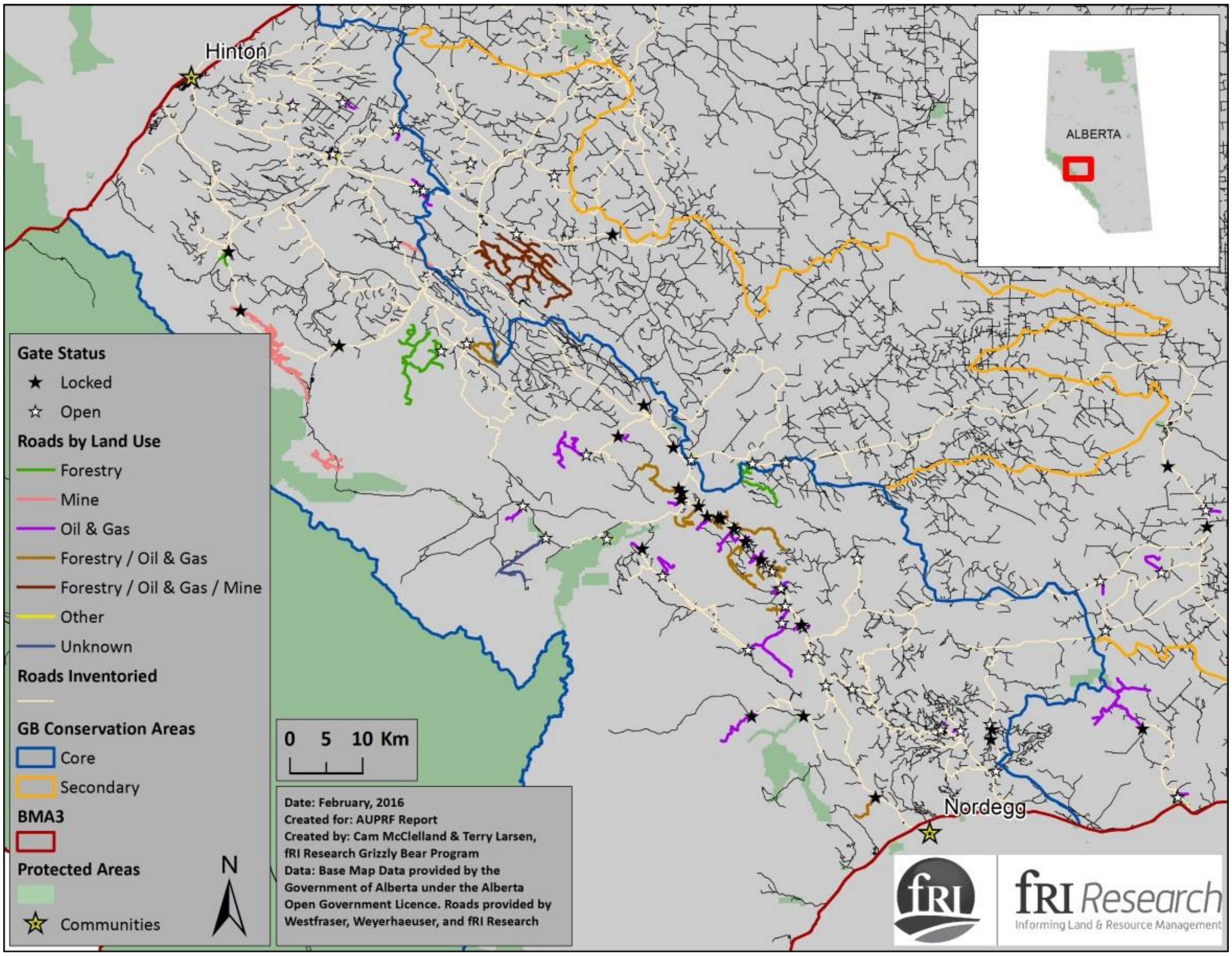

Figure 3.2. Map showing the location of gates relative to the roads inventoried within the Yellowhead population unit (BMA 3). The gate status (locked vs. unlocked) and the land use activities associated with the gated roads are shown.

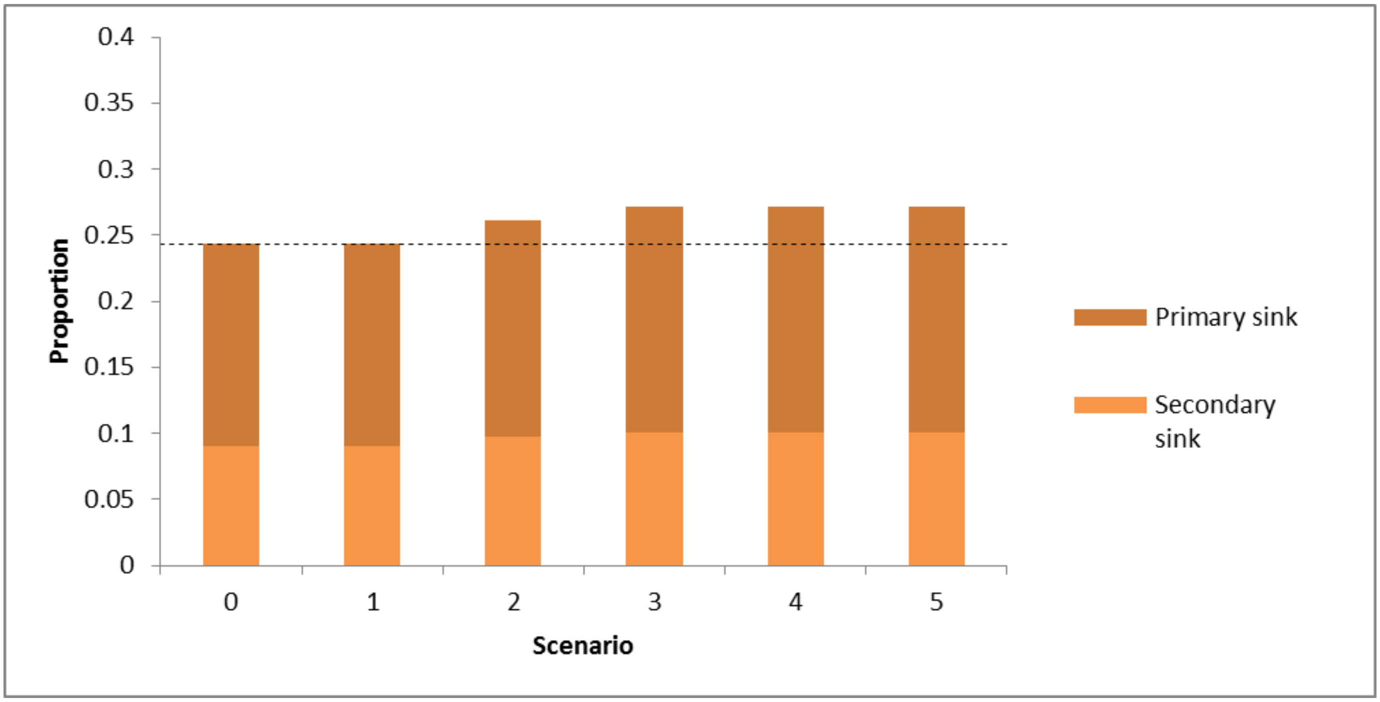

Figure 3.3. The proportion of primary and secondary sink habitat by road removal scenario within core and secondary grizzly bear conservation areas. The dashed line represents the proportion of total sink habitat where all roads were removed (scenario=0). Scenario 1 (primary roads added), 2 (primary and secondary roads added, 3) primary, secondary and decommissioned roads added), 4 (gated roads removed following scenario 3), and 5 (locked gated roads removed following scenario 3).

