



Grizzly Bear Response to Oil and Gas Development and Activities in Alberta

Alberta Upstream Petroleum Research Fund 2011 Final Report



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Foothills Research Institute Grizzly Bear Program**

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Executive summary

The Kakwa region in west-central Alberta has ongoing recreational use, timber harvesting activities, and extensive oil and gas activities, and it is expected that resource extraction in this area will increase in the near future. The Kakwa also contains important habitat for grizzly bears, a species designated as threatened in Alberta. In 2010 and 2011, the Foothills Research Institute Grizzly Bear Program (FRIGBP) received funding from the Alberta Upstream Petroleum Research Fund (AUPRF) and other program partners to investigate how grizzly bears are responding to oil and gas activities within the Kakwa study area. To our knowledge, there are currently no published data regarding grizzly bear response to ongoing oil and gas operations in western Canada. The overall goal of this two year research project is to assist the oil and gas industry and resource managers in assessing, managing and mitigating the potential impacts of development on grizzly bears and their habitat.

Our investigation of bear response to oil and gas activities was focused to address the main potential impacts of oil and gas development: 1) grizzly bear use of habitat containing oil and gas development and activities, 2) grizzly bear use or avoidance of oil and gas wellsites, 3) grizzly bear movement in relation to oil and gas activities, and 4) grizzly bear mortality risk in relation to oil and gas development.

We investigated whether bears were closer, no different, or further from oil and gas features than expected based on a conditional randomization analysis. Our results show that grizzly bears use habitat with oil and gas activities differently than what was expected at random. Bears in our study generally did not avoid habitat containing oil and gas features during spring. During summer, males used habitat with oil and gas development less than expected, and fall was the season with the most changes in large scale habitat use in response to oil and gas features. At a smaller spatial scale, we analyzed selection ratios to determine if bears were selecting for the wellpad area, and we completed vegetation assessments at wellsites. Our results show that the majority of bears selected for wellpads, and most bears did not avoid the 500m zone surrounding wellsites. Use of the wellpad is likely related to the growth of bear foods on the wellpad and along the edges of the wellsites.

To investigate grizzly bear movement rates in response to oil and gas features, we used movement velocities and a novel spatial analysis method to look at areas of slow movement (latent areas). There were no obvious increases in grizzly bear movement rates in direct response to the presence of wellsites in our analysis; however, our results indicate faster movement when roads or pipelines were present.

To evaluate mortality rates and predicted mortality risk, we analyzed current mortality datasets and applied mortality risk models to create annual mortality risk surfaces specific to the Kakwa study area. Human-caused mortalities were similar to those observed in other areas of Alberta. Our estimated annual mortality rate was 1.7%. Mortality risk steadily increased throughout 2004 to 2010. The mean mortality risk ranged widely between home ranges. Comparison of reported mortality locations with predicted mortality risk values indicates that the current mortality risk model is a good predictor of mortality risk for the Kakwa study area.

This research addresses the current knowledge gap regarding how grizzly bears respond to oil and gas operations. Results and management recommendations presented in this project may be applied in the Kakwa region and across other areas of oil and gas development in North America to enhance and improve land management in grizzly bear range.

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Chapter 1: Background, study area, and research objectives

Authors: Tracy McKay¹ and Gordon Stenhouse¹

Background

Alberta has an abundance of petroleum reserves that are currently being explored, developed and utilized. The Kakwa region in west-central Alberta (Figures 1 and 2) has ongoing timber harvesting activities as well as extensive oil and gas exploration and development. As additional shale gas opportunities emerge in this area, it is expected that development will increase in the near future. The Kakwa region also contains important habitat for grizzly bears, a species designated as threatened in Alberta. This region contains designated core grizzly bear conservation areas as defined by the provincial government (Alberta Sustainable Resource Development [ASRD]). In both 2010 and 2011, the Foothills Research Institute Grizzly Bear Program (FRIGBP) received funding from the Alberta Upstream Petroleum Research Fund (AUPRF) and other funding partners to investigate how grizzly bears are responding to oil and gas activities within the Kakwa study area. The overall goal of this two year research project was to assist the oil and gas industry and resource managers in assessing, managing and mitigating the potential impacts of energy sector development on grizzly bears and their habitat.

Study Area

The study area was comprised of 8,334 square kilometres within a diverse, multi-use landscape in west-central Alberta, Canada (Figures 1 and 2). The area includes high elevation snow, rock, and ice in the west along with increasing anthropogenic disturbance in the low elevation foothills to the east. Elevation ranges from 549m to 2446m, annual precipitation varies from 550mm to 1050 mm, and mean daily temperatures range from 4.7 to 11.3°C (Natural Regions Committee 2006). Over half of the area is conifer or conifer-dominated mixed forest. Resource extraction industries have been active in the area for a number of decades (White et al. 2011), with most disturbances in the area arising from the forest industry and oil and gas development (Schneider 2002). Approximately 76% of the forested land base in the Kakwa region is managed for timber harvesting.

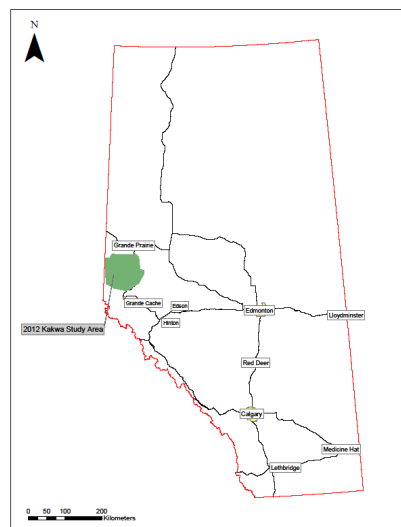


Figure 1: Kakwa study area in Alberta.

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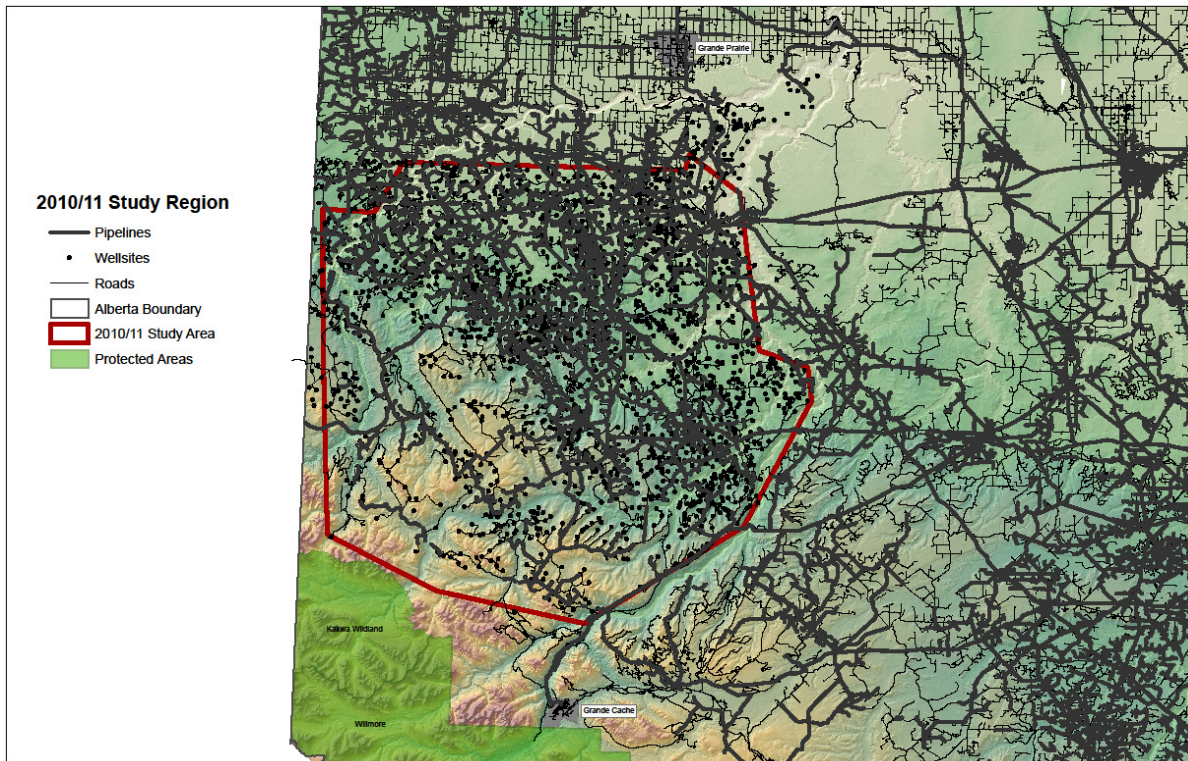


Figure 2: Study area with current development.

Previous studies of grizzly bear response to industrial development have included significant research regarding roads and forestry operations. A number of previous studies have also investigated the response of bears to oil and gas exploration and development, including seismic surveys, exploratory drilling, construction of facilities and roads, and human-bear conflicts at camps and facilities (Harding & Nagy, 1980; Schallenberger, 1980; Tietje & Ruff, 1983; Reynolds et al., 1986; McLellan & Shackleton, 1989; Follmann, 1990; Amstrup, 1993). Additional work has investigated grizzly bear landscape use in response to seismic cutlines (Linke, 2005), and the use of edge habitat along roads and pipelines (Stewart, 2011). Preliminary investigation of grizzly bear response to oil and gas wellsites in the Kakwa study area of Alberta suggested that bears do not avoid wellsites, but may select for the area around the wells (Sahlén, 2010). To our knowledge, there are currently no published data regarding grizzly bear response to ongoing oil and gas operations in western Canada.

The Kakwa region has a relatively high density of oil and gas development and activities, and the density of oil and gas features is increasing each year (Appendix A). As oil and gas development continues to expand through grizzly bear habitat, it is important to understand how these activities may impact grizzly bears.

Research objectives

Our investigation of bear response to oil and gas activities was focused on addressing the main potential impacts of oil and gas development: effects on habitat use (broad scale and fine scale), influence on movement patterns, and changes to mortality risk. The specific research objectives were:

1. Grizzly bear use of habitat containing oil and gas development and activities:
 - a. Do grizzly bears use habitat containing oil and gas development (active wellsites, inactive wellsites, roads, and pipelines) more, less, or no differently than expected in each season?
 - b. Do grizzly bears use habitat containing oil and gas development active wellsites, inactive wellsites, roads, and pipelines) more, less, or no differently than expected during day and night (in each season)?
 - c. Does grizzly bear response change during the life cycle of oil and gas operations; is selection of wellsites affected by the age of the wellsite (years since initial drilling)?
2. Grizzly bear use or avoidance of oil and gas wellsites:
 - a. Do grizzly bears show selection (use) or avoidance of the wellpad itself and/or the zone immediately surrounding the wellpad?
 - b. Are grizzly bear foods available on wellpads?
3. Grizzly bear movement in relation to oil and gas activities:
 - a. Are there differences in grizzly bear movement rates (velocities) related to the presence or absence of disturbance features in the vicinity?
 - b. Are the densities of disturbance features different in areas of slow movement as compared to the rest of the home range?
4. Grizzly bear mortality risk in relation to oil and gas development:
 - a. What are the numbers of reported mortalities and their causes in the Kakwa region?
 - b. What is the predicted annual mortality risk in the Kakwa study area, and how does annual mortality risk change from 2005 to 2010?
 - c. How does mortality risk vary between grizzly bear home ranges, and from year to year for individual bears?
 - d. How do known mortality locations in the Kakwa compare to predicted risk values from the existing mortality risk model?

This research addresses the current knowledge gap regarding how grizzly bears respond to oil and gas operations. Results from this project may be applied in the Kakwa region and other areas of western North America to enhance and improve land management in grizzly bear range.

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Chapter 2: Grizzly bear use of habitat containing oil and gas development and activities

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Abstract

Oil and gas development is increasing in areas of Alberta that are also home to threatened grizzly bear (*Ursus arctos*) populations. The effects of forestry operations and roads on grizzly bear habitat use have been well studied. However, researchers are only beginning to specifically examine possible impacts of the oil and gas industry. In this chapter, we characterize the spatial patterns of grizzly bear habitat use in the Kakwa area of Alberta, Canada in relation to oil and gas development and operations. Datasets were obtained for roads, pipelines, and wellsites. Wells were categorized as active or inactive. Grizzly bear telemetry data collected from 2005–2010 were partitioned by year, foraging season, and age/sex classes, and individual home ranges were created. Data were also analyzed by time of day (day/night). A series of resource selection functions (RSFs) were created for each season of each year. Telemetry locations were randomized conditional to home ranges and RSFs to create expected grizzly bear locations. To determine if bear locations were closer, further, or no different than expected from oil and gas features, the distances from observed locations to oil and gas features were compared to the distance distribution of randomized locations. In general, bears were closer than expected to all features during spring. Adult males were farther than expected to all features during the summer season. Active wellsites were avoided by all groups in the fall. Out of the wellsites available within their home ranges, bears generally selected for older wellsites (11-14 years post-development).

Introduction

In Alberta, Canada it is estimated that fewer than 700 individual grizzly bears (*Ursus arctos*) remain (Alberta Sustainable Resource Development 2010). As such, the species was designated as *Threatened* by the provincial government in 2010 (Clark & Slocombe 2011). It is thought that the current abundance and distribution of this species in Alberta can be directly attributed to excessive human-caused mortality through overhunting, poaching, management removal, and defense of life and property over the last century (Weaver et al. 1996; Garshelis et al. 2005). Ongoing activities related to natural resource extraction create an abundance of new linear features (i.e. roads, seismic lines, and pipelines), increasing levels of human access into grizzly bear habitat. Human access into grizzly bear habitat becomes a management concern, as grizzly bear mortality rates have been shown to rise with increasing road density (Benn & Herrero, 2002; Nielsen et al. 2004a).

Understanding grizzly bear habitat use and response to natural resource extraction is essential for effective conservation and recovery efforts in Alberta. Telemetry data collection has been widely used to determine the movements of grizzly bears and to understand their habitat use (Nielsen, 2004). As large omnivores, grizzly bears must devote considerable time to foraging over large areas (Schwartz et al. 2003). Grizzly bears are known to change their diet to correspond with seasonal changes in food availability (Munro et al. 2006). Knowledge of grizzly bear habitats, landscape conditions and anthropogenic features has contributed to the creation of

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resource selection functions (RSFs) that spatially describe grizzly bear habitat quality and predict seasonal bear occurrence (Nielsen 2007). An RSF describes the probability of resource use across the landscape (Manly 2002), and many studies have utilized RSFs to analyze the impact of human disturbance on habitat use, including studies on elk (Edge et al. 1987), southern mule deer (Bowyer and Bleich 1984), and grizzly bears (Nielsen 2005; Ciarniello et al. 2007).

Many large carnivores have been shown to alter their use of habitat under various anthropogenic pressures, ranging from industrial development to tourism (Olson et al. 1998; Boydston et al. 2003). Previous studies have shown that grizzly bear habitat selection is impacted by human activity (McLellan 1990; Gibeau et al. 2002; Roever et al. 2008; Graham et al. 2010). Changes to habitat use may be spatial, such as selecting or avoiding an area; temporal, using the area at different times of the day or year; or a combination of both. In Scandinavia, where most of the landscape is affected by the presence of humans, it was observed that bears did not avoid habitat with human presence, but used the habitat at night when human activity was lower (Martin et al. 2010). This spatial-temporal avoidance of humans has also been previously observed with wolves in Alberta (Hebblewhite & Merrill 2008) and grizzly bears in Alaska (Rode et al. 2006).

Behavioural adaptations to human activity have been shown to manifest differently between male and female grizzly bears (Gibeau et al. 2002) and between adults and subadults (Gibeau et al. 2002; Mueller et al. 2004). For example, adult male grizzly bears have been shown to use high quality roadside habitat at night, while females used this period of human inactivity to forage near other features such as human settlements (Gibeau et al. 2002). In an analysis of road crossings in west-central Alberta, Graham et al. (2010) reported that males had lower crossing indices than females during daylight hours. Further, a study by Mueller et al. (2004) on the selection of habitat containing anthropogenic features showed spatial-temporal differences in selection for subadults, and suggested that their avoidance of the more dominant adult males superseded avoidance of humans.

Oil and gas development and related activities are expanding in many areas of Alberta that are designated as core and secondary conservation zones for grizzly bears. The drilling of wellsites represents a period of concentrated intense human activity on the landscape. Unlike research related to roads and forestry, limited research has been completed regarding the specific effects of oil and gas activities on grizzly bear habitat selection (Linke et al. 2005; Sahlen 2010). Knowing how grizzly bears in this region react to disturbances is crucial to outlining successful conservation strategies (Weaver et al. 1996). While there is evidence that grizzly bears show selection for anthropogenic disturbances, such as forestry cutblocks (Elgmork and Kaasa 1992; Nielsen et al. 2004b; Stewart et al. 2012), this selection increases the risk of human-bear interactions, and results in increased mortality risk for bears (Nielsen et al. 2004b). Alternatively, avoidance of anthropogenic features and activities can result in functional habitat loss (Dyer et al. 2001). As is the case with many human disturbances, the effects of oil and gas development can be examined through two lenses: increased human presence on the landscape and the alteration of the landscape itself.

The objective of our research was to determine if grizzly bear habitat use is affected spatially and/or temporally by oil and gas development and activities. To achieve this we framed our research to answer the following questions:

- a. Do grizzly bears use habitat containing oil and gas development (active wellsites, inactive wellsites, roads, and pipelines) more, less, or no differently than expected in each season?
- b. Do grizzly bears use habitat containing oil and gas development (active wellsites, inactive wellsites, roads, and pipelines) more, less, or no differently than expected during day and night (in each season)?
- c. Does grizzly bear response change during the life cycle of oil and gas operations; is selection of wellsites affected by the age of the wellsite (years since initial drilling)?

