Grizzly bears and pipelines:
response to unique linear features

Year 2 (2013) Final Report
Alberta Upstream Petroleum Research Fund
(13-AU-ERPC-03)

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March 2014

Acknowledgements

Appreciation is extended to all who helped out over the two years of this project. Many thanks for the work of our field crews, including Leonie Brown, Lindsey Dewart, Michael Oliveira, Chris Sharp, Amy Stenhouse, and Paul Stenhouse. Julie Duval, Darren Wiens, and Kevin Myles provided extensive assistance with GIS analysis and data management for all sections of this project. Thanks to Karine Pigeon, Terry Larsen, and Etienne Cardinal for advice and assistance with study design, analysis, camp logistics, and help in the field. Appreciation is also extended to Tom Churchill from Alberta Energy, for his patience and assistance with the original pipeline dataset. Thanks to Alberta Environment and Sustainable Resource Development for their use of the Kakwa camp and for additional support, and thank you to Amit Saxena and Fauve Blanchard of Devon Energy Corporation, who volunteered as our AUPRF Project Managers.

This project would not have been possible without funding provided by the Alberta Upstream Petroleum Research Fund, TransCanada Pipelines, and Pembina Pipelines. Thanks also go out to the many other partners of the Foothills Research Institute Grizzly Bear Program, for contributing to this long term data set.

Executive Summary

This report includes results from two years of research investigating grizzly bear response to oil and gas pipelines in the Kakwa region of west-central Alberta. We investigated grizzly bear habitat selection patterns on pipeline RoWs and other linear features, parameters influencing the use of pipeline Rows, bear food occurrence on pipelines, the spatial relationship between grizzly bear predation and linear features, and factors that influence grizzly bear mortality risk on pipelines.

Grizzly bears used pipelines, pipeline-road right-of-ways, and roads significantly more than expected based on availability. Male bears also used seismic lines more than expected, while female bears appeared to avoid seismic lines during spring and fall. A number of bear foods were more common on pipeline RoWs and edges than in other available habitats, including dandelion, clover and ants, known to be important bear foods in our region. There were differences between age-sex classes in use of pipeline habitat, with some sexual segregation of habitat use. Bears were more likely to use younger pipelines (mean age ~ 7 years) and pipelines in areas of lower pipeline and road densities. Our spatial analysis of grizzly bear predation sites did not find evidence that ungulate predation events occurred close to linear features.

Analysis of factors influencing grizzly bear mortality risk on pipelines indicated that sightability of bears from pipeline-road intersections was most influenced by topography and shrub cover. All pipelines investigated in our study were used by people and by grizzly bears, suggesting that bear-human encounters could occur on pipeline RoWs.

Based on our research findings over two years, we believe that grizzly bears use pipeline RoWs primarily for travel and foraging, and that the presence of bear foods along these RoWs plays a role in their selection.

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Background

Approximately 350,000 km of oil and gas transmission pipelines have been constructed on the Alberta landscape (Alberta Environment and Sustainable Resource Development 2013). Understanding grizzly bear habitat use and response to these linear features is important for effective conservation, management, and recovery of this threatened species. This information may also be useful for mitigation actions related to pipeline development planning. Other wildlife species such as woodland caribou (*Rangifer tarandus*) are reported to avoid linear features (James & Stuart-Smith 2000, Dyer et al. 2001). Previous research has also shown that wolves may use linear corridors as travel routes (Thurber et al. 1994, Musiani et al. 1998, James & Stuart-Smith 2000, Whittington et al. 2005, McKenzie et al. 2012). Despite the fact that pipelines have been a part of the Alberta landscape for several decades, there has been limited research published regarding the response of grizzly bears to pipelines in North America. Labaree et al. (2014) reported that grizzly bears in the Kakwa area were not farther than expected from pipelines during the spring, while response during other seasons depended on age-sex class and time of day. Grizzly bear use of the edges created by pipelines has also been reported in the Kakwa region (Stewart et al. 2013). However, grizzly bear habitat use and movement at the small spatial scale of linear feature RoWs has not been previously published.

The Foothills Research Institute Grizzly Bear Program (FRIGBP) has been working in the Kakwa region of west central Alberta since 2005 (Figure 1). Grizzly bear location data along with the presence of extensive linear features in this region provide an opportunity to investigate grizzly bear response to pipelines. In 2012, the FRIGBP initiated an AUPRF-funded study to address the knowledge gap regarding grizzly bears and pipelines, and this research was continued into a second year (2013). This report constitutes the final summary of this two year project.

In the first year of this project (2012), we focused on the primary knowledge gaps around grizzly bears and pipelines, including habitat selection patterns, grizzly bear activities, and movement patterns. Preliminary results from the first year of this study suggested that some grizzly bears may use pipelines and other linear feature RoWs more than expected based on habitat availability. Analysis of field data from the first year of this study also indicated that bears were using pipeline RoWs for a range of foraging activities, with anting as the most common activity. An analysis of movement rates in the first year showed that grizzly bears traveled significantly faster on road RoWs, road-pipeline RoWs, pipeline RoWs, and seismic RoWs as compared to in non-linear habitat, suggesting that linear feature RoWs may serve as movement corridors for grizzly bears in our study area.

Research objectives in 2012 and 2013 were addressed by utilizing and expanding upon our existing grizzly bear GPS location dataset in the Kakwa study area. GIS analyses of existing data were supplemented by fieldwork in 2012 and 2013 at selected sites within the region. Based on preliminary results suggesting that bears may use pipelines, in the second year of this project (2013) we were interested in determining what parameters may predict grizzly bear use of pipelines, including: pipeline attributes, the characteristics of the surrounding landscape, and bear food availability on pipeline RoWs compared to the surrounding habitat. In addition, based on evidence that grizzly bears may be using RoWs for movement, we investigated whether bears may be using RoWs for access to ungulate prey.

Linear corridors also provide human access into remote grizzly bear habitat. Pipeline RoWs may be used for a variety of human activities, including ATV travel, hunting, and general recreation. In addition, pipelines are often constructed next to roads, and frequently intersect with roads. Human-caused mortality is considered to be the primary limiting factor for grizzly bears in Alberta (Alberta Sustainable Resource Development [ASRD] 2008), and areas with a higher level of human access are associated with an increased risk of human-caused grizzly bear mortalities and lower survival rates (Jalkotzy et al. 1997, Benn 1998, Nielsen et al. 2004a, Boulanger et al. 2013). Grizzly bear use of pipelines has the potential to increase their exposure to humans and subsequently increase the risk of human-caused grizzly bear mortality. In the second year of this project, we also investigated factors associated with pipeline RoWs that could increase the probability of bear-human encounters, including the visibility of bears on pipelines from roads and the actual levels of human use on RoWs.

Study Area

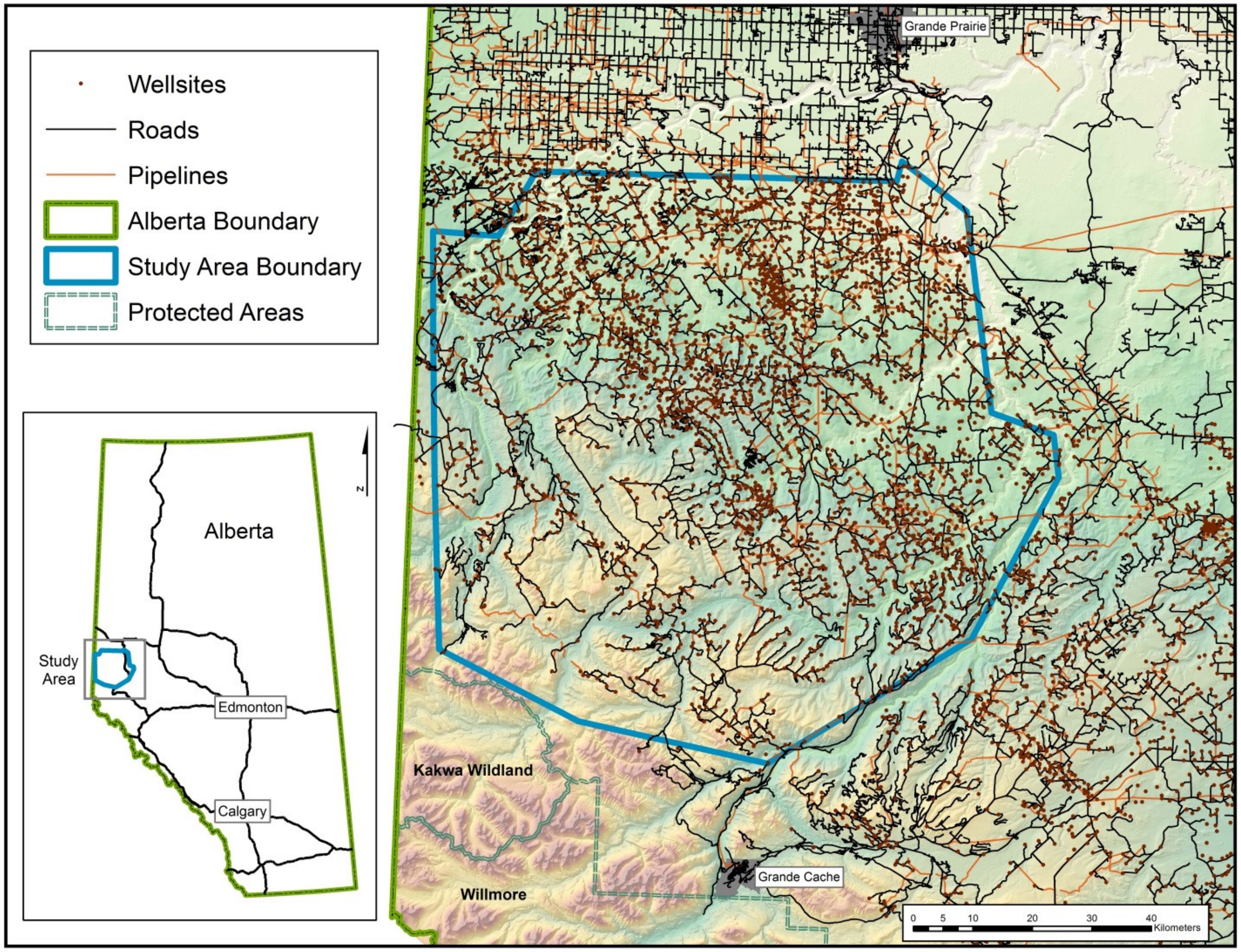

Figure 1: Kakwa study area.

Research objectives

Objectives in the second year of this project expand on knowledge gained in the first year, and incorporate additional data obtained in 2013 into the initial (first year) habitat use analysis:

I. Analysis of grizzly bear habitat selection patterns on pipeline RoWs:
   a. Do grizzly bears use pipelines and other linear features more, less, or no differently than expected?
   b. How do selection patterns compare between linear feature types?

II. Determination of parameters influencing use of RoWs:
   a. Is grizzly bear use of pipeline RoWs influenced by pipeline characteristics and/or adjacent habitat and/or other landscape characteristics?
   b. Is grizzly bear use of pipelines influenced by food availability on RoWs?

III. Investigation of the use of RoWs for predation:
   a. What is the spatial relationship between linear features and grizzly bear predation sites?

IV. Evaluation of factors that might influence grizzly bear mortality risk on pipelines:
   a. What is the sightability of grizzly bears on RoWs from current road access features?
   b. What parameters predict sightability of grizzly bears on pipeline RoWs?
   c. What is the level of human use along pipeline RoWs, what are the types of use (i.e. recreational, pipeline maintenance, hunting), and are there seasonal differences?

Chapter 2: Grizzly bear habitat selection patterns on pipeline right-of-ways

Introduction

Within west-central Alberta, researchers have reported that grizzly bears select for cutblocks (Nielsen et al. 2004b, Stewart et al. 2012), wellsites (Sahlen 2010, McKay et al. 2011) and roads (Roever et al. 2008a, Graham et al. 2010). Other authors have reported grizzly bear use of pipeline edges (Stewart et al. 2013), and Labaree et al. (2014) reported that grizzly bears were not farther than expected from pipelines during the spring. However, patterns of grizzly bear habitat use directly at linear feature RoWs have not been previously reported.

The main objective of our analysis was to determine how grizzly bears respond to pipeline right of ways. However, in investigating grizzly bear use of pipeline RoWs, it is also important to acknowledge the presence of many other linear features on the landscape. Therefore, we also investigated how use of pipelines differs from grizzly bear selection patterns of other linear features such as roads and seismic lines. Habitat selection can vary with age-sex class and season (Nielsen 2005, Berland et al. 2008, Graham et al. 2010, Roever et al. 2010) and these factors were also considered in our analysis of grizzly bear use of linear features. Building on results from Year 1 of this study, we expanded our dataset in Year 2 to include data from 2013.

Methods

Grizzly bear location data:

Location data were obtained from collared grizzly bears within the Kakwa study area during 2006-2013. Aerial darting, leg-hold snaring, and culvert traps were used to capture grizzly bears; all trapping and collaring efforts met or exceeded the standards of the Canadian Council of Animal Welfare (animal use protocol number 20010016, G. Stenhouse, pers. comm.). Capture procedures are described in Cattet et al. (2003a, 2003b). The capture of bears using leg hold snares was stopped in 2008, following results indicating long term effects with this capture technique (Cattet et al. 2008).

Bears were fitted with Televilt (Followit) or Telemetry Solutions GPS collars. Data from collars were collected remotely using monthly Very High Frequency (VHF) data upload equipment during fixed-wing aircraft flights during 2006 to 2012, and/or via satellite transmissions during 2011 to 2013. Across the years of data collection, collars were programed for a range of GPS acquisition schedules, including hourly fixes, every two hours, 4 hour fixes, and 6 hour fixes. We also observed variation across the collars with regards to the success rate of obtaining fixes. Missed GPS fixes or low fix rates have the potential to introduce bias in habitat selection analysis (Frair et al. 2004). To reduce GPS fix rate bias (Friar et al. 2004), we limited our dataset to collars that obtained ≥4 fixes per day.

Televilt collars average 18m and 265m error distances for 3D and 2D locations respectively (Sager-Fradkin et al. 2007), and Telemetry Solutions collars are assumed to have similar accuracy. Due to the small spatial scale of linear features in our analysis, we removed 2D locations from our dataset to reduce the potential for location errors.

To define the area available to an animal, we determined annual home ranges as Minimum Convex Polygons (MCPs) (Nielsen et al. 2004b, Roever et al. 2008a). MCPs were generated in a Geographic Information System (ArcGIS) using ACCRU tools. The ACCRU tool runs a Python script in ArcInfo, and draws a line around the outermost points in the dataset (personal communication, Charlene Nielsen, University of Alberta).

To standardize sampling intensity for random (available) locations, we generated random locations at a density of five points per square kilometer within each MCP, based on the area of the home range for each bear (Nielsen et al. 2004b, Roever et al. 2008a). For MCPs that extended outside of the Kakwa study area, only use and available points that fell within the study area boundary were used in analysis. Den entry and exit dates were determined for each bear, based on when GPS collars stopped collecting data in the fall, and started successfully obtaining fixes again in the spring. Only non-denning locations were retained in the final dataset. Use locations were separated by established foraging seasons for our area, including hypophagia (spring; May 1^{st} to June 15th), early hyperphagia (summer; June 16^{th} to July 31st), and late hyperphagia (fall; August 1^{st} to October 31^{st}) (Nielsen 2005). For each season, we restricted our analysis to bears with GPS collar locations that included at least half of that season. Based on previous knowledge that habitat selection can vary between the sexes, data were grouped by sex class, but only two classes were included (i.e. females and males), as age-sex class/reproductive status were included as a variable in our investigation of parameters influencing the use of pipelines.

Linear feature datasets:

Linear pipeline data (updated to 2013) were obtained from Alberta Energy; these data were originally provided to Alberta Energy by pipeline operators in the Kakwa area. Roads data were obtained from Alberta Environment and Sustainable Resource Development (AESRD), and were manually updated on an annual basis by FRIGBP staff. Power transmission lines (powerlines) and seismic line data were also provided by AESRD. Seismic line data were last updated in 2008; however, the vast majority of seismic lines built after 2008 were low-impact seismic. Tigner et al. (2013) found that black bear use of seismic lines ≤2m wide was not different than habitat use of undisturbed forest. Low-impact seismic lines in our study area are meandering, narrow in width (≤ 3m), and difficult to discern in remote sensing imagery. Therefore, we did not consider low-impact seismic lines as significant linear features for the purpose of our analysis, and we used only conventional seismic lines constructed prior to 2008.

A construction date was provided for the majority of the pipeline segments. For those pipelines without a construction date, a construction year was determined using satellite imagery. For multi-pass pipelines, we applied the earliest construction date, to represent the year the RoW first appeared on the landscape. Other linear feature datasets were limited in accuracy with regards to construction dates. Roads data included a “built before” year, while powerlines and seismic lines could be assigned an approximate construction period.

Based on the limitations in the data regarding, assigning a specific construction date (i.e. month and day) or season to the linear feature segments was not appropriate; therefore, we generated annual linear feature datasets. Pipeline data that originally included a construction date were assigned to annual datasets as follows: construction dates prior to August 1st for a given year were considered to be present on the landscape during that year and any subsequent years. Pipelines with a minimum construction date on or after August 1st were only considered present on the landscape during subsequent years. The cutoff of August 1st was selected to maintain consistency with other linear feature datasets; SPOT imagery used to confirm construction years was usually captured in early August, therefore this date corresponded with the dates used to designate built-before years for roads. The majority of pipeline segments built during 2006-2013 were constructed during January to April (before den exit) or November and December (after den entry); therefore, this cutoff date was applied to a relatively small number of pipeline segments.

All linear feature data were initially represented as line segments; therefore, we needed to generate a dataset that represented the actual areas of the features on the ground. We calculated the median RoW width for pipelines as measured at over 300 RoWs in the field. To determine median RoW widths for the various road classes, powerlines, and seismic lines, random locations were generated along the linear features and overlaid on LiDAR imagery in a GIS. LiDAR imagery was generated by subtracting 0.5 m heights from bare earth, making road and vegetated right-of-ways discernible. The width of the linear feature was measured at each random point using the GIS measuring tool. Median widths for all linear features were divided by half for use as a buffer along each side of the linear feature line segment. The relatively narrow footprint of linear features also makes them sensitive to collar location errors. To account for collar error, we added 18m (3D collar error distance, see above) on each side of a linear feature polygon. McKenzie et al. (2009, 2012) applied a similar approach in their investigation of wolf movements on seismic lines, buffering their line data by the average seismic RoW width plus estimated collar error.