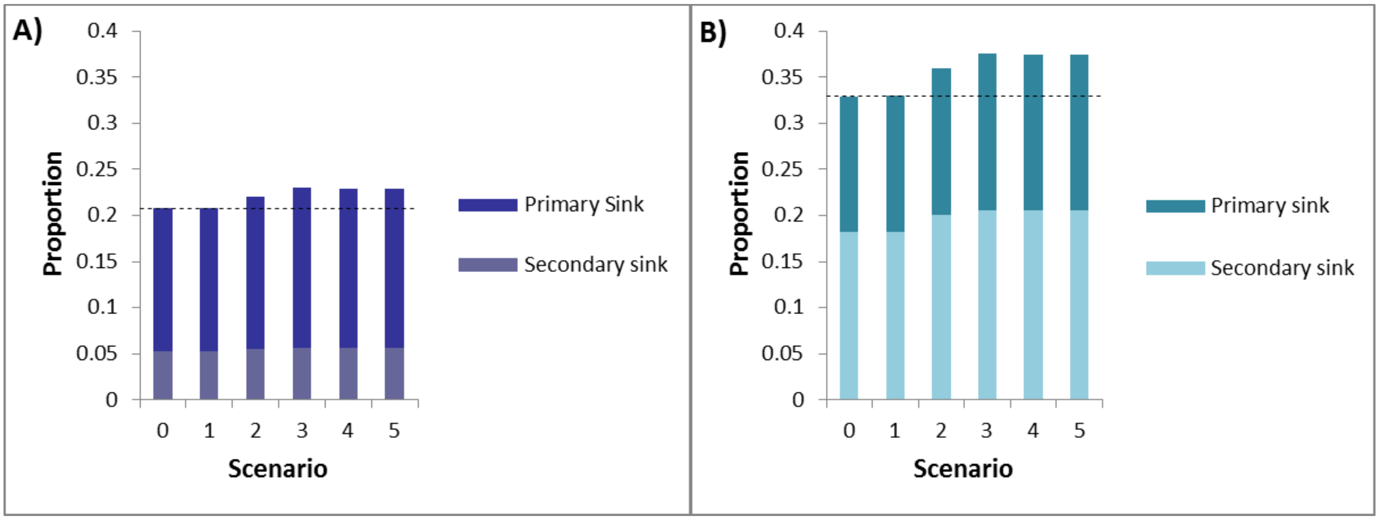

Figure 3.4. The proportion of primary and secondary sink habitat by road removal scenario within A) core and B) secondary grizzly bear conservation areas. The dashed line identifies the proportion of total sink habitat where all roads were removed (scenario=0). Scenario 1 (primary roads added), 2 (primary and secondary roads added, 3) primary, secondary and decommissioned roads added), 4 (gated roads removed following scenario 3), and 5 (locked gated roads removed following scenario 3).

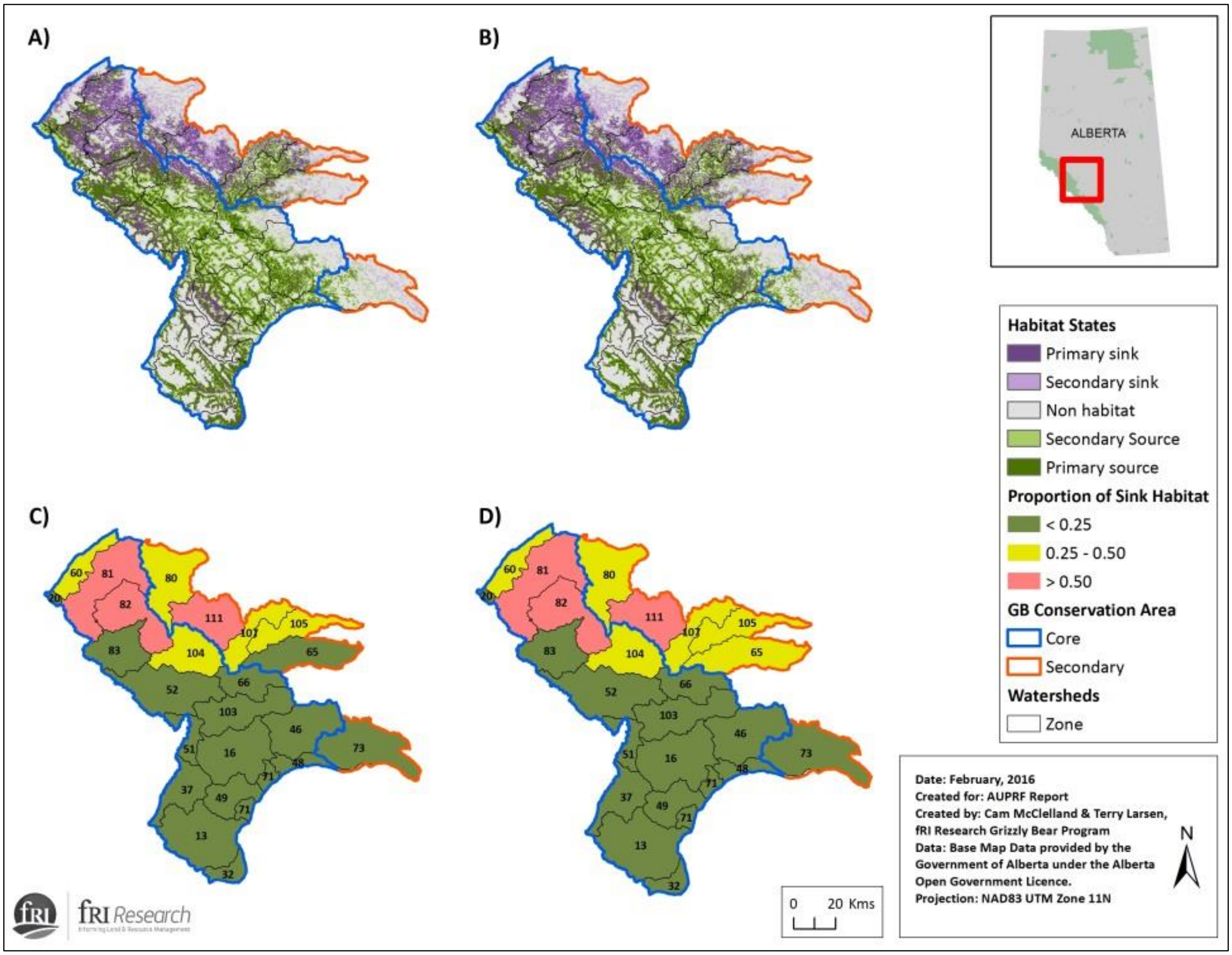

Figure 3.5. Habitat states (A & B) with the grizzly bear conservation area and the proportion of sink habitat (C & D) by watershed within core and secondary grizzly bear conservation areas. Watersheds with low (<0.25), medium (0.25-0.5), and high (>0.5) levels of sink habitat according to road removal scenarios where all roads were either removed (A & C) or included (B & D) are displayed.

4. Grizzly bear habitat use and movement in response to access control measures

4.1 Introduction

Here we use a three year GPS location dataset from collar grizzly bears to determine if bears responded differently to roads with access control measures (gates). More specifically, we investigate grizzly bear habitat selection in proximity to roads (near [<100 m], far [100-500 m]) as well as the frequency with which road crossings occurred. Our specific objectives were: 1) evaluate grizzly bear response (selection/avoidance) to habitats in proximity to roads with and without gates; 2) determine the frequency of road crossings in relation to roads with and without gates; and 3) determine if variation in bear response and crossings in relation to roads can be attributed to biological (age class, gender) and/or temporal (seasonality, time of day) factors. We hypothesized that grizzly bears would select road side habitat both near and far from roads with gates, and also cross roads more frequently where gates limited human access. We also hypothesized that these patterns would be present after accounting for biological and temporal factors. We used an information theoretic approach (competing models) to show support for or against our working hypotheses.