To meet our objectives, we took a spatial pattern approach to quantifying the impact of oil and gas activity on grizzly bear habitat use. Based on theory in spatial ecology (Fortin & Dale, 2005) and spatial statistics (Getis and Boots, 1978; Haining, 2003), we built our research on the notion that spatial patterns are an expression of spatial processes. When it is not possible to measure spatial processes directly, characterizing spatial patterns is a mechanism for characterizing the nature of processes on the landscape. Here, we used spatial patterns of grizzly bears on the landscape in reference to the distribution of oil and gas related disturbance as a mechanism for characterizing how oil and gas activities have impacted grizzly bear habitat use.

Methods

Datasets

Grizzly bear telemetry data:

Telemetry data were collected for 33 grizzly bears from 2005–2010. Aerial darting, leg-hold snaring, and culvert traps were used to capture grizzly bears following capture protocols accepted by the Canadian Council of Animal Care for the safe handling of bears (animal use protocol number 20010016) (Stenhouse & Munro 2000). Captured bears were fitted with a Televilt/Followit brand GPS collar (Lindesburg, Sweden), which collected grizzly bear locations once per hour. Data from collars were collected remotely using monthly VHF data upload flights from fixed winged aircraft.

Telemetry data were cleaned for accuracy using positional dilution of precision (PDOP), which evaluates three-dimensional accuracy of locations (D'Eon & Delparte 2005). While the removal of GPS locations with dubious accuracy has been addressed in habitat selection studies (Frair et al. 2004), we decided to eliminate spatially inaccurate locations in this study, given our analysis methods focus on Euclidean distance. Of the 116,611 grizzly bear points analyzed, 2984 (3%) of the points had a PDOP > 10 and were excluded from the analysis. Grizzly bear telemetry data were separated into seasonal categories following established feeding patterns for our study area (Munro et al. 2006; S. Nielsen, pers. comm.). Seasons were defined as spring (1 May to 15 June), summer (16 June to 31 July), and fall (1 August to 15 October) (Nielsen 2005).

Grizzly bear data were partitioned into sets of telemetry points for individual bears by separate years and seasons. The full dataset was also divided into daytime and nighttime locations based on sunrise and sunset calculators (pers. comm. Julie Duval, FRI). Data falling into crepuscular periods (twilight morning and twilight

evening), were removed in order to restrict analysis to distinct periods of daylight and darkness presumed to correspond with periods of human activity. Data were grouped based on age/sex classes, with bears 3 to 4 years of age considered as subadults and those 5 and greater considered as adults. Datasets with less than 50 GPS locations were excluded due to the effects of small sample sizes on home range calculations (Seaman & Powell 1996). The demographic breakdown of grizzly bear data points is shown in Table 1 (all points) and Table 2 (by day and night).

Table 1: Grizzly bear demographics for points from all times of the day. Values indicate number of bears, with number of points in brackets.

	Spring	Summer	Fall
Males	8(5421)	7(10981)	5(7075)
Females	11(10686)	12(16566)	12(16884)
Subadult Males	5(2604)	7(10957)	6(11255)
Subadult Females	5(3401)	5(4166)	5(5308)

Table 2: Grizzly bear demographics for points separated into day and night points, with crepuscular points removed. Values indicate number of bears, with number of points in brackets.

	Spring		Summer		Fall	
	Day	Night	Day	Night	Day	Night
Male	8(3924)	7(1398)	7(8193)	5(2698)	5(4132)	5(2943)
Female	11(7972)	11(2689)	12(12279)	12(4244)	12(9128)	12(7756)
Subadult Male	5(1943)	3(592)	7(8292)	6(2649)	6(6418)	6(4837)
Subadult Female	4(2479)	4(860)	5(3030)	4(1005)	5(2957)	5(2351)

Oil and gas features and activity:

Disturbance datasets were obtained describing oil and gas wellsites, pipelines, and roads. Wellsite and pipeline data were provided to us from a database maintained by Alberta Energy; spatial data and attributes were originally obtained directly from oil and gas operators. Roads in this area are the product of oil and gas development as well as forestry activities. The roads dataset was originally obtained from Alberta Sustainable Development, and subsequently updated by our research team through heads-up digitizing using medium and high resolution imagery. Road data were attributed with a year of disturbance (if constructed after 1994), pipeline data were attributed with date of construction, and wellsite data were attributed with date of initial clearing and drilling, first date of active pumping, and reclamation/deactivation dates. Wellsites were further divided into active and inactive wells based on dates of original drilling and end of production or abandonment. Activity status for wells was specific for each season, and a status of “active” indicates that a well was drilled and actively pumping during that seasonal time period.

Resource selection functions:

Grizzly bear habitat quality was inferred from resource selection functions (RSF) values. A series of seasonal RSFs were generated in order to condition the randomization process described below. An RSF is estimated through a comparison of observed resource use to availability of resource units (Boyce et al. 2002). We created our seasonal RSF following Nielsen et al. (2009). Individual RSFs were created for each foraging season (spring, summer, and fall) and each year of our study area (2005–2010), creating a total of 18 RSFs. The RSF model predicts probability of resource use based on land cover, crown closure, species composition (conifer canopy), compound topographic index, distance to streams, and distance to forest clearings (Nielsen et al. 2009). Models were created from a random sample of 90% of the telemetry data, with the remaining set aside for model evaluation. RSF accuracy was evaluated using the remaining 10% of the training data using Spearman rank coefficients. The results from 2007 showed p-values of 0.005, 0.0013, and 0.0010 for the spring, summer, and fall, respectively, indicating sufficient accuracy for use in further analysis.

Analysis

To determine if grizzly bears were closer, further, or no different than expected to oil and gas features, the Euclidean distance from each telemetry point to the nearest oil and gas feature of each type was calculated. For each bear, the average observed distance was compared to an expectation. Average observed and randomized distances were also compared and results of individual bears summarized for seasonal/age/sex classes. Comparisons of observed and expected (randomized) average distance to oil and gas features were repeated for telemetry data partitioned by time of day. Sets of individual grizzly bear locations (single bear, in a single season, in a single year) were compared to available wellsites within their home range to determine if wellsites that were selected were significantly different in age compared to those that were not-selected.

1. Randomization of grizzly bear data

Randomization (Monte Carlo) approaches were used to generate the expectation for comparison (i.e., Nelson & Boots 2005). For each grizzly bear, in each season, telemetry locations were randomized and the average distance from randomized telemetry locations to oil and gas features calculated. Randomization was performed 99 times, enabling statistical tests with a critical value of 0.01.

Intuitively, we know that grizzly bear habitat use is not random, and comparisons to complete spatial randomness will yield unreasonable results. Therefore, randomization was conditioned by limiting locations to the grizzly bear home range. Home ranges were generated for each bear using kernel density estimation (KDE). The 95th percentile by volume contour was applied to a KDE surface generated from telemetry points using a Gaussian kernel (Seaman and Powell 1996; Borger et al. 2006). KDE was chosen for generating home ranges because it is a well accepted method in wildlife management (Laver and Kelly 2008) and does not tend to overestimate home range area (Powell 2000). The bandwidth for the KDE was calculated using least-squares cross-validation (LSCV). For each individual bear, LSCV values ranged from 500 m to 1000 m.

Even within a home range we do not expect habitat to be used randomly. Therefore, we determined the frequency distribution of RSF values at locations where use was observed, as determined by bear locations. The randomized locations were determined based on the observed frequency distribution of RSF usage. For instance, if 15% of observed grizzly bear locations were found to have RSF values greater than eight, then 15% of the randomized bear locations were allocated to RSF values greater than eight.

2. Comparison of observed and expected distances to oil and gas features

Each set of grizzly bear locations (individual bear, in a single year, in a single season) was labelled as either closer, neutral, or farther than expected from each type of oil and gas feature based on comparison of average observed and expected distances to oil and gas features ($\alpha = 0.05$). For bears with multiple years of data, each bear-year was considered as an individual dataset. Once the statistical comparisons were made for each individual bear, results were summarized by season, sex, and age class. For example, the percentage of adult female bears with an average minimum distance statistically closer, neutral, or further than expected was calculated for each feature.

3. Day/night distance comparison

In order to determine if oil and gas features were influencing temporal use of habitat, day and night KDE home ranges were constructed for each bear, for each season, for each year. For each season, each set of daytime grizzly bear locations (individual bear, in a single year) and each set of nighttime locations (individual bear, in a single year) was labelled as either closer, neutral, or farther than expected from each type of oil and gas feature ($\alpha = 0.05$), based on comparison of average observed and expected distances to oil and gas features. Results were summarized by

sex/age class. In addition, the mean observed distance to each of the disturbances was calculated for all of the bear locations by age/sex class for each season for day and night. For comparison, the mean expected distances (based on conditional randomization) were also calculated. The observed distances to each disturbance type were compared between day and night using a Mann-Whitney u-test ($\alpha = 0.05$) to determine if there were significant differences between daytime and nighttime distances.

4. Wellsite age comparison

To investigate whether the selection of habitat containing wellsites was impacted by the age (years since initial drilling) of the wells, individual grizzly bear home ranges were used to identify the wellsites within the home range (available wellsites) for each bear. For this analysis, active and inactive wellsites were combined. Each wellsite within each grizzly bear's home range was buffered by 100m. The wellsite was defined as selected if the density of observed telemetry points inside the buffer was significantly higher than the density of expected points from the randomization process. For each individual bear, a list of selected and not-selected wellsites was generated, and the mean wellsite ages were calculated. Given the variation in wellsite ages amongst home ranges, the normalized ages⁶ of the wellsites were calculated for each group of bears and seasons in order to determine statistical difference between selected and not-selected wellsites. The normalized ages were compared using a one-sided Mann-Whitney U-test to determine if selected wells were significantly older than not-selected wells. To typify those wells being selected, the mean ages of selected and not-selected wells were calculated by bear age/sex class and season.

Results

For each age/sex class and season, distance results are described as: 1) closer, neutral, or farther than expected from oil and gas features (all points, based on comparison to expected points generated in the randomization) 2) closer, neutral, or farther than expected, points separated by day and night, and 3) numerical (mean) distances to features (in metres).

During spring, habitat containing oil and gas features (pipeline, roads, active and inactive wellsites) was generally not avoided by grizzly bears. The majority of adult females were significantly closer than expected to all features, while most adult males were closer than expected to pipelines, roads, and inactive wellsites (Figure 1). All (100%) subadult males were closer than expected to pipelines, roads, and active wellsites, and most subadult females (80%) were closer than expected to both active and inactive wellsites. When the day/night use of habitat was examined separately, the majority of subadult males and females were closer than expected to all features at night (Table 3). In contrast, nighttime locations for adult males were not closer than expected to pipelines or wellsites, and only 43% of bears were closer to roads at night (Table 4). However, when comparing daytime to nighttime, mean distances at night were

⁶ Normalized wellsite age = (wellsite age) – (mean of available wellsites) / (standard deviation of wellsite ages)

significantly smaller than the daytime distances for all disturbance features for adult males (Table 3). In other words, although adult males were not closer than expected to disturbance features during night, they were closer during nighttime than during the day.

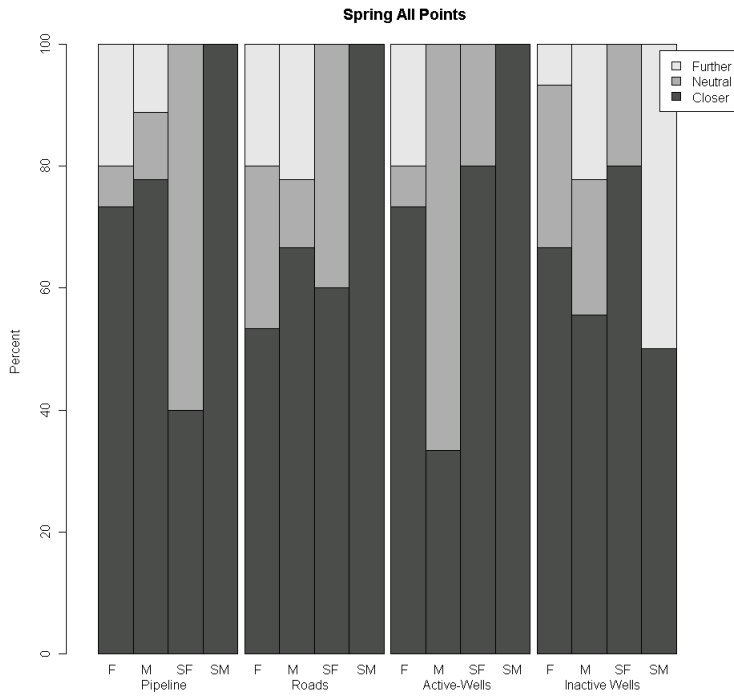


Figure 1: Grizzly bear habitat selection in the spring foraging season for all age classes (F-adult females, M-adult males, SF – subadult females, SM-subadult males). Observed bear locations were compared statistically to expected locations and the percentage of bears either significantly farther or closer than expected at random tallied. Locations that were not significantly different from random were considered neutral.

Table 3: The largest proportional response to oil and gas features by each bear class in each season, partitioned by day and night. The mean of the observed distances to each feature was calculated for individual bears and statistically compared to expected distances. No significant difference was considered neutral.

	Female		Subadult Female		Male		Subadult Male	
	Day	Night	Day	Night	Day	Night	Day	Night
Spring	Largest Mean Response (C=% Bears Closer; N=Neutral; F=Farther)							
Pipeline	63% C	44% C	80% N	80% C	42% C	57% N	40% F&N	67% C
Roads	44% C	50% N	60% N	60% C	50% N	43% C&N	80% C	100% C
Active Wells	63% C	50% C	60% N	60% C	50% N	57% N	60% N	67% C
Inactive Wells	56% C	50% C	60% C	60% C	58% N	43% F	80% C	67% C
Summer								
Pipeline	42% C	58% C	50% C	60% C	62% F	75% F	78% C	86% C
Roads	53% C	58% C	67% C	80% C	54% F	75% F	78% C	71% C
Active Wells	42% C	47% N	50% F	40% N	62% F	75% F	78% C	57% C
Inactive Wells	42% C	47% N	50% F	60% C	46% F	50% F	56% C	43% C&N
Fall								
Pipeline	53% F	56% C	80% F	60% F	50% C	56% C	71% C	57% C
Roads	47% F	56% C	60% C	60% C	50% C	78% C	57% C	78% C
Active Wells	58% F	44% C	60% F	60% F	50% C	56% N	57% F	43% F&N
Inactive Wells	42% F	50% C	80% F	60% N	50% C&F	44% C	86% C	71% C

Table 4: Mean observed and expected distances to the oil and gas features during day and night. * Indicates significant difference between observed day and night mean distances at $\alpha = 0.05$ using a Mann-Whitney U-test.

		Female		Subadult Female		Male		Subadult Male	
		Day	Night	Day	Night	Day	Night	Day	Night
	Spring								
Pipeline	Observed	985m	999m	1431m	1418m	1432m	*959m	2008m	1904m
	Expected	1042m	1056m	1596m	1626m	1444m	1019m	1983m	2029m
Roads	Observed	522m	518m	587m	585m	907m	*695m	689m	668m
	Expected	594m	586m	664m	682m	885m	719m	787m	802m
Active wells	Observed	1527m	1496m	2273m	2314m	1986m	*1379m	2253m	2170m
	Expected	1640m	1652m	2538m	2608m	1979m	1505m	2335m	2398m
Inactive wells	Observed	1500m	1515m	2090m	2117m	1984m	*1682m	2041m	2095m
	Expected	1647m	1699m	2278m	2338m	2098m	1715m	2187m	2256m
	Summer								
Pipeline	Observed	1292m	*1231m	1507m	1613m	2507m	*2236m	1759m	*1480m
	Expected	1244m	1257m	1697m	1888m	1902m	1566m	1798m	1755m
Roads	Observed	599m	*518m	488m	510m	1889m	*1711m	907m	*769m
	Expected	629m	650m	708m	758m	1372m	1173m	860m	803m
Active wells	Observed	2009m	*1932m	2672m	2662m	3517m	*3225m	2557m	*2426m
	Expected	2004m	1949m	2916m	2967m	2407m	2392m	2338m	2318m
Inactive wells	Observed	1525m	*1472m	2260m	*2161m	3351m	*2968m	2096m	*2063m
	Expected	1571m	1610m	2285m	2452m	2782m	2392m	2065m	2041m
	Fall								
Pipeline	Observed	1352m	*1305m	2176m	*2031m	2424m	*2113m	3111m	**2951m
	Expected	1270m	1260m	1909m	1734m	2360m	1974m	1543m	1490m
Roads	Observed	655m	*602m	616m	635m	1195m	*1018m	935m	*881m
	Expected	682m	685m	699m	722m	1392m	1239m	1132m	1008m
Active wells	Observed	2239m	*2053m	3126m	*2795m	3346m	*3069m	3280m	3263m
	Expected	2028m	1942m	2549m	2231m	2951m	2538m	2941m	2773m
Inactive wells	Observed	1605m	*1539m	2475m	*2244m	2476m	2247m	2150m	*2074m
	Expected	1616m	1612m	2282m	2110m	2809m	2517m	2548m	2443m

*One subadult male bear (G229) was observed on average 4 km from pipelines, day and night, over two separate years leading to the skewness of the data.