The final median widths and buffers applied to each linear feature class are summarized in Table 1. In the case of overlapping adjacent buffers (e.g. a pipeline next to a road), pipeline or powerline buffers that overlapped with road buffers were identified as a unique linear feature, and were subsequently classified as road-pipeline or road-powerline combined RoWs. In areas where linear features intersected, precedence was given to the feature with the largest RoW width, followed by the feature with the highest level of human disturbance (e.g. roads versus pipelines). Features with higher precedence replaced those with lower precedence if they coincided on the landscape. Powerlines took precedence over pipelines (individually and in combined RoWs). For roads, paved roads took precedence over gravel, which took precedence over unimproved roads. As the smallest features, seismic lines took the lowest priority, and were overridden by any other linear feature. The end result was a polygon dataset representing the approximate areas of each class of linear feature on the ground.

Table 1: Buffers applied to linear features in the Kakwa study area, based on widths measured in the field or using a GIS.

Linear Feature Class	Sample Size	Median/2 (m)	Collar Error (m)	Final buffer width (m) (applied to both sides of line segment)
Pipeline	322	10	18	28
Roads: unimproved	27	8	18	26
Roads: one and two lane gravel	29	18	18	36
Roads: paved	5	38	18	56
Power transmission lines	5	35	18	53
Seismic lines	20	3	18	21

Using the polygons generated by the above buffers, habitat within the Kakwa study area was classified into five groups: pipeline RoWs, pipeline-road combined RoWs, roads, seismic lines, and the remaining non-linear habitat.

Analysis:

Methods used for the habitat analysis in the first year of this study were based on selection ratios. The assumptions of the Chi-square test used in calculation of selection ratios are not met if expected values are less than five, and standard errors and confidence limits are not reliable if observed values are less than five (Manly et al. 2002). A number bear location datasets did not meet these criteria, and were excluded from our sample in Year 1. In the current analysis, we applied a different technique, and maintained a larger sample size for the analysis. It is expected that results may differ slightly between the two analyses.

For each year of data, use and available locations for each bear were intersected with the annual linear feature dataset for that year. We compared bear locations (use) with random (available) locations to assess the probability of habitat selection for pipelines, roads, pipeline-road RoWs, and seismic lines versus expected habitat use based on availability. We calculated a random effect resource selection function (RSF) model at the population level for each season (spring, summer, and fall) using a generalized linear mixed-effects logit model (gllamm) in Stata 12.1^{TM} (StataCorp, Texas, U.S.A). Use and available were defined by individual bear (“design III”, Manly et al. 2002), and individual bear was included as the random effect (random intercept) to account for the unbalanced sample among bears. To allow the estimation of a resource selection probability function where each of the habitat categories has a different probability of use (Manly et al. 2002), indicator variables with 0/1 values were created corresponding with the five habitat categories (pipelines, roads, pipeline-road RoWs, seismic lines, non-linear habitat). Results for each habitat class were reported as coefficients with 95% confidence intervals, interpreted as the use of each habitat class compared to that expected based on habitat availability, with a significance level set at p=0.05.

We also compared habitat selection between the different linear feature types. Each use and available point was assigned a habitat class from 1 to 5, with non-linear habitat as the reference category. We ran a random effects logit model (xtlogit) in Stata 12.1^{TM} (StataCorp, Texas, U.S.A) for each season (spring, summer, and fall) with individual bear as the random intercept. For each seasonal model for females and males, pairwise comparisons of marginal linear predictions were generated to contrast habitat selection between the different linear feature types. Bonferroni corrections were applied to 95% confidence intervals for pairwise comparisons to adjust for multiple comparisons across habitat classes, with an overall significance level set at p=0.05.

Results

During 2006 to 2013, a total of 125,624 collar locations were collected from 30 individual grizzly bears, including 15 females and 15 males. Spring, summer, and fall datasets included 20, 29, and 22 bears, respectively.

In the spring, female bears used pipelines, pipeline-road RoWs, and roads significantly more than expected based on habitat availability, but seismic lines were used significantly less than expected (Table 2). During summer, females again used pipelines, pipeline-road RoWs, and roads more than expected, while use of seismic lines was not significantly different than expected (p=0.13). The pattern in the fall was the same as the spring, with use of pipelines, pipeline-road RoWs, and roads significantly greater than expected, and use of seismic lines significantly less than expected (Table 2).

Table 2. Seasonal model coefficients, standard errors, and 95% confidence limits for female grizzly bear habitat selection of linear features. Results in bold indicate that use was significantly different than expected based on habitat availability.

					95% CI	
	Linear feature	**β**	**SE**	**p**	**Lower**	**Upper**
Spring	Pipeline	**0.389**	**0.078**	**<0.001**	**0.237**	**0.542**
	Pipeline-road RoW	**0.445**	**0.046**	**<0.001**	**0.355**	**0.535**
	Road	**0.262**	**0.053**	**<0.001**	**0.159**	**0.365**
	Seismic line	**-0.226**	**0.045**	**<0.001**	**-0.314**	**-0.138**
Summer	Pipeline	**0.889**	**0.060**	**<0.001**	**0.772**	**1.007**
	Pipeline-road RoW	**0.989**	**0.036**	**<0.001**	**0.919**	**1.059**
	Road	**0.684**	**0.042**	**<0.001**	**0.602**	**0.766**
	Seismic line	0.056	0.037	0.129	-0.016	0.129
Fall	Pipeline	**0.644**	**0.055**	**<0.001**	**0.538**	**0.751**
	Pipeline-road RoW	**0.650**	**0.034**	**<0.001**	**0.583**	**0.716**
	Road	**0.487**	**0.039**	**<0.001**	**0.410**	**0.565**
	Seismic line	**-0.165**	**0.033**	**<0.001**	**-0.230**	**-0.100**

For male bears, pipelines, pipeline-road RoWs, roads, and seismic lines were all used more than expected based on availability in the spring, summer, and fall (Table 3).

Table 3. Seasonal model coefficients, standard errors, and 95% confidence limits for male grizzly bear habitat selection of linear features. All results are significantly different than expected based on habitat availability.

					95% CI	
	Linear feature	**β**	**SE**	**p**	**Lower**	**Upper**
Spring	Pipeline	0.431	0.112	<0.001	0.211	0.651
	Pipeline-road RoW	0.377	0.069	<0.001	0.241	0.513
	Road	0.352	0.086	<0.001	0.183	0.521
	Seismic line	0.293	0.057	<0.001	0.181	0.405
Summer	Pipeline	0.683	0.071	<0.001	0.543	0.823
	Pipeline-road RoW	0.655	0.044	<0.001	0.568	0.742
	Road	0.592	0.053	<0.001	0.488	0.696
	Seismic line	0.257	0.040	<0.001	0.178	0.336
Fall	Pipeline	0.981	0.071	<0.001	0.842	1.120
	Pipeline-road RoW	0.550	0.049	<0.001	0.453	0.646
	Road	0.489	0.060	<0.001	0.373	0.606
	Seismic line	0.754	0.038	<0.001	0.680	0.827

In comparing probability of use of the different linear features, females used seismic lines significantly less than all other linear features in the spring, summer, and fall (Table 4). In the summer, females also used roads less than pipelines and pipeline-road RoWs. During fall, females again used roads less than pipeline-road RoWs, but use of roads was not significantly different from use of pipelines ($p=0.099$). There were no significant differences in use between pipelines and pipeline-road RoWs in any season.

For males, there were no significant differences in use of linear features in the spring. However, similar to females, males used seismic lines less than all other linear features in the summer ($p<0.001$). In the fall, the pattern of use changed, with seismic lines used more than pipeline-road RoWs and roads, and pipelines used more than all other linear features (Table 5).

Table 4. Matrix of comparisons of female grizzly bear use of linear feature types. Seasonal model coefficients, standard errors, and 95% confidence limits indicate the likelihood of use of the linear feature type on the left as compared to the linear feature type across the top of the table. Confidence intervals were corrected using the Bonferonni adjustment for comparison across multiple habitat types. Results in bold indicate statistically significant differences.

		Pipeline					**Pipeline-road**					**Road**				
					95% CI					95% CI					95% CI	
		β	SE	p	Lower	Upper	β	SE	p	Lower	Upper	β	SE	p	Lower	Upper
Spring	Pipeline-road	0.05	0.09	1.000	-0.21	0.30										
	Road	-0.12	0.09	1.000	-0.38	0.14	-0.17	0.07	0.151	-0.36	0.03					
	Seismic	**-0.62**	**0.09**	**<0.001**	**-0.87**	**-0.37**	**-0.66**	**0.06**	**<0.001**	**-0.84**	**-0.49**	**-0.50**	**0.07**	**<0.001**	**-0.69**	**-0.31**
Summer	Pipeline-road	0.10	0.07	1.000	-0.09	0.30										
	Road	-0.20	0.07	0.047	-0.41	-0.001	-0.31	0.05	<0.001	-0.46	-0.15					
	Seismic	**-0.83**	**0.07**	**<0.001**	**-1.02**	**-0.63**	**-0.93**	**0.05**	**<0.001**	**-1.07**	**-0.79**	**-0.62**	**0.05**	**<0.001**	**-0.78**	**-0.47**
Fall	Pipeline-road	-0.01	0.06	1.000	-0.19	0.17										
	Road	-0.17	0.07	0.099	-0.36	0.02	**-0.16**	**0.05**	**0.019**	**-0.30**	**-0.015**					
	Seismic	**-0.82**	**0.06**	**<0.001**	**-1.00**	**-0.64**	**-0.80**	**0.05**	**<0.001**	**-0.94**	**-0.67**	**-0.64**	**0.05**	**<0.001**	**-0.79**	**-0.50**

Table 5. Matrix of comparisons of male grizzly bear use of linear feature types. Seasonal model coefficients, standard errors, and 95% confidence limits indicate the likelihood of use of the linear feature type on the left as compared to the linear feature type across the top of the table. Confidence intervals were corrected using the Bonferonni adjustment for comparison across multiple habitat types. Results in bold indicate statistically significant differences.

		Pipeline					**Pipeline-road**					**Road**				
					95% CI					95% CI					95% CI	
		β	SE	p	Lower	Upper	β	SE	p	Lower	Upper	β	SE	p	Lower	Upper
Spring	Pipeline-road	-0.06	0.13	1.000	-0.43	0.30										
	Road	-0.09	0.14	1.000	-0.47	0.31	-0.02	0.11	1.000	-0.32	0.29					
	Seismic	-0.14	0.12	1.000	-0.49	0.21	-0.08	0.09	1.000	-0.33	0.17	-0.06	0.10	1.000	-0.35	0.22
Summer	Pipeline-road	-0.01	0.08	1.000	-0.25	0.22										
	Road	-0.08	0.09	1.000	-0.33	0.17	-0.07	0.07	1.000	-0.26	0.12					
	Seismic	**-0.42**	**0.08**	**<0.001**	**-0.65**	**-0.20**	**-0.41**	**0.06**	**<0.001**	**-0.57**	**0.24**	**-0.34**	**0.06**	**<0.001**	**-0.52**	**-0.16**
Fall	Pipeline-road	**-0.42**	**0.09**	**<0.001**	**-0.66**	**-0.18**										
	Road	**-0.48**	**0.09**	**<0.001**	**-0.73**	**-0.22**	**-0.05**	**0.08**	**1.000**	**-0.27**	**0.16**					
	Seismic	**-0.24**	**0.08**	**0.026**	**-0.46**	**-0.02**	**0.18**	**0.06**	**0.023**	**0.01**	**0.35**	**0.24**	**0.07**	**0.005**	**0.04**	**0.43**

Discussion

Determining grizzly bear habitat response to pipeline RoWs is the first critical step in investigating how pipelines may affect bears in Alberta. Both males and females in our study used pipelines, pipeline-road RoWs, and roads more than expected by availability, across all seasons. Results from this analysis differ somewhat from results previously reported in Year 1 of this study. Methods used in the first year of this study involved calculation of selection ratios, which resulted in more limited sample sizes due to restrictions imposed by the assumptions of the method. The RSF approach in this analysis incorporated a larger sample size, with more even representation among the age-sex classes, potentially providing a clearer picture of grizzly bear selection patterns around linear features.

A number of other authors have reported grizzly bear use of anthropogenic features in west-central Alberta. Nielsen et al. (2004b) reported that grizzly bears selected for harvested areas more than expected during the summer, Roever et al. (2008a) showed that grizzly bears selected habitats close to roads in spring and early summer, and Graham et al. (2010) found that females with cubs were within 200m of roads more than expected in spring. McKay et al. (in review) reported that female bears used wellsites more than expected across all seasons, while males used wellsites more than expected in summer and fall. Stewart et al. (2013) also reported grizzly bear use of edge habitat created by cutblocks, roads, and pipelines. The use of anthropogenic openings by grizzly bears has been attributed to the presence of bear foods growing along edges and within young or deforested habitats (Nielsen et al. 2004c, Munro et al. 2006, Roever et al. 2008b, Larsen 2012, Stewart et al. 2013). Similar to other anthropogenic disturbances, pipelines provide edges and openings that could also support the growth of bear foods; a comparison of bear food distribution on pipelines is included in Chapter 4 of this report. Results from the first year of this study indicated that bears in the Kakwa region use pipelines for a range of foraging activities. Analysis of movement rates in the first year also showed that grizzly bears traveled significantly faster on pipelines, pipeline-road RoWs, roads, and seismic lines as compared to non-linear habitat, suggesting that linear features may serve as movement corridors for grizzly bears in our study area.

While previous research reported that grizzly bears were not farther than expected from pipelines during the spring (Labaree et al. 2014), to our knowledge, there is no previously published research regarding habitat use directly at linear feature RoWs. Linear corridors are relatively narrow features on the landscape. It can be difficult to detect effects at such a small spatial scale, particularly with hourly GPS data; the timing of a GPS collar location may not exactly coincide with a bear location in a narrow right-of-way. However, analyses of this type provide direct information regarding grizzly bear use of these features, building on information obtained from larger landscape scale analyses. In spite of the relatively narrow areas of linear features, we detected significant differences in habitat use between linear features and non-linear habitat in our analysis, with both male and female grizzly bears using pipelines, pipeline-road RoWs, and roads more than expected based on availability.

Tigner et al. (2013) reported that black bears used conventional seismic lines more than forest interiors, but the analysis was based on camera data, and was not analyzed by sex class. In our study, male bears used seismic lines more than expected in all seasons, while females appeared to avoid seismic lines in the spring and fall. Other authors have reported sexual segregation of habitat use in grizzly bears (Rode et al. 2006). Females in our study area may be avoiding seismic lines in order to avoid male bears. Steyaert et al. (2013) reported spatiotemporal segregation in habitat selection between females with cubs-of-the-year and adult males during the mating season (spring). Our habitat analysis did not separate habitat selection patterns of females with cubs from females without young. Further investigation of grizzly bear use of seismic lines is beyond the scope of this report, but could contribute more knowledge to sexual segregation of habitat use by grizzly bears. Male grizzly bear use of seismic lines may also have implications for caribou, as it has been shown that seismic lines may facilitate predator access to caribou (Whittington et al. 2011, McKenzie et al. 2012).

It is important to note that although grizzly bears used these linear features more than expected based on availability, grizzly bears spend the majority of their time within nonlinear habitat. Pipelines are relatively narrow disturbances compared to other anthropogenic disturbances (e.g. forest cutblocks), and in our study it appears that these features are not causing avoidance or displacement of grizzly bears. However, the primary limiting factor for grizzly bears in Alberta is human-caused mortality (ASRD 2008). Greater use of these features than expected based on availability suggests that bears are attracted to linear features. The presence of bears on linear features has the potential to increase their exposure to humans, and subsequently increase the risk of human-caused grizzly bear mortality. Mortality risk factors including sightability of bears on pipelines and levels of human use on pipeline RoWs in the Kakwa region are discussed in Chapter 6 of this report.

Chapter 3: Parameters influencing the use of pipeline right-of-ways.

Introduction

Our habitat selection analysis suggests that grizzly bears are using pipeline right-of-ways. Based on these selection patterns, we wanted to gain a more detailed understanding of what parameters may influence bear use of pipelines. A number of ecological and landscape factors could affect whether individual grizzly bears use or avoid particular pipelines, including grizzly bear age-sex class, reproductive status of bears, pipeline characteristics, and the characteristics of the surrounding habitat. Grizzly bear use of wellsites has been attributed to disturbance age and characteristics of the surrounding area (McKay et al. in review), while use of cutblocks has been related to disturbance age, cutblock shape, and site preparation methods (Nielsen et al. 2004b). Information regarding parameters influencing use of pipelines may provide a better understanding of the mechanisms behind grizzly bear use of these features, and could help predict which pipelines are more likely to be used by bears in the Kakwa region.

Methods

Location data:

Location data were obtained from collared grizzly bears within the Kakwa study area during 2006-2013, and we generated random (available) locations within home ranges at a standard density of five points per square kilometre (see Chapter 2, Grizzly bear location data). For each year of data, use and available locations for each bear were intersected with the annual linear feature dataset for that year (see Chapter 2, Linear feature datasets). Use and available locations from the habitat analysis in Chapter 2 were carried forward into this analysis of parameters influencing use of pipelines if they intersected with pipelines or pipeline-road combined RoWs.

Factors influencing pipeline use:

We investigated the influence of pipeline characteristics, grizzly bear age class and reproductive status, surrounding habitat and forest cover, and surrounding anthropogenic disturbance on grizzly bear use of pipelines.

During pipeline construction, a right-of-way (RoW) is cleared through the existing habitat. Following the construction phase, re-vegetation occurs along the RoW, but the RoW may also be disturbed at a later date for pipeline repairs or the addition of another pipe within the RoW. Pipeline age (i.e. years since clearing) may be an indicator of plant succession and abundance of bear foods on the RoW. Therefore, we hypothesized that potential differences in grizzly bear use of pipelines could be influenced by the number of years since pipeline construction or clearing. Two different parameters were extracted for vegetation succession on pipelines, including 1) the number of years since the pipeline was first cleared for construction (original pipeline age), and 2) the number of years since the most recent construction (disturbance age). These parameters were based on approximate construction dates provided in the original dataset. Each pipeline location was also classified as to whether it was a single pass pipeline (only one pipeline constructed within the RoW) or multi-pass pipeline (RoW disturbed more than once).

For single pass pipelines, the most recent construction was the original clearing, and these dates were identical.