4.2 Methods

4.2.1 Use-available data

We define habitat use as three years (2013-2015) of grizzly bear location data (use sample). Grizzly bears were captured using aerial darting and culvert traps following protocols accepted by the Canadian Council of Animal Care (University of Saskatchewan animal use protocol number 20010016). We fit each animal with a Followit© satellite GPS collar programmed to collect locations hourly or every 30 minutes. In addition, we extracted a premolar tooth to estimate the age of each animal from cementum annuli counts (Stoneberg and Jonkel 1966). For our purpose, we considered GPS location data that fell within three distinct seasonal periods of food resource supply known to influence grizzly bear foraging behavior: hypophagia (low food intake; May 1 to June 15), early hyperphagia (high food intake; June 16 to July 31) and late hyperphagia (August 1 to September 15) (Nielsen et al. 2004c). We defined availability for each grizzly bear as random locations (10 points per km^2) within multi-annual grizzly bear minimum convex polygons (MCPs). Locations that occurred within the relatively large Federal (Jasper and Banff National Parks) and Provincial (Whitehorse Wildland and White Goat Wilderness area) parks and protected areas were not considered (Figure 2.1).

4.2.2 Resource selection analysis

We calculated the Euclidean distance of our use-available sample to the nearest gated or not gated road. Locations associated with gated roads identified in this study were classified according to land use activity (mining, [forestry, mining], or other), whereas roads without gates were assigned a type (primary, secondary, and decommissioned). Primary access routes are major roads that lead to secondary roads, which are typically associated with industrial activities such as forestry and oil and gas. Decommissioned roads are assumed to be not passable by a highway vehicle. We then classified locations based on their proximity (near [≤100 m] and far [100-500 m]) from roads by type and class (industrial activity; locked vs. unlocked gates). We considered locations within 500 m of a road as part of our analysis since grizzly bear mortalities tend to be more frequent at this distance (Nielsen et al. 2004b). Because gated roads were relatively rare, we did not investigate bear response to locked vs.

unlocked gates. To evaluate individual and population level habitat use by grizzly bears, we calculated selection ratios (W_i) following (Manly et al. 2002):

$$Wi=oi/\pi i \quad (1)$$

where o_i (u_i/u_+) is the sample proportion of used (>65 GPS points per bear and season) units in category i and π_i (m_i/m_+) is the sample proportion (≥5%) of available units in category i. Where selection ratios exceed one and without overlapping confidence intervals, habitat was deemed to be selected, whereas ratios below one would suggest avoidance by bears. We used linear regression was used to predict the mean and variance for each category. To account for the repeated measures of individuals associated with our habitat categories, we used a cluster variable to identify each grizzly bear. We used Akaike Information Criterion corrected for small sample size (AIC_c) to identify the most parsimonious model and evaluate support for our working hypotheses (Anderson and Burnham 2002) (Table 2.1). We then used Akakie weights (w_i) to determine the probability (>0.9) a particular model would be the 'best' given the candidate set (Anderson and Burnham 2002). Because of our sample size relative to the habitat categories, we did not investigate bear response due to time of the day.

4.2.3 Road crossing analysis

We created line segments (paths) between successive GPS collar locations for each grizzly bear using the statistical program RStudio (Version 0.99.879, © 2009-2016 RStudio, Inc.). Because we wanted to minimize the spatial error associated with grizzly bear road crossing events, we removed locations that exceeded the scheduled hourly fix interval. We then intersected the paths with our roads layer (see section 1 of this report) to identify the spatial location of each crossing event. For each grizzly bear, we determine the number of road crossings by season, road type, and gate class (industrial activity; locked vs. unlocked gates). Again,because gated roads were relatively rare, we did not investigate bear response to locked vs. unlocked gates We then calculated a road crossing index similar to Graham et al. (2010):

$$I_{ijk} = C_{ijkl}/(M_{ij}\text{-}1)/L_{ijk} \quad (2)$$

where *I* was the crossing index for bear *i* in season *j* for road type and class *k* and time of day *l*; *C* was the number of road crossings by bear *i* in season *j* for road type and class *k* and time of day *l*; *M* is the number of data points for bear *i* in season *j* considering location and road year; and *L* is the length of roads by type and class *k* within each bear *I* MCP. Diurnal (includes morning and evening twilight) versus nocturnal crossings were determined from sunrise/sunset tables from the study area (Munro et al. 2006).

Similarly, we used linear regress to predict the mean (log [crossing index]) and variance of road crossing indices as a function of covariates (Table 2.1). To account for multiple measures of individuals as previously described, we used bear id as a cluster variable. Again, we used Akaike Informaiton Criterion corrected for small sample size (AIC_c) to identify the most parsimonious model, and we used Akakie weights (w_i) to determine support (>0.9) for the selected model (Anderson and Burnham 2002). Our strategy for model building has two steps. In the first step we select the most parsimonious variables according to each group (Table 2.1). In this case, our road variable was best represented by coding roads as follows: 1) primary; 2) secondary; 3) decommissioned; 4) mine roads with gates (locked and unlocked); and 5) forestry and/or oil and gas roads (locked and unlocked). In step two, we fit the best models from step 1 according to their group and included all possible combinations as our candidate set of *a priori* models (Table 2.1). We did not included crossings where roads were not associated with industrial land use activity.

4.3 Results

We used 34,775 GPS locations from 26 grizzly bears (M16, F10) between the spring (May) of 2013 and the fall (October) of 2015 to investigate response to habitat in proximity to roads as well as road crossing frequency.

The top AICc selected model explaining variation in grizzly bear selection (W_i) of habitat within 100 m of gated roads associated with mining was bear gender. Otherwise, a null model (intercept only) was the best fitting model for the other road distance and class categories. Males (mean = 1.64, 95% C.I. = 1.16-2.23) tended to select for these road side habitats, whereas females (mean = 0.70, 95% C.I. = 0.55-0.84) showed avoidance. Within a 100 m of a forestry / oil and gas road that was gated, bears appeared to use these habitat at random (neutral selection) even though selection was on average positive (mean = 1.22, 95% C.I. = 0.73-1.72). For habitats between 100 and 500 m of a mine road that was gated, selection by bears was neutral (mean = 0.84, 95% C.I. = 0.58-1.09), whereas bears avoided forestry / oil and gas roads (mean = 0.70, 95% C.I. = 0.52-0.87).

Our model selection approach revealed differences in bear habitat selection relative to roads without gates. For habitats within 100 m of primary and secondary roads, bear gender was the most supported model; otherwise, a null model was most supported for the other road distance and type categories. Relative to habitats within 100 m of primary roads, male bears showed a neutral response (mean = 1.24, 95% C.I. = 0.82-1.66), whereas female response was significant and positive (mean = 1.69, 95% C.I. = 1.39-1.98). Similarly, both males (mean = 1.69, 95% C.I. = 1.39-1.97) and females (mean = 1.26, 95% C.I. = 1.10-1.41) selected habitat near secondary road types, and avoided those habitats near decommissioned roads (mean = 0.54, 95% C.I. = 0.32-0.76). Our assessment of habitats between 100 and 500 m from primary (mean = 1.10, 95% C.I. = 0.90-1.30) and secondary (mean = 1.01, 95% C.I. = 0.85-1.17) roads showed that bear responses were neutral, and negative relative to decommissioned roads (mean = 0.54, 95% C.I. = 0.35-0.74).