In summer, fewer bears were closer than expected to the oil and gas features than in spring (Figure 4). This trend was most pronounced in the adult males; the majority were farther than expected to all disturbance features. About half of adult females were closer than expected to all disturbances (42-53%), marking a decrease from the previous season. The majority of subadult males (67-78%) were still closer than expected to all features, and 83% of subadult females were closer to roads. When data were analyzed separately for day/night, no distinct differences in response were observed (Table 3). For example, 53% of adult females were closer than expected to roads during the day, and this only increased to 58% of bears at night. When comparing mean observed distances during daytime to distances at night, mean distances to all features were significantly smaller at night compared to day for adult females, adult males, and subadult males (Table 4). For subadult females, the mean observed distance to inactive wells was also significantly smaller at night compared to day (Table 4).

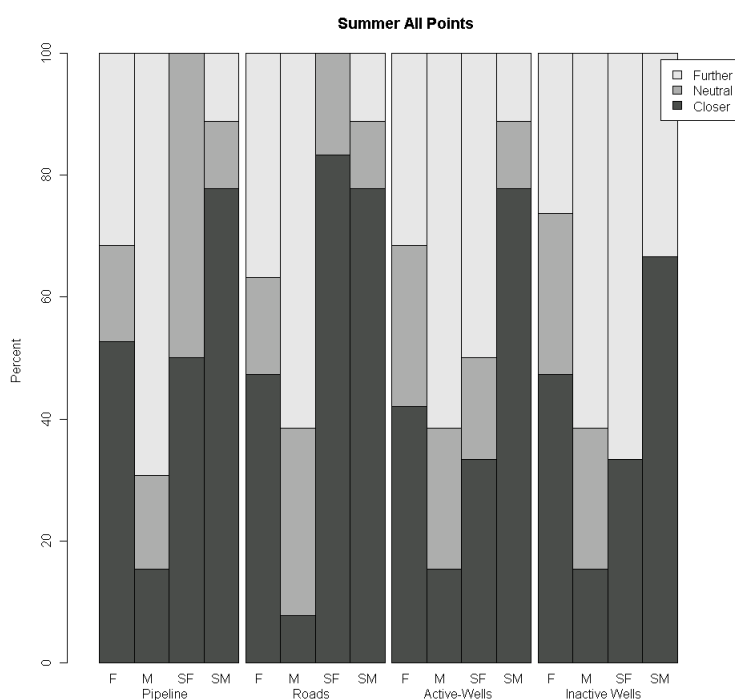


Figure 2: Grizzly bear habitat selection in the summer foraging season for all age classes (F-adult females, M- adult males, SF – subadult females, SM-subadult males). Observed bear locations were compared statistically to expected locations and the percentage of bears either significantly farther or closer than expected at random tallied. Locations that were not significantly different from random were considered neutral.

In the fall, the most striking result is the consistency with which all bear classes are closer than expected to roads, and farther than expected to active wells (Figure 3). Seventy eight percent of adult males were closer to roads than expected in the fall, a dramatic increase from 8% in summer. When daytime and nighttime use of habitat use were separated, this response was relatively unchanged, as the majority of adult males, subadult males, and subadult females were closer than expected to roads during both day and night (Table 3). However, day/night differences were observed for adult females; the majority of

females were farther than expected from all features during the day, and closer than expected at night (Table 3). In addition, the mean observed distance to all features was significantly smaller during night compared to day for adult females (Table 4). In the case of subadult males and pipelines, while the mean distances to pipeline was almost 3 km (Table 4), the majority of subadult males were closer than expected to pipelines (Table 3). This was likely due to one bear (G229) with an average distance of 4 km from pipelines during two different fall seasons.

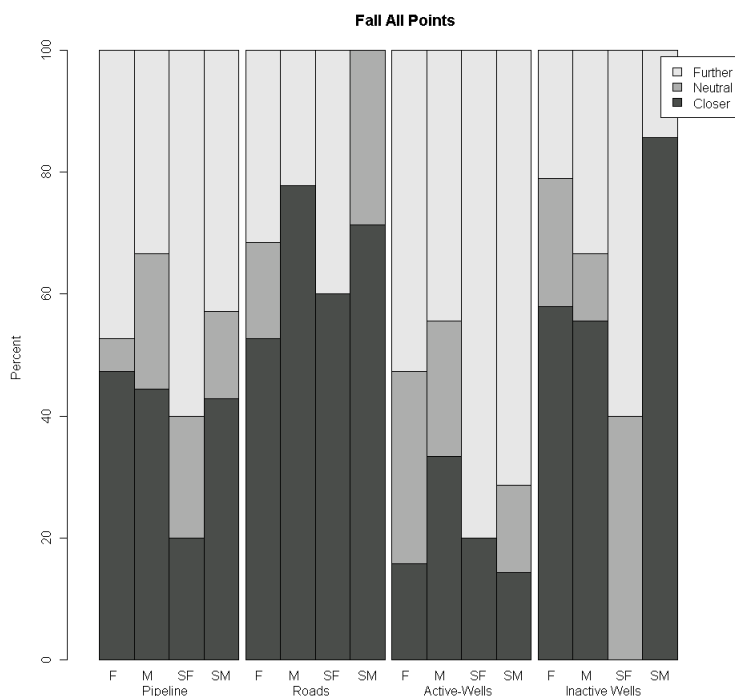


Figure 3: Grizzly bear habitat selection in the fall foraging season for all age classes (F-adult females, M- adult males, SF – subadult females, SM-subadult males). Observed bear locations were compared statistically to expected locations and the percentage of bears either significantly farther or closer than expected at random tallied. Locations that were not significantly different from random were considered neutral.

Plotting the mean observed distances for each of the age/sex classes allows us to visualize trends in relative proximity for each sex/age class of bears to each disturbance feature (Figure 4). For all groups, the smallest distances to oil and gas features were for roads, over all seasons, during both day and night. Active wells had the largest distances for all groups in each season (Figure 4). Adult females generally had the smallest distances to all features across all seasons and times of day, although subadult females had slightly smaller distances to roads during the day in summer and fall (Figure 4; Table 4). As the seasons progressed, there was an increase in distances to active wells for adult females, from around 1.5 km in the spring to 2.0 km in summer and 2.2 km in fall. The largest change in distance to wellsites from spring to summer was observed with adult males for daytime locations; mean distances increased from 2 km to 3.5 km for active wells and from 2 km to 3.3 km for inactive wells.

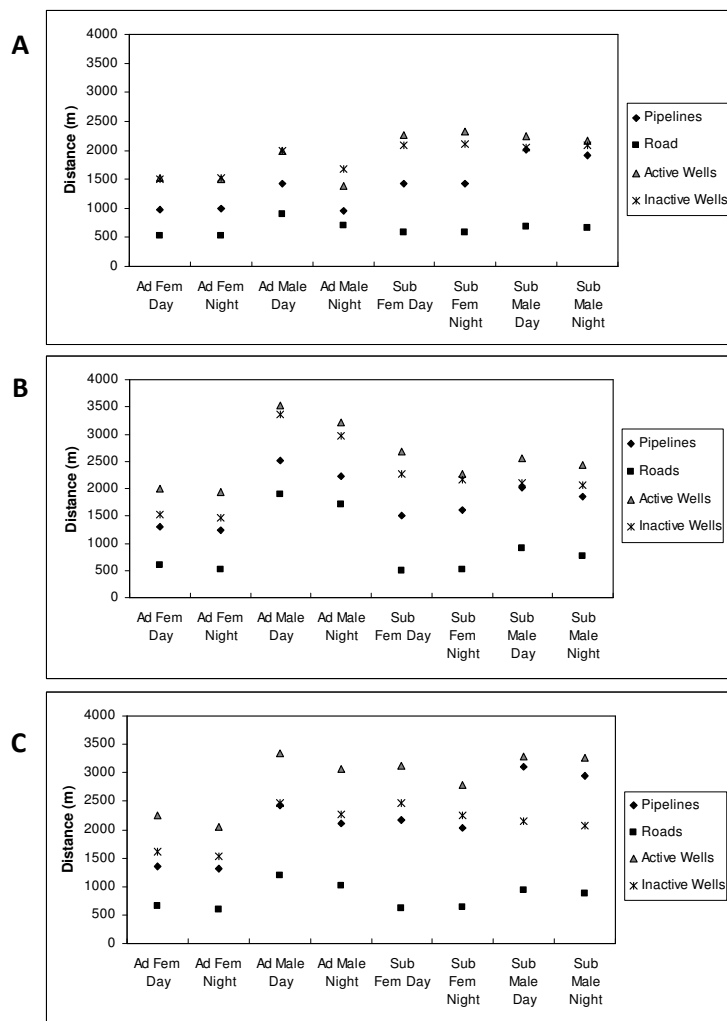


Figure 4. The observed mean distances for all bear groups to the various oil and gas features during A) Spring; B) Summer; C) Fall.

Results from the comparison between the age of selected versus not-selected wellsites are presented in Table 5. For all classes, the normalized age of the selected wellsites was significantly higher than the age of the not-selected wellsites, indicating that bears are generally selecting for older wellsites out of those that are available to them within their home range. Seasonally, the oldest wellsites were selected for in the summer, with the average age of selected wellsites ranging from 12.4 years for subadult males, to 13.6 years for those selected by adult females.

Table 5: Comparison between the mean age of selected and not-selected wellsites. For each individual bear, selected wellsites were determined by comparing the number of observed telemetry points within 100m of a well and the number of randomized points within that same buffer. Not-selected wellsites were those remaining within the home range. Results were tabulated by age/sex class. Significance($p \leq 0.05$ *) was determined using the normalized wellsite age, which was calculated for each bear by subtracting the mean wellsite age from the individual values and dividing by the standard deviation.

Bear Class	Mean Age of Selected Wells (Years)	Mean Age of Not-selected Wells (Years)	Mean Age of All Wells (Years)
Spring			
Adult Female	11.3	10.4	10.5
Adult Male	11.8	10.2	10.3
Subadult Female	13.6	18.0	17.7
Subadult Male	*12.2	8.5	8.6
Summer			
Adult Female	*13.6	10.2	10.7
Adult Male	*13.2	9.9	10.0
Subadult Female	13.2	13.3	13.3
Subadult Male	*12.4	8.4	8.5
Fall			
Adult Female	*12.7	10.7	11.0
Adult Male	11.5	11.8	11.7
Subadult Female	12.4	14.0	13.8
Subadult Male	*13.1	9.4	9.5

Discussion

Selection of habitat can be thought of as a trade-off between acquiring resources, finding mates and minimizing mortality risk (Frid & Dill 2002). The requirement for vast amounts of habitat in an area of increasing resource extraction pressures may put grizzly bear populations at greater risk. While human disturbance increases human/wildlife interactions and leads to greater mortality risk, changes to the landscape from resource extraction industries can also create new foraging opportunities for grizzly bears (Nielsen et al. 2004b; Stewart et al. 2012). Given increasing oil and gas activities in Alberta grizzly bear habitat, it was our objective to examine the spatial-temporal effects that existing oil and gas activities might have on grizzly bear habitat use. We used the locations of features associated with the oil and gas industry as a surrogate for human presence and influence in grizzly bear habitat. The expected distances used for comparison were based on RSF values in order to rule out the effects of habitat quality and allow clear interpretation of results as a response to the oil and gas features on the landscape.

In the spring, there was little avoidance of habitat containing oil and gas development and activities by all groups of bears. Bears also had the shortest mean observed distances to all features in spring. Drilling of wellsites in the Kakwa region occurs throughout the year, however, the highest frequency of drilling takes place in the winter, with moderate levels of drilling in summer and fall (Appendix 2). Wells

are infrequently drilled during spring, as the saturated ground is too soft for heavy equipment. Drilling represents a period of intense human activity on the landscape, and its absence during spring could explain why bears are closer to oil and gas features during this time compared to other seasons. Daytime and nighttime are assumed to correspond with times of human activity and inactivity, respectively. Spring was observed to have the fewest day/night differences, supporting the notion that human activity has the least effect on bear habitat selection during this season.

Adult males were the sex/age class with the largest distances to roads in each foraging season, similar to the results of McLellan & Shackleton (1988), Chruszcz et al. (2003) and Graham et al. (2010). In contrast, an opposite result was found by Gibeau et al. (2002), who observed females farthest from roads, while males were the closest group at night. The observed summer distances for adult males in our study were >500m larger than expected distances, indicating an avoidance of roads by adult males in summer. Adult males were also farther than expected to the other oil and gas features, suggesting a general avoidance of all anthropogenic features during the summer. It is not clear why adult males are often observed farther away from roads and other anthropogenic features than bears of other sex/age classes, and this phenomenon has been identified as an area that requires further investigation (Graham et al. 2010). However, it has been suggested that due to the sexual dimorphism seen in grizzly bears, some of the differences in habitat use patterns observed in adult males could be due to their different nutritional requirements (Rode et al. 2006).

Understanding impacts that the oil and gas industry may have on adult females is paramount for effective conservation planning (Gibeau et al. 2002; Mueller et al. 2004; Nielsen et al. 2006). In our study, adult females were most consistent in their response to the various oil and gas features across the seasons. Adult females were observed closest to all oil and gas features as compared to other sex/age classes. However, during fall they were farther than expected from active wells and, to a lesser extent, pipelines, suggesting a spatial avoidance of oil and gas development during this period. When data were partitioned by day and night, adult females were also found farther than expected during the day and closer than expected at night for all features, suggesting a temporal avoidance of human activity. Gibeau et al. (2002) suggested that adult females were the most risk-averse, and, consistent with our findings, found that they were closer to human features during the “human inactive” period.

In summer, subadult females were observed to be the closest to roads out of all sex/age classes during both day and night, consistent with results reported in Mueller et al. (2004). It is also worth noting that there were no significant day/night differences in distances to roads for subadult females. Similarly, Mueller et al. (2004) observed that subadult females had the least difference in day/night use of roads. Similarly, subadult males were consistently closer than expected to almost all disturbances across seasons. Subadult males have been shown to use habitat close to human disturbances such as large highways, especially during night (Gibeau et al. 2002). The subadult results in our day/night analysis need to be interpreted with caution, due to the low number of individuals, and our findings on this question should be considered preliminary.

Disturbance by oil and gas industries includes direct alteration of the landscape through clearing the forest to create roads, pipelines, or well pads. Such clearing of the forest increases sunlight to the area,

creating locations where bear foods can grow (Nielsen et al. 2004c). However, oil and gas disturbance also involves human presence, including high levels of noise and activity during drilling, and periodic human activities during operations. To differentiate between the effects of habitat change versus the impacts of human presence on the landscape, we examined active wellsites separately from inactive wellsites. Differences between the two categories of wellsites were most pronounced in the fall season, when more bears were closer than expected to inactive wellsites compared to active wells. These results cannot simply be explained by the timing of drilling operations (Appendix 2), as the frequency of drilling during summer and fall is very similar. Maintenance visits to the active wellsites are also not likely to be different between the two seasons, while human presence at inactive wellsites is rare. Data collected during field sampling at wellsites within our study area indicated that a number of berry species are abundant along the edges of wellsites in the Kakwa area (Foothills Research Institute [FRI], unpublished data). A possible explanation for the preference for habitat containing inactive wellsites in fall is that the inactive wells provide bears with a predictable source of berries in locations with relatively low levels of human activity. The alteration of the landscape in this case could provide the bears with a foraging opportunity without the associated human activity.

During summer and fall, the mean age of wellsites that were selected by bears was significantly older than for wellsites that were not selected, and the oldest wellsites were selected during summer. Field data indicate that the proportion of a wellsite covered by dandelion (*Taraxacum officinale*), clover (*Trifolium* spp), and horsetails (*Equisetum* spp) increases after initial clearing of the wellpad, then begins to level off after approximately 10 years (FRI, unpublished data). These foods form a major part of a grizzly bear's diet in the summer (Nielsen et al. 2004c; Munro et al. 2006). The mean age of selected wellsites in our study was greater than 10 years (from 11.3 to 13.6 years) across all age/sex classes and seasons, suggesting that bears are selecting for wellsites with an abundance of these important foods.

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Chapter 3: Grizzly bear use or avoidance of oil and gas wellsites

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Introduction

The Kakwa region in west-central Alberta currently has extensive oil and gas development and activities, with a current wellsite density of approximately 0.43 wells/km². As additional oil and gas development opportunities emerge in this region, it is expected that the number of wellsites will increase in the future. Wellsites result in habitat alteration along with human presence and noise at the wellsite. Previous studies of grizzly bear response to industrial development has largely focused on roads and forestry operations, and research investigating bear response to oil and gas activities has mainly focused on impacts of exploration and development (Harding & Nagy, 1980; Schallenberger, 1980; Tietje & Ruff, 1983; Reynolds et al., 1986; McLellan & Shackleton, 1989; Follmann, 1990; Amstrup, 1993). To our knowledge, there are currently no published data regarding grizzly bear response to wellsite operations in Alberta. Information regarding habitat use around oil and gas wellsites could assist in grizzly bear management in these areas.

Anecdotally, grizzly bears are known to visit wellpads, as indicated by sightings of bears at wellsites and observations of scat and tracks. Previous FRIGBP research in the Kakwa area suggested that some bears selected for areas near wellsites (Sahlén 2010, Labaree et al. 2012a). Results from Chapter 2 of this study (Labaree et al. 2012) indicated that bears were closer than expected to wellsites, but the overall response was captured at a large spatial scale; mean distances to wellsites were in the range of 1500m to 3000m. Sahlén's (2010) analysis included habitat selection in 5 buffer zones within 500m of the wellsite, with the smallest buffer at 224m from the wellsite centre; the remaining home range was not included in the selection analysis. Results from these previous analyses provided important initial information regarding selection around wellsites, but did not show use or avoidance of the wellpad itself, or provide information about the relative use of these zones in the context of home ranges.