Behavioral responses to anthropogenic features have been shown to differ by grizzly bear age-sex class and reproductive status (Darling 1987, Rode et al. 2006, Nellemann et al. 2007, Elfström and Swenson 2009), and we included reproductive status as a variable in our model of parameters influencing pipeline use. Grizzly bears ≥ 5 years old were considered adults. Bears were classified as subadults if they were <5 years old, > 2 years old, and independent from their mother. Age determination was completed using cementum analysis of a pre-molar tooth extracted at capture. Female bears were classified as females with cubs of the year if it could be confirmed by sightings that they were accompanied with one or more cubs of the year. To maintain sample sizes across age-sex classes, females with yearlings or two year olds were grouped into the adult female class along with females without young. This grouping was based on preliminary analysis in this study indicating similar patterns within these groups of females, previous habitat analysis results (McKay et al. in review), and previous research indicating that the largest differences between home range size and movement patterns are between females with cubs of the year and the other age-sex classes (Graham et al. in press). Due to the fact that females may lose their cubs over the course of the year, reproductive status was specific to season (spring, summer, and fall) for each year. Data from female bears with unconfirmed reproductive status were not included in our models. Final age-sex classes included: 1) females with cubs of the year, 2) adult females (with yearlings, two year olds, or no cubs), 3) adult males, 4) subadult males, and 5) subadult females.

Characteristics in the region surrounding a pipeline were calculated within a 400m radius of the use and available pipeline locations, based on the average hourly travel distance for male grizzly bears in our study area. Adjacent habitat has the potential to influence foraging decisions and small scale habitat use on features such as RoWs. To describe available adjacent habitat, we used landcover classes originally derived from Landsat7 imagery (McDermid 2005). Landcover classes were grouped as herbaceous habitat, shrublands, forest, and cutblocks classified by forest age (0 to 20 years, and greater than 20 years since clearing). For each use and random location, adjacent landcover was defined as the dominant landcover within a 400m radius. Adjacent canopy cover (hiding cover) was defined as the average percent canopy cover within a 400m radius of each use and random location.

The Kakwa study area is a highly altered landscape, including both forestry and oil and gas development. The density of anthropogenic features varies across the study area, with different levels of habitat alteration and human presence. On a section of pipeline RoW, there is potential for the surrounding disturbance to influence grizzly bear use of that anthropogenic feature. We considered road densities and pipeline densities as indicators of the level of disturbance and human use in the area surrounding each pipeline location. We calculated road and pipeline densities (km/km^2) in a 400m radius around each use and random location. Distance to the nearest road (km) was also investigated as an index of human disturbance in the area.

Analysis:

Pipeline RoWs and pipeline-road combined RoWs were considered as separate habitat types, and were modeled separately. For both RoW types, we generated a set of *a priori* logistic regression models for each season, for a total of six model sets. Models were created by grouping parameters according to areas of ecological relevance, including: bear-specific factors, pipeline-specific factors, surrounding level of anthropogenic disturbance, habitat/food-related factors, and combinations of these groups (Table 1). Model combinations were focused around bear specific factors (age-sex class), based on previous data suggesting that habitat selection patterns differ by age-sex class. Interaction factors were also limited to age-sex class and human disturbance parameters, as the response to human features is the main focus of our investigation.

Parameters were checked for correlation and collinearity using Pearson's correlation coefficients, variance inflation factors, and regression of independent variables against each other. Variables with a correlation coefficient ≥0.6, VIF >1.5, or highly significant regression coefficients were considered to be correlated, and were not included together in any candidate models. Distance to the nearest road and road density were correlated (r=0.6). In preliminary analyses, road density explained more variation in the data, and therefore distance to road was not included in the models. Landcover class is closely related to tree cover, and landcover class and canopy cover were also correlated. We chose to exclude canopy cover and include landcover in our models, as landcover provides both information on habitat type and indirect information regarding hiding cover. The original pipeline age and disturbance age were also highly correlated. Pipeline age variables were assessed separately for each of the six model sets, with further candidate models including the age that explained the most variation in the data for that RoW type/season.

Table 1. Candidate models.

Model	**Description**	**Parameters**
1	Bear specific factors	Age-sex class (including female reproductive status) (AS3)
2	Pipeline specific factors	Original pipeline age or disturbance age, multipass/single pass, and surrounding pipeline density
3	Level of human disturbance in area	Road density and pipeline density
4	Food availability (vegetation succession) and habitat	Original pipeline age or disturbance age, landcover class
5	Bear specific and disturbance	Age-sex class, road density, pipeline density
6	Bear specific and disturbance with interactions	Age-sex class, road density, pipeline density, interaction factors
7	Bear specific and food availability	Age-sex class, pipeline age
8	Bear specific, food availability, disturbance	Age-sex class, pipeline age, road density, pipeline density
	Global model	Age-sex class, pipeline age, multipass/single pass, landcover, road density, pipeline density, interaction factors

We used random intercept mixed-effects logit models (xtlogit) in Stata 12.1^{TM} (StataCorp, Texas, U.S.A) with individual bear as the random effect. Model selection was based on comparing differences in Akaike's Information Criterion corrected for small sample sizes (ΔAIC_C). We used conventional AIC methods for model selection rather than the conditional AICs sometimes applied to random effects models, because we were interested in inferences to the population of grizzly bears in our area rather than to individuals (Vaida & Blanchard 2005, Hebblewhite & Merrill 2008). Controversy exists regarding appropriate cutoffs for selecting and/or averaging top models, with recommended ΔAIC values ranging from 2 to 6 and beyond (Burnham & Anderson 2002, Richards 2008, Arnold 2010). However, the addition of a single parameter to a model can result in a model with ΔAIC ≤2 even if the additional parameter does not have any explanatory ability, since a one unit increase in the number of parameters will only increase AIC by 2, and the selection of models with larger ΔAIC values often results in retention of uninformative parameters (Guthery et al. 2005, Arnold 2010). We chose an approach that included careful consideration of model weights and ΔAIC values along with a review of the parameters that were retained in each of the top models. For each season, we reviewed the models with the highest AIC weights and ΔAIC≤ 2, and verified that models with ΔAIC~2 were not simply the result of adding one more parameter to the top model (Richards 2008, Arnold 2010). If applicable, we carried out model averaging to calculate parameter estimates. Coefficient values and confidence intervals were taken into account in interpretation of model results. To contrast effects of categorical variables, pairwise comparisons of marginal linear predictions were calculated after model generation. Bonferroni corrections were applied to 95% confidence intervals for pairwise comparisons to adjust for multiple comparisons across categories, with an overall significance level set at p=0.05.

Results

For pipeline RoWs, the top model in the spring retained the variable of age-sex class, and accounted for 0.693 of the total AIC_c weight (AIC_cW) (Table 2). Pairwise comparisons of age-sex class indicated that adult females were more likely to use pipelines than females with cubs of the year (p=0.043), but no other significant differences were observed between age-sex classes in spring (Figure 1).

For summer, age-sex class and disturbance age (years since most recent clearing) were both retained in the top model, with an $AIC_cW=0.77$. Females with cubs were more likely to use pipelines than subadult males, and subadult females were more likely to use pipelines than subadult males (Figure 1). Disturbance age had a negative influence on use of pipelines, with the probability of use decreasing with increasing pipeline age (Figure 2). The mean disturbance age of used pipelines was 5.7 years, versus 7.7 years for available pipelines.

The top model for the fall included the variables of age-sex class and disturbance age ($AIC_cW=0.66$). The second ranked model in the fall also included the variables of road density and pipeline density ($AIC_cW= 0.31$, $\Delta AIC_c = 1.54$) and this model was included in model averaging and calculation of coefficients for fall. There were a number of significant differences in the probability of pipeline use between age-sex classes in the fall (Figure 1). Females with cubs were more likely to use pipelines than adult females, subadult males, and subadult females. Subadult females were less likely to use pipelines than adult females and adult males, and subadult males were less likely to use pipelines than adult males. Again, disturbance age had a negative influence on use of pipelines (Figure 2); mean disturbance age of used pipelines was 5.7 years and 7.3 years for available pipelines. Surrounding pipeline density and road density also had a negative influence on use of pipelines, with the probability of use decreasing with increasing densities.

Table 2. Pipeline RoW **c**andidate models and AIC$_c$ values for pipeline parameters*. Top models are in bold, and superscripts indicate top models for: 1) Spring, 2) Summer, 3)a and 3)b Fall. Variables include age-sex class (AS), disturbance age (DA), multi-pass (MP), pipeline density (PD), road density (RD), and landcover (LC).

			Spring				**Summer**				**Fall**			
Model	**Parameters**	**K**	**LL**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$W**	**LL**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$W**	**LL**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$W**
Null		1	-732.43	1467.08	5.93	0.036	-1315.43	2633.02	22.33	0.000	-1436.12	2874.45	82.06	0.000
1^{1}	**AS**	5	**-723.43**	**1461.15**	**0.00**	**0.693**	-1307.93	2628.60	17.90	0.000	-1392.63	2799.01	6.62	0.024
2	DA + MP + PD	4	-730.79	1472.24	11.09	0.003	-1303.67	2617.07	6.38	0.032	-1428.71	2867.77	75.38	0.000
3	RD + PD	3	-731.80	1471.09	9.95	0.005	-1314.03	2635.05	24.36	0.000	-1433.49	2874.31	81.92	0.000
4	LC + DA	5	-727.56	1469.40	8.25	0.011	-1301.20	2615.13	4.43	0.084	-1417.81	2849.37	56.98	0.000
5	AS + RD + PD	7	-722.85	1469.04	7.89	0.013	-1306.43	2632.46	21.77	0.000	-1389.36	2800.72	8.33	0.010
6	AS + RD + PD + AS*RD + AS*PD	15	-721.68	1555.37	94.22	0.000	-1298.60	2657.50	46.81	0.000	-1370.59	2829.17	36.78	0.000
$7^{2,3a}$	**AS +DA**	6	-722.41	1463.29	2.14	0.238	**-1297.35**	**2610.69**	**0.00**	**0.768**	**-1387.4**	**2792.39**	**0.00**	**0.660**
8^{3b}	**AS + RD + PD + DA**	8	-721.88	1472.85	11.70	0.002	-1295.45	2614.47	3.78	0.116	**-1383.43**	**2793.93**	**1.54**	**0.306**
Global	AS + DA + MP + RD + PD + LC4 + AS*RD +AS*PD	19	-716.97	2153.94	692.79	0.000	-1283.71	2700.41	89.72	0.000	-1354.24	3126.47	334.08	0.000

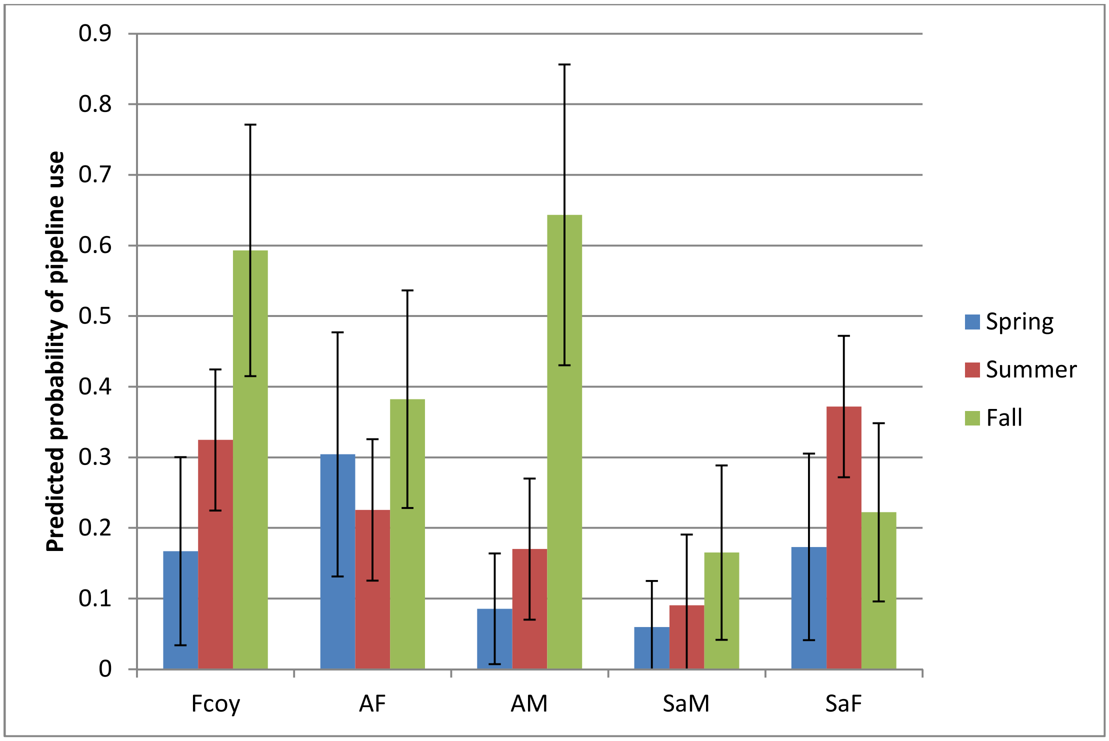

Figure 1. Predicted probability of pipeline use by age-sex class and season. Age-sex classes include females with cubs of the year (Fcoy), adult females (AF), adult males (AM), subadult males (SaM), and subadult females (SaF).

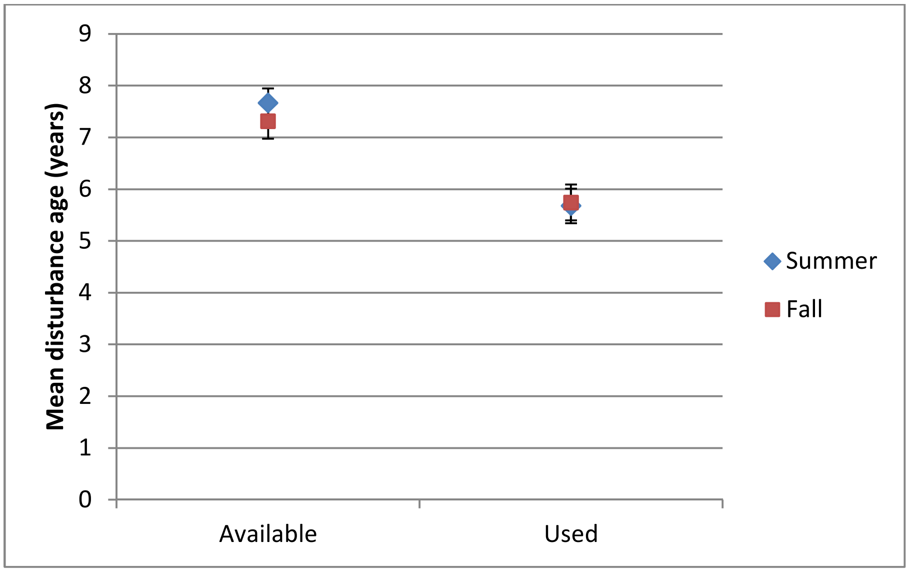

Figure 2. Mean disturbance age for available and used pipeline sites, summer and fall.

For pipeline-road RoWs, the top model for spring included age-sex class, road density, and pipeline density, with AIC_cW=0.52 (Table 3). The second ranked model also included the variable of original pipeline age (ΔAIC_c = 0.17, AIC_cW=0.47); both models were used for inference. These same four variables (age-sex class, road density, pipeline density, and original pipeline age were all retained in the top model for summer (AIC_cW =1.00), and for the two top models for fall (Table 3).

Table 3. Pipeline-road RoW **c**andidate models and AIC_c values for pipeline parameters*. Top models are in bold, and superscripts indicate top models for: 1)a and 1)b Spring, 2) Summer, 3) Fall. Variables include age-sex class (AS), original pipeline age (PA), multi-pass (MP), pipeline density (PD), road density (RD), and landcover (LC).

			Spring				**Summer**				**Fall**			
Model	**Parameters**	**K**	**LL**	**AIC_c**	**ΔAIC_c**	**AIC_cW**	**LL**	**AIC_c**	**ΔAIC_c**	**AIC_cW**	**LL**	**AIC_c**	**ΔAIC_c**	**AIC_cW**
Null		1	-2019.86	4041.94	75.23	0.000	-3738.21	7478.56	299.84	0.000	-3679.61	7361.41	130.49	0.000
1	AS	5	-1987.13	3988.55	21.85	0.000	-3673.95	7360.51	181.79	0.000	-3634.83	7283.41	52.49	0.000
2	PA + MP + PD	4	-2007.23	4025.13	58.43	0.000	-3648.16	7305.98	127.26	0.000	-3636.44	7283.23	52.31	0.000
3	RD + PD	3	-1999.23	4005.96	39.26	0.000	-3686.82	7380.61	201.88	0.000	-3664.85	7337.04	106.12	0.000
4	LC + PA	5	-2012.30	4038.89	72.19	0.000	-3661.21	7335.02	156.30	0.000	-3652.76	7319.27	88.35	0.000
5	**AS + RD + PD^{1a}**	**7**	**-1971.69**	**3966.70**	**0.00**	**0.520**	-3668.78	7356.90	178.17	0.000	-3624.05	7270.11	39.19	0.000
6	AS + RD + PD + AS*RD + AS*PD	14	-1968.23	4048.45	81.75	0.000	-3624.75	7307.50	128.77	0.000	-3606.83	7301.66	70.74	0.000
7	AS + PA	6	-1981.44	3981.34	14.63	0.000	-3605.41	7226.64	47.92	0.000	-3608.38	7234.35	3.43	0.152
8	**AS + RD + PD + PA^{1b,2,3}**	**8**	**-1968.89**	**3966.87**	**0.17**	**0.479**	**-3577.76**	**7178.73**	**0.00**	**1.000**	**-3601.92**	**7230.92**	**0.00**	**0.848**
Global	AS + PA + MP + RD + PD + LC + AS*RD +AS*PD	19	-1962.35	4644.71	678.00	0.000	-3562.70	7247.84	69.11	0.000	-3570.84	7559.68	328.76	0.000

Similar to results for pipeline RoWs, adult females were more likely to use pipeline-road RoWs in the spring than females with coy (p=0.001). Both subadult males and subadult females were less likely to used pipeline-road RoWs than adult males, and the probability of use for subadult males was also lower than for all adult females (Figure 3). The pattern of use shifted in the summer, with adult females and adult males less likely to use pipeline-road RoWs than females with cubs. The probability of use for subadult males was lower than for all other age-sex classes in summer, and this pattern continued in the fall. Adult females also used pipeline-road RoWs less than females with coy in the fall.