Our top AIC_c selected model explaining variation in road crossing frequency was best predicted by road class (primary, secondary, decommissioned, mine roads with gates, and forestry / oil and gas roads with gates), time of day, and bear age class (Table 2.4). Akaike weights suggested that this model had overwhelming (>0.9) support (Table 2.4).The relationship between road crossing frequency and age class was negative and marginally significant (β = -0.792, S.E. = 0.50, P = 0.11), whereas the relationship between road crossings and time of day was positive (β = 0.628, S.E. = 0.14, $P < 0.01$). Adult grizzly bears crossed roads less than sub-adults (mean=8.45, SE=0.43) and road crossings tended to occur more during the day (mean=8.23, SE=0.22) compared to at night (mean=7.71, SE=0.25). In relation to our road classification, grizzly bears crossed secondary roads more than primary or decommissioned, and crossings associated with gates tended to be less frequent than roads that did not have gates (Figure 2.2). Comparing, gated roads relative to land use activity, we found no difference in the frequency of crossings between roads associated with an open pit coal mine and forestry / oil and gas (χ^2=1.33, df=1, p=0.25).

4.4 Discussion

We failed to find support for our hypothesis that bears would select habitats both near (<100 m) and far (100-500 m) from roads, nor did we find that bears crossed roads more frequently where gates most likely prevented human access. For the most part, grizzly bears showed a neutral response (random use of habitat) to habitats in proximity to roads where access control measures are in place. However, there was an exception in that male and female bears selected and avoided habitats within 100 m of roads that were associated with mining, respectively. Although this is positive result, roads within the boundary of mines are arguably more secure in that people are not allowed to trespass within the lease boundary. Gates did not appear to enhance habitat condition since habitats between 100-500 m from gated roads associated with forestry / oil and gas were avoided. Conversely, both male and females tended to be attracted to habitats within 100 m of primary and secondary road types. This is consistent with other research in Alberta and is most likely due to the occurrence of food resources (Roever et al. 2008; Stewart et al. 2013). This suggests that access management control measures in their current form are not functioning in a way that is likely to reduce human-caused mortality risk at the landscape level, which questions the utility of building such barriers as a means to reduce human access and at the same time enhance grizzly bear habitat conditions.

Our finding that grizzly bears avoided habitats both near and far from decommissioned roads supports the contention that road decommissioning is a viable approach to reduce human-caused mortality. Compared to gates and depending on the method used, road decommissioning may be more cost effective (Switalski et al. 2004). In addition, gates require maintenance to function properly and depending on the motivation of the individual, gates might be more easily bypassed, which means that gates are likely less effective in reducing human access potential than decommissioning. However, more research is needed to confirm the effectiveness of one method versus the other considering both the economics and response of bears. Switalski and Nelson (2011) showed that black bear were more likely to use road side habitat where roads were completely removed compared to roads with barriers or gates.

4.5 Management Recommendations

Although we were unable to conduct a more robust assessment of bear response to access control measures (gates), it should be recognized that gated roads were relatively rare on the landscape and further research investigating the value of access control measures is warranted. To conduct such an assessment requires that access control measures be increased at the landscape level by installing more gates strategically. We suggest that this could be done experimentally using a before-after controlled impact design. Overall, managers should consider multiple access control measures (gates, road decommissioning) as part of management strategies. In addition, focus and attention should be given to both primary and secondary road types if and when access management planning moves forward.

4.6 Tables

Table 2.1. Variables used to explain patterns of grizzly bear habitat use and road crossings in west-central, Alberta, Canada.

Group	Name	Description
Biological	Gender	Male vs. female
	Age	Sub-adult (<5 years of age) vs. adult
Temporal	Time	Time of the day (diurnal/crepuscular[morning and evening twilight] vs. night)
	Season	Hypophagia (May 1 - June 15); hyperphagia (June 16 - July 31); late hyperphagia (August 1 - October 15)
Road	Gate	Gate present/absent
	Mine	Gated road associated with mining and other land use activity
	Other	Gated road associated with forestry and/or oil and gas activity
	Type	No gate road classified as primary, secondary, or decommissioned

Table 2.2. Regression model loglikelihoods (LL), Akaike Information Criteria values (AICc) and Akaike weights (wi) used to predict variation in grizzly bear (n) habitat use in relation to gated roads by distance and type categories.

Road Distance	Road Type	Model	n	LL	*k*	AIC_c	ΔAIC_c	w_i
≤100 m	Mine/Other	Intercept	20	-43.54	1	89.30	4.44	0.03
		Gender	20	-40.08	2	84.86	0.00	0.27
		Age	20	-42.06	2	88.83	3.97	0.04
		Season	20	-41.04	3	89.58	4.72	0.03
		Gender + Age	20	-38.84	3	85.17	0.31	0.23
		Gender + Season	20	-37.2	4	85.07	0.21	0.25
		Age + Season	20	-39.62	4	89.90	5.04	0.02
		Gender + Age + Season	20	-36.01	5	86.30	1.44	0.13
	Forestry/Oil and Gas	Intercept	14	-29.72	1	61.78	0.00	0.47
		Gender	14	-29.63	2	64.34	2.57	0.13
		Age	14	-28.88	2	62.85	1.08	0.27
		Season	14	-28.87	3	66.15	4.37	0.05
		Gender + Age	14	-28.86	3	66.13	4.35	0.05
		Gender + Season	14	-28.85	4	70.14	8.36	0.01
		Age + Season	14	-28.34	4	69.11	7.34	0.01
		Gender + Age + Season	14	-28.3	5	74.10	12.32	0.00
100-500 m	Mine/Other	Intercept	20	-35.24	1	72.70	0.04	0.16
		Gender	20	-33.98	2	72.66	0.00	0.17
		Age	20	-34.45	2	73.60	0.94	0.10
		Season	20	-32.71	3	72.93	0.27	0.15
		Gender + Age	20	-32.89	3	73.27	0.61	0.12
		Gender + Season	20	-31.29	4	73.24	0.58	0.12
		Age + Season	20	-31.67	4	74.00	1.34	0.09
		Gender + Age + Season	20	-29.85	5	73.99	1.33	0.09
	Forestry/Oil and Gas	Intercept	15	-14.47	1	31.25	0.00	0.41
		Gender	15	-13.63	2	32.27	1.02	0.25
		Age	15	-13.75	2	32.49	1.25	0.22
		Season	15	-14.12	3	36.43	5.18	0.03
		Gender + Age	15	-13.34	3	34.87	3.62	0.07
		Gender + Season	15	-12.95	4	37.90	6.65	0.01
		Age + Season	15	-13.16	4	38.31	7.06	0.01
		Gender + Age + Season	15	-12.54	5	41.74	10.49	0.00

Table 2.3. Regression model loglikelihoods (LL), Akaike Information Criteria values (AICc) and Akaike weights (wi) used to predict variation in grizzly bear (n) habitat use in relation to non-gated roads by distance and type categories.

