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Oil and gas development is widespread in west–central Alberta, yet little is known about the potential impacts of oil and gas activities on grizzly bear habitat use. Focusing on the impacts of one component of energy development, we studied the selection patterns of radio-collared grizzly bears in relation to oil and gas wellsites in the Kakwa region of west–central Alberta. For each grizzly bear foraging season (spring, summer, and fall), we calculated a population level resource selection function (RSF) to assess the probability that bears would select for wellsites versus non-wellsite habitat. We used mixed-effects logistic regression and model selection to examine factors that could influence the probability of wellsite use, including: grizzly bear reproductive status, wellsite age, wellsite operational status, surrounding road and wellsite densities, adjacent forest canopy cover, and adjacent habitat. Bear reproductive status, surrounding road and wellsite densities, and adjacent canopy cover had the most influence on the probability of wellsite use. Females used wellsites more than expected in all seasons, and males selected for wellsites in summer and fall. Males used wellsites less than females, and females with young used wellsites more than both single females and males. Bears were more likely to use wellsites that had lower densities of disturbance (roads and wellsites) in the surrounding area. In the fall, older wellsites were also more likely to be used by bears. In areas with human access, grizzly bears attracted to anthropogenic features are at a higher risk of human-caused mortality; therefore, their use of wellsites could have negative results for this threatened population.

Canada is one of the foremost oil-producing countries in the world, and oil and gas development has heavily influenced the landscape of Alberta, especially in western parts of the province (Schneider et al. 2003). Landscape disturbance and human-caused grizzly bear mortalities are significant threats to the Alberta grizzly bear *Ursus arctos* population (Nielsen et al. 2004b, Festa-Bianchet 2010), which was provincially designated as 'Threatened' in 2010. Oil and gas development continues to alter grizzly bear habitat in the foothills of west–central Alberta, and could have negative impacts on bears in this area.

Oil and gas operations have been documented to affect a number of mammal species in North America, including caribou *Rangifer tarandus* (Dyer et al. 2001, 2002, Joly et al. 2006), mule deer *Odocoileus hemionus* (Sawyer et al. 2006, 2009), and elk *Cervus elaphus* (Powell 2003). However, previous investigations of the response of bears to energy sector activities in North America have mainly focused on the impacts of the exploration and development phase, including seismic surveys and exploratory drilling (Harding and Nagy 1980, Reynolds et al. 1986, McLellan and Shackleton 1989a), construction of facilities and roads (Harding and Nagy 1980, Schallenberger 1980, Tietje and Ruff 1983), and human–bear conflicts at camps and facilities (Harding and Nagy 1980). Recent research in Alberta has included grizzly bear landscape use in response to existing seismic cutlines (Linke et al. 2005), the use of edge habitat along roads and pipelines (Stewart et al. 2013) and large scale habitat use patterns in response to oil and gas features (Labaree et al. 2014). Results from these studies suggested relatively low levels of spatial avoidance and displacement of grizzly bears in response to oil and gas features.

A number of ecological and landscape factors could influence how individual grizzly bears respond to wellsites. Behavioral responses to human activities have been shown to differ by grizzly bear sex class or reproductive status (Darling 1987, Rode et al. 2006, Nellemann et al. 2007, Elfström and Swenson 2009). Differences in food availability are presumed to influence grizzly bear habitat selection (Nielsen et al. 2010), and the abundance of bear foods at wellsites in our study area showed variation with wellsite age (i.e. years since construction McKay et al. unpubl.). Wellsites are relatively small features on the landscape; therefore, habitat characteristics in the adjacent area also have the potential to influence habitat selection at wellsites. Earlier research on bear response to human features has suggested that it can be human activity at a site rather than the anthropogenic feature itself that leads to disturbance effects on bears (Swenson et al. 1996, Olson et al. 1998, Martin et al. 2010, Ordiz et al. 2013); differences in the level of human activities could also have an influence on wellsite use by bears. Previous studies have also shown that grizzly bears may compensate for human activity by using areas of increased cover in the vicinity of anthropogenic features (McLellan and Shackleton 1988, 1989b, Ordiz et al. 2011).

Grizzly bear habitat use in response to anthropogenic features can impact foraging patterns, movement patterns, energetic output, stress levels and mortality risk (White et al. 1999, Nielsen et al. 2006, Roever et al. 2008a, b, Ordiz et al. 2013, Bourbonnais et al. 2014). The development of oil and gas wellsites results in both direct habitat alteration and an increase in human presence and noise in the area. However, to our knowledge, grizzly bear response at the small spatial scale of the wellsite has not been previously investigated. As oil and gas development expands throughout Alberta, knowledge about the possible impacts of wellsites on grizzly bear habitat use may be important in order to manage bears in areas with current or planned oil and gas activities.

Our objective was to investigate how grizzly bears respond to the disturbance associated with wellsite construction and operations in the Kakwa region of west–central Alberta. To determine whether bears may be using or avoiding oil and gas wellsites, we assessed habitat selection for wellsites versus remaining available 'non-wellsite' habitat. In addition, based on the range of attributes associated with individual grizzly bears and wellsites on the landscape, we investigated what parameters might influence grizzly bear response to oil and gas wellsites.