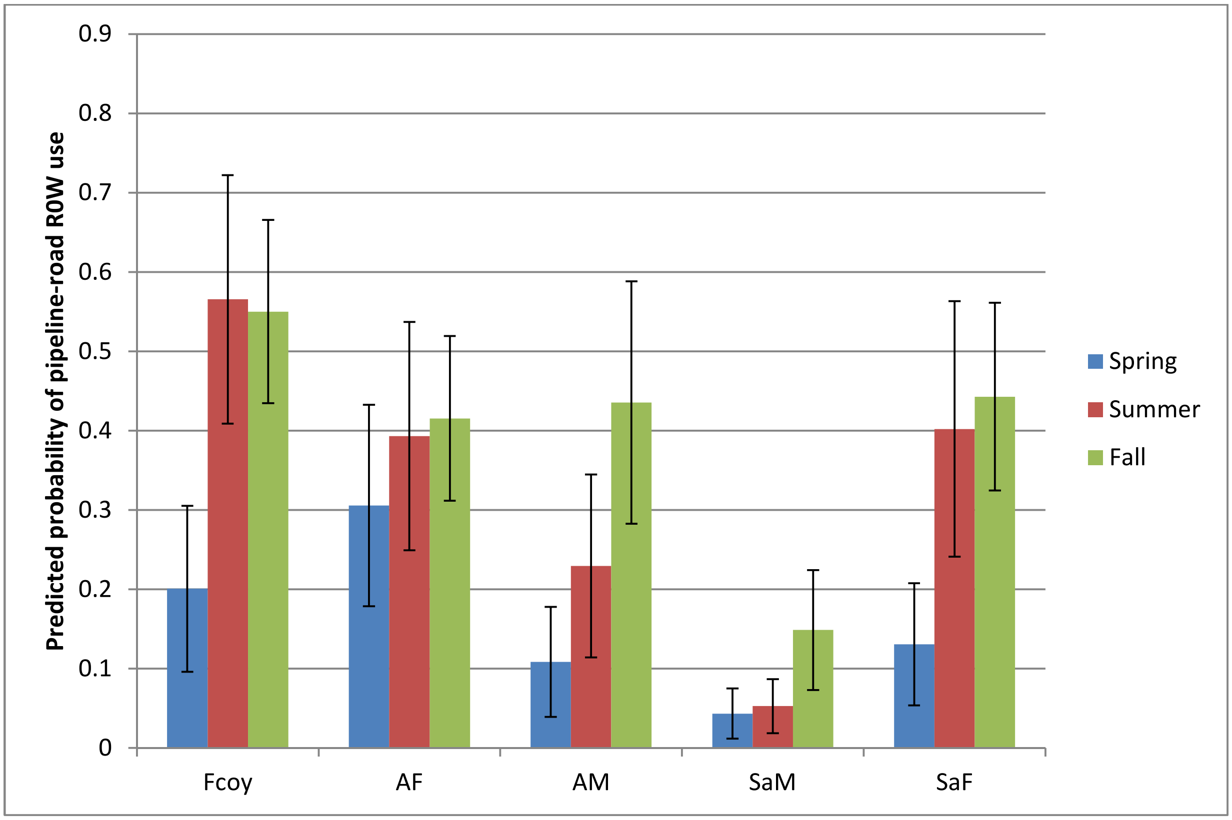

Figure 3. Predicted probability of pipeline-road RoW use by age-sex class and season. Age-sex classes include females with cubs of the year (Fcoy), adult females (AF), adult males (AM), subadult males (SaM), and subadult females (SaF).

For all three seasons, original pipeline age had a negative influence on pipeline-road RoW use, with the probability of use decreasing as pipeline age increased (Figure 4). Across seasons, mean pipeline age was consistently lower for used pipelines (overall mean=7.4 years) versus those available (mean =9.1 years). Surrounding pipeline and road density also had a negative influence on selection of pipeline-road RoWs across all seasons, with the probability of use decreasing with increasing pipeline and road densities (Figures 5 and 6).

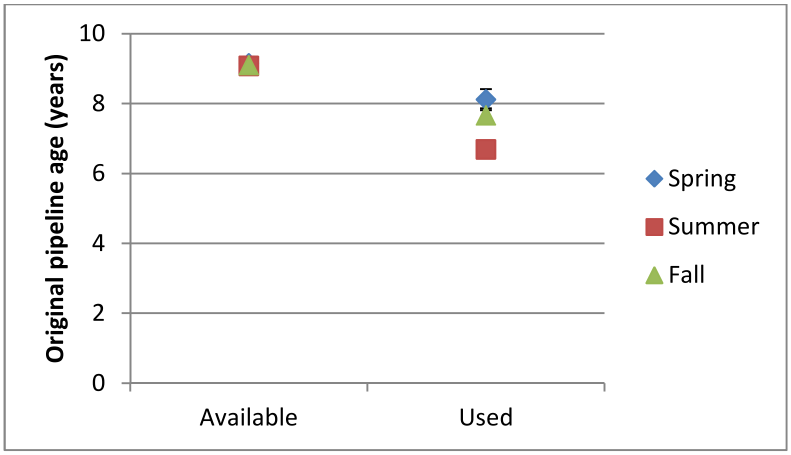

Figure 4. Mean pipeline age for available and used pipeline-road RoW sites, by season.

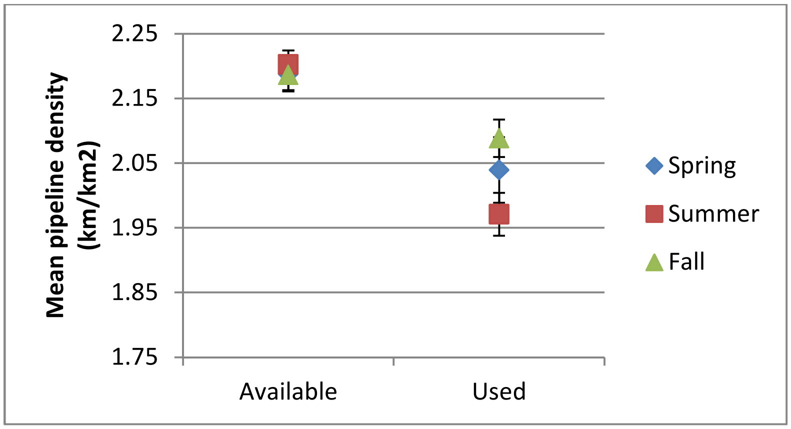

Figure 5. Mean pipeline densities for available and used pipeline-road RoW sites, by season.

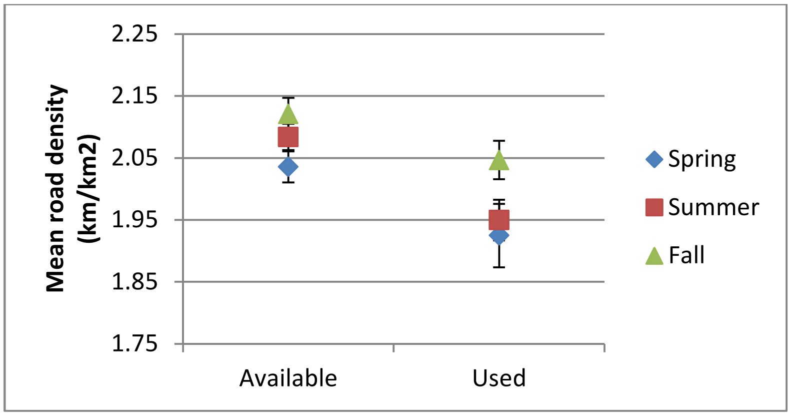

Figure 6. Mean road densities for available and used pipeline-road RoW sites, by season.

Discussion

In the spring, females with cubs of the year were less likely to use both pipelines and pipeline-road RoWs than adult females without cubs. This pattern shifted completely in the summer, when females with cubs were more likely to use pipeline-road RoWs than single females, and in the fall, females with cubs were more likely to use both pipelines and pipeline-road RoWs than adult females. We did not detect significant differences in pipeline use between females with cubs and adult males, although females with cubs were observed to use pipeline-road RoWs more than adult males in the summer. In Sweden, Steyaert et al. (2013) reported a strong pattern of spatiotemporal segregation in habitat selection between female brown bears with cubs-of-the-year and adult males during the mating season. Females with cubs selected for areas closer to buildings, but generally avoided areas close to roads and trails. The authors also noted a shift in habitat selection after the mating season, when females with cubs followed a pattern more similar to other female bears (Steyaert et al. 2013). Other authors have also reported sexual segregation of habitat use in grizzly bears, and suggested that females with cubs may perceive the risk of male grizzly bears as greater than the risk of humans (Rode et al. 2006). Previous work in Alberta has found that females used areas near roads more than males (Graham et al. 2010), females with cubs used habitat near roads more than other bears in British Columbia (McLellan & Shackleton 1988), and females with cubs in the Kakwa region were more likely to use wellsites than male bears (McKay et al. in review), similar to findings for other populations. We also observed that subadult males and subadult females displayed different selection patterns than adult bears, and subadult males in particular used pipelines and pipeline-road RoWs less than other age-sex classes. While differences between age-sex classes varied across seasons, it appears that some sexual segregation of habitat use could be taking place on pipelines.

Disturbance age (years since most recent disturbance) and original pipeline age (years since original pipeline construction) were predictors of the use of pipelines and pipeline-road RoWs, respectively. Both parameters serve as an index of vegetation succession, and potentially of bear food availability. Disturbance age and original pipeline age both had a negative influence on use of pipelines/pipeline-road RoWs, with the probability of use decreasing as pipeline age increased. In spite of a relatively small difference in average age of pipelines between used and available (e.g. 7.4 and 9.1 years, respectively), this relationship was consistent for both pipelines and pipeline-road RoWs, with a strong effect for age across all seasons for pipeline-road RoWs. These results are in contrast to the response reported for wellsites in our area (McKay et al. in review), where bears were more likely to select older wellsites rather than recently cleared wellsites. Pipelines are narrow features, and may grow in more quickly than larger openings such as wellsites or cutblocks. Early colonizing bear food species such as clover and dandelion may peak a few years after a pipeline is cleared, and as a result of vegetation succession, the pipeline may become overtaken by grass, alder, willow, and other non-berry producing shrubs. If grizzly bears are mostly using pipeline RoWs to access clover and other colonizing species, they may select for those pipelines in the earlier stages of succession. Preliminary analysis in this study indicated that there was a higher occurrence of clover at pipeline use sites than at pipeline random locations, suggesting that bears are targeting clover on pipeline RoWs. Previous results from year 1 of this study also indicated that bears use pipelines for travel, and a pipeline may become less suitable for fast movement as vegetation and shrub cover increases.

Surrounding pipeline and road density had a negative influence on use of pipelines in the fall and pipeline-road RoWs across all seasons. With increasing pipeline and road densities in the 400m surrounding pipelines/pipeline-road Rows, the probability of use decreased. These results are analogous to the grizzly bear response to wellsites in the Kakwa region reported by McKay et al. (in review). The authors reported that with increasing wellsite and road densities in the surrounding area, the probability of grizzly bear use of a wellsite decreased. In a working landscape such as the Kakwa, wellsite, pipeline, and road densities reflect the level of resource extraction and human activity in the area. Although bears appear to be selecting for pipelines, these results suggest that they may prefer habitat in areas of lower overall human presence. Other research has suggested that anthropogenic features may not directly cause disturbance effects (i.e. avoidance), but the associated human activities may have an impact on bears (Swenson et al. 1996, Jalkotzy et al. 1997, Olson et al. 1998, Ordiz et al. 2011). Boulanger and Stenhouse (in review) found that grizzly bear survival was related to road density, and identified threshold levels at which population levels would decline. While bears in our study area appear to show a positive selection for pipelines, they may be compensating by using pipelines in areas with a lower risk of encountering humans. There may be a threshold for pipeline and road density above which bears avoid pipelines, resulting in an effective overall loss of habitat. This is an important consideration for grizzly bear habitat in the Kakwa region, as oil and gas development continues in this area.

Chapter 4: Food availability on pipeline right-of-ways.

Introduction

Our habitat selection analysis suggests that grizzly bears are using pipeline right-of-ways, and bears have also been reported to use pipeline edges in the Kakwa region (Stewart et al. 2013). Based on these selection patterns, we wanted to gain a more detailed understanding of what may influence bear use of pipeline RoWs. Research suggests grizzly bear use of anthropogenic openings is related to the presence of bear foods growing along edges and within the early successional habitats created by disturbance (Nielsen et al. 2004c, Roever et al. 2008b, Larsen 2012, Stewart et al. 2013). Similar to other anthropogenic disturbances, pipelines provide edges and openings that could also support the growth of bear foods. Other authors have reported that both roadsides and cutblocks have a higher frequency of some bear foods than nearby forest habitat (Nielsen et al. 2004c, Roever et al. 2008b). During pipeline construction, a right-of-way (RoW) is cleared through the existing habitat. Following the construction phase, early colonizing species move in to the disturbed area along the RoW. Dandelion, clover, and *Equisetum* species are frequent colonizers of disturbed areas, and these plants are known to be important bear foods grizzly bears in west-central Alberta (Munro et al. 2006). Based on the assumption that differences in the availability of food could have a strong influence on grizzly bear use of pipelines, our research objective was to determine whether the distribution of bear foods on pipeline RoWs and in pipeline RoW edges were different from that of other available habitat types.

Methods

Study site selection:

In 2012/2013, prior to the field season, random locations were generated within the study area using a GIS, stratified by habitat type, and randomly subsampled to generate field sites for vegetation sampling. Habitat types used in the analysis included conifer forest (≥80% conifer), broadleaf and mixed forests (<80% conifer), regenerating forest (cutblocks of various age), pipeline RoWs, and pipeline edges. Random locations within pipeline RoWs were also stratified according to pipeline age, in order to capture a range of vegetation succession on RoWs. The FRIGBP also conducted extensive fieldwork in the Kakwa area during 2006 and 2007 for a previous study, and these data were incorporated into our analysis. During 2006 and 2007, random points were paired with use sites for bears from those years, and were generated based on a random cardinal direction and a distance of 300m from bear use points. Based on this method of point generation, the locations were not entirely random on the landscape. However, vegetation cover was not compared between use and random points, spatial distribution of study sites was consistent across the study area, and the number of points within each habitat type was similar. Therefore, data from 2006 and 2007 study sites were included in the vegetation analysis.

Field methods:

Field crews visited sampling sites in the Kakwa study area during 2006-2007 and 2012-2013. Field protocols and data collection were consistent between the two sampling periods, allowing for use of the previously collected 2006-2007 data in the current study. Personnel navigated to within 2 metres of the coordinates of the sampling site location using a hand held GPS unit. For pipeline sites, plots were centered on the RoW, each plot was 30m long, and included the width of the RoW plus 5 metres into the forest edge on each side. For non-pipeline sites, the GPS coordinate for the sampling site was plot centre, and each plot was 30m by 30m.

At each plot, we recorded the presence/absence and abundance of all plant species known to be common bear foods in west-central Alberta (Munro et al. 2006). Plots were also searched for the presence of ants (mounds or woody debris) and for the presence of ungulate pellets. Ungulate pellets were not considered as an index of ungulate abundance, rather as an indicator of ungulate presence/absence (Nielsen et al. 2004c), and all ungulate species were grouped together. At pipeline plots, food presence was recorded separately for the RoW and each edge plot, and these plots were considered as separate habitat types.

Analysis:

Out of the 29 bear foods recorded at our sampling sites, we chose to focus on 14 bear foods for our analysis (Table 1), based on common foods specifically identified in scat from bears within the Kakwa area (Larsen & Pigeon 2006), foods commonly found in disturbed areas (Roever et al. 2008b), and berry shrubs commonly observed at pipeline sites in our study area. *Hedysarum alpinum*, an important bear food in west-central Alberta (Munro et al. 2006) was essentially detected only at use sites, and therefore was not common enough to include in occurrence models for our study area.

Table 1. Bear foods used in analysis.

Food	Common name/description
Ants	Hills/mounds or woody debris, confirmed presence of ants/anting
Equisetum sp.	Horsetail species
Heracleum lanatum	Cow parsnip
Lonicera involucrata	Honeysuckle
Ribes sp.	Currant/Gooseberry species
Rubus sp.	Raspberry species
Shepherdia canadensis	Buffalo berry
Taraxacum officinale	Dandelion
Trifolium sp.	Clover
Ungulates	Presence of pellets: deer, moose, elk
Vaccinium caespitosum	Dwarf blueberry
Vaccinium membranaceum	Huckleberry
Vaccinium myrtilloides	Wild blueberry
Vaccinium vitis-idaea	Lingonberry

We used logistic regression to compare the occurrence of each bear food at random locations between coniferous forest, mixed/deciduous forest, cutblocks, pipeline RoWs, and pipeline edges. Each food model was run in Stata 12.1^{TM} (StataCorp, Texas, U.S.A), with conifer forest as the reference habitat category. Chi-square likelihood ratios were used to determine the significance of individual food models.

We used pairwise comparisons of marginal linear predictions to contrast the probability of bear food occurrence between habitat types. Bonferroni corrections were applied to 95% confidence intervals for pairwise comparisons to adjust for multiple comparisons across categories, with an overall significance level set at p=0.05. Results are reported as odds ratios, interpreted as the probability of bear food occurrence versus the probability of bear food occurrence in the comparison habitat. Pairwise comparisons of habitat types were completed for significant food models. As the focus of our investigation was to compare food occurrence on pipelines to other habitats, odds ratios and p values for pairwise comparisons are reported only if significant differences were detected between pipeline and other habitat categories. Contrasts between pipeline RoWs and pipeline edge plots are not reported in our analysis, since these plots were not considered independent.

Results

Field crews visited 366 use points and 101 random points on pipelines during 2012 and 2013, and 14 non-pipeline random study sites in 2013. An additional 110 non-pipeline random and 197 use sites were visited in the Kakwa area during 2006 and 2007, and included directly comparable bear food data. In total, field crews visited 54 sites in coniferous forest, 60 sites in broadleaf and mixed forests, 85 sites in regenerating forest, 87 sites on pipeline RoWs, and 172 plots on pipeline edges.

Individual food models showed significant prediction of bear food presence for ants, *Equisetum sp., Heracleum lanatum, Lonicera involucrata, Taraxacum officinale, Trifolium sp.,* Ungulates, *Vaccinium membranaceum,* and *Vaccinium vitis-idaea.* Food models for *Shepherdia canadensis, Vaccinium caespitosum,* and *Vaccinium myrtilloides* were not significant, indicating that habitat type was not a significant predictor of occurrence for these species in our study area. The frequency of occurrence of bear foods in each habitat type and model significance for each bear food are summarized in Table 2.

Table 2. Frequency of occurrence (percentage of plots with bear food present) of bear foods by habitat type.