Road Distance	Road Type	Model	n	LL	*k*	AIC_c	ΔAIC_c	w_i
≤100 m	Primary	Intercept	9	-31.589	1	65.75	2.52	0.18
		Gender	9	-28.617	2	63.23	0.00	0.63
		Age	9	-30.418	2	66.84	3.60	0.10
		Season	9	-31.057	3	72.91	9.68	0.01
		Gender + Age	9	-28.38	3	67.56	4.33	0.07
		Gender + Season	9	-27.98	4	73.96	10.73	0.00
		Age + Season	9	-29.739	4	77.48	14.24	0.00
		Gender + Age + Season	9	-27.711	5	85.42	22.19	0.00
	Secondary	Intercept	26	-63.367	1	128.90	3.56	0.07
		Gender	26	-60.408	2	125.34	0.00	0.44
		Age	26	-63.108	2	130.74	5.40	0.03
		Season	26	-61.801	3	130.69	5.36	0.03
		Gender + Age	26	-59.856	3	126.80	1.47	0.21
		Gender + Season	26	-58.78	4	127.46	2.13	0.15
		Age + Season	26	-61.466	4	132.84	7.50	0.01
		Gender + Age + Season	26	-58.104	5	129.21	3.87	0.06
	Decommissioned	Intercept	14	-30.611	1	63.56	0.21	0.23
		Gender	14	-29.611	2	64.31	0.96	0.16
		Age	14	-29.855	2	64.80	1.45	0.12
		Season	14	-27.475	3	63.35	0.00	0.26
		Gender + Age	14	-28.665	3	65.73	2.38	0.08
		Gender + Season	14	-26.866	4	66.18	2.83	0.06
		Age + Season	14	-26.642	4	65.73	2.38	0.08
		Gender + Age + Season	14	-25.875	5	69.25	5.90	0.01
100-500 m	Primary	Intercept	25	-67.232	1	136.64	0.00	0.47
		Gender	25	-67.023	2	138.59	1.95	0.18
		Age	25	-67.041	2	138.63	1.99	0.17
		Season	25	-66.547	3	140.24	3.60	0.08
		Gender + Age	25	-66.868	3	140.88	4.24	0.06
		Gender + Season	25	-66.37	4	142.74	6.10	0.02
		Age + Season	25	-66.305	4	142.61	5.97	0.02
		Gender + Age + Season	25	-66.166	5	145.49	8.85	0.01
	Secondary	Intercept	26	-46.752	1	95.67	0.85	0.16
		Gender	26	-45.891	2	96.30	1.48	0.11
		Age	26	-46.302	2	97.13	2.30	0.08
		Season	26	-43.866	3	94.82	0.00	0.24
		Gender + Age	26	-45.261	3	97.61	2.79	0.06
		Gender + Season	26	-42.694	4	95.29	0.47	0.19
		Age + Season	26	-43.459	4	96.82	2.00	0.09
		Gender + Age + Season	26	-42.081	5	97.16	2.34	0.07

Decommissioned	Intercept	21	-44.457	1	91.12	0.00	0.49
	Gender	21	-44.341	2	93.35	2.22	0.16
	Age	21	-44.19	2	93.05	1.92	0.19
	Season	21	-43.881	3	95.17	4.05	0.06
	Gender + Age	21	-43.971	3	95.35	4.23	0.06
	Gender + Season	21	-43.813	4	98.13	7.00	0.01
	Age + Season	21	-43.566	4	97.63	6.51	0.02
	Gender + Age + Season	21	-43.413	5	100.83	9.70	0.00

Table 2.4. Regression model loglikelihoods (LL), Akaike Information Criteria values (AICc) and Akaike weights (wi) used to describe variation in grizzly bear (n=26) road crossings.

Model	LL	k	AIC_c	ΔAIC_c	wi
Null	-1026.63	1	2055.43	308.85	0.00
Biological	-1019.68	2	2043.88	297.29	0.00
Temporal	-1026.06	3	2055.21	308.62	0.00
Biological + Temporal	-1018.75	4	2044.06	297.47	0.00
Road	-873.273	5	1773.70	27.11	0.00
Road + Biological	-860.496	6	1753.81	7.22	0.03
Road + Temporal	-872.882	7	1766.18	19.59	0.00
Road + Temporal + Biological	-859.696	8	1746.58	0.00	0.97

4.7 Figures

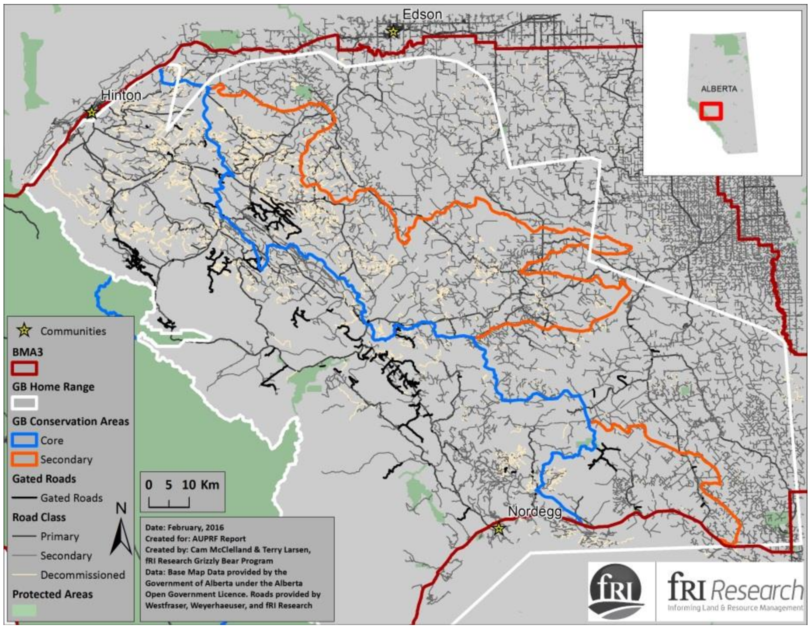

Figure 2.1. Study area map depiction roads with gates in relation to primary, secondary, and decommissioned roads.

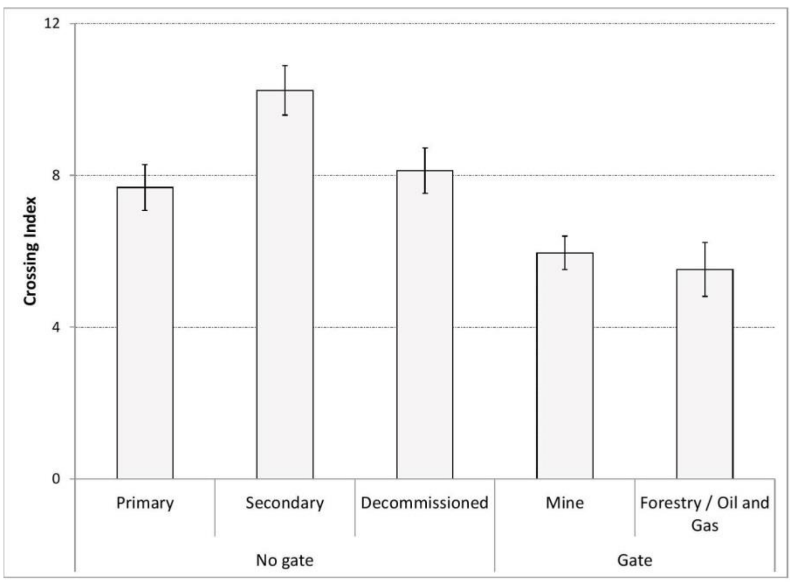

Figure 2.2. Regression model estimates (mean, standard error) representing grizzly bear (n=26) road crossings according to our road classification. Mean estimates represents other covariates (age class, time of day) held at their mean value.

5. Do oil and gas features predict the spatial abundance of grizzly bears in west-central Alberta?

5.1 Introduction

Wildlife managers need to understand what factors influence the distribution and abundance of animal populations to make informed decisions. This is particularly vital for threatened species where recovery efforts can be hastened if mitigation strategies are able to target those factors that potentially limit the population. In Alberta, grizzly bears are designated threatened due to lower than expected population size and ongoing impacts on their habitats from anthropogenic factors. Because the grizzly bear population in Alberta is believed to have declined from historic levels due to unsustainable levels of human caused grizzly bear mortalities, and recovery strategies to a large extent have been focused on reducing human-caused mortality risk associated with access. Considerable research has linked human access (proximity, density) to elevated levels of grizzly bear mortality risk, which consequently reduces bear survival that ultimately influences the demography and distribution and abundance of grizzly bears (Nielsen et al. 2004b, 2010; Boulanger et al. 2013; Boulanger and Stenhouse 2014).