Material and methods

Study area

The Kakwa study area includes a region of 8300 km^2 in west–central Alberta, Canada, along the British Columbia (BC) border (Fig. 1). The elevation ranges from 549 m to 2446 m, and the area is mainly comprised of the Lower Foothills, Upper Foothills and Central Mixed Wood Subregions (Natural Regions Committee 2006). Forest structure includes conifer and mixed forests of lodgepole pine *Pinus contorta*, black spruce *Picea mariana*, white spruce *Picea glauca*, aspen *Populus tremuloides* and balsam poplar *Populus balsamifera*. During May to September, average monthly precipitation ranges from 14 mm to 160 mm, and average daily temperatures range from 3.2 to 14.2°C (Environment Canada 2013). Resource extraction activities have been ongoing in this region since the 1950s, including oil and gas development and forest harvesting (Andison 1998). The Kakwa region is part of the Alberta Deep Basin, an area known to

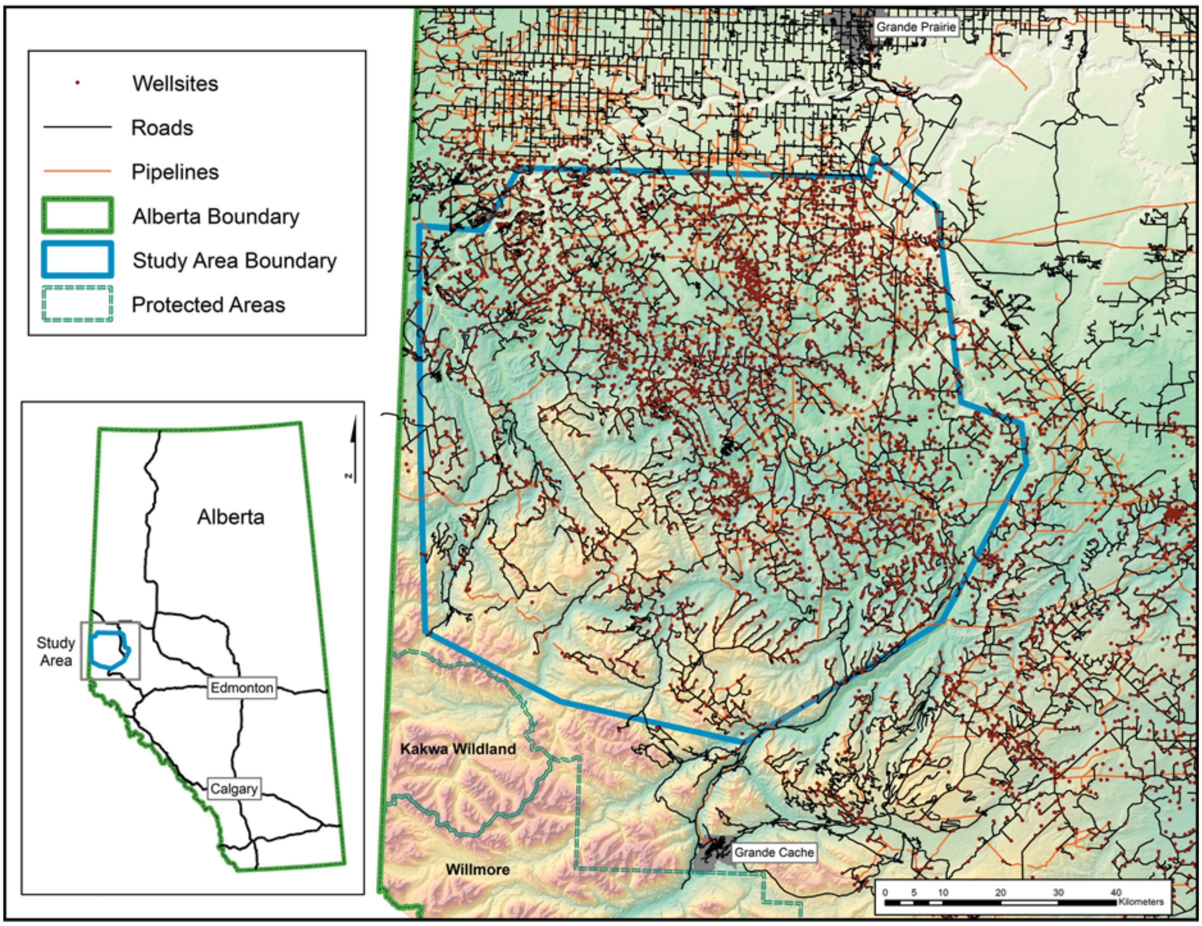

Figure 1. Kakwa study area in west–central Alberta, Canada.

contain large volumes of natural gas (Welte et al. 1984), and oil and gas development has greatly increased in the region since 2000 (White et al. 2011). As of 2012, the overall road and wellsite densities in the Kakwa study area were 0.64 km km^{-2} and 0.46 wellsites km^{-2}, respectively. However, across the study area, there is a wide range in the density of human disturbance