Food item	**Coniferous forest**	**Mixed or deciduous**	**Cutblocks**	**Pipeline RoW**	**Pipeline Edge**	**Model significance**
Ants	1.9	3.3	3.5	39.1	5.2	<0.0001
Equisetum sp.	79.6	73.3	91.8	97.7	79.7	<0.0001
Heracleum lanatum	27.8	43.3	35.3	43.7	25.0	0.0105
Lonicera involucrata	44.4	28.3	36.5	60.9	51.7	0.0003
Ribes sp.	44.4	81.7	62.4	57.5	43.0	<0.0001
Rubus sp.	14.8	53.3	52.9	94.3	68.0	<0.0001
Shepherdia canadensis	14.8	36.7	21.2	24.1	20.9	0.0726
Taraxacum officinale	1.9	5.0	28.2	88.5	35.5	<0.0001
Trifolium sp.	1.9	3.3	17.6	88.5	41.3	<0.0001
Ungulates	64.8	68.3	68.2	19.5	8.1	<0.0001
Vaccinium caespitosum	25.9	20.0	24.7	20.7	18.6	0.7227
Vaccinium membranaceum	48.1	6.7	47.1	28.7	20.9	<0.0001
Vaccinium myrtilloides	37.0	16.7	28.2	27.6	23.8	0.1408
Vaccinium vitis-idaea	72.2	11.7	58.8	26.4	34.9	0.0001
Vaccinium sp.	88.9	28.3	76.5	55.2	50.6	<0.0001
Number of plots	54	60	85	87	172	

Tables 3a. and 3b. Comparison of probability of occurrence of bear foods at pipeline RoWs compared to coniferous forest, deciduous/mixed forest, and regenerating forest (cutblocks). Significant differences are in bold.

Pipeline RoW versus comparison group

	Ants		*Equisetum sp.*		*Lonicera involucrata*		*Ribes sp.*		*Rubus sp.*	
Comparison group:	Odds ratio	p	Odds ratio	p	Odds ratio	p	Odds ratio	p	Odds ratio	p
Coniferous forest	**34.0**	**0.006**	**10.9**	**0.026**	1.95	0.574	1.69	1.000	**94.3**	**<0.001**
Deciduous/ mixed forest	**18.6**	**0.001**	**15.5**	**0.004**	**3.94**	**0.001**	**0.303**	**0.027**	**14.4**	**<0.001**
Cutblocks	**17.5**	**<0.001**	3.8	1.000	**2.71**	**0.015**	0.816	1.000	**14.6**	**<0.001**

Pipeline RoW versus comparison group

	Taraxacum		*Trifolium sp.*		Ungulates		*Vaccinium membranaceum*		*Vaccinium vitis-idaea*	
Comparison group:	Odds ratio	p	Odds ratio	p	Odds ratio	p	Odds ratio	p	Odds ratio	p
Coniferous forest	**408**	**<0.001**	**408**	**<0.001**	**0.13**	**<0.001**	0.43	0.208	**0.14**	**<0.001**
Deciduous/ mixed forest	**146**	**<0.001**	**223**	**<0.001**	**0.11**	**<0.001**	**5.65**	**0.024**	2.72	0.332
Cutblocks	**19.6**	**<0.001**	**35.9**	**<0.001**	**0.11**	**<0.001**	0.453	0.139	**0.25**	**<0.001**

Tables 4a. and 4b. Comparison of probability of occurrence of bear foods at pipeline edges compared to coniferous forest, deciduous/mixed forest, and regenerating forest (cutblocks). Significant differences are in bold.

Pipeline edge versus comparison group

	Lonicera involucrata		*Ribes sp.*		*Rubus sp.*		*Taraxacum*	
Comparison group:	Odds ratio	p	Odds ratio	p	Odds ratio	p	Odds ratio	p
Coniferous forest	0.70	0.571	0.944	1.00	**12.2**	**<0.0001**	**29.1**	**0.010**
Deciduous/ Mixed forest	**0.08**	**0.013**	**0.170**	**<0.0001**	1.83	0.424	**10.4**	**0.001**
Cutblocks	0.80	0.703	**0.456**	**0.038**	1.89	0.191	1.40	1.000

Pipeline edge versus comparison group

	Trifolium sp.		Ungulates		*Vaccinium membranaceum*		*Vaccinium vitis-idaea*	
Comparison group:	Odds ratio	p	Odds ratio	p	Odds ratio	P	Odds ratio	p
Coniferous forest	**37.2**	**0.004**	**0.048**	**<0.001**	**0.29**	**0.001**	**0.21**	**<0.001**
Deciduous/ Mixed forest	**20.4**	**<0.001**	**0.041**	**<0.001**	3.70	0.173	4.06	0.012
Cutblocks	**3.28**	**0.002**	**0.041**	**<0.001**	**0.30**	**<0.001**	0.38	0.003

A number of bear foods had a higher probability of occurrence on pipeline RoWs than in other habitats. Ants, *Rubus sp., Taraxacum sp.* and *Trifolium sp.* had a significantly higher probability of occurrence on RoWs than in all other habitat types. In particular, odds ratios for *Taraxacum sp.* and *Trifolium sp.* at RoWs versus coniferous forest were extremely high (Tables 3a and 3b); these species were present at 88.5% of RoW plots visited, versus less than 2% in coniferous forest (Table 2). For *Equisetum* species, RoWs had a higher occurrence than either forest type, but the probability of occurrence was not different from cutblocks. Ungulate pellets were less likely to occur on pipeline RoWs than any other habitat type. Occurrence patterns for *Lonicera, Ribes* species, and *Vaccinium* species were variable.

For pipeline edges, *Trifolium sp.* also had a significantly higher probability of occurrence than in all other habitat types, *Taraxacum officinale* was more likely to occur in pipeline edges than in either forest type, and *Rubus sp*. were more likely to occur in pipeline edges than in coniferous forest (Table 4a). As for pipeline RoWs, ungulates were less likely to occur in edges than in all other habitat types. Again, occurrence patterns for *Lonicera, Ribes* species, and *Vaccinium* species were varied, but in all cases where significant differences were detected, these berry shrubs were less likely to occur in pipeline edges than in other habitat types.

Discussion

Our results indicate that a number of bear foods are more common on pipeline RoWs and edges than in other available habitats. In particular, dandelion and clover had a much higher probability of occurrence on pipelines than in other habitat types. These species are common to recently disturbed areas (Haeussler et al. 1999; Roberts and Zhu 2002), and known to be commonly used bear foods in our study area (Larsen & Pigeon 2006). Nielsen et al. (2004c) and Roever et al. (2008b) also reported a higher occurrence of dandelion and clover in cutblocks and roadsides, respectively. Ants were also more common on pipeline RoWs than in other available habitats. These results are consistent with the analysis from year 1 of this study, when anting was observed at approximately 25% of grizzly bear use sites on pipelines. Other authors have also reported a higher occurrence of ants in disturbed areas (Nielsen et al. 2004c, Roever et al. 2008b). Ants are an important source of protein in west-central Alberta (Munro et al. 2006). The high occurrence of dandelion, clover, and ants on RoWs may serve as an attractant to pipelines.

A number of authors have reported grizzly bear use of edge habitat (Blanchard 1983, Larsen 2012, Stewart et al. 2013). It has been suggested that bears use edges because food is more abundant (Nielsen et al. 2008). In our analysis, berry shrubs (*Lonicera, Ribes species,* and *Vaccinium* species) were not more likely to occur in pipeline edges than in forest habitat. Other research in the Kakwa area found that *Vaccinium* species and other berry shrubs were observed to be relatively abundant in wellsite edges (T. McKay, unpublished data), and Vaccinium berry abundance was highest in close proximity to forestry cutblock edges (~1m) and declined rapidly within 10m (T. Larsen, unpublished data). Harper et al. (2003) also reported that *Vaccinium myrtilloides* was more abundant in forest edges compared to interior black spruce boreal forests in Quebec. Harper and Macdonald (2002) reported a decrease in some berry shrubs (*Ribes oxycanthoides, Rubus idaeas,* and *Lonicera involucrata*) and an increase in others (*Amelanchier alnifolia* and *Prunus pensylvanica*) near the forest edge in mixed wood forest in

Alberta. However, to our knowledge, previous research has not been completed regarding the distribution and abundance of berry shrubs in pipeline edges. Other research suggests that *Vaccinium* species abundance is related to elevation, soil moisture, and forest stand composition (Larsen 2012); these factors were not investigated in our analysis. Further work on characterizing pipeline edge and the relationship between bear food presence/abundance, adjacent habit, and other factors could provide a clearer picture of bear food availability in pipeline edges. Regardless, it is possible that due to the narrower width of RoWs, pipelines do not allow as much light to penetrate the forest edge, so pipeline edges may not function in the same way as edges of other anthropogenic features for grizzly bear food availability.

Based on the high occurrence of some important bear foods at pipelines, pipeline RoWs could provide good grizzly bear foraging habitat. However, while bears may be attracted to pipelines, the potential increase in mortality risk could counteract the direct positive effect of higher food abundances in these areas.

Chapter 5: Linear features and predation.

Introduction

The habitat analysis from this study (Chapter 2) indicates that bears are using pipelines, and field evidence (see Chapters 4 and 6) also indicates that ungulates use pipelines in our study area; therefore, encounters could occur between bears and ungulates on pipelines. Results from the first year of this study also showed that grizzly bears in the Kakwa area use pipelines for travel, which could influence encounter rates with prey. Thus grizzly bear use of linear features could have impacts for ungulate prey species, including caribou populations where they overlap with grizzly bear range.

Previous research has shown that wolves use linear corridors, potentially increasing encounter rates and predation risk for ungulates. It has been reported that wolves use areas near linear features such as roads, trails, railway lines, pipelines, and seismic lines (James & Stuart-Smith 2000, Whittington et al. 2005, Neufeld 2006, Latham et al. 2011, DeCesare 2012), and that travel speeds are faster along these features (Musiani et al., 1998, McKenzie et al. 2012). Use of linear features by wolves has been well demonstrated; however, to our knowledge, no research has been published directly connecting linear features with grizzly bear predation events in Alberta.

Location cluster analysis has been previously used in predation research for grizzly bears and other species (Anderson & Lindsey 2003, Webb et al. 2008, Krofel et al. 2013, Merrill et al. 2013), and has the potential to decrease the amount of fieldwork required for kill-site data collection by targeting locations with a higher probability of predation (Rauset et al. 2012). We generated location clusters from GPS collared bears and visited these clusters in the field to determine whether or not predation events occurred. These sites were modeled with linear feature data (pipelines, pipeline-road RoWs, roads, and seismic lines) to determine the spatial relationship between grizzly bear predation sites and linear features.

Methods

i. Grizzly bear location data and study site generation:

Bears were fitted with Followit or Telemetry Solutions GPS collars or GPS satellite collars. Data from GPS collars were collected monthly using Very High Frequency (VHF) data upload equipment from a fixed-wing aircraft during 2006 and 2007, and data from GPS satellite collars were collected via satellite transmission in 2013. To maximize sample size, three sources of field data were combined: previous FRI data (2006 and 2007), data collected by FRI staff during 2012 and 2013, and data collected by University of Calgary researchers for a thesis project in 2013. As a result, three different methods of sampling site generation were used.

FRI sampling sites during 2006 and 2007 were generated after each monthly VHF data acquisition. GPS collar locations were separated by time of day (day, night, and crepuscular periods) and randomly subsampled to obtain an equal number of points for each bear for each time period to assess habitat use, activity, and diet. Although, the goal of data collection during 2006 and 2007 was not to maximize detection of killsites, we were able to use this data for this predation analysis, due to similar field data collection methods.

During the two field seasons of this research project (2012 and 2013) collar data were downloaded via satellite every two weeks, with a goal of maximizing the probability of detecting killsites. Collar data were processed using a Python script in ArcGIS, and clusters of three or more consecutive points less than or equal to 100m apart in space and less than or equal to 2 hours apart in time were generated. We screened these initial location clusters using criteria similar to those in Rauset et al. (2012), including the time period (total time) of the cluster and the number of daily activity periods. Daily activity periods are defined by the diurnal patterns of grizzly bear activity, separated into two periods of higher activity (morning/evening) and two periods of inactivity (afternoon/night). Inclusion of both a low and high activity period reduces the probability that a group of points is a bedding cluster. Final sampling sites to be visited in the field included only location clusters that spanned more than one activity period, with a cluster time period of greater than or equal to 8 hours.

One of the goals of the research initiated by the University of Calgary was to develop a predictive killsite model for application to historic GPS data. For this project, location clusters were generated using a space-time statistical clustering approach (Kulldorff 2001, Webb et al. 2008), stratified by cluster size (number of points), and sampling sites were selected from an even distribution of cluster sizes (Kermish-Wells, pers. comm.).

The application of different methods to select sampling sites has the potential to influence results. We classified field data into three types based on the above methods of sampling site generation, and included field data type as a parameter in our analysis to account for these potential differences.

We determined annual home ranges for each collared bear using Minimum Convex Polygons (MCPs) (see Chapter 2, Grizzly bear location data). To standardize sampling intensity for random (available) locations, we generated random locations at a density of five points per square kilometer within each MCP, based on the area of the home range for each bear (Nielsen et al. 2004b, Roever et al. 2008a). Use and available points that fell within the Kakwa study area boundary were used in the analysis. Only non-denning locations were retained in the final dataset (see Chapter 2, Grizzly bear location data).

ii. Field data:

During 2006, 2007, and 2012 field crews visited bear use points within one month of the location date. In 2013, we visited cluster sites within two weeks of the location date whenever possible, but at least 7 days after the last point in the cluster, in order to avoid encountering bears at killsites. During 2006/2007, field crews navigated to the use point and searched for any bear activities within a 30mx30m plot centered at the use location. In 2013, field crews navigated to the centre of the cluster (as determined by the mean UTMs of the cluster points) and searched outwards in a spiral pattern for any evidence of bear activities or signs of a kill. Sites were searched outward to a 50m radius from the centre point.

In all years, study sites were confirmed as a predation site if a carcass, or parts thereof, was located. Crews identified the prey species based on observation of hooves, legs, antlers, other body parts, hair, and/or hide. When possible, the age class of the prey species was classified as calf, yearling, or adult based on body size, jaw size, presence of antlers, and the eruption pattern of teeth. To gain information about what species killed the prey (i.e. grizzly bear, wolves, coyotes, or cougar), crews recorded the presence/absence of other predator sign (tracks or scat) and additional information including whether or not a carcass was buried, if the hide was present or absent, if the carcass was disarticulated, cracked femurs, and presence of hair piles. However, it was often difficult to confirm whether a grizzly bear killed the animal, or if the animal was previously killed by other predators and subsequently scavenged by the bear. Any other bear activities or sign were also recorded, including evidence of bedding, anting, berry feeding, foraging, digging, scat, or tracks.

iii. Analysis:

We used a GIS to measure the distance from each random location, killsite location, non-killsite use location (field-confirmed), and GPS collar location to the nearest pipeline, pipeline-road combined RoW, road, and seismic line, using disturbance datasets specific for each year (see Chapter 2, Linear feature datasets).

Similar to the methods of James and Stuart-Smith (2000), we compared the distance to the nearest linear feature between: 1) use locations and available (random) locations, 2) random locations and killsites, and 3) killsites and non-killsite use locations. Based on our results indicating that grizzly bears use most linear features more than expected based on availability (Chapter 2), we hypothesized that grizzly bear use sites and/or killsites may also be closer than expected to linear features than random locations. The interpretation of distance from killsites to linear features could be confounded by the fact that non-killsite use locations might also be closer to than expected to pipelines; therefore, we wanted to also compare killsite locations to grizzly bear use locations. However, not all GPS collar locations were visited in the field, and it was not possible to confirm whether all locations were killsites or not. We used only field-confirmed grizzly bear killsite and non-killsite use locations for our comparison of killsites versus non-killsites. Based on previous research suggesting that predation behaviour differs between individual bears (Cristescu et al. 2011, K.Graham unpublished data), analysis of all three comparison groups were run for each individual bear using logistic regression. Distance to the nearest pipeline, pipeline-road RoW, road, and seismic line were included as predictor variables. For the comparison of killsite versus non-killsite use points (field data), an effect was included for field data type.

Distance variables were checked for correlation and collinearity using Pearson's correlation coefficients and variance inflation factors (VIF), respectively. VIF values were relatively low (≤1.6), but distance to pipelines and distance to pipeline-road RoWs were correlated (r~0.6). Therefore, these variables were included in separate models with the other distance to linear feature variables (distance to road and distance to seismic). For each bear, coefficients were reported from each model for distance to pipeline and distance to pipeline-road RoW, and averaged between the two models for distance to road and distance to seismic lines.

Results

Our final dataset included hourly GPS collar data and killsite data for one bear from 2006, two bears from 2007, and five bears in the 2013 season. FRIGBP field crews visited 300 use sites in 2006/2007, 12 clusters in 2012, and 25 clusters in 2013. University of Calgary researchers visited an additional 158 cluster sites in 2013. The final field dataset included 489 field sites at grizzly bear use locations, and 58 of these were confirmed predation sites (Table 1). The number of killsites visited per individual bear ranged from 3 to 14 (Table 1).

In general, use locations (GPS collar data, killsites, and non-killsite use) were closer to linear features than available locations (Figure 1). Some differences were observed between mean values between killsite locations, random locations, and non-killsite use locations, but these differences were not consistent or statistically significant. Mean distances to linear features by individual bear are in Table 1, and coefficients and p values from regression analyses are included in Tables 2 through 5. Grizzly bear predation sites were not significantly closer to linear features than non-predation grizzly bear use sites, and were not closer to linear features than expected based on availability.