Managing roads within a multiple use landscape presents a formidable challenge for land use managers given that the amount of road access present on the landscape today is relatively high and the future needs of multiple users this is likely to increase. One approach is to prioritize areas where road densities thresholds would be capped in an effort to enhance grizzly bear survival and population growth (Nielsen et al. 2009; Boulanger and Stenhouse 2014). Although this is an essential step towards mitigating the negative effects of roads in support of recovery, it does not allow for specific roads associated with certain land use practices to be targeted for management. Presumably land use activities such as oil and gas, which can dramatically increase road density, could disproportionately affect the survival and spatial distribution and abundance of grizzly bears. However, measures of road density are often correlated with other landscape features such as forestry cutblocks (Boulanger et al. 2013), but it is not known if different road types and their associated land use activities are similarly correlated. If not, specific roads could be targeted for management where the relationship between the distribution and abundance of grizzly bears is negatively associated with these features.

In this section, we investigate relationships between the abundance of grizzly bears to anthropogenic land use features specifically associated with oil and gas activity within a portion of the Yellowhead population unit (BMA 3). Our approach was to use the 2014 grizzly bear population inventory dataset (Stenhouse et al. 2015) to spatially relate counts of unique male and female grizzly bears to underlying habitat conditions associated with different types of roads and land use activities using a regression model. We then use an information theoretic approach to evaluate support for our working hypothesis, which is that roads, particularly secondary access (roads that connect to primary [major] access routes and that are typically associated with development from the energy sector) routes and features (pipelines, well-sites) associated with oil and gas activity would be a better predictor of grizzly bear abundance than all roads combined. Furthermore, these types of roads in association with oil and gas activities are often attractive to grizzly bears likely because of seasonal food resources(Roever et al. 2008; Laberee et al. 2014; McKay et al. 2014).

5.2 Methods

5.2.1 Grizzly bear abundance data

We used the genetic library of the fRI Research Grizzly Bear Program to identify unique male and female grizzly bears. The genetic information was collected as part of the 2014 DNA –based capture-mark-recapture population inventory work conducted within a portion of the Yellowhead population unit (BMA 3) (Figure 5.1) (Stenhouse et al. 2015). The 2014 census was designed, in part, to compare the distribution and abundance of grizzly bears by resampling 153 of the original cells (7 x 7) inventoried during the 2004 census (Figure 5.2). Although the 2014 census area expanded to include other portions of BMA 3, the White Goat Wilderness, and the south half of Jasper National Park, for our purpose, we only considered the 153 cells that occurred largely within the provincial land base. The gender and unique id of each grizzly bear was determined by genotyping (8 markers) hair samples collected bi-weekly at barbwire hair snag sites; sites were sampled four times (sessions) between June and July and at each visit scent lure was added to attract bears (Woods et al. 1999; Boulanger et al. 2006). There were only three cases where sites were only visited three times due to late snow conditions at the higher elevations. We calculated the number of unique male and female grizzly bears within each of the grid cells (sample unit).

5.2.2 Land use mapping

We used spatial databases representing the Alberta road network, active open pit coal mines, and features associated with energy sector (well-sites, pipelines) to map landscape conditions circa 2014. We classified roads (excluding decommissioned or reclaimed) as either primary (main access routes) or secondary (roads that connect to main access routes) road types that were determined from attribute information. In addition, we identified roads that were most likely associated with oil and gas activities using attribute information from Alberta Energy and the Government of Alberta (DIDs data) or through examination of SPOT imagery. For each grid cell, we calculated the number of well-sites and the density of pipelines as well as the density of roads. Roads were distinguished according to type and land use activity and categorized as: 1) all roads; 2) secondary roads not associated with oil and gas activity; 3) primary roads associated with oil and gas activity; and 4) secondary roads associated with oil and gas activity. Decommissioned (reclaimed) roads were not considered in our calculations.

5.2.3 Modeling grizzly abundance associated with land use

We used ordinal logistic regression to model the relationship between male and female grizzly bear abundance (ordinal categories: 0=1; 1=2; and ≥2=3) in relation to anthropogenic land use features. To determine support for or against our working hypothesis, we used an information theoretic approach (Akaike Information Criteria [AIC]) to select a best model from our candidate set determined and structured a priori (Anderson et al. 2000). The candidate models included: 1) null (intercept-only); 2) road density (all roads); 3) density of primary roads not associated with oil and gas activity; and 4) density of primary and/or secondary roads associated with oil and gas activity. AIC values were then used to select the most parsimonious model, and Akaike weights were used to evaluate the probability that a model would be selected given those in the candidate set (Anderson and Burnham 2002). Due to issues of collinearity ($r>0.7$) and multicollinearity ($VIF>3$), we did not consider well-sites or pipelines in our analysis because these variable were strongly correlated with secondary roads associated with oil and gas activity. Significance tests were used to meet the parallel regression assumption inherent in ordinal logistic regression, and we used K-fold ($k=5$) cross validation to assess the fit (pseudo-R-squared) of the top AIC selected models.

5.3 Results

Of the 153 cells we focused on in this study, 63 were occupied by grizzly bears. Considering those occupied cells, we found 16 instances where male and female bears occupied the same cell, whereas 24 were solely occupied by males and 23 by females.

Counts of unique bears varied between occupied grid cells both for males (mean=1.7, median = 1, SD = 1.2, max = 7) and females (mean = 1.5, median = 1, SD = 0.8, max = 4). Road density also varied on the grid and differed by road type and land use designation (Table 5.1).

Our top AIC selected model for both male and female grizzly bears was the all roads density variable (Table 5.2). However, Akaike weights suggested that a model containing the effect of primary roads associated with oil and gas for males and secondary roads associated with oil and gas for females was also supported. This could be explained by the relatively high correlation between all roads and the energy sector roads (primary oil and gas |r=0.59|; secondary oil and gas |r=0.66|) we examined. Although both male (β = -1.86, S.E. = 0.70, P <0.01) and female (β = -1.36, S.E. = 0.68, P = 0.05) models were significant and yielded a significant negative effect associated with road density (all roads) (Figures 5.3 & 5.4), model evaluation (K-fold cross validation) suggested poor fit to the data (Table 5.3). Although the predictive ability of the ordinal models are questionable, the relationship between the distribution (outcome 0 [positive]) and abundance (outcomes 1 & 2 [negative]) of grizzly bears in relation road density (all roads) is consistent between males and females (Figure 3 & 4).

5.4 Discussion

Our hypothesis that the density of secondary access routes associated with oil and gas activity would be negatively correlated with relative grizzly bear abundance was confirmed, but the model that fit the data the best based on the principles of parsimony was road density (all roads). This suggests that the problem of roads relative to grizzly bear mortality risk is not dependent on the type of road or the associated land use activity, and that current management strategies to focus entirely on road densities are warranted and supported by this research and also work by Nielsen et al. 2009; Boulanger and Stenhouse 2014). However, Akaike weights of less than 0.9 for both the male and female models suggested that support for this model was not overwhelming, and that secondary roads associated with oil and gas activity was also important. This was likely due to moderate levels of correlation (0.66) that we observed between these variables. Collectively, this suggests that efforts to manage the density of roads within grizzly bear range should consider secondary access routes associated with oil and gas activities specifically as part of access management planning and implementing mitigation strategies.

Anthropogenic disturbance history can have lasting effects on grizzly bear populations through long-term exposure to human-caused mortality risk (Linke et al. 2013). For this reason, access management is viewed as a critical step towards achieving recovery and maintaining self-sustaining grizzly bear populations (Merrill et al. 1999; Austin 2004; Summerfield et al. 2004; Alberta Grizzly Bear Recovery Team 2008; Nielsen et al. 2009; Festa-Bianchet 2010).