The purpose of this investigation was to expand upon and refine the previous analysis of wellsite selection in this area (Sahlén 2010). Our analysis used an updated wellsite dataset with improved spatial and temporal accuracy, and an additional 6 grizzly bears in the location dataset. We focused specifically on the wellpad and surrounding zone, within the context of individual home ranges. Previous research has suggested that a zone of influence exists around anthropogenic disturbances; a zone where the effects of human activity extend out from the disturbance feature (Gibeau et al. 1996, Forman 2000). Other grizzly bear studies have applied a 500m "zone of influence" (ZOI) around human developments (Mace et al. 1996, Berland 2008, Sahlén 2010), and a 500m zone was investigated in this study. Based on the assumption that some bears may select for wellpads, we also set out to investigate whether selection could be based on availability of bear foods at wellsites, including the presence/abundance of bear foods on the wellpads or along the edges.

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Therefore, we framed our research to answer the following questions:

- d. Do grizzly bears show selection (use) or avoidance of the wellpad itself and/or selection or avoidance of the zone immediately surrounding the wellpad?
- e. Are grizzly bear foods available on wellpads?

To meet these objectives, we analyzed selection ratios in three habitat zones: 1) the wellpad, 2) the surrounding zone, and 3) the remaining home range. In addition, we visited wellsites to assess vegetation cover and approximate bear food abundance.

Methods:

a. Bear selection (use) or avoidance of the wellpad and ZOI

Telemetry data were collected for 37 grizzly bears in the Kakwa region during 2005–2011. Aerial darting, leg-hold snaring, and culvert traps were used to capture grizzly bears following capture protocols accepted by the Canadian Council of Animal Care for the safe handling of bears (animal use protocol number 20010016) (Stenhouse & Munro 2000). Captured bears were fitted with a Televilt/Followit brand GPS collar (Lindesburg, Sweden) programmed to collect hourly locations.

Location points were limited to those with a dilution of precision (DOP) ≤ 6 (Ganksopp & Johnson, 2007), as a high level of spatial accuracy was required for the small scale of this analysis. Only non-denning points that fell within calculated home ranges (95% Kernel) were included in the analysis. We restricted our dataset to bears with $\geq 90\%$ of their annual home range area within the study area boundary.

At the small spatial scale of this analysis, there were not enough data to separate results by season. However, seasonality could affect habitat selection patterns, due to the seasonal availability of bear foods. Nielsen (2004) determined hypophagia (spring), early hyperphagia (summer), and late hyperphagia (fall) foraging seasons for grizzly bears in west-central Alberta. To prevent data from being skewed when data were missing for an entire season, we only used data for those bears with GPS collar locations across all three foraging seasons (hypophagia, 1 May 1st to June 15th; early hyperphagia, June 16th to July 31st; and late hyperphagia, August 1st to October 15th). Data were also investigated to determine if selection ratio results were correlated with the number of location points.

Using a Geographic Information System (GIS), a 100m radius buffer was generated around the centre of each wellsite (point data) to create an area that incorporated the cleared wellpad along with the edge habitat immediately adjacent to the wellpad, but essentially limited to the wellsite (Figure 1). For the “zone of influence”, we generated a 500m buffer around wellsites. The area of the 100m buffer was erased from the 500m buffer to create distinct (separate) buffer zones.

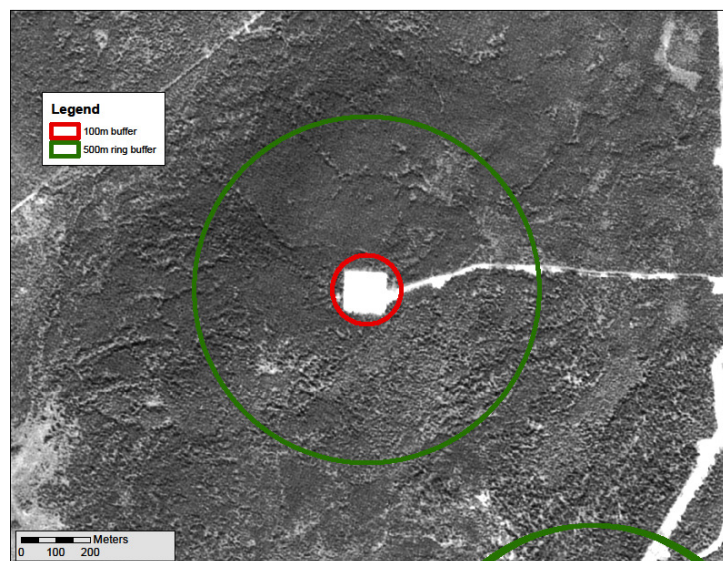


Figure 3: Wellsite with 100m and 500m buffer zones.

Annual home ranges for each bear were calculated based on 95% kernels using the program ABODE (Laver 2005) in ArcGis. Fixed biweight kernels were calculated using a volume contouring method. We used a least squares smoothing factor (Silverman 1986) and a grid cell of 300m. Data were standardized using the unit variance. We only included grizzly bears with location data for the entire non-denning period to ensure the home range estimate was representative of the full active period (Arthur & Schwartz 1999, Belant and Follmann 2002, Girard 2002). We used the seasons from Nielsen (2004) and the following number of locations per season based on Belant and Follmann (2002) to ensure annual home range estimates were based on locations that spanned all three foraging seasons ; spring: > 30 locations; summer: > 49 locations and fall: > 49 locations.

The 100m and 500m buffer zones were subtracted from the total annual home range area for each bear to obtain a third zone incorporating all home range area >500m from wellsites. Habitat selection was investigated for the three resulting habitat zones:

1. Wellsite area and edge habitat (100m buffer zone)
2. 500m zone of influence (ZOI)
3. Home range zone >500m from wellsites

Grizzly bear collar locations from 2005 to 2011 were intersected with these three zones, and the number of points within each area was calculated for each bear for each year (bear-year). Locations that intersected with wellsite buffers (both 100m and 500m) were carried forward to the selection analysis if the bear location date was later than the initial drilling date for the corresponding well, to ensure that the wellsite was present at the time of the bear location.

The total areas (square kilometres) for each habitat zone for each bear-year are shown in Table 1. As wellsites are drilled throughout the year, the number of wellsites within each bear's home range changed; therefore, the total area of each habitat zone changed from spring to fall. For our analysis, it

was not feasible to calculate a weekly or monthly area for each habitat zone; analysis was completed by year. However, to provide the best annual estimates, we examined the dates of wellsite construction over the 7 years of our study, and determined that approximately half of the wellsites were constructed before July 15th each year. Therefore, this date was chosen as the cutoff for area calculations, to approximate the mean area of wellsite buffers for each bear-year.

Table 1: Areas of home ranges and habitat zones.

Bear	Total home range area (km ²)	Total area of 100m buffers (km ²)	Proportional area 100m buffer zone	Total area of 500m ZOIs (km ²)	Proportional area 500m ZOI	Total area >500m from wellsites (km ²)	Proportional area zone >500m from wellsites
G223	607.39	6.52	0.01	137.10	0.23	463.77	0.76
G224	629.46	3.39	0.01	76.23	0.12	549.83	0.87
G230	656.42	1.24	0.00	27.75	0.04	627.43	0.96
G236	527.93	8.38	0.02	153.27	0.29	366.27	0.69
G238	886.47	6.74	0.01	142.82	0.16	736.91	0.83
G253	267.31	1.12	0.00	24.94	0.09	241.25	0.90
G254	244.65	0.97	0.00	19.87	0.08	223.81	0.91
G257	4149.43	33.42	0.01	700.91	0.17	3415.10	0.82
G258	423.70	5.47	0.01	115.96	0.27	302.28	0.71
G260	1275.35	15.69	0.01	310.78	0.24	948.88	0.74
G262	3257.35	41.44	0.01	840.62	0.26	2375.29	0.73
G264	586.04	2.15	0.00	48.47	0.08	535.42	0.91
G265	186.29	0.75	0.00	16.21	0.09	169.33	0.91
G269	363.21	1.43	0.00	29.77	0.08	332.01	0.91
G270	1840.05	22.31	0.01	433.04	0.24	1384.70	0.75
G271	319.38	3.00	0.01	61.05	0.19	255.33	0.80

We used selection ratios to determine whether grizzly bears were using each habitat zone more, less, or no differently than expected. Selection ratios compare observed habitat use to expected habitat use based on the relative availability of each habitat zone. We calculated selection ratios for each zone as in Manly et al. (2002), where

selection ratio = $\frac{\text{the proportion of the sample of used resource units that are in each category}}{\text{the proportion of available resource units that are in that category}}$.

For our analysis, the proportion used (observed) was calculated from the number of locations that intersected each zone divided by the total number of locations within the home range (Table 2). The proportion of available resource units was based on the proportional area of each zone, calculated from the area of each zone divided by the total area of the home range.

For individual male and female bears with multiple years of collar locations (i.e. >1 bear-year), data were grouped by bear for calculation of selection ratios. However, due to the fact that reproductive status was different each year for each female bear, data were analyzed separately by bear-year for comparison of differences in selection ratios between females with or without young.

To determine if patterns of habitat selection were significantly different than expected, the chi-squared goodness of fit test was calculated for each set of selection ratios. The chi-squared test evaluates the null hypothesis that animals are randomly selecting habitat in proportion to availability (Manly et al. 2002). In order for the chi-squared test to be valid, the dataset must meet the assumption that expected and observed frequencies are not less than five (Manly et al. 2002). In this case, results from datasets with location counts (expected or observed) of less than five in any of the habitat zones were interpreted as non-significant.

If the chi-squared test for the set of ratios is significant, the calculation of confidence intervals for each selection ratio indicates further whether or not the selection ratio for each habitat zone is significantly different from expected selection. We calculated 95% confidence intervals based on the standard error of the selection ratio using the following formula (Manly et al. 2002):

$$se(\hat{w}_i) = se(o_i / \pi_i) = \sqrt{\{o_i (1 - o_i) / (u_+ \pi_i^2)\}}, \text{ where}$$

o_i = the proportion of the sample of used resource units that are in each category,

u_+ = the total number of resource units sampled, and

π_i = the proportion of available resource units that are in each category.

In our analysis, if the chi-squared test for the set of selection ratios was significant ($p < 0.05$) and the confidence interval for the selection ratio did not include 1, the selection ratio was considered significantly different from expected selection. An additional approximate test for significance of the selection ratio estimate¹ was calculated and compared to the chi-squared distribution for one degree of

¹ Approximate significance (p) = $\{(w_i - 1) / se(w_i)\}^2$

freedom, as in Manly et al. (2002); these statistics were used as an additional test for significance of the selection ratios.

We compared selection ratios between males and females, females with/without young, and daytime/nighttime. Females were considered to have young if they were accompanied with cubs of the year or yearlings. If reproductive status could not be confirmed, females were classified as without young. Day and night time locations were defined based on sunrise and sunset calculators (pers. comm. Julie Duval, FRI), and data falling into crepuscular periods (twilight morning and twilight evening), were included with night locations. Selection ratio results were tested for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests in SPSS, as well as visual inspection of histograms. For datasets that were not normally distributed, non-parametric statistical tests were used for analysis. Selection ratios were compared between males and females (by bear) and between females with and without young (by bear-year) using the Mann-Whitney U test ($\alpha=0.05$) in SPSS. Day/night data for 100m buffer locations (wellpad) were compared using a paired Wilcoxon signed-rank test ($\alpha=0.05$), and day/night data for ZOI and the home range >500m from wellsites were compared using a paired t-test.

b. Availability of bear foods at wellsites

Bear food availability estimates at wellsites in the Kakwa study area were collected in August 2011. Study sites were selected to include both categories of wellsite status (active versus inactive) and a range of wellsite ages (based on years since initial drilling).

We collected general data regarding the overall characteristics of the wellsite, the percentage of the wellpad covered with vegetation, percent barren ground, and percent water. The approximate abundance of bear foods on the wellpad and along the four wellsite edges were estimated using the following cover classes:

- + (present, <1%)
- 1 (<5%)
- 2 (5-25%)
- 3 (26-50%)
- 4 (51-75%)
- 5 (76-100%)

Any bear activity (scat, digging, anting, tracks) detected on the wellpad or along wellsite edges was also recorded.

Results

a. Bear selection (use) or avoidance of the wellpad and ZOI

Our final analysis included location datasets for 16 individual bears across seven years of data collection (2005 through 2011), and a total of 30 bear-years. The sample included 10 adult females (19 bear-years), 4 adult males (7 bear-years), and 2 subadults (4 bear-years). Selection ratio results were not correlated with the number of location points in each dataset, indicating that results for our final sample of bears were not biased by the variation in sample size for locations. Total number of locations and locations in each zone for each bear are presented in Table 2.

Table 2: Total locations within home ranges and locations within habitat zones. Expected numbers of locations were calculated based on total locations for each bear and the proportional area for each zone (see Table 1).

Bear	Total locations	Years of data	Observed 100m buffer locations	Expected 100m locations	Proportion 100m locations	Observed 500m ZOI locations	Expected 500m ZOI locations	Proportion 500m locations	Observed locations >500m from wellsites	Expected locations >500m from wellsites	Proportion locations >500m from wellsites
G223	6191	2	72	66	0.0116	1340	1397	0.2164	4779	4727	0.7719
G224	3146	2	77	17	0.0245	765	381	0.2432	2304	2748	0.7324
G230	1267	1	9	2	0.0071	69	54	0.0545	1189	1211	0.9384
G236	2097	1	14	33	0.0067	507	609	0.2418	1576	1455	0.7515
G238	3673	2	31	28	0.0084	503	592	0.1369	3139	3053	0.8546
G253	1943	1	20	8	0.0103	223	181	0.1148	1700	1754	0.8749
G254	3340	2	98	13	0.0293	364	271	0.1090	2878	3056	0.8617
G257	6979	3	107	56	0.0153	1268	1179	0.1817	5604	5744	0.8030
G258	6440	2	268	83	0.0416	1770	1763	0.2748	4402	4594	0.6835
G260	15810	5	594	194	0.0376	4971	3853	0.3144	10245	11763	0.6480
G262	3251	3	52	41	0.0160	628	839	0.1932	2571	2371	0.7908
G264	949	1	10	3	0.0105	118	78	0.1243	821	867	0.8651
G265	1954	1	22	8	0.0113	399	170	0.2042	1533	1776	0.7845
G269	2607	2	106	10	0.0407	365	214	0.1400	2136	2383	0.8193
G270	778	1	20	9	0.0257	273	183	0.3509	485	585	0.6234
G271	1620	1	63	15	0.0389	361	310	0.2228	1196	1295	0.7383

Selection ratios by bear for each habitat zone are presented in Table 3. In the 100m buffer zone, ten of sixteen bears had ratios significantly greater than 1.00, indicating selection of the wellpad region (Table 3). One bear had a selection ratio significantly less than 1.00, indicating avoidance of wellpads, while selection ratios for 3 bears were not significantly different from expected. Two bears (G230 and G264) had counts of less than five for expected locations in the 100m zone (Table 2); therefore, selection ratio results for these bears fail to meet the assumptions of the chi-squared goodness of fit test. Confidence intervals and significance estimates strongly suggest selection of the 100m zone in both cases; however, a conservative interpretation of results classifies the response of these two bears as not significant. The mean selection ratio for the 100m zone was 3.28 (SD = 2.52, range = 0.42-10.31) (Table 3).

Table 3: Selection ratios by individual bear. (NS = no significant relationship detected).