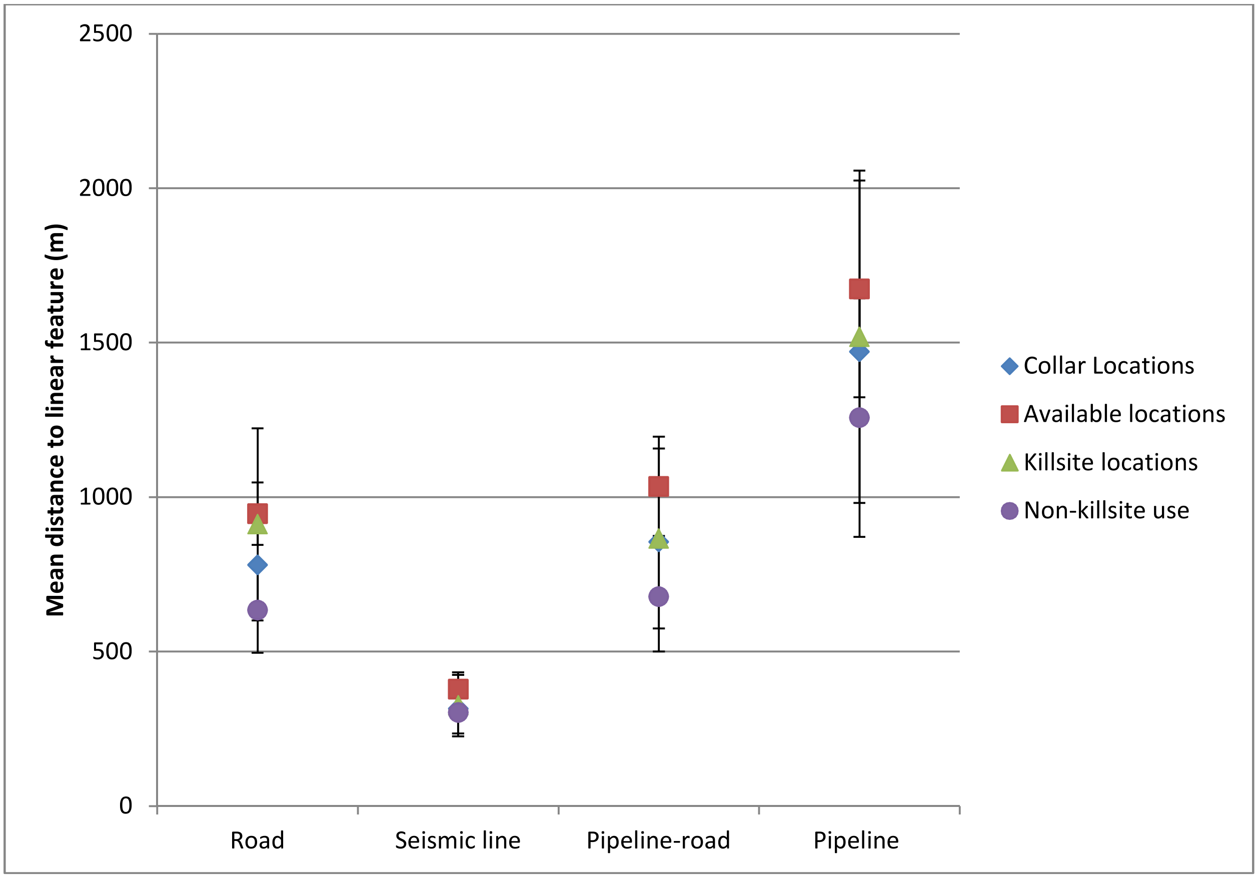

Figure 1. Mean distances to roads, seismic lines, pipeline-road RoWs and pipelines, by location type.

Table 1. Average distance to linear feature for individual grizzly bears, by use points (GPS collar locations), available points (random locations), confirmed predation sites (killsites), and confirmed non-predation use sites. Mean values with significant differences are in bold, and contrasts between comparison groups are indicated by a) significant differences between use and available, and b) significant difference between killsites and available.

		Use(GPS collar locations)		**Available (random locations)**		**Killsites**		**Non-predation use sites**	
	Linear feature	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
G223	Road	2763	**688**[a]	2897	791	3	884	29	615
	Seismic		**278**[a]		304		228		224
	Pipeline-Road		**959**[a]		831		317		639
	Pipeline		**1171**[a]		1283		780		889
G236	Road	2400	**691**[a]	5241	639	3	871	88	654
	Seismic		**369**[a]		305		413		419
	Pipeline-Road		**846**[a]		685		537		927
	Pipeline		**1043**[a]		942		1198		1071
G238	Road	2120	**634**[a]	5618	879	6	390	60	576
	Seismic		**343**[a]		370		362		284
	Pipeline-Road		1174		1201		1071		593
	Pipeline		**2317**[a]		2108		1671		2200
G260	Road	4647	**722**[a]	5593	835	10	564	127	481
	Seismic		**302**[a]		305		266		259
	Pipeline-Road		**569**[a]		824		819		533
	Pipeline		**1002**[a]		1229		1004		1034
G270	Road	3740	**876**[a]	7840	1065	14	**1290**[b]	58	812
	Seismic		**331**[a]		464		326		270
	Pipeline-Road		**887**[a]		1458		673		682
	Pipeline		**1850**[a]		2476		1796		1399
G280	Road	2704	**734**[a]	2067	902	7	1099	19	735
	Seismic		**347**[a]		482		462		256
	Pipeline-Road		1080		1247		1524		865
	Pipeline		**1935**[a]		2000		2745		1395
G284	Road	2338	892	7007	828	10	712	7	499
	Seismic		**200**[a]		237		150		136
	Pipeline-Road		**888**[a]		724		655		862
	Pipeline		**1371**[a]		964		805		1103
G287	Road	1664	**629**[a]	14007	1003	5	504	24	674
	Seismic		**297**[a]		357		250		340
	Pipeline-Road		**653**[a]		1019		299		344
	Pipeline		**997**[a]		1671		804		587

Table 2. Coefficients and confidence intervals by individual grizzly bear for analysis of distance to nearest road for: 1) use versus available locations, 2) killsites versus available locations, and 3) killsite versus non-killsite use locations. Significant results are in bold.

	Use versus available				**Killsites versus available**				**Killsites versus non-killsite use**			
			95% CI				95% CI				95% CI	
Bear	β	p	Lower	Upper	β	p	Lower	Upper	β	p	Lower	Upper
G223	**-0.00025**	**0.000**	**-0.00033**	**-0.00016**	0.00034	0.672	-0.00123	0.00191	0.00143	0.350	-0.00155	0.00441
G236	**0.00014**	**0.041**	**0.00003**	**0.00025**	0.00101	0.387	-0.00126	0.00328	0.00133	0.332	-0.00135	0.00400
G238	**-0.00055**	**0.000**	**-0.00063**	**-0.00047**	-0.00169	0.131	-0.00387	0.00050	-0.00101	0.414	-0.00343	0.00141
G260	**-0.00013**	**0.000**	**-0.00019**	**-0.00008**	-0.00069	0.272	-0.00193	0.00054	0.00040	0.505	-0.00076	0.00157
G270	**-0.00011**	**0.002**	**-0.00016**	**-0.00006**	0.00051	0.083	-0.00004	0.00107	0.00045	0.176	-0.00020	0.00110
G280	**-0.00033**	**0.000**	**-0.00041**	**-0.00024**	0.00021	0.616	-0.00061	0.00103	-0.00081	0.533	-0.00334	0.00172
G284	0.00009	0.088	0.00001	0.00017	-0.00031	0.604	-0.00148	0.00086	0.00270	0.228	-0.00165	0.00705
G287	**-0.00063**	**0.000**	**-0.00072**	**-0.00053**	-0.00101	0.316	-0.00299	0.00096	-0.00083	0.409	-0.00280	0.00114

Table 3. Coefficients and confidence intervals by individual grizzly bear for analysis of distance to nearest seismic line for: 1) use versus available locations, 2) killsites versus available locations, and 3) killsite versus non-killsite use locations. Significant results are in bold.

	Use versus available				**Killsites versus available**				**Killsites versus non-killsite use**			
			95% CI				95% CI				95% CI	
Bear	β	p	Lower	Upper	β	p	Lower	Upper	β	p	Lower	Upper
G223	**-0.00033**	**0.023**	**-0.00054**	**-0.00012**	-0.00098	0.719	-0.00633	0.00437	-0.00150	0.674	-0.00848	0.00549
G236	**0.00086**	**0.000**	**0.00068**	**0.00103**	0.00130	0.483	-0.00234	0.00495	-0.00001	0.939	-0.00405	0.00403
G238	**-0.00025**	**0.010**	**-0.00040**	**-0.00009**	0.00021	0.864	-0.00221	0.00263	0.00121	0.480	-0.00192	0.00435
G260	**0.00028**	**0.001**	**0.00013**	**0.00042**	-0.00033	0.795	-0.00281	0.00216	0.00013	0.935	-0.00292	0.00317
G270	**-0.00071**	**0.000**	**-0.00083**	**-0.00059**	-0.00080	0.373	-0.00254	0.00094	0.00112	0.356	-0.00123	0.00347
G280	**-0.00108**	**0.000**	**-0.00126**	**-0.00090**	-0.00042	0.667	-0.00235	0.00151	0.00259	0.311	-0.00237	0.00756
G284	**-0.00101**	**0.000**	**-0.00125**	**-0.00077**	-0.00266	0.231	-0.00702	0.00170	-0.00675	0.373	-0.02140	0.00791
G287	**-0.00039**	**0.001**	**-0.00058**	**-0.00019**	-0.00088	0.665	-0.00489	0.00312	-0.00165	0.353	-0.00514	0.00184

Table 4. Coefficients and confidence intervals by individual grizzly bear for analysis of distance to nearest pipeline for: 1) use versus available locations, 2) killsites versus available locations, and 3) killsite versus non-killsite use locations. Significant results are in bold.

	Use versus available				**Killsites versus available**				**Killsites versus non-killsite use**			
			95% CI				95% CI				95% CI	
Bear	β	p	Lower	Upper	β	p	Lower	Upper	β	p	Lower	Upper
G223	**-0.00011**	**<0.001**	**-0.00017**	**-0.00006**	-0.00073	0.414	-0.00247	0.00102	-0.00022	0.838	-0.00235	0.00191
G236	**0.00014**	**<0.001**	**0.00008**	**0.00020**	0.00026	0.677	-0.00096	0.00147	0.00012	0.830	-0.00093	0.00116
G238	**0.00011**	**<0.001**	**0.00008**	**0.00014**	-0.00010	0.739	-0.00066	0.00047	-0.00024	0.410	-0.00080	0.00033
G260	**-0.00026**	**<0.001**	**-0.00030**	**-0.00021**	-0.00017	0.641	-0.00090	0.00055	-0.00005	0.885	-0.00080	0.00069
G270	**-0.00010**	**<0.001**	**-0.00013**	**-0.00008**	-0.00021	0.213	-0.00054	0.00012	0.00023	0.321	-0.00023	0.00069
G280	**0.00005**	**0.019**	**0.00001**	**0.00009**	0.00032	0.165	-0.00013	0.00078	0.00064	0.132	-0.00019	0.00148
G284	**0.00052**	**<0.001**	**0.00047**	**0.00057**	-0.00019	0.664	-0.00106	0.00068	-0.00305	0.098	-0.00667	0.00056
G287	**-0.00029**	**<0.001**	**-0.00034**	**-0.00024**	-0.00050	0.396	-0.00165	0.00065	0.00116	0.271	-0.00091	0.00323

Table 5. Coefficients and confidence intervals by individual grizzly bear for analysis of distance to nearest pipeline-road RoW for: 1) use versus available locations, 2) killsites versus available locations, and 3) killsite versus non-killsite use locations. Significant results are in bold.

	Use versus available				**Killsites versus available**				**Killsites versus non-killsite use**			
			95% CI				95% CI				95% CI	
Bear	β	p	Lower	Upper	β	p	Lower	Upper	β	p	Lower	Upper
G223	**0.00026**	**<0.001**	**0.00019**	**0.00033**	-0.00232	0.212	-0.00597	0.00133	-0.00223	0.366	-0.00705	0.00260
G236	**0.00034**	**<0.001**	**0.00026**	**0.00041**	-0.00068	0.576	-0.00308	0.00172	-0.00099	0.422	-0.00340	0.00143
G238	0.00002	0.386	-0.00003	0.00007	-0.00006	0.881	-0.00090	0.00077	0.00049	0.336	-0.00051	0.00149
G260	**-0.00064**	**<0.001**	**-0.00071**	**-0.00057**	0.00016	0.729	-0.00075	0.00107	0.00071	0.122	-0.00019	0.00161
G270	**-0.00034**	**<0.001**	**-0.00038**	**-0.00030**	**-0.00093**	**0.022**	**-0.00172**	**-0.00014**	0.00035	0.634	-0.00108	0.00177
G280	0.00005	0.169	-0.00002	0.00011	0.00021	0.559	-0.00049	0.00090	0.00043	0.472	-4.94887	2.29020
G284	**0.00035**	**<0.001**	**0.00029**	**0.00042**	-0.00007	0.896	-0.00109	0.00095	-0.00058	0.680	-0.00336	0.00219
G287	**-0.00039**	**<0.001**	**-0.00047**	**-0.00031**	-0.00217	0.140	-0.00506	0.00071	-0.00124	0.896	-2.76339	2.41860

Discussion

Models using wolf and caribou telemetry data have predicted that encounter rates would be significantly higher between predators and prey in areas of high seismic density (McKenzie et al. 2012) and in proximity to other linear features (Whittington et al. 2011). However, limited research is available regarding the occurrence of confirmed predation events on or near linear features. James and Stuart-Smith (2000) found that wolves were closer than expected to linear corridors, but predation sites were not significantly closer than random locations or telemetry locations. DeCesare (2012) reported that linear features resulted in higher search rates for wolves, but did not positively affect the kill rate, and Latham et al. (2011) reported that caribou mortalities did not occur closer to linear features than live caribou. Results from our analysis suggest that grizzly bear predation events in our study area did not occur closer to linear features non-predation use sites or compared to that expected based on availability. However, previous results from the Kakwa area indicated that grizzly bears are using linear features for travel, similar to predator movement patterns in other areas (Musiani et al. 1998, McKenzie et al. 2012).

Sample sizes for killsites were low in our study, possibly limiting the power to detect significant differences. Research planned in the Kakwa area during 2014 includes further investigation of grizzly bear predation in caribou range. The outcomes of the study will include: spatial and temporal models describing grizzly bear use and movement relative to linear features within the summer range of mountain caribou herds, estimates of caribou kill rates by grizzly bears from this area, and new predictive models of grizzly bear predation identifying anthropogenic and other factors influencing the distribution of caribou mortalities. This study will also include the development of new techniques (stable isotope analysis from bear hair and/or scat) which could be used to monitor caribou consumption by grizzly bears and other predators found within all caribou ranges in Alberta and across Canada. The use of isotope analysis has the potential to reduce the amount of field data necessary for predation studies.

Predator use of linear features has the potential to increase kill rates of large ungulates (Webb et al. 2008, McKenzie et al. 2009). Based on our current analysis, we have no evidence to suggest that this pattern occurs with grizzly bears, ungulate prey species, and pipeline RoWs in our study area. Movement along linear features in our study area has the potential to increase grizzly bear access to prey; however, based on our distance to linear feature analysis, it is uncertain whether bears traveled on linear features prior to predation events. We anticipate that results from research in 2014 will aid in understanding the complexity of grizzly bear predation behaviour in the boreal forest.

Chapter 6: Mortality risk factors

A. Sightability of grizzly bears on pipeline RoWs.

Introduction

Human-caused mortality is considered to be the primary limiting factor for Alberta grizzly bears (ASRD 2008), and areas with a high level of human access are associated with an increased risk of mortality (Jalkotzy et al. 1997, Benn 1998, Nielsen et al. 2004a, Boulanger et al. 2013). The use of linear features by grizzly bears for travel and/or foraging may put them at a higher risk of human-caused mortality, but this risk may be partially dependent on the visibility of bears at road/pipeline intersections

A number of authors have previously measured hiding cover and the visibility of bears and other species, including the distance at which a simulated animal is detected, the amount of "animal" that is visible, and the maximum distance visible along a linear feature, or line-of-sight distance (Sunde et al. 1998; Switalski &Nelson 2011; Kjellander et al. 2012). Sunde et al. (1998) found that the tolerance of lynx to human presence depended on cover, and Switalski and Nelson (2011) reported that the frequency of black bears photographed along roads in Montana was negatively correlated with line-of-sight distance, and positively correlated with hiding cover. Based on the potential for mortality risk, we were interested in investigating the visibility on pipelines from a road. We examined visibility of grizzly bears at varying distances and collected data on factors that may affect visibility. A variety of equipment and methods have been applied to measure visibility (Collins & Becker 2001; Ordiz et al. 2009), and we adapted these techniques to measure visibility of grizzly bears at pipeline-road intersections in the Kakwa area. We proposed that visibility of bears may depend on vegetation, pipeline age, adjacent habitat, presence of a trail, and topography (e.g. slopes, depressions). Using knowledge gained in the examination of these factors, a spatial model would be developed to predict which pipelines in the Kakwa study area had high visibility and therefore grizzly bears would have a high risk of human-caused mortality on these sections of pipelines. This visibility Information will provide an indication of their vulnerability to human-caused mortality (illegal killing) while on pipelines.

Methods

Site selection:

A Geographic Information System (GIS) was used to determine locations of pipeline and road intersections. Pipelines parallel to roads were not included as part of this analysis. The intersections were stratified by age class of pipeline and randomly subsampled to generate field sites for data collection.

Field methods:

Based on the average height and length of grizzly bears in our area, we constructed a rectangle out of brown cloth, approximately 1m tall (based on shoulder height) and 1.5m wide. The rectangular section of cloth was mounted on stakes to allow it to be displayed in the field, and marked into four quarters to assist with estimating the percent visible. With one person stationed on the road at a randomly generated distance from the pipeline edge, the second person walked 50m up the edge of the pipeline, traversed out onto the pipeline at a different randomly generated distance from the edge, and held out the cloth “bear”. The person at the road estimated the percent of “bear” visible, and recorded any obstruction, including grass/forbs, shrubs, trees, hill, depression, corner, and “other”, (e.g. infrastructure or logging debris). We called this a road random-pipe random paired locations measure. If wildlife or an off-highway vehicle (OHV) trail was present down the pipeline from the road, three additional paired location visibility estimates were taken. The person at the 50m distance on the pipeline would move across the pipeline to the trail and visibility of the “bear” on the trail was assessed by the person at the random location on the road (road random –pipe trail paired locations). The person on the road then moved along the road to look down the trail and estimated % of the “bear” visible down the trail (road trail-pipe trail paired locations) and lastly the person at the 50m mark moved back to the 50m random location and the person standing at the road-trail junction did a forth visibility estimate (road trail – pipe random paired locations). Tree, shrub and grass/forb cover > 25 cm tall were visually estimated using cover classes (Table 1) for the entire 50 m length of pipeline, and height of vegetation was measured at the random pipeline location and the trail location. Adjacent habitat on both sides of the pipeline was classified to conifer species (lodgepole pine, white spruce or black spruce) and canopy cover (open, moderate or dense), other habitat types (mixed forest, broadleaf forest, open wetland, treed wetland, shrubs, herbaceous or water) or anthropogenic habitat (cutblock or wellsite).

Table 1. Percent cover classes used to estimate forbs/grass and shrubs > 25 cm tall and tree canopy cover on pipelines.