Our study along other research conducted in Alberta and elsewhere highlights the need to reduce human access (road density) as part of management given the negative association between roads and grizzly bear occurrence and abundance (Mowat et al. 2005; Nielsen et al. 2010; Boulanger and Stenhouse 2014). Roads may impact grizzly bear populations indirectly through its effect on survival (Boulanger and Stenhouse 2014), and can directly influence bears through avoidance behavior. McKay et al. (2014) found that grizzly bears were more likely to utilize disturbed habitats (well-sites) in areas of lower road density. Because use of well-sites by bears are often associated with foraging behavior, road densities may reduce foraging opportunities for certain individuals that tend to respond negatively. Pigeon et al. (2014) showed that areas suitable for denning could be reduced in areas of high road densities, which could compromise an important life history strategy.

5.5 Management recommendations

Access management strategies in grizzly bear habitat in Alberta should aim to reduce road densities whenever possible. This can be achieved by installing and actively maintaining locked gates in strategic locations, establishing seasonal closures, or decommissioning roads. Managers should also aim to reduce the amount and lifespan of roads scheduled to be built because human-caused mortality risk can have lasting effects at the population level. It is also important to point out that the observed relationships between road densities and bear mortalities is not simply a function of road densities per se, but rather the relationship between people using these roads and their behaviour towards bears that may be encountered. Therefore there may be a needed shift in identifying ways to manage people who are using these access features.

5.6 Tables

Table 5.1. Summary statistics of road density (km/km2) by road category (type and land use) used to explain variation in relative grizzly bear abundance. Statistics are based on 153 grid cells sampled during the 2014 inventory of the Yellowhead population unit (BMA 3) in west-central Alberta.

Road Category	Mean	S.D.	Min	Max
All roads	0.40	0.29	0	1.25
Secondary roads (no oil and gas)	0.09	0.14	0	0.67
Primary roads (oil and gas)	0.09	0.11	0	0.55
Secondary roads (oil and gas)	0.16	0.17	0	0.82

Table 5.2. Log likelihood, AIC score, and Akaike weight (wi) for ordinal logistic regression models selected a priori.

Gender	Model	LL	k	AIC	ΔAIC	w_i
Male	Intercept-only	-114.4	1	230.74	5.77	0.03
	All roads	-110.5	2	224.97	0.00	0.55
	Other roads	-113.1	2	230.29	5.31	0.04
	Energy sector roads	-110.9	2	225.74	0.76	0.38
Female	Intercept-only	-111.7	1	225.35	2.23	0.14
	All roads	-109.6	2	223.12	0.00	0.42
	Other roads	-111.6	2	227.25	4.13	0.05
	Energy sector roads	-109.6	2	223.27	0.15	0.39

Table 5.3. Likelihood ratio (LR) χ2test and associated significance (P), McFadden's R2, and model evaluation (pseudo-R-squared) using K-fold (mean and range) cross validation.

Model	LR χ^2	*P*	R^2	K-fold
Male	7.76	<0.01	0.03	0.07 (0.01-0.16)
Female	4.23	0.04	0.02	0.03 (0.01-0.09)

5.7 Figures

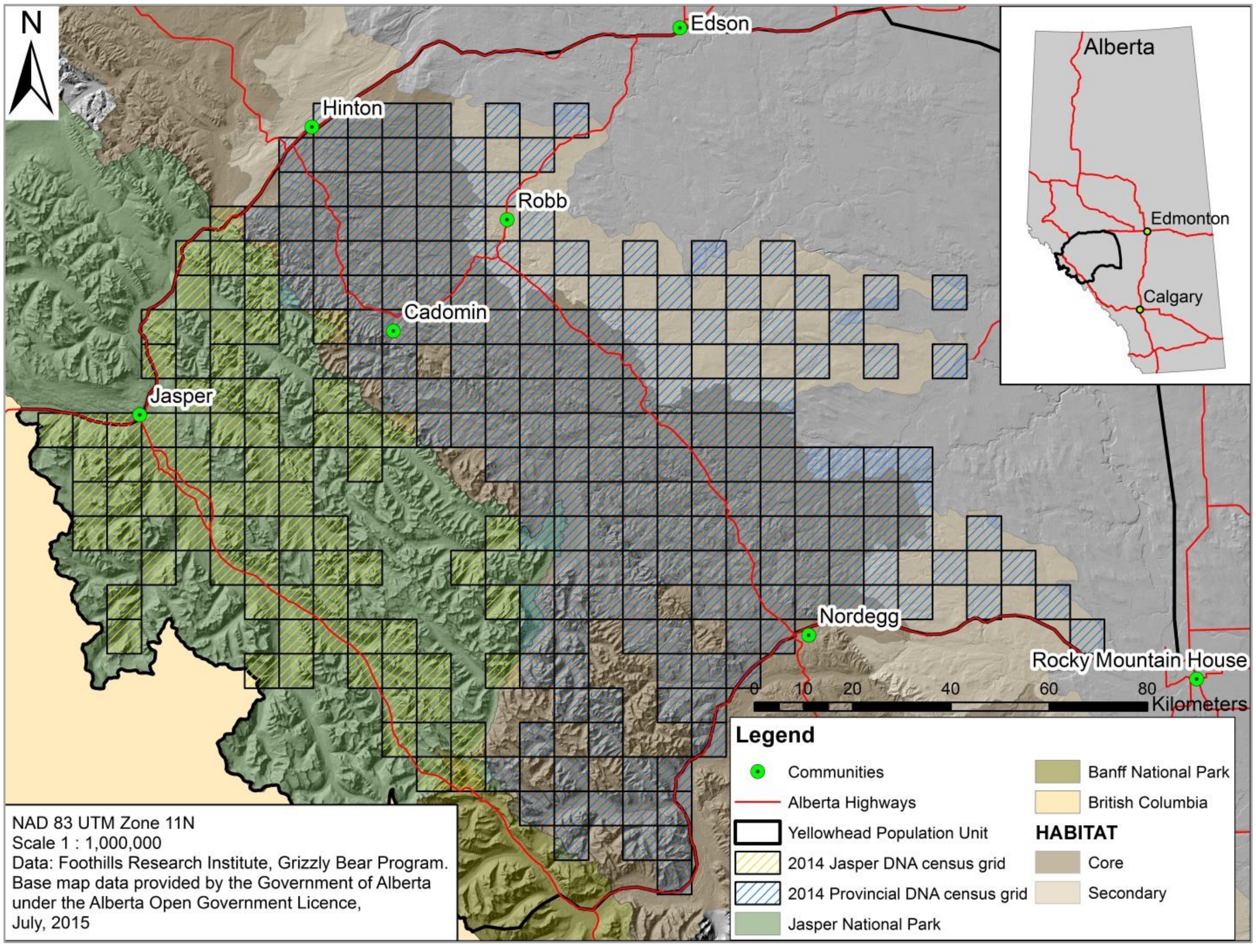

Figure 5.1. Census grid cells (7 x7 km) used to inventory grizzly bears witin the Yellowhead population unit (BMA 3). Parks and protected areas along with core and secondary conservation areas are displayed.