Bear	Chi-squared probability	100m buffer zone						500m zone of influence						Home range >500m from wellsites					
		Selection Ratio	SE	95% CI		Pattern of habitat use	Significance estimate	Selection Ratio	SE	95% CI		Pattern of habitat use	Significance estimate	Selection Ratio	SE	95% CI		Pattern of habitat use	Significance estimate
G223	0.1838	1.08	0.13	0.83	1.33	NS	0.5122	0.96	0.02	0.91	1.00	NS	0.0764	1.01	0.007	1.00	1.02	NS	0.1160
G224	0.0000	4.54	0.51	3.54	5.54	Selection	0.0000	2.01	0.06	1.88	2.13	Selection	0.0000	0.84	0.009	0.82	0.86	Less	0.0000
G230	0.0000	3.76	1.25	1.31	6.21	NS*	0.0270	1.29	0.15	0.99	1.58	NS*	0.0559	0.98	0.007	0.97	1.00	NS*	0.0100
G236	0.0000	0.42	0.11	0.20	0.64	Avoidance	0.0000	0.83	0.03	0.77	0.90	Avoidance	0.0000	1.08	0.014	1.06	1.11	More	0.0000
G238	0.0003	1.11	0.20	0.72	1.50	NS	0.5780	0.85	0.04	0.78	0.92	Avoidance	0.0000	1.03	0.007	1.01	1.04	More	0.0001
G253	0.0000	2.46	0.55	1.39	3.53	Selection	0.0077	1.23	0.08	1.08	1.38	Selection	0.0030	0.97	0.008	0.95	0.99	Less	0.0002
G254	0.0000	7.41	0.74	5.97	8.86	Selection	0.0000	1.34	0.07	1.21	1.47	Selection	0.0000	0.94	0.007	0.93	0.95	Less	0.0000
G257	0.0000	1.90	0.18	1.55	2.26	Selection	0.0000	1.08	0.03	1.02	1.13	Selection	0.0057	0.98	0.006	0.96	0.99	Less	0.0000
G258	0.0000	3.23	0.19	2.85	3.60	Selection	0.0000	1.00	0.02	0.96	1.04	NS	0.8344	0.96	0.008	0.94	0.97	Less	0.0000
G260	0.0000	3.05	0.12	2.81	3.29	Selection	0.0000	1.29	0.02	1.26	1.32	Selection	0.0000	0.87	0.005	0.86	0.88	Less	0.0000
G262	0.0000	1.26	0.17	0.92	1.60	NS	0.1367	0.75	0.03	0.70	0.80	Avoidance	0.0000	1.08	0.010	1.07	1.10	More	0.0000
G264	0.0000	2.88	0.90	1.10	4.65	NS*	0.0381	1.50	0.13	1.25	1.76	NS*	0.0001	0.95	0.012	0.92	0.97	NS*	0.0000
G265	0.0000	2.81	0.59	1.64	3.97	Selection	0.0024	2.35	0.10	2.14	2.55	Selection	0.0000	0.86	0.010	0.84	0.88	Less	0.0000
G269	0.0000	10.31	0.98	8.39	12.24	Selection	0.0000	1.71	0.08	1.55	1.87	Selection	0.0000	0.90	0.008	0.88	0.91	Less	0.0000
G270	0.0000	2.12	0.47	1.20	3.04	Selection	0.0167	1.49	0.07	1.35	1.63	Selection	0.0000	0.83	0.023	0.78	0.87	Less	0.0000
G271	0.0000	4.14	0.51	3.14	5.15	Selection	0.0000	1.17	0.05	1.06	1.27	Selection	0.0022	0.92	0.014	0.90	0.95	Less	0.0000
		Mean 3.28						Mean 1.30						Mean 0.95					
		SD 2.52						SD 0.44						SD 0.08					

*These datasets had <5 expected locations and failed to meet the assumptions of the chi-squared goodness of fit test.

Within the 500m ZOI, selection was significantly greater than expected for nine bears, significantly less than expected for three bears, and not significant for 4 bears. Overall, selection was not as strong for the 500m zone compared with the 100m zone, with a mean selection ratio of 1.30 (SD=0.44, range = 0.75-2.35). Results were consistent across the two zones, and no contradictory results were observed; in other words, there were no results that indicated selection of the 100m zone with avoidance of the surrounding 500m zone. For nine of the ten bears that selected for the 100m zone, results also indicated selection for the 500m ZOI, while the remaining bear had neutral results in the 500m zone. Similarly, the bear that showed avoidance of the 100m zone also avoided the 500m zone (Table 3). There were no cases of selection of the 500m zone without selection of the 100m zone.

The habitat zone >500m from wellsites makes up a much larger area than the two wellsite buffer zones, and is comprised of the remaining home range for each bear. Therefore, results cannot be interpreted as “selection” or “avoidance” in this zone, as it is not possible for the bear to “avoid” its home range. However, we would expect that more or less use of the smaller zones would be reflected in shifts in use of the remaining home range. Selection ratios for this zone are interpreted as habitat use that is “less than expected”, “more than expected”, or neutral, and these results should correspond with results observed for the 100m and 500m zones. For example, for the 10 bears that showed selection of the 100m and/or 500m zones, the use of the remaining home range was less than expected. Similarly, for 3 bears that showed avoidance of the 100m and/or 500m zones, use of the zone >500m from wellsites was more than expected (selection ratios significantly greater than 1.00). Results were consistent across the three zones, with no contradictory results. The remaining 3 bears did not have significant results. Overall, use of the home range >500m from wellsites was slightly less than expected, with a mean selection ratio of 0.95.

Comparatively, the mean selection ratio for the 100m zone (3.28) was more than twice as high as the mean SR for the 500m zone (1.30), and about three times the mean SR for the remaining home range (0.95).

Although the mean selection ratio was slightly larger for females (3.69) than for males (2.38) within the 100m zone (Tables 4 and 5), no significant differences between males and females were detected for any of the three habitat zones (Mann-Whitney U test, p values >0.20). Similarly, no significant differences were detected for selection ratios between females with young and females without (p values >0.32). When daytime and nighttime selection ratios were compared for females, the mean nighttime selection ratio was greater than daytime, but no significant differences were detected for the 100m zone (Wilcoxon signed-rank test, p=0.441). However, nighttime selection ratios for females were significantly higher than daytime selection ratios in the 500m ZOI (Paired t-test, p=0.010), and accordingly, use of the zone >500m from wellsites was significantly lower during the day (Paired t-test, p=0.011). For males, there were no significant day/night differences in selection of the 100m zone (Wilcoxon signed-rank test, p=0.465), 500m zone (p=0.068), or home range >500m from wellsites (p=0.068).

Table 4: Selection ratios for individual females.

Bear	100m	500m	>500m
G223	1.08	0.96	1.01
G224	4.54	2.01	0.84
G236	0.42	0.83	1.08
G238	1.11	0.85	1.03
G253	2.46	1.23	0.97
G254	7.41	1.34	0.94
G258	3.23	1.00	0.96
G260	3.05	1.29	0.87
G265	2.81	2.35	0.86
G269	10.31	1.71	0.90
G271	4.14	1.17	0.92
Mean	3.69	1.34	0.94
SD	2.93	0.49	0.08

Table 5: Selection ratios for individual males.

Bear	100m	500m	>500m
G230	3.763991	1.288362	0.981791
G257	1.90387	1.075604	0.975639
G262	1.257392	0.748522	1.084509
G264	2.875052	1.503425	0.946906
G270	2.120415	1.491013	0.828393
Mean	2.38	1.22	0.96
SD	0.96	0.32	0.09

b. Availability of bear foods at wellsites

We visited 16 wellsites in the Kakwa study area, including 9 active wellsites and 7 inactive wells. Bear foods were present on the wellpads at 14 of 16 wellpads. The two wellpads at which bear foods were absent had both been cleared within the previous year and were 100% barren of vegetation. There was a consistent relationship between age of the wellsite (years since clearing) and percent of the wellpad that was vegetated, for both active and inactive wellsites ($R^2=0.87$) (Figure 2).

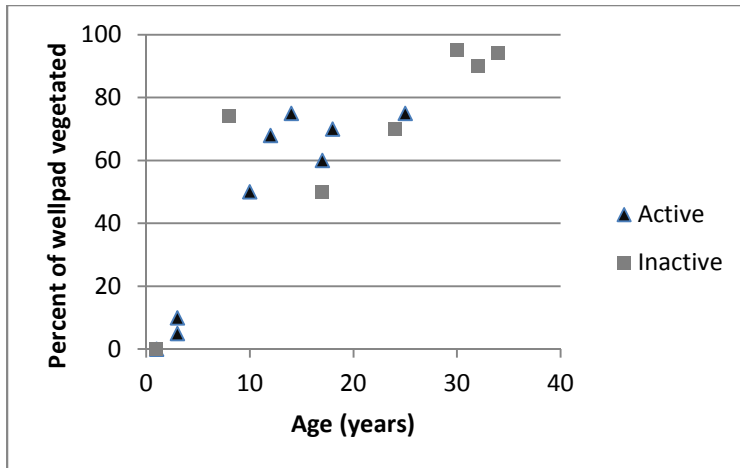


Figure 4: Percent of wellpad vegetated versus age of wellpad (years since initial clearing).

A similar relationship was observed between age of wellsite and relative abundance of bear foods known as initial colonizers of disturbed areas, including dandelion (*Taraxacum officinale*), clover (*Trifolium* spp), and horsetails (*Equisetum* spp) (Figure 3). There was no significant difference (unpaired t-test) in the approximate abundance of the dandelion/clover/*Equisetum* group between active and inactive wellsites. Clover was the most abundant bear food on wellpads, (modal value = the 5-25% cover class), followed by *Equisetum* and dandelion. Alfalfa (*Medicago* sp.), strawberry (*Fragaria* sp.), *Rubus* species, and anthills were also common on wellpads.

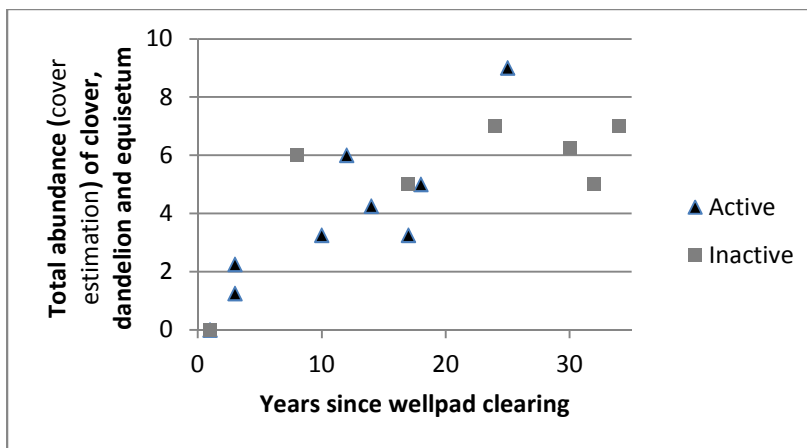


Figure 5: Total abundance of dandelion, clover and *Equisetum* versus wellpad age (year since initial clearing).

Berry species were relatively abundant along the edges of all 16 wellsites, ranging in abundance (total of all berry species) from cover class 2 (5-25%) to cover class 3 (26-50%). Berry species included *Vaccinium* species, *Rubus* sp., *Viburnum* sp., and *Ribes* sp. *Vaccinium* species included *Vaccinium myrtilloides*, *V. membranaceum*, *V. vitis-idaea*, and *V. caespitosum*. The abundance of all *Vaccinium* species (grouped) ranged from cover class 1 (<5%) to cover class 3 (26-50%). There was no apparent relationship between the abundance of berries along wellsite edges and the number of years since clearing.

Discussion

More than half (10 of 16, or 62.5%) of the bears in our study selected for wellpads, and only one bear showed avoidance. These results are in contrast to the avoidance of wellsites reported for other species including mule deer (Sawyer et al. 2009), caribou (Dyer et al. 2001), and elk (Powell 2003). Sahlén (2010) previously reported that grizzly bears in the Kakwa area generally selected for areas <224m from the wellsite centre. Results from Chapter 2 of this study (Labaree et al. 2012) indicated that bears were generally closer than expected to wellsites during spring, while the response in other seasons depended on sex/age class. Grizzly bears have been reported to select for other anthropogenic disturbances such as forestry cutblocks and road clearings. In the foothills of west-central Alberta, Nielsen et al. (2004a) 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. Stewart (2011) also reported grizzly bear use of edge habitat created by cutblocks, roads, and pipelines.

When forests are cleared to construct oil and gas wellsites, the existing vegetation and top soil is removed, piled up, and stored next to the well pad. For reclaimed wellsites, guidelines include planting species which are representative of that natural sub-region, ecosite, and plant community to obtain “equivalent land capability” (Alberta Environment, 2010). However, during production (usually over a 20 year period), these areas are not usually replanted. After initial clearing, early colonizing plant species begin to grow, and edge habitat is created where the openings meet the surrounding forest. Therefore, changes to the landscape due to resource extraction can create potential habitat for grizzly bears (Nielsen et al. 2004a, Stewart 2011). Results from our study indicate that a number of bear foods grow on wellpads and along the edges of wellsite clearings. Dandelion, clover, and *Equisetum* spp are frequent colonizers of disturbed areas, and these species were abundant on wellpads. Similarly, Roever et al. (2008b) reported that roadsides had a higher frequency of *Equisetum* spp., *Taraxicum officinale*, and *Trifolium* spp than forest habitats. These plants are an important part of the diet for grizzly bears in the foothills of west-central Alberta (Munro et al. 2006), and have also been identified as significant food items in the Kakwa region (Larsen & Pigeon 2006). Berry species were also relatively abundant along the wellsite edges, including important fall food items such as *Vaccinium* species. Although most research reports the avoidance of wellsites by wildlife, some species have been reported to select for oil and gas features when a valuable resource is associated with the feature, such as deer selection of saline seepage at gas wells in West Virginia (Campbell et al. 2004).

Our analysis did not account for effects of additional factors affecting selection at a broader scale, such as habitat quality, or the presence of adjacent cutblocks, roads, and pipelines. However, these factors are unlikely to have an effect at the small scale of the 100m buffer zone, which incorporated only the wellpad and immediate edge. At the small spatial scale of our analysis, the selection patterns can be interpreted as use of the wellpad. Our results indicated a stronger selection for the wellpad than for the surrounding area; overall, bears were at least twice as likely to select for the wellpad than for the 500m zone, and about three times as likely to use wellpads compared to the rest of the home range. Sahlén (2010) also found that bears generally had the highest selection ratios in the zone <224m from the

wellsite centre compared to additional buffers within 500m of the wellsite, although results only included bear locations within 500m of the well site, and selection was not compared to rest of home range. Anecdotal evidence from the Kakwa region includes sightings of bears foraging on wellpads, as well as observations of bear scat containing clover and Equisetum. Results from this study suggest that bears are attracted to wellsites by the abundance of food available on the wellpads and along the edges. On visual inspection of location points in GIS, we observed that selected wellpads were commonly visited by more than one bear over multiple days and years (Figure 4). One individual bear that showed strong selection for wellsites had 68 locations at one wellpad, across 10 different days and three different months, suggesting that the bear returned to the site repeatedly during that year.

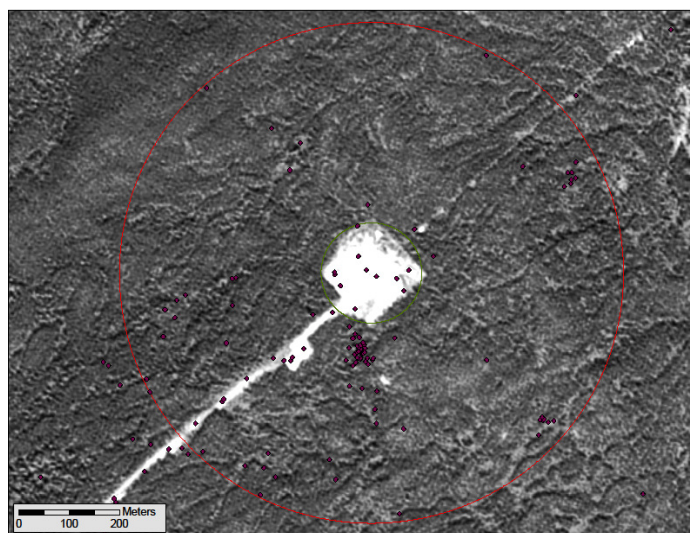


Figure 6: Wellpad with 100m and 500m buffer. Points on the wellpad include locations for G229 (2006), G238 (2007), G265 (2007), and G254 (2008 and 2009).

There was individual variation in selection patterns among individuals, with some bears showing very strong selection for wellpads (e.g. $SR=10.31$), while one bear had a pattern of avoidance. Variation in selection ratios was not explained by sex class or reproductive status. These results are in contrast to other studies that have reported differences in habitat use and response to anthropogenic features between age-sex classes (Roever et al. 2008a, Graham et al. 2010, Stewart 2011), including differences in habitat use between males and females in response to wellsites, pipelines, and roads (Labaree et al. 2012). Females with unknown reproductive status were grouped with females without young in this analysis; the potential presence of young with some of these females may have affected results. The relatively small sample size in this study may have prevented detection of significant differences; however, it is possible that differences in selection were related to individual foraging patterns rather than sex/age class or reproductive status. Differences in behaviour and feeding patterns have between individual bears have been previously reported (Stenhouse, unpublished data).

While not all bears showed selection for the 500m zone in our study, the vast majority of bears (13 of 16, or 81%) did not avoid this “zone of influence” surrounding the wellsite. Previous studies of grizzly bears have designated a ZOI around human disturbances (Mace et al. 1996, Benn 1998, Berland 2008). Benn (1998) reported that 89% of human-caused mortalities occurred within 500m from roads.

Ungulates have also been observed to have a zone of influence or avoidance of wellsites of about 1000m (Hebblewhite 2011), but no previously published research has specifically investigated a ZOI for bears and wellsites. A zone of influence or avoidance does not appear to apply to wellsites in our study region. Interestingly, in our study, all bears that selected for the 500m zone also selected for the wellpad itself. The 500m zone is a larger area than the wellpad itself, and other factors may be affecting habitat selection in this zone. Habitat quality, along with the presence of cutblocks, roads, and pipelines as well as the presence of other bears within the 500m zone were not accounted for in this study. Therefore, while the lack of avoidance in this zone is conclusive, selection for this zone must be interpreted with caution.

No significant differences were detected between day and night time selection of the wellpads, but nighttime selection was significantly higher than daytime selection for the 500m zone of influence. Due to relatively small sample sizes at the small spatial scale of the wellpad, we were unable to separate active and inactive wellsites in our analysis; therefore, potential response to human activity directly at the wellpads was not investigated. Sahlén (2010) found significant higher selection ratios in the 224m wellsite buffer at night, and Labaree et al (2012) reported that bears were generally closer to oil and gas features at night. Previous research also indicates that bears used cutblocks more during the crepuscular and nocturnal periods (Nielsen et al., 2004a). It has been suggested that bears may avoid human presence by shifting their use of habitat near disturbances to periods of lower human activity (Aune & Kasworm 1989, Schwartz et al. 2010). Bears in our study may have been bedding down in the surrounding zones, or may have been avoiding human activity in these zones by using these areas at night. The 500m zone surrounding each wellsite in our study contains roads used to access the wellsite, and may also contain additional wellsites and other human developments (pipelines, cutblocks). Human activity levels could be higher in the 500m zone compared to the wellpad, which may explain why these areas are used less during the day. The influence of roads was not investigated in this study, but in part 1 of this project, results also indicated that bears were further from roads during the day versus the night (Labaree et al. 2012a). As previously discussed, selection in this 500m zone surrounding the wellsite may be influenced by a number of additional factors, and must be interpreted with caution.