Grass/Forb and Shrub Cover Class	Percent Grass/Forb or Shrub Cover	Midpoint value used in analysis	Tree Canopy Class	Percent Tree Canopy Cover	Midpoint value used in analysis
+	< 1	0.5	1	1-10	5.5
2	< 5	2.5	2	11-30	20.5
3	5-25	15	3	31-50	40.5
4	26-50	38	4	51-70	60.5
5	51-75	63	5	71-90	80.5
6	76-100	88	6	91-100	95.5

Measurements were repeated at 100m, 150m, and 200m distances down the pipeline, or until 0% of the bear was visible. At that point it was assumed that the visibility of the “bear” would continue to be zero up until 200m.

The maximum line-of-sight down the pipeline from the road intersection was measured using a rangefinder. Maximum line-of-sight was measured to the furthest point at which >0% of a bear would be visible. Pipeline RoW width and the presence/absence of a belt of shrubs or trees next to the road were also recorded.

Analysis:

We completed exploratory summaries of the data. We tested for differences in the percentage of bear visible among the location pairs (RdRandom-PipeRandom, RdRandom_PipeTrail, RdTrail-PipeRandom and RdTrail-PipeTrail) and the 4 distances (50m, 100m, 150m, 200m). We used an ordinal logistic regression because of the large number of 0% visibility values. Percent visible values were categorized into 4 visibility classes (0-25%, 26-50%, 51-75%, and 76-100%).

We conducted a generalized linear model (GLM) analysis to determine the important factors in predicting maximum line-of-sight down a pipeline from a road intersection. Age of pipeline was obtained in a Geographic Information System (GIS) based on pipeline construction dates provided by Alberta Energy. Pipelines with more than one construction date (i.e. a second or additional pipeline had been construction down the same pipeline right-of-way at a later date) were removed from the GLM analysis because field data collection did not distinguish between vegetation estimates from the older and recent portions of the pipeline; therefore, dates could not be confidently matched to vegetation estimates. A Terrain Ruggedness Index (TRI) and a Compound Topographic Index (CTI) were extracted at each pipeline-road intersection visited. Terrain Ruggedness index (TRI) provided a measure of the unevenness of the terrain at a 30m scale, as averaged across the 8 surrounding 30m pixels (Riley et al. 1999), based on a Digital Elevation Model (DEM). The CTI provided a measure of moisture in a 150m radius at each pipeline-road intersection. We log-transformed the maximum line-of-sight distance (m) to improve normality, and tested for collinearity using variance inflation factors (VIF) among all the variables prior to the analysis.

Results

Field crews collected data from 66 pipelines in 2013, twenty (30%) of which had trails present. Eighty percent of trails were classed as OHV, and 20% were classed as a wildlife trail. The average maximum line-of-sight down a pipeline from a road intersection was 164.5m, with a range of 2-900m and a median of 112.5m. Forty-eight percent of pipelines had a maximum line-of-sight < 100m; 3% had a maximum line-of-sight > 500m (Figure 1).

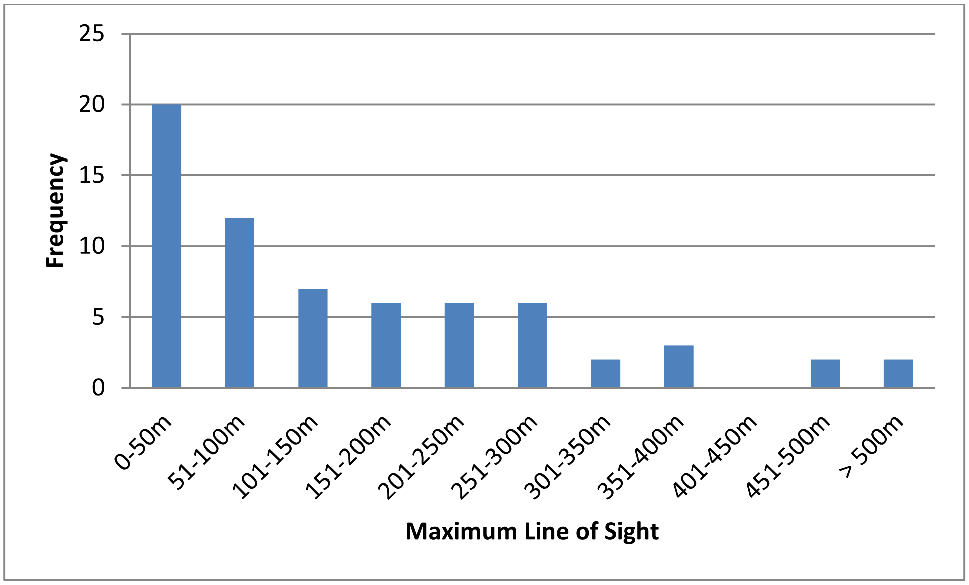

Figure 1. Frequency of maximum line-of-sight distances down pipelines from road intersections in the Kakwa Study area.

Sites with shrubs or trees recorded as the obstruction were pooled into a shrub/tree obstruction class due to small sample sizes. A vegetation belt at the pipeline-road intersection occurred at only 2 sites, and these were also pooled with the shrub/tree obstruction class. Sites with a hill, berm, or depression as the obstruction were also pooled to create a topography obstruction class.

Topography was the main cause of obstruction of maximum line-of-sight at over 50% of the sites, followed by pipeline corners, shrubs, and grass/forbs (Figure 2).

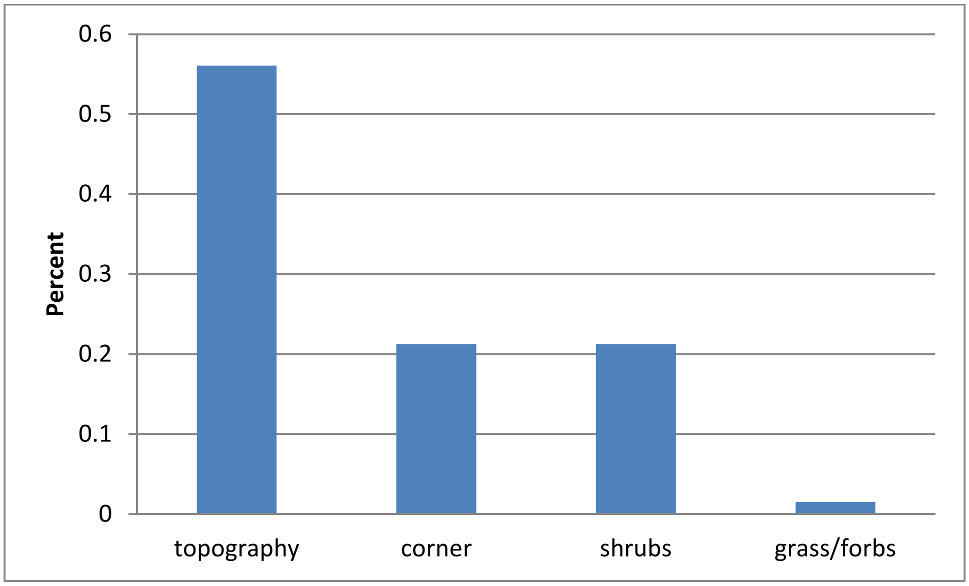

Figure 2. The maximum line-of-sight obstruction types at 66 pipeline-road intersections in the Kakwa study area.

At 50m distance from the road, on average 20% of the “bear” was visible when looking from the road to a random pipeline location (n= 66); compared to 34% visible when looking down a trail with the “bear” on the trail (n=20; Figure 2). At the 200m distance, 7-8 % of the bear was visible regardless of whether the “bear” was on a trail. Mean height of vegetation at random pipeline locations (mean=77.4 cm, n=40) was significantly different than on trails (mean = 53.4 cm, n=40; paired t-test: t =2.94; df=39; P = 0.005).

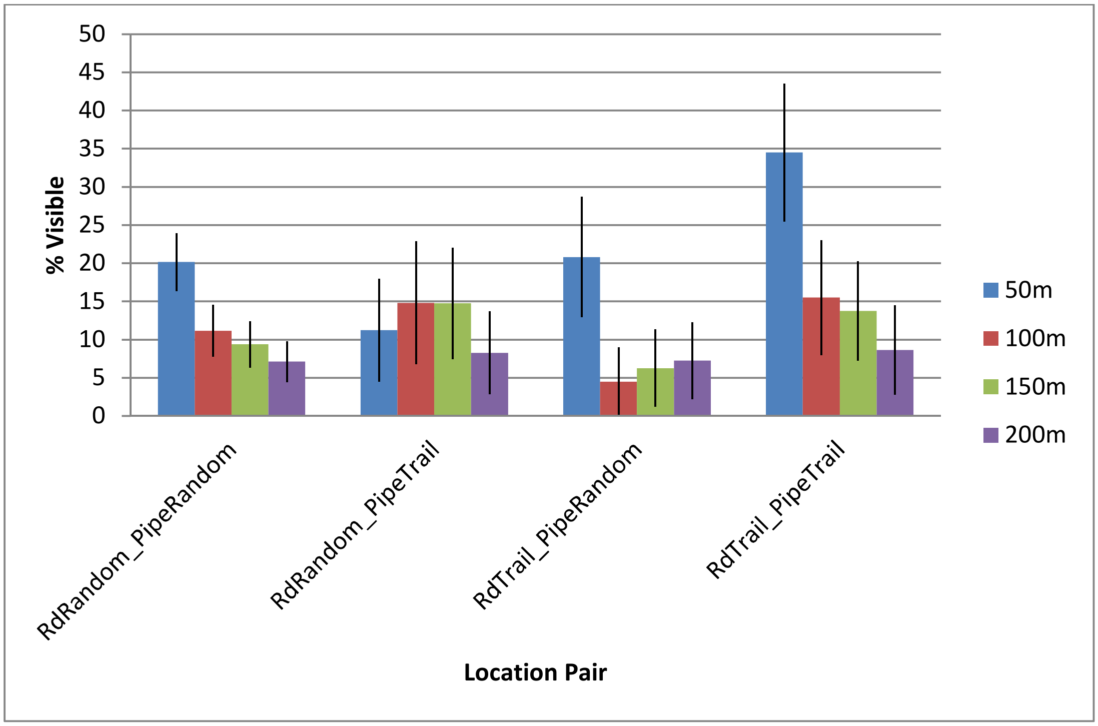

Figure 3. Average percent of a “grizzly bear” visible in 50m increments down a pipeline from a road intersection at different location pairs for a total of 504 “bear” locations. Standard error bars are shown.

The ordinal logistic regression looking at location pairs and distance from a road down a pipeline found distance from road was a significant predictor of visibility (z = -3.32, P = 0.001), but the 4 location pairs was not (P > 0.05; Figure 3).

Visibility was reduced most often by shrubs/trees (42% of the 504 “bear” locations), followed by topography (37.5%), grass/forbs (8%), corners (7%), and other (1%; Figure 3). Shrubs/trees and topography were important obstructions at all 4 distances, while grass/forb and “other” were more important at the 50m distance. Pipeline corners were most important at 150m and 200m distances (Figure 3).

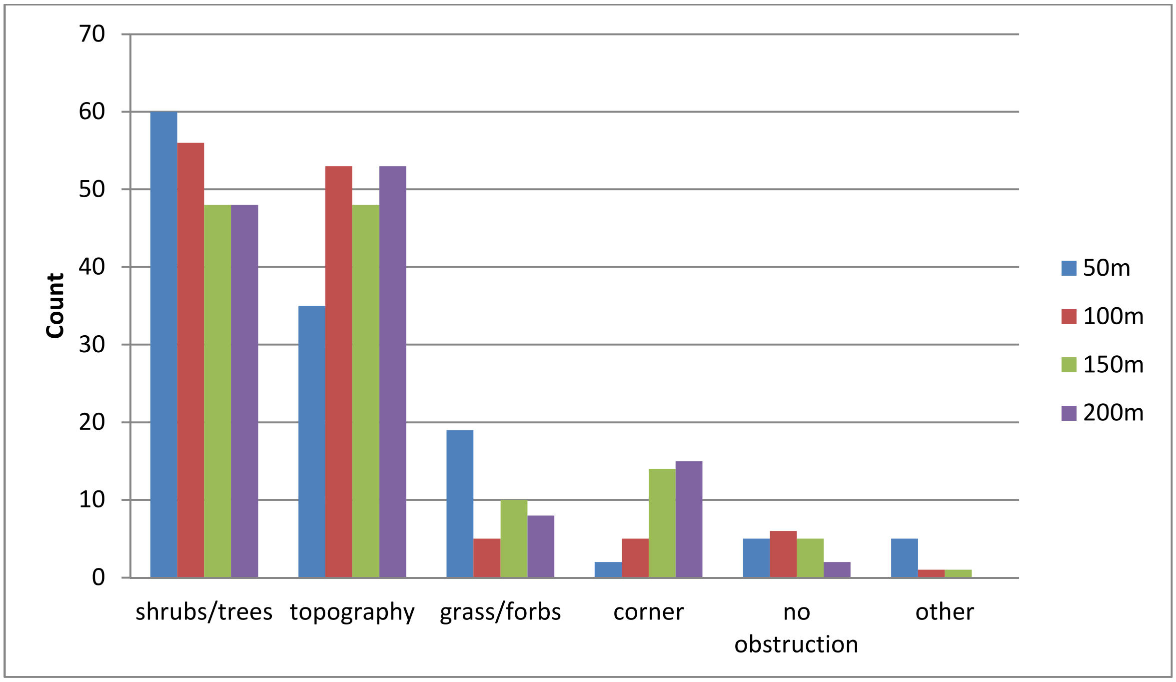

Figure 3. Count of obstruction type by distance (m) down pipelines at road-pipeline intersections at 504 “bear” locations.

Of the 66 pipelines visited, we excluded 16 due to missed data or multiple construction years. Based on our exploratory examination, we developed three *a priori* models based on vegetation, terrain or pipeline attributes to explain maximum line-of-sight (Tables 2 and 3). We used elevation as a surrogate for tree species in the adjacent habitat. Elevations ranged from 695m to 1314m. Forested sites below 1050m consisted mainly of deciduous tree species (89%), while sites above 1050m were mainly coniferous species (86%). There was no collinearity among the parameters in Table 2 with all variance inflation factors (VIF) < 1.99. The model with the most AIC support was the vegetation model, which included shrub cover and vegetation height, and explained 90% of the variability (Table 4).

Table 2. Explanatory variables used for assessing maximum line-of-sight down pipelines at road intersections in the Kakwa study area.

Variable	Source	Description	Range
ShrubTCover	Field measure	Average shrub/tree cover (%) on a pipeline using midpoint of cover classes (Table 1)	0-63 %
VegHeight	Field measure	Average vegetation height (cm) on a pipeline	0-202 cm
Elevation	GIS Raster	Elevation of location based on a 30 m Digital Elevation Model (DEM)	695-1314m
Year	Alberta Energy	Construction Year of pipeline	1981-2012
width	Field measure	Width of pipeline (m)	9-60m
CTI	GIS Raster	Compound Topographic (wetness) Index– at a 150m scale	6-11
TRI	GIS Raster	Terrain Ruggedness Index – at a 90m scale	0-15

Table 3. A priori candidate models used to describe the maximum line-of-sight down pipelines at road intersections in the Kakwa study area.

Model Number	Model Name	Parameters	Number of observations
	Null (logdistance)	none	50
1	Vegetation	Shrub cover, vegetation height	50
2	Terrain	Elevation, TRI, CTI	50
3	Pipeline	Year, RoW width	50
4	Global	Shrub cover, vegetation height, CTI, elevation, TRI, year, RoW width	50

Table 4. AICc-selected models for predicting the maximum line-of-sight down pipelines at road intersections in the Kakwa study area. The model with the highest AIC weight is in bold.

Model Number	Log Likelihood	K	AiCc	Δ_i	w_i
Null	-37.001	1	76.08533	6.757594	0.030666
1	**-31.403**	**3**	**69.32774**	**0**	**0.899606**
2	-36.666	4	82.22089	12.89315	0.001427
3	-34.463	3	75.44774	6.12	0.042180
4	-28.447	8	76.4062	7.078456	0.026121

We examined whether shrub/tree cover or vegetation height were associated with construction year or CTI. We found no relationship between construction year and shrub/tree cover (t = 1.65; P > 0.05) or vegetation height (t = 0.05; P > 0.05). Similarly there was no relationship between CTI and shrub/tree cover (t = -0.27; P > 0.05) or vegetation height (t = -0.76; P> 0.05).

Discussion

At the start of this research, our intention was to create a model that could be applied to the entire study area, in order to highlight pipelines with the farthest sightability (maximum line-of-sight) at road intersections. These intersections would present the highest grizzly bear mortality risk and could therefore be targeted for mitigation. This analysis required GIS layers that were potential predictors of maximum line-of-light for our study area. Our exploratory analysis and GLM indicated that shrub cover and/or vegetation height were important predictors, but a GIS layer including vegetation information for all pipelines in the study area was not available. Therefore, we examined whether construction year or CTI could be used as a surrogate for these vegetation parameters, but found no relationship. In addition, the index of topography (TRI) used in the GLM analysis was a poor predictor of maximum line-of-sight; in spite exploratory work indicating that topography was the most important obstruction of sight lines. We suspect that the TRI was not at the right spatial scale to detect the small hills and depressions that could hide a grizzly bear. Without suitable GIS layers for model development and testing, we did not pursue this analysis further.

We had expected that construction year would predict our shrub cover estimates or vegetation heights; however, this was not the case. It is possible that the pipeline construction year did not accurately represent when the last disturbance event occurred, as it is unknown whether pipelines were cleared again after their initial construction date. It is also plausible that shrub growth is related to many other factors other than last disturbance date, such as light intensity and duration, soil seed bank, soil type etc. These factors were not investigated in our analysis.

Over half of our sites had a maximum line-of-sight of > 100m down the pipeline from a road intersection. Topography blocked maximum line-of-sight at over 50% of our plots, and was also important in reducing bear visibility at 50-200m down a pipeline. Shrubs were less important in determining maximum line of sight compared with topography, but were important in reducing bear visibility at 50-200m down a pipeline. Based on these results, creating an earth berm along road intersections and/or encouraging shrub growth within the first 50m of a road intersection could help to reduce grizzly bear mortality risk on pipelines at road intersections.

The presence of a trail, although not significant in affecting visibility of a “bear” compared to random locations, did result in more of the “bear” being seen, especially at the 50m distance. If a trail is required on a pipeline, the trail-road junction could be hidden by shrubs or a berm to reduce visibility while still allowing workers to travel on the pipelines.