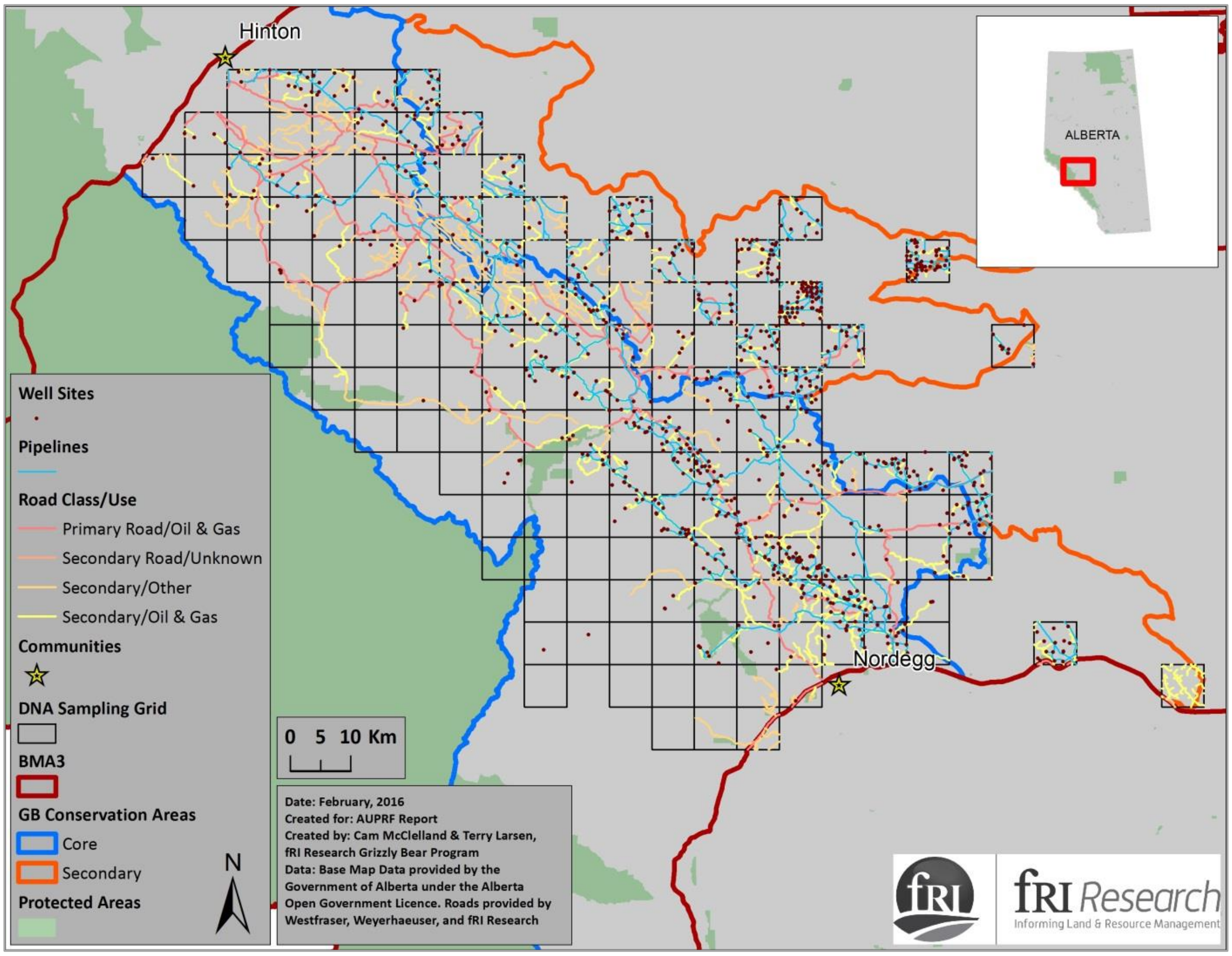

Figure 5.2. Map depicting grid cells (7 x7 km) sampled for the 2004 and 2014 grizzly bear inventory work and in relation to anthropogenic land use features (roads, well-sites, and pipelines). The boundaries of parks and protected areas as well as core and secondary grizzly bear conservation areas are shown.

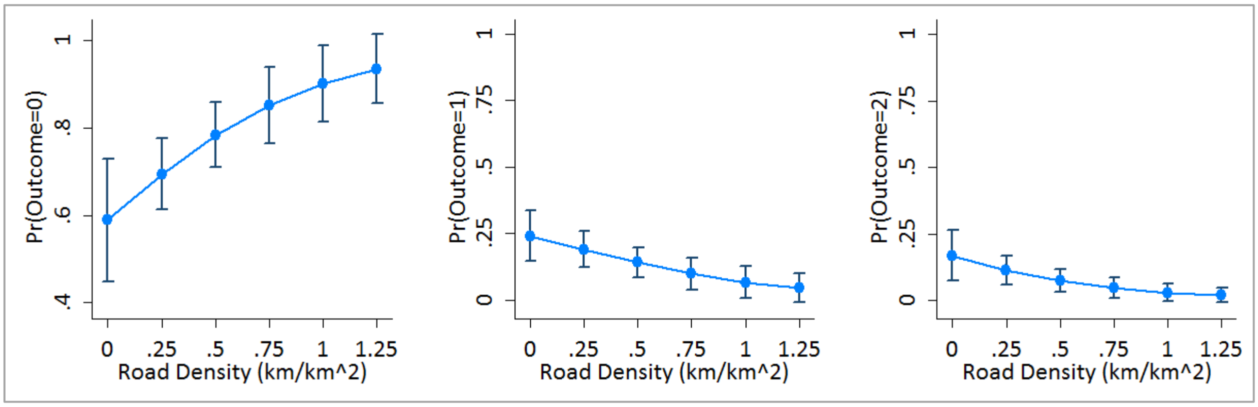

Figure 5.3. Relative probability of an outcome (0[left]; 1[middle]; and 2[right]) as a function of road density for ordinal logistic regression models describing the abundance of male grizzly bears within a portion of the Yellowhead bear management unit (BMA 3). Outcome refers to our dependent variable; 0=no bears, 1=one unique bear, 2=two unique bears

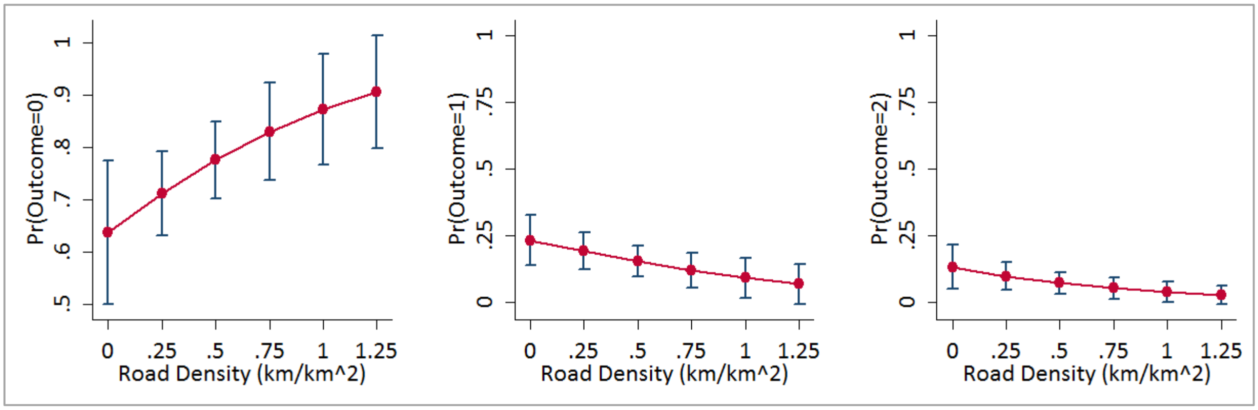

Figure 5.4. Relative probability of an outcome (0 [left]; 1[middle]; and 2[right]) as a function of road density for ordinal logistic regression models describing the abundance (outcome 0-2) of female grizzly bears within a portion of the Yellowhead bear management unit (BMA 3). Outcome refers to our dependent variable; 0=no bears, 1=one unique bear, 2=two unique bears.

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