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Chapter 4: Grizzly bear movement in relation to oil and gas activities

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Introduction

In response to increasing scientific and public concern over the low population estimates of grizzly bears (*Ursus arctos*) in Alberta, the species was designated as *Threatened* by the provincial government in 2010 (Clark and Slocombe 2011). The Alberta populations are characterized by especially low fecundity and low population densities, which further hinders their recovery (Nielsen et al. 2009). Loss and fragmentation of grizzly bear habitat resulting from human disturbance is an additional concern (Ross 2002). The Kakwa region of Alberta, Canada is home to ongoing activities related to the extraction of natural resources. Recent research included in Chapter 2 of this report (Laberee et al. 2012) has indicated that bears in this area were closer than expected to some oil and gas related disturbances in some seasons, but further than expected from other features. Bears have also been shown to use cutblocks in this area (Nielsen et al. 2004; Berland et al. 2008; Stewart et al. 2012).

In addition to studies that link grizzly bear locations to different features on the landscape, studies of movement can give us an indication of how the landscape is being used by wildlife (Dickson et al. 2005; Chetkiewicz et al. 2006). Anthropogenic disturbance can result in changes in movement patterns. Patterns in the timing of daily movement of grizzly bears have been reported to change under increasing anthropogenic pressures (Schwartz et al. 2010). In a movement study of another large carnivore, the cougar (*Puma concolor*), the authors reported faster velocities through urban areas (Dickson et al. 2005). Results from part one of this study (Laberee et al. 2012) provide information regarding whether grizzly bears use habitat containing oil and gas features, but behaviours or movement patterns associated with this habitat use are unknown.

The objective of our research was to determine if resource extraction activities influence the movement of grizzly bears in the Kakwa region of Alberta, Canada. To achieve this we framed our research to answer the following questions:

- a. Are there differences in grizzly bear movement rates (velocities) related to the presence or absence of disturbance features in the vicinity?
- b. Are the densities of disturbance features different in areas of slow movement as compared to the rest of the home range?

We took two approaches to characterizing movement. The first movement measure is a standard measure of velocity or the speed travelled, calculated as a ratio of the distance and time between two consecutive telemetry points. The second involves the use of a novel method

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adapted from time geography and ecological movement models (Morales et al. 2004; Long and Nelson, 2012) to identify areas of slow movement, defined as “latent areas”. The latent area is a specific geographic area where bears are observed to spend the largest amount of consecutive time with minimal distance traveled. For both objectives, we related movement to the various disturbance features (wells, roads, pipelines, and cutblocks) within 500m of bear location points.

Grizzly bears are sexually dimorphic, with the much larger males requiring maximum foraging opportunities (Rode et al. 2006). Males are known to travel more widely than their female counterparts (Proctor et al. 2004); therefore, we expect that males should have different movement patterns from females. As well, the predominance of various foraging activities (herbivory, root digging, frugivory, insect foraging, and ungulate kills) changes seasonally (Munro et al. 2006), and we expect that movement patterns should also vary by season. As such, we also expect to observe distinct seasonal differences in movement rates and the characteristics of latent areas. Therefore, we examined adult female and male grizzly bear movements separately, for three distinct foraging seasons (spring, summer, and fall).

Methods

Grizzly bear telemetry data

Telemetry data were collected for 33 grizzly bears in west-central Alberta, Canada from 2005-2010. Grizzly bear capture followed the accepted protocols of the Canadian council of animal care for the safe handling of bears (animal use protocol number 20010016) (Stenhouse and Munro 2000). Bears were captured using a combination of aerial darting, leg-hold snaring and culvert traps, and bears were fitted with a Televilt/Followit brand GPS collar (Lindesburg, Sweden).

Telemetry data were cleaned for accuracy using positional dilution of precision (PDOP), which evaluates three-dimensional accuracy of locations. Telemetry locations with a PDOP value greater than 10 were eliminated (D'Eon and Delparte 2005). Grizzly bear telemetry data were separated into seasonal categories following established feeding patterns for our study area (Munro et al. 2006). Seasons were defined as spring (1 May until 15 June), summer (16 June to 31 July), and fall (1 August to 15 October) (Nielsen 2004).

Oil and gas features

Disturbance datasets were obtained describing oil and gas wellsites, pipelines, and roads. Wellsite and pipeline data were provided to us from a database maintained by Alberta Energy; spatial data and attributes were originally obtained directly from oil and gas operators. The roads dataset was originally obtained from Alberta Sustainable Development, and subsequently updated by our research team through heads-up digitizing using medium and high resolution imagery. Roads in this area not exclusively used by the oil and gas industry, but for the purpose of this study, they are considered to be a feature of this industry. Roads data were attributed with a year of disturbance (if constructed after 1994), pipeline data were attributed with date of construction, and wellsite data were attributed with date of initial clearing and drilling.

Disturbance data

A series of stand replacing forest disturbances were created through image differencing of a series of satellite image pairs from 1973 – 2008 , based on Landsat imagery (see White et al. 2011). This dataset detects all natural and anthropogenic stand-replacing disturbances; however, we were concerned specifically with cutblocks. Following the change classification routines of Stewart et al. (2009), non-harvest disturbances were eliminated. The cutblock data were then integrated into the oil and gas disturbance database.

Resource Selection Functions

A resource selection function (RSF) is estimated through comparisons of observed resource use to availability of resource units (Boyce et al. 2002). We created our seasonal RSFs following Nielsen et al. (2009). Individual RSFs were created for each foraging season (spring, summer, and fall periods, as defined for grizzly bear telemetry data) and each year of our study area (2005–2010), creating a total of 18 RSFs. The RSF model predicts probability of resource use based on land cover, crown closure, species composition (conifer canopy), compound topographic index, distance to streams, and distance to forest clearings (Nielsen et al. 2009). Models were created from a random sample of 90% of the telemetry data, with the remaining set aside for model evaluation. RSF accuracy was evaluated using the remaining 10% of the training data using Spearman rank coefficients. The results from 2007 showed p-values of 0.005, 0.0013, and 0.0010 for the spring, summer, and fall, respectively, indicating sufficient accuracy for use in further analysis.

Methods

Disturbance Buffers

A 500m buffer was generated around each bear location point. Within each buffer, the number of wells, length of roads and pipelines (metres), and area of cutblocks (km²) was determined. Location points were partitioned into two categories: 1) those that had zero disturbances within 500m (disturbance absent), and 2) those that had greater than zero disturbances within 500m (disturbance present).

Velocity Analysis

The Euclidean distances between telemetry fixes were calculated. A simple measurement of displacement velocity (m/hr) was calculated between every two consecutive GPS locations for adult male and female grizzly bears in each season. A Kolmogorov-Smirnov (K-S) test was used to compare velocities at points with zero disturbances (disturbance absent) to those with greater than zero disturbances (disturbance present) within the 500m buffer. Velocities were examined separately for each disturbance category (wells, roads, pipelines, and cutblocks). Data were also grouped by oil and gas related disturbances (wells, roads, and pipelines), and with all disturbances included (wells, roads, pipelines and cutblocks).

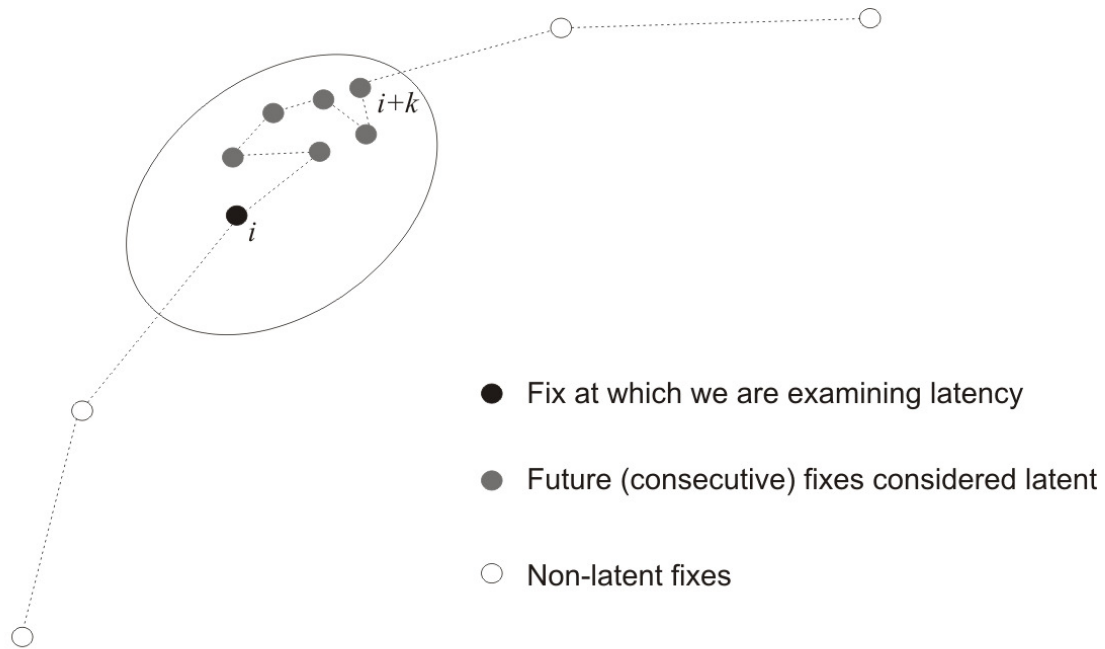
Latent Areas

Following Long and Nelson (2012), we calculated grizzly bear home ranges using the potential path area (PPA) home range method. The PPA home range is the potential area accessible to the animal, given its sequence of telemetry fixes and a parameter of movement ability termed v_{max} , related to the animal's maximum travelling speed. For each telemetry fix, an ellipse is created between that location and the next fix in the telemetry dataset. The size of this ellipse is governed by the v_{max} parameter and the time difference between the fixes (Figure 1). This ellipse encompasses the entire area the bear could have traversed based on its movement ability (as defined by v_{max}). Combining the $n-1$ ellipses (from a dataset of n telemetry fixes) results in the PPA home range (Long and Nelson, 2012).

We developed a novel method of analyzing grizzly bear telemetry data in order to quantify "latency" in grizzly bear movement paths. Our new latency measure utilizes the PPA home range described above to determine the time periods and areas where individual grizzly bears spend the longest continuous period of time in each season.

As a concept, latency includes those behaviours where the grizzly bear exhibits little or no movement. Using GPS telemetry data, we can observe latency behaviour by identifying spatial clusters of *consecutive* fixes. The key distinction with latency compared to other cluster-based concepts (e.g. core areas) is that the fixes must be consecutive in order to be considered latent. A natural choice for identifying latency in telemetry data is to delineate a latent area around a telemetry fix, and count the number of subsequent consecutive fixes that occur within this area. The count statistic, denoted L_i , can be computed for each fix in the telemetry dataset. The simplest method for calculating the area-of-latency for each telemetry fix would be to compute a spatial buffer (with a fixed width) around each fix, and compute L_i . However, this would require the objective selection of a buffer width. Rather than a spatial buffer, we chose to use the PPA ellipse (described above) as the latent area for each telemetry fix. Use of the PPA ellipse is advantageous in two ways: first, it does not include any inaccessible areas in the latent area, given the known movement trajectory; and second, it degenerates to a circle (or spatial buffer) when the bear is completely stationary.

The maximum value of L_i was identified and used in subsequent analysis. Based on the derivation above, this latent period consists of a subset of consecutive fixes from the telemetry dataset. We extracted those fixes that made up the latency period; for example, if $\max L_i = 24$, along with fix i we extract the 24 subsequent fixes following fix i . We then computed the PPA home range of the latent fixes only, which provides a spatial representation of the latent area. The latent area is a subset of the home range, much in the same way a core area is a subset of the home range. Each latent area in each season was often used by a bear for a period of several days.



The latent period is defined as the sequence of k fixes contained in the PPA ellipse of fix defined for fix i and $i + 1$. In this example the latency is $k = 6$.

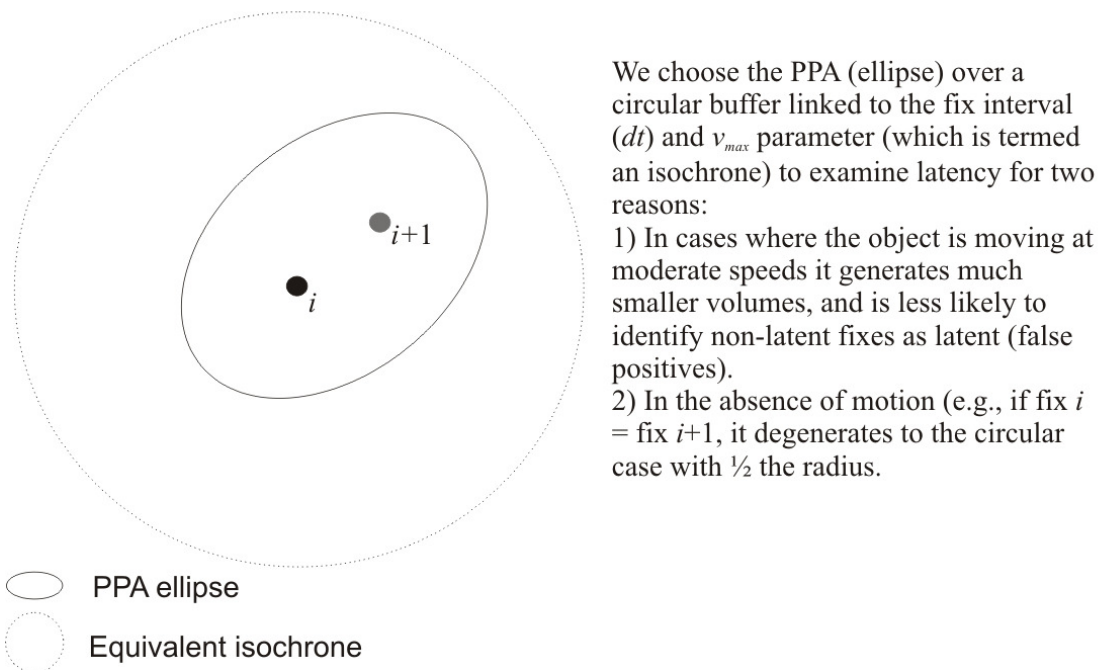


Figure 1. The determination of a PPA ellipse to define latent areas.

The home range of each individual grizzly bear was divided into two regions: latent areas and non-latent areas. Based on whether or not a location fell within a latent or non-latent area, each location point was then classified as latent or non-latent. To provide more detailed information than presence/absence, the number of wellsites, length of roads and pipelines (metres), and area of cutblocks (km²) present within the 500m buffer areas were calculated for latent and non-latent points. The number (or length or area) of disturbance features was compared between latent and non-latent points using a Kolmogorov-Smirnov test.

RSFs predict grizzly bear occurrence based on environmental covariates, and RSF values are often used to infer habitat quality. The average RSF values for the latent areas and non-latent areas were also calculated for each sex and season, and RSF values were compared between the latent and non-latent areas to determine if habitat quality affected latency results.

Telemetry Interpolation

As is inevitable with GPS-based telemetry data, missing fixes can occur due to physical obstructions and/or technical malfunctions (Rempel et al. 1995). Missing locations can result in biases in subsequent analyses (Frair et al. 2004), and are problematic when considering the temporal trajectory of telemetry data. In this study, we are interested in quantifying latency, defined as stationary behaviour determined from GPS telemetry data. Latency is directly related to the temporal structure of telemetry data, and missing fixes can disrupt this structure. In order to improve the analysis of latent areas/time periods, we estimated records for those fixes that are missing.

To account for missing fixes, a linear interpolation technique was used. The result is a telemetry dataset where fixes (observed and estimated) are taken at a regular time interval. We chose a linear interpolation technique over more complex alternatives (e.g., Wentz et al. 2003, Tremblay et al. 2006). When the GPS-signal was disrupted for an extended period of time (i.e., > 4 fixes), we analyzed the bear trajectory separately on either side of the disruption. This procedure avoids introducing biases associated with unreliable interpolation of numerous consecutive fixes.

Results

Mean grizzly bear velocity results related to the presence or absence of features (wellsites, roads, pipelines, and cutblocks) within the 500m disturbance buffers are presented in Table 1.

For wellsites, significant differences in velocities were detected in fall, but results differed between the sexes. For females, velocities were higher in the presence of wells, while for males, velocities were lower when wellsites were present. No significant effects were observed in spring or summer. At locations where roads were present within the 500m buffer, grizzly bear movement velocities were significantly greater than movement velocities at locations where roads were absent. These results were consistent across males/females and all seasons other than females in the fall. Grizzly bear velocities were also significantly higher for all sexes and seasons when pipelines were present. When oil and gas related disturbances were considered

as a group (wellsites, roads, and pipelines), significantly higher velocities were found for all bear groups if any of the oil and gas disturbances were present, compared to locations where none of these features were present within 500m.

The effects of cutblocks varied with bear group and season. Females in spring had lower velocities at points where cutblocks were present within 500m, while velocities in the summer were lower if cutblocks were absent. In the summer, males had significantly higher velocities when cutblocks were present. All other comparisons with cutblocks showed no significant differences in velocities. When all disturbance features were grouped (wellsites, roads, pipelines, and forest cutblocks), velocities were higher in the presence of any disturbance compared to velocities at locations with no disturbances within 500m. Significant differences were seen in summer and fall for females, and spring and summer for males.

The average RSF values partitioned by sex and season are compared graphically in Figure 2. RSF values were not significantly different between latent and non-latent areas, in any seasons, or between males and females.

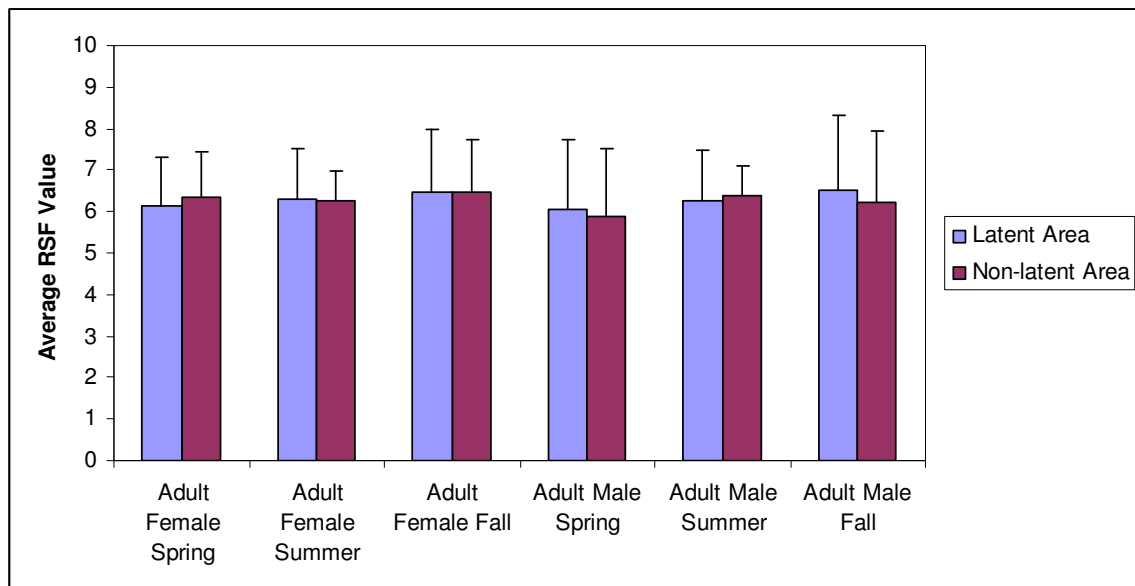


Figure 2. A comparison of average RSF values for latent and non-latent areas. Error bars are one standard deviation.

Table 1. Average velocity (m/hr) observed for grizzly bear telemetry locations in undisturbed (disturbance = 0) and disturbed areas. O&G represents cumulative disturbance associated with wells, roads, and pipelines. All represents cumulative disturbances associated with wells, roads, pipelines, and cutblocks. * Indicates significant difference as calculated with a K-S test.

	Female Spring		Female Summer		Female Fall		Male Spring		Male Summer		Male Fall	
	Disturbance		Disturbance		Disturbance		Disturbance		Disturbance		Disturbance	
	0	>0	0	>0	0	>0	0	>0	0	>0	0	>0
Wells	266	222	315	395	258	*261	572	681	463	524	397	*357
Roads	240	*260	297	*321	261	*257	524	*699	436	*546	335	*531
Pipelines	242	*262	300	*324	242	*283	539	*721	453	*529	373	*499
Cutblocks	264	*244	233	*299	254	238	557	629	459	*491	437	388
O&G	228	*264	286	*325	246	*266	502	*702	435	*529	356	*467
All	278	247	291	*315	224	*269	469	*671	427	*517	345	453

The number of wellsites within 500m of latent location points was significantly greater than for non-latent points for adult females in spring (Table 2). For all other groups, the number of wells within 500m was not significantly different between latent and non-latent points. In the spring, there was a significantly shorter length of roads within 500m of latent points for adult males and females, but only female latent points had significantly less roads in summer (Table 2). However, in fall, latent points for both adult males and females had a significantly greater length of roads within 500m as compared to non-latent points. Response to pipelines varied by sex and season (Table 2). In the spring, there was a significantly greater length of pipeline within 500m of adult female latent points, while in the summer there was significantly less pipeline within 500m of adult male latent points. In fall, both adult bear groups had significantly more pipeline within 500m of latent telemetry points.

While the area of cutblocks within 500m of latent telemetry points was significantly different than non-latent points for all comparisons, results were not consistent (Table 2). Males in spring, females in summer, and both sexes in fall had significantly less harvested area within 500m of their latent points.

Table 2. Average values of measures of anthropogenic disturbances (number of wells, metres of roads and pipelines, and km² of cutblocks) within 500m of grizzly bear latent points (L) and non-latent points (NL). Latent points were compared to the non-latent points with a K-S test; z scores are listed. with * indicating a significant difference.

Disturbance		Spring			Summer			Fall		
		L	NL	z	L	NL	z	L	NL	z
Wells (number)	Females	0.53	0.35	*3.210	0.39	0.35	0.939	0.24	0.31	1.728
	Males	0.18	0.19	1.027	0.07	0.16	1.780	0.08	0.15	1.375
Roads (m)	Females	484.9	555.9	*2.503	451.3	491.3	*2.882	768.2	531.5	*9.006
	Males	476.1	552.0	*2.226	279.2	271.5	1.926	770.5	383.9	*4.492
Pipelines (m)	Females	993.9	664.2	*2.513	623.8	614.1	1.037	818.8	635.1	*6.172
	Males	613.2	773.4	1.624	200.9	358.4	*2.594	902.9	332.8	*11.277
Cutblocks (km ²)	Females	0.130	0.108	*4.436	0.094	0.109	*3.076	0.080	0.120	*4.526
	Males	0.043	0.096	*3.270	0.074	0.071	*3.246	0.045	0.069	*6.597

Discussion

We used the relationships between consecutive grizzly bear telemetry points to characterize movement patterns, using velocities of travel as well as areas and points of slow movement (latency). Information regarding movement patterns complements knowledge about habitat use, providing more information to assist in management for grizzly bears in areas of oil and gas development.

RSF values were similar between the latent areas and the non-latent areas. This indicates that use of latent areas by grizzly bears was not explained by the landscape characteristics (environmental covariates) incorporated in the RSF values (land cover, crown closure, species composition, compound topographic index, distance to streams, and distance to forest clearings). Therefore, use of latent areas may be related to other influences on habitat use, such as nearby disturbances (Chetkiewicz et al. 2006).

The presence of wellsites was not related to higher velocities for males in any season, or for females in either spring or summer. In the spring, latent points for females also had significantly more wellsites than non-latent locations, with no differences for summer or fall. These results suggest that grizzly bear movement rates are not generally faster in the presence of wellsites. Results from Chapter 3 of this report suggest that wellsites may provide valuable food sources for bears (McKay et al. 2012). Foods available on wellsites (clover, equisetum, and dandelion) are known to be important spring and summer foods for bears (Nielsen et al. 2004c; Larsen & Pigeon 2006, Munro et al. 2006), and slow movement rates (latency) in the presence of wellsites is consistent with foraging at these sites.

In contrast, roads and pipelines were associated with higher velocities for both males and females across almost all seasons, but the average length of roads and pipelines within 500m of latent points varied by season. In other words, higher movement velocities were consistently associated with roads and pipelines, but in some seasons, latent (low movement) points had more kilometres of roads or pipelines nearby. This apparent contradiction in results between the velocity analysis and latency analysis indicates that velocity of travel may not be directly determined by the total length of roads or pipelines within 500m of a bear.

Our previous work (Laberee et al. 2012) found somewhat variable response to roads and pipelines, but both males and females were generally closer to both roads and pipelines in spring and fall. In a study of grizzly bear response to roads in the foothills of west-central Alberta, Graham et al. (2010) also reported variable results across sex/age classes and seasons; some groups were close to roads more than expected, while others were close to roads less than expected. In research completed in Chapter 2 of this report, bears were closer to roads than to any other type of oil and gas related feature, in spite of a greater density of pipelines in the area. The consistently higher velocities in the presence of roads and pipelines could indicate faster movement through these areas to avoid human presence, or it could indicate use of these linear features as travel corridors. At the spatial scale of our analysis (linear features within

500m), it is not possible to determine whether the bears were on the linear features themselves.

Research on other large carnivores has shown that the highest movement rates are in areas of human disturbance (Dickson et al. 2004). The response of animals to disturbance, including changes in behaviour or displacement, can cause energetic losses (Bradshaw et al. 1998, Cassirer et al. 1992, Frid & Dill 2002, White et al. 1995).

While some wildlife species appear to avoid linear developments, previous research has also shown that wolves (and other species) use linear corridors (roads, seismic lines, trails, railway lines) as travel routes (Thurber et al. 1994, Musiani et al. 1998, James and Stuart-Smith 2000, Whittington et al. 2005). Nielsen et al. (2004) modeled the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies, and found that grizzly bear mortalities were more likely to occur closer to linear human use features. If bears in our study are moving faster through areas with roads and pipelines to avoid human activity, there could be energetic consequences resulting from the faster movement rates. On the other hand, if bears are using roads and pipelines as travel corridors, there could be consequences for survival.

Collectively, the group of oil and gas related disturbances (wellsites, roads, and pipelines) were always associated with significantly higher average velocities. However, based on the analyses of separate disturbance features, roads and pipelines are associated with higher velocities, and are likely affecting the grouped results. All wellsites have an associated road access, but roads do not always have wellsites in the proximity. These associations may complicate interpretation of results; however, distinctly different patterns were observed with wellsites (no increase in velocity) as compared to roads (increased velocity). Therefore, it seems likely that the effects of wellsites and roads were separated out in our analysis.

Velocities associated with cutblocks were not consistent across groups and seasons. During summer, both males and females had significantly greater average velocities when cutblocks were present; however, the area of cutblocks within 500m of latent points was greater during summer for males. Compared to velocities in the presence of other disturbance features, average velocities in the presence of cutblocks were the lowest. These results suggest that bears do not generally have higher movement rates in the presence of forestry cutblocks. Bears have been shown to select for cutblocks due to food resources they provide, particularly in the summer (Nielsen et al. 2004; Berland et al. 2008), and lower movement rates in these areas are consistent with bears using these features. A lesser area of cutblocks was associated with latent points during fall, consistent with the decrease in the use of cutblocks in fall previously reported in the literature (Nielsen et al. 2004).

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Chapter 5: Mortality risk related to oil and gas development

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Introduction:

Based on the results from Chapters 2 through 4 of this report, it appears that grizzly bears have variable patterns of habitat use around oil and gas developments. Although some sex/age classes avoided developments in some seasons, our results did not indicate a strong pattern of avoidance of oil and gas features across all sex/age classes and seasons. In some cases, our results suggested selection or use of these features, potentially for food resources or movement. The primary limiting factor for grizzly bears in Alberta is human-caused mortality (Festa-Bianchet 2010). In other regions of Alberta, it has been shown that increased development may create habitat for grizzly bears (Nielsen et al. 2004a), but development can also result in increased grizzly bear mortality risk due to human access into grizzly bear habitat (Nielsen et al. 2004b). Human-caused mortalities are common in grizzly bears, and the mortalities are related to linear access features (Benn 1998, McLellan et al. 1999; Benn and Herrero 2002; Nielsen et al. 2004b). Benn (1998) reported that 89% of human-caused grizzly bear mortalities in the Central Rockies Ecosystem of Alberta (1972-1996) occurred within “zones of influence” along roads and trails. As development increases in grizzly bear habitat, bears may further increase their individual mortality risk by selecting and using development features as attractive sinks (Nielsen 2007); their presence near these features increases their risk of bear-human interactions.

With increased mortality risk as a potential consequence of grizzly bear habitat use around oil and gas developments, specific information regarding grizzly bear mortalities and mortality risk in the Kakwa is important for management. Our objectives were to examine data on known grizzly bear mortalities in the Kakwa as well as to investigate the changes in mortality risk that result from ongoing development. An additional objective was to compare predicted mortality risk values with the locations of actual mortality events, to determine if our current models are accurately predicting risk for this area. Based on these objectives, we developed the following research questions:

- a. What are the numbers of reported mortalities and their causes in the Kakwa region?
- b. What is the predicted annual mortality risk in the Kakwa study area, and how does annual mortality risk change from 2005 to 2010?
- c. How does mortality risk vary between grizzly bear home ranges, and from year to year for individual bears?
- d. How do known mortality locations in the Kakwa compare to predicted risk values from the existing mortality risk model?

To meet our objectives, we analyzed current mortality datasets and applied updated datasets using mortality risk models to create annual mortality risk surfaces specific to the Kakwa study area.

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Methods

Mortality data

Sources of reported mortalities included Alberta Fish and Wildlife and the Foothills Research Institute Grizzly Bear Program (FRIGBP), and data used for the analysis were maintained in a FRIGBP database. Mortalities were mainly detected through registration of legal hunting (previous to 2006), bears found incidentally, collared bears found using radio telemetry, and “problem” bears killed through management actions. Data were up to date as of December 2011. Mortality data included the location at which the bears were found (usually the presumed site of death), mortality location accuracy, approximate date of death, and mortality cause. Based on information available at the time of mortality, causes were categorized as follows: legally hunted, illegally hunted, legal defense of life or property, management actions, research related, mistaken for black bear, road kill, natural causes, rail kill, and unknown. Although the database contained reported mortalities from as early as 1972, early data were summarized by population unit, and did not consistently include mortality locations until 1999. Therefore, only mortalities within the Kakwa study area that occurred during or after 1999 were included in this analysis. Mortalities were summarized by year (1999 through 2010) and by mortality cause. For comparison to mortality data from other regions in Alberta, the number of mortalities per year per 1000 square kilometres was calculated using the area (8334km²) of the study area.

Mortality events in our dataset include only those that have been reported to Alberta Fish and Wildlife or to the GBP. In a review of mortality data from Alberta, British Columbia, and the western United States, McLellan et al. (1999) estimated that without the mortality information gained from radio-collared bears, management agencies would have been aware of only about 60% of human-caused deaths. To account for unreported mortality events, we increased our estimate of human-caused mortalities by 40% (Festa-Bianchet 2010).

To estimate the mortality rate for the Kakwa study area, we used the corrected human-caused mortality number along with a population density estimate. A DNA inventory study in 2008 estimated the population density in the non-protected area of the Grande Cache population unit (including the Kakwa study area) at approximately 16.18 bears per 1000km² (Alberta Grizzly Bear Inventory Team 2008).

Mortality risk surfaces

Mortality risk surfaces were calculated using the existing FRIGBP mortality risk model, incorporating datasets updated and improved in 2011. The mortality risk model is a spatial model that describes the relative probability of human-caused grizzly bear mortality as a function of landscape variables, developed in May 2007 by Dr. Scott Nielsen. The model is based on multivariate logistic regression analysis of a sample of 297 anthropogenic grizzly bear mortalities within the Central Rockies Ecosystem (CRE), dating from 1971 to 2002. In this model, mortality risk is a function of 9 variables:

1. cost distance to road (distance to road, incorporating terrain)
2. distance to stream
3. distance to forest edge
4. terrain ruggedness index (TRI)
5. proportion of upland tree

6. upland tree squared
7. proportion of protected area (federal and provincial parks and protected areas)
8. cost distance to trail x proportion protected
9. cost distance to trail x proportion White Zone (agricultural zone)

All nine variables are derived from six base layers: landcover, TRI, roads/trails, White Zone (agricultural land), streams, and protected areas. Risk values are calculated for each pixel, and values range from 0 (no risk) to 10 (high risk).

Mortality risk surfaces are currently included in the GBP deliverables, provided to program partners each year. These risk surfaces were based on the data available at the time the annual deliverables were published. Datasets obtained for the habitat use and movement analyses in Chapters 2 to 4 of this report are more spatially and temporally accurate than previously available data. Improvements in spatial accuracy translates to more accurate depiction of mortality risk on the landscape, and improvements in temporal accuracy means that development features can be included in risk models at the appropriate time. Our objective was to focus specifically on mortality risk in Kakwa area, using the most detailed and up-to-date datasets possible, including updated landcover data, road layers, and cutblock polygons, in addition to an improved and updated oil and gas feature dataset with additional attribute data. Use of these datasets for the period of our analysis (2004 to 2010) also produces more consistent and directly comparable datasets across years, improving predictability of the risk surfaces and allowing for direct year to year comparisons for this region. Starting with 2004 as the baseline risk surface for the model, we added annual changes to the landscape each year as “new” openings and roads to generate annual mortality risk surfaces for 2005 through 2010. The distance to road and distance to forest edge variables change with each addition of new openings or roads. Adding these annual changes to the baseline year allowed for a direct year to year comparison of the change in mortality risk.

The mean mortality risk within each individual annual home range was calculated for comparison of variability in risk across the study area and between sex/age classes. Mean mortality risk values by individual home range were tested for normal distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests in SPSS, as well as visual inspection of histograms. The majority of datasets were not normally distributed; therefore, non-parametric statistical tests were used for analysis. Mean mortality risk values (by annual home range) were compared between males, females, and subadults using a Kruskal-Wallis test. Correlation between age of individual bears and mean mortality risk values was investigated for females and males using a Spearman’s rank-order correlation for non-parametric samples.

Mortality risk datasets

Roads:

Roads in the Kakwa region are the product of oil and gas development as well as forestry activities. The roads dataset was originally obtained from Alberta Sustainable Development, and subsequently updated by our research team through heads-up digitizing using medium and high resolution imagery. An additional detailed update was completed in January 2012 for roads data in the Kakwa study area. Road segments were attributed with a year of disturbance, based on remote sensing imagery from July or August of each year. Roads were presumed to be on the landscape before July 31st of the year of disturbance, and that year was applied to determine when a road segment was added to the mortality risk surfaces. Road segments directly influence the “cost distance to roads” parameter in the mortality risk model, and the coefficient for this parameter is positive, meaning that risk increases with proximity to roads.

Forestry cutblocks:

Cutblock data are maintained by the FRIGBP. In January 2011, cutblocks were updated for 2009 to 2011 for the Kakwa study area, and using improved available imagery, our GIS team filled in areas that were previously missing for 2005 and 2007.

Oil and gas features:

Wellsite, pipeline, and facilities data were provided from a database maintained by Alberta Energy; spatial data and attributes were originally obtained directly from oil and gas operators. Wellsites, pipelines, and facilities create new openings and linear features that result in changes in mortality risk model input parameters. Original wellsite data were point data, and conversion to polygons was required to include these developments as openings (areas) on the landscape. The Foothills Research Institute has access to the provincial Digital Integrated Dispositions (DIDs) database, which includes polygons of mineral surface leases (MSLs) and other dispositions. If a wellsite corresponded to a disposition polygon in the DIDs dataset, the associated polygon was used in the analysis as the forest opening. If there was no corresponding MSL data in the DIDS dataset, the wellsites were buffered by 70m, creating an area of approximately 1.5 hectares, equal to the average area of wellsite MSLs in the DIDS dataset. Original pipeline data were line data, and were not buffered, as they are considered as linear features (trails) in the risk model. Addition of pipeline segments influences the “cost distance to trail” parameter in the model.

Wellsite data were attributed with a date of initial clearing and drilling, and pipeline data were attributed with a date of construction. Risk models were generated annually, but inclusion of all features added during each year would overestimate the features (and risk) on the landscape during the non-denning (active) period for bears. The mid-date for the non-denning period (averaged across all sex-age classes) was July 28th, and imagery used for updating roads was also from July or August of each year. Based on these factors, July 31st was selected as the cutoff date for developments included in annual risk models, to approximate an average value of developments present, and to keep data

consistent with roads data. In other words, any wellsites or pipelines added to the landscape after July 31st were not included in risk calculations for that year.

Data for oil and gas facilities were in the form of point data, representing the centroid of the section of land on which they were built, and data were not attributed with dates of construction. Based on the large number (1372) of facilities in our dataset, we investigated methods of including these features in calculation of mortality risk surfaces. However, the low spatial accuracy and lack of temporal data for these features was problematic. On visual inspection using remote imagery, most facilities were also small and/or were contained within the footprints of other oil and gas features (i.e. pipelines and wellsites). Therefore, only large facilities (gas plants, central treatment plants, and waste plants) were included in the analysis. Areas were included as disposition polygons obtained from the DIDS dataset.

Landcover:

Landcover is a raster-based GIS layer, identifying 10 land cover classes derived from remote sensing imagery (Landsat TM7) at 30m resolution (pixel size). We used a 2004 landcover layer as the baseline for the mortality risk surfaces. This layer was updated for 2004 disturbances using improved imagery available in 2012.

Comparison of predicted mortality risk values to reported mortality locations

The original mortality risk model was derived and validated using data from the central Rocky Mountains of Alberta. Our dataset was not large enough to statistically validate the model for the Kakwa study area. However, the reported mortalities in our dataset provided an opportunity to investigate whether the risk model accurately predicts where mortalities take place in the Kakwa region.

Depending on how a mortality event was reported, location accuracy varied from within 100m to a general location within a township and range section (accuracy ~7000m). We created buffers around mortality locations based on the reported location accuracy, and used the buffer areas to calculate the mean mortality risk value within the buffer area, based on the mortality risk surface generated for the year of each mortality.

Results

Within the Kakwa study area, there were 21 reported grizzly bear mortalities during 1999-2011, corresponding to an average of 1.75 mortalities per year, or 0.21 mortalities per year per 1000km². Total reported mortalities for each year are included in Figure 1, and mortalities categorized by mortality cause are included in Table 1. The number of annual reported mortalities decreased from 1999 (6 mortalities) to 2010 (1). The most common cause of mortality during 1999-2010 was legal hunting (11 mortalities), followed by illegal hunting (3). However, following suspension of the legal grizzly bear hunt in 2006, the most common causes of mortality were illegal hunting (2) and road kill (2).

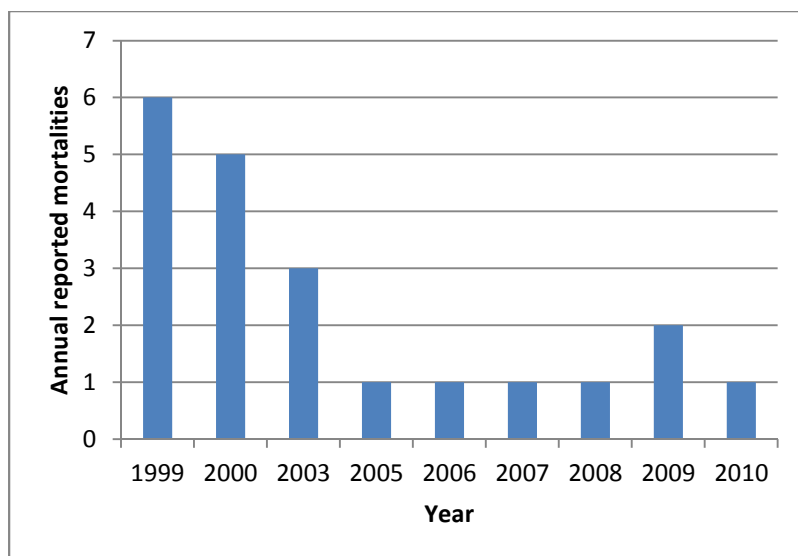


Figure 1: Reported grizzly bear mortalities by year, Kakwa study area.

Table 1: Total reported mortalities in the Kakwa study area from 1999 – 2011, by mortality cause.

Mortality cause	Number of mortalities
Illegally hunted	3
Legal defense of life or property	2
Legally hunted	11
Research	1
Road kill	2
Unknown	2
Total	21

Overall, 19 of the 21 reported mortalities (90%) were human-caused, with the remaining 2 resulting from unknown causes. Applying a 40% correction for unreported mortalities, we estimate human-caused mortalities at 27, approximately 2.2 human-caused mortalities per year, or 0.27 mortalities per year per 1000km². Using this estimate of 0.27 human-caused mortalities per year per 1000km² and the regional population density estimate of 16.18 bears per 1000km² (Alberta Grizzly Bear Inventory Team 2008), we estimate human-caused mortality rates in the Kakwa study area at approximately 1.7%.

During 2004 to 2010, the average mortality risk across the Kakwa study area increased from 6.21 to 6.36, an increase of 2.4% (Figure 2). The largest increases in risk were between 2004 to 2005 and 2005 to 2006.

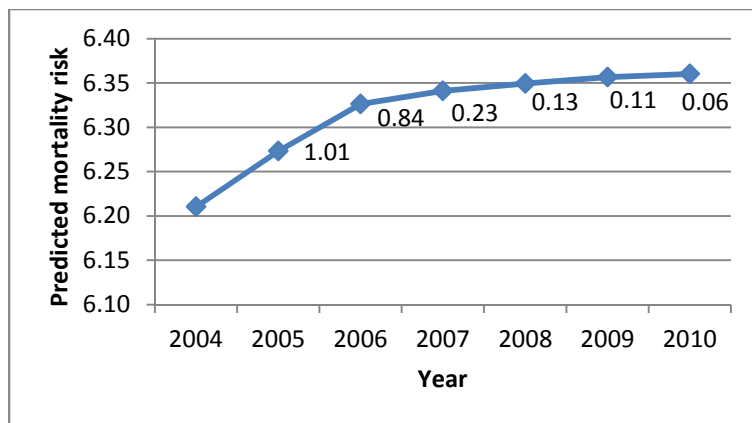


Figure 2: Predicted mortality risk in the Kakwa study area by year. Percent increases shown for each year.

A map of mortality risk in the Kakwa area for 2010 is presented in Figure 3.

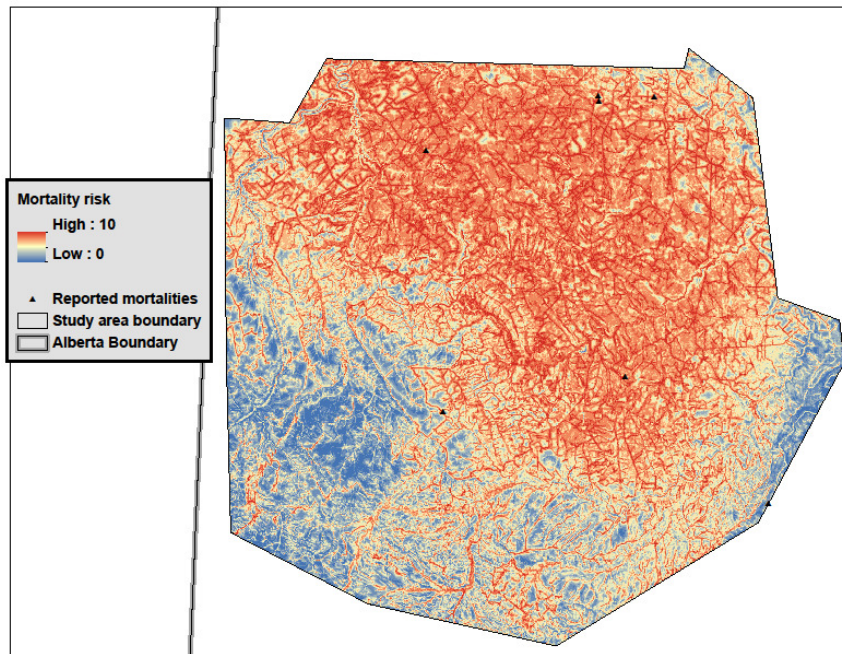


Figure 2: Mortality risk values in the Kakwa study area for 2010, including reported mortalities for 1999-2011.

There was a wide range of mortality risk values between individual home ranges, with mean mortality risk ranging from 2.79 to 8.27. Mortality risk was highest in the northeast region of the study area, and lowest in the southwest, due to differing levels of development in these regions (Figure 2). No significant differences were detected in mean mortality risk between home ranges of adult males, adult females, or subadults. Age of individual bears was not correlated with mean home range mortality risk.

Predicted mortality risk values compared to observed mortality locations are included in Table 2. The overall mean predicted mortality risk value at mortality locations was 7.76 (range = 4.77 to 9.32). All mortality locations except for one had predicted risk values of greater than 7 (Figure 2, Table 2).

Table 2: Mean predicted mortality risk values at locations of reported mortalities, 2005-2010.

Year	Mortality cause	Mean risk value
2005	Legally hunted	7.14
2006	Research	9.32
2007	Illegally hunted	7.56
2008	Unknown	8.20
2009	Road kill	9.03
2009	Illegally hunted	8.31
2010	Road kill	4.77

Discussion

Average annual mortalities per 1000 km² (since 1999) were slightly higher in the Kakwa study area (0.21) compared to the Yellowhead population unit (0.15) and the Grande Cache population unit overall (0.17). The proportion of reported mortalities that were human-caused was very similar to results previously calculated for 1999-2008 for the entire province of Alberta (87% human-caused, FRI unpublished data). In moderate (non-optimal) habitats, it is estimated that the sustainable human caused mortality rate for a grizzly bear population is approximately 2.8% (McLoughlin 2003). Our estimated mortality rate for 1999 to 2010 was 1.7%, which falls below this value. It appears that current mortality rates are sustainable by the grizzly bear population in the Kakwa area, but future increases could make mortality rates unsustainable for this population.

The mean predicted mortality risk within the entire study area was moderate. Mortality risk steadily increased throughout the study period, although at a relatively low rate. The most pronounced increase in mortality risk occurred between 2004/2005 and 2005/2006, which corresponds with the largest number of wellsites, pipelines and roads added to the landscape in a single year during our study period (see Appendix A). There were no significant differences in risk within home ranges across sex/age classes, indicating that different sex-age classes are not likely selecting areas with different risk. There were no indications of patterns of survival related to predicted mortality risk, as age was not correlated with a lower risk value. The mean predicted mortality risk ranged widely between home ranges. Bears living in the southwestern portion of the study range are subject to much lower development and correspondingly lower mortality risk as compared to bears in the northeastern range of the study area. As development increases, mortality risk will increase further, and without mitigation measures, it is likely that mortality rates could increase in these relatively undeveloped areas.

Comparison of reported mortality locations with predicted mortality risk values indicates that the current model is a good predictor of mortality risk for the Kakwa study area. Compared to the possible values of 0 to 10, all mortality locations but one had relatively high (>7) predicted mortality risk values. These results indicate that applying current models to predict mortality risk in the Kakwa is a useful tool for grizzly bear management in this area.

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Chapter 6: Conclusions and Recommendations

Conclusions

Alberta is the largest producer of oil and natural gas in Canada. The province is also home to a threatened population of grizzly bears, a species with both cultural and ecological significance. Our research addresses the current knowledge gap regarding how grizzly bears respond to oil and gas operations. Results and management recommendations presented in this project may be applied in the Kakwa region, across Alberta, and in other areas of oil and gas development in North America to enhance and improve land management in grizzly bear habitat.

Our results show that grizzly bears used habitat containing oil and gas activities (wellsites, roads, and pipelines) differently than what would be expected from habitat values (RSFs). Differences in habitat use with oil and gas disturbance features varied spatially (by season and by sex/age class), and temporally (day versus night). Bears in our study generally did not avoid habitat containing oil and gas features during spring. This may be due to lower levels of human activity during this time, as the least amount of drilling takes place in the spring. During summer, males used habitat with oil and gas development less than expected, and fall was the season with the most changes in large scale habitat use in response to oil and gas features, with all bears avoiding habitat containing active wellsites. Our results also suggested a temporal shift of habitat use by adult females in fall, with less use of habitat containing oil and gas features during the day compared to nighttime. Patterns of habitat use vary; however, it appears that there may be some displacement of male bears from habitat containing oil and gas features during the summer.

At a smaller spatial scale, our results show that the majority of bears selected for wellpads, and most bears did not avoid the 500m zone surrounding wellsites. Therefore, bears continued to use habitat surrounding wellpads, and were not displaced. Bears were likely attracted to the abundance of bear foods growing on wellpads and along forest edges surrounding the wellsites; these bear foods are more abundant on older wells (>10 years since initial clearing).

There were no obvious increases in grizzly bear movement rates in response to wellsites in our analysis. Our results indicate faster movement when roads or pipelines were present, indicating either a response to disturbance (displacement) or possible use of these linear features as movement corridors. At the spatial scale of the analysis (linear features present/absent within 500m), it was not possible to determine whether the bears were on the linear features themselves. The FRIGBP has received funding from the AUPRF to initiate a study in 2012 involving an investigation of grizzly bear use of pipelines as movement corridors, and comparison to movement patterns along roads. Results from the 2012 research will specifically investigate movement along these linear features, and will build on current results to provide information for management and mitigation of oil and gas development in grizzly bear habitat.

Human-caused mortalities were similar to those observed in other areas of Alberta. Our estimated mortality rate for 1999 to 2010 was 1.7%, below the estimated sustainable human caused mortality rate for grizzly bear populations in moderate habitats (2.8%). The mean predicted mortality risk within the

entire study area was moderate, and mortality risk steadily increased throughout the study period. Comparison of reported mortality locations with predicted mortality risk values indicates that the current model is a good predictor of mortality risk for the Kakwa study area.

While clearings such as wellpads may provide new foraging habitat or movement corridors for grizzly bears, bear use of human features such as wellsites also increases the potential for bear-human interactions. It appears that bears are using wellsites for access to food, but it is unknown if wellpads represent an important source of foraging habitat within our study area. Grizzly bear mortality risk is known to increase near human features; therefore, wellsites may result in an increased risk of human-caused mortality for bears foraging on the wellpads. As development in the Kakwa region increases, mortality risk will further increase, likely making human-caused mortality rates unsustainable.

Recommendations

The primary limiting factor for grizzly bears in Alberta is human-caused mortality, and reduction in human-caused mortality is included in the Alberta Grizzly Bear Recovery Plan (Alberta Grizzly Bear Recovery Team 2008). Mortality risk is directly related to specific characteristics of industrial developments, such as linear access and sightability of bears; therefore, these characteristics provide opportunities for mitigation. Mitigation measures that reduce linear access to grizzly bear habitat and/or reduce sightability of grizzly bears near openings created by development activities in this region would reduce the probability of human-caused grizzly bear mortalities. The FRIGBP is currently developing a tool that will allow resource managers to select particular linear features within a specific area for decommission to maximize the benefits for grizzly bears with the lowest kilometres of roads reclaimed.

The FRIGBP is interested in presenting results from this study at a stakeholder meeting with oil and gas operators in 2012, in order to exchange information and to discuss additional on-the-ground mitigation opportunities that could be applied to oil and gas operations in the Kakwa region. Consultation with oil and gas operators will provide an opportunity to apply the information gained in this study in combination with industry expertise, in order to develop practical applications in daily operations.

Results from this project serve as baseline information to fill the knowledge gap regarding oil and gas development and grizzly bears. Future studies will continue to address this knowledge gap, and provide more information to better manage development to assist in recovering this threatened species.