Although maximum line-of-sight was often > 100m, this is the distance when a bear was presumed to be completely hidden. At a 50 m distance from the majority of road intersections, 10-35% of a “bear” was visible. This suggests that many pipelines have topography, curves or shrub cover that partially hide a grizzly bear from the view of passing vehicles. Our sightability results also suggest that workers or recreationists using pipelines for travel may not be able to see a grizzly bear on a pipeline from long distances. We recommend that pipeline workers be trained in bear awareness and safety when working in bear habitat. We examine the human use of pipelines in the next section (6B).

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B. Levels of human and wildlife use on pipeline RoWs.

Introduction

It is well known that human access is associated with an increased risk of human-caused grizzly bear mortalities (Jalkotzy et al. 1997, Benn 1998, Nielsen et al. 2004a, Roever et al. 2008a, Boulanger et al. 2013). However, while the risk of mortalities can be predicted, the actual occurrence of mortality events depends on human-bear encounters and the attitudes and behaviours of the people encountering bears. We set out to examine levels of human use of pipelines within the Kakwa study area, and to assess the probability of these encounters taking place.

Methods

Previous work by our staff in this study area suggested an overall low level of human presence on pipelines; therefore, we decided to situate cameras to maximize the probability of detecting any use of pipelines by humans. We installed cameras just prior to and during the hunting season in the fall. Camera locations were subjectively determined based on observations of human use on pipelines, the configuration of the pipeline across the landscape, and the distance to the nearest road. Potential sites were mapped in a GIS. Sites were selected within 100m of a main gravel road that either: a) spanned a large distance across the study area, in which case cameras were placed at different entry points, or b) were on a short pipeline but provided entry to areas where road access was limited.

The cameras installed for this data collection included Bushnell Trophy Cams, Cuddyback No Flash, and Cuddyback AttackIRs. At each site, cameras were locked inside protective metal cases and attached to a tree with screws at a height of between 0.75-1.5 m, depending on the height of the terrain in front of the camera. Tall grass, forbs and shrubs were cleared from the camera field of view.

Photo processing:

Each photo was visually assessed, and photo date, time, photo subject, and direction of travel were entered into a database. Wildlife species were recorded as well as human use. An event was defined as a sequence of photos within 5 minutes of each other triggered by the same animal or person. We also identified “linked” events, when two events of the (presumed) same individual (based on physical characteristics) occurred within the same day. Most of these linked events were of people with distinguishable features such as ATV or clothing. For grizzly bear sightings, we used data to confirm whether a collared bear was at a location at different times of the day. We used colour and size to determine if it was the same uncollared bear, but only if the events occurred within the same hour, in order to minimize misidentification of individuals. Antlers and size of animal helped to determine the unique identity of male ungulates, however, it was not possible to determine the unique identity for coyotes, lynx or female ungulates.

Each photo subject was identified to species whenever possible. Observations of ATVs were classified as work-related, recreational, or unknown. Although it was not possible to confirm peoples’ activities, we used the presence of coveralls, cruise vests, or equipment strapped to the ATV as evidence of work-related activities. ATV-unknown included photos with poor visibility of the vehicle and/or people. For each camera site, we standardized the frequency of photos by photo subject per 100 camera-days.

Results

Seven cameras were installed between 31 July and 1 Aug 2013 (Figure 1). One camera (Ridge) failed immediately after deployment, and another camera (Comeau) was removed after 20 days due to nearby construction of a pipeline. The Camp camera missed 20 days in early September as a result of hundreds of misfires that filled the SD card. Cameras were removed from between 10-15 Oct 2013. The Comeau site collected pictures for 20 days, the Camp camera for 55 days, and the remaining 4 sites collected pictures for 72-76 days.

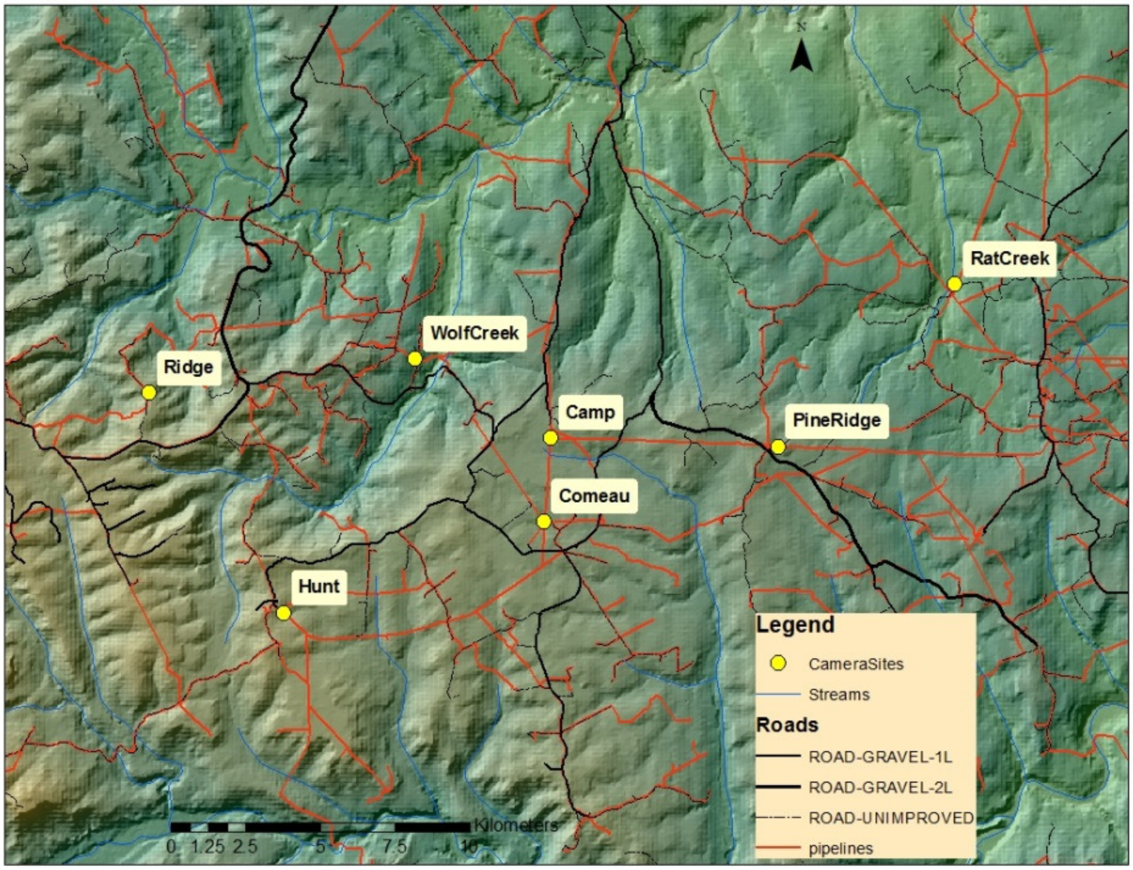

Figure 1. Locations of 7 cameras located on pipelines within the Kakwa study area.

A total of 1280 photos were obtained from six cameras, with 345 photos (27%) attributed to an observable photo subject (person or animal), for a total of 144 events. The remaining 935 photos (93%) did not have a person or animal detected. It appeared that the wind may have resulted in misfires, and some photos may have been triggered by an animal too small or moving too fast for the camera to capture.

Table 1 shows counts for each photo subject by camera site. Species observed only once were pooled into a miscellaneous group including elk, gray jay, lynx, and mule deer. Of the 144 events, 38% were ATVs (including quads and side-by-sides), followed by grizzly bears at 19%, white-tailed deer at 19%, coyote and moose at 5%, people on foot or helicopter at 4%, deer at 3%, miscellaneous at 3% and bears of unknown species and unknown animals both at 2%.

ATVs were detected at all six camera sites. Of the ATV events, 65% appeared to be work related, 9% may have been recreational, and 26% were unknown. In addition, 59% of ATV sightings were linked to one or more events in the same day, typically observed going in one direction in the first photo and in the opposite direction in the linked photo. All human detections occurred during daylight hours. A firearm was seen in 28% of the ATV photos, all of which came from one site and likely the same individual.

Table 1. Count of photos by photo subject across the 6 camera sites. *Miscellaneous includes one photo each of an elk, mule deer, gray jay, and lynx.

Camera Site	ATV	Grizzly Bear	White-tailed Deer	Coyote	Moose	Persons on foot or heli	Deer Sp.	Misc.*	Bear Sp.	Unk	Grand Total
Camp	6	16	3	6		3	1	1	3	2	41
Comeau	2		1		2						5
Hunt	34		1		1	2	1	1			40
PineRidge	3	10	8	1	2		2			1	27
RatCreek	2	2	5			1	1	1			12
WolfCreek	7		9		2			1			19
Grand Total	**54**	**28**	**27**	**7**	**7**	**6**	**5**	**4**	**3**	**3**	**144**

Grizzly bears were detected at 3 of the camera sites, with two of the sites providing 93% of the detections. Of the 28 events, 18% were linked and all linked events occurred at the Camp site. Forty-seven percent of grizzly bear detections occurred at night (Figure 1), followed by day (40%), dusk (9%) and dawn (4%). White-tailed deer were the most ubiquitous species; detected at all 6 sites with 52% detections occurring at night, 44% during the day and 4% at dusk.

Figure 1. Remote camera picture of a grizzly bear event from the Pine Ridge site. One of these bears is an adult male grizzly bear (G270) wearing a GPS collar.

Using standardized values for each camera site and only the first event for linked events, all six sites had an average of 9.1 ATV events/100 camera days (SD=8.9). The Hunt site had the highest (26.3 ATV events/100 camera days) and the Rat Creek and Pine Ridge sites the lowest (2.6 ATV events/100 camera days, Figure 2). Grizzly bears were detected at the Camp site most often at 20 events/100 camera days, followed by the Pine Ridge site at 13 events/100 camera days and lastly at the Rat Creek Site at 2.7 events/100 camera days.

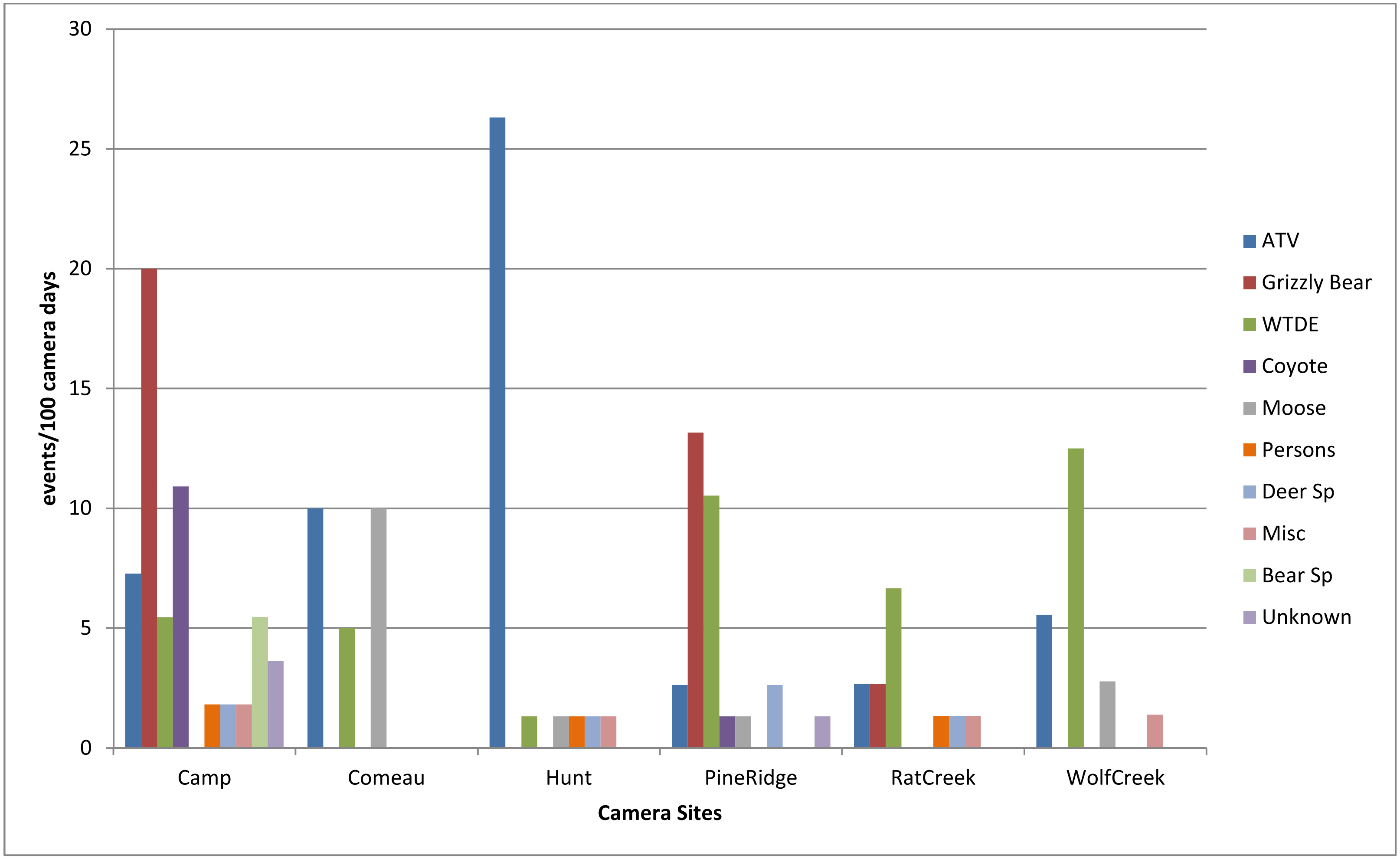

Figure 2. Events/100 camera days across sites by photo subject.

Discussion

Cameras were an efficient method to quantify human use, although frequent checks were needed to determine whether SD cards were full, batteries were dead, cameras had malfunctioned, or events (e.g. construction) near the camera could put the camera at risk of being damaged or removed. Over 90% of the pictures did not detect anything, suggesting problems with camera sensitivity.

All pipelines monitored were used by people, always during the day, and often while driving off-highway vehicles for what appeared to be work-related activities. Pipelines were also used during the day by grizzly bears, which points to the possibility that bear-human encounters could occur on pipelines in the Kakwa study area. Further, as we found in Chapter 6A, topography and shrubs on pipelines can reduce visibility of a grizzly bear to < 50m. It is hoped that industry workers are trained in grizzly bear safety, awareness, and behaviours. It is recommended that bear spray be provided to all field workers with appropriate training in its use, as evidence has shown that bear spray is an effective deterrent against grizzly bears (Smith et al. 2008) and has advantages over a gun (Floyd 1999, Smith et al. 2012).

Reducing human-caused mortality by reducing access development and use is the first recommendation in the Alberta Grizzly Bear Recovery Plan (ASRD 2008). Up to thirty-five percent of human detections on the pipelines may have involved recreational activities. Minimizing the use of pipelines to the public would lower the risk of human-bear encounters and possibly human-caused mortalities. As suggested in Chapter 6A, creating a shrub or berm visibility shield at pipeline-road intersections could potentially hide trails used by workers, and reduce the number of recreationists using pipelines.

Chapter 7: Final Conclusions

The main objective of this two-year research project was to address the knowledge gap regarding grizzly bear habitat use, foraging patterns, and movement patterns on pipelines, along with the possible mechanisms behind patterns of grizzly bear use of pipelines. Investigation of grizzly bear use of pipeline RoWs in our study area also required consideration of other linear features present on the landscape, including roads and seismic lines.

In the first year of this project (2012), we focused on habitat selection patterns, grizzly bear activities, and movement patterns related to pipeline RoWs. Research objectives in the second year of this project (2013) expanded to investigate grizzly bear use of pipelines in more detail, including parameters that may predict use of pipelines, and the spatial relationship between grizzly bear predation sites and linear features. We also investigated factors that could increase the probability of bear-human encounters, and therefore influence the risk of human-caused grizzly bear mortality. These factors include the visibility of bears on pipelines from roads, and levels of human use on RoWs.

Results from our habitat analyses indicate that grizzly bears used pipelines, road-pipeline right-of-ways, and roads significantly more than expected based on availability. Male bears also used seismic lines more than expected, while female bears appeared to avoid seismic lines during spring and fall. It appears that grizzly bears in the Kakwa study area are not generally avoiding linear features. Our analysis of bear food availability on pipelines indicated that a number of bear foods are more common on pipeline RoWs and edges than in other available habitats; in particular, dandelion, clover and ants had a much higher occurrence on pipelines than in forested habitat. These species are known to be important bear foods in our study area, and bears may be attracted to pipelines due to the occurrence of these foods. Field data collected during both years of this study indicated that bears were using pipeline RoWs for a range of foraging activities, with anting as the most common activity. For small and threatened populations like the grizzly bear population in west-central Alberta, pipelines could function as habitat sinks - areas of high quality habitat with high mortality risk. However, over the course of our research we have no records of radio-collared grizzly bears being killed along pipeline RoWs; human caused mortalities were in close proximity to all-weather gravel roads.

An analysis of movement rates in the first year showed that grizzly bears traveled significantly faster on road RoWs, road-pipeline RoWs, pipeline RoWs, and seismic RoWs as compared to in non-linear habitat, suggesting that linear feature RoWs may serve as movement corridors for grizzly bears in our study area. However, grizzly bear predation events in our study area did not occur closer to linear features than expected based on availability, or as compared to other use sites. Based on our current analysis, we have no evidence to suggest that grizzly bears used linear features to access ungulate prey species; however, grizzly bear movement patterns prior to predation events are still unclear. Research activities planned for 2014 will provide more information regarding grizzly bear predation patterns and the relationship with anthropogenic features.

Based on the combined results from the analyses of habitat selection, bear activities, movement rates, and bear food occurrence on pipelines, it is likely that grizzly bears in our study area use pipeline RoWs for a combination of foraging and travel. Whether for foraging or movement, the presence of bears on linear features has the potential to increase their exposure to humans, and subsequently increase the risk of human-caused grizzly bear mortality. All pipelines monitored in our study were used by people, suggesting that bear-human encounters on pipelines in this area are a real possibility. In our analysis, surrounding pipeline and road density had a negative influence on use of pipelines and pipeline-road RoWs. Although bears appear to be selecting for pipelines, these results suggest that they may prefer habitat in areas of lower overall human presence. Our sightability analysis indicated that many pipelines had topography, curves or shrub cover that would partially hide a grizzly bear from the view of passing vehicles. These findings provide potential mitigation options to reduce grizzly bear mortality risk at pipeline-road intersections.

Results from this research project address the knowledge gap regarding grizzly bear response to oil and gas pipelines. We believe this new knowledge will play an important role in grizzly bear recovery efforts and resource management in Alberta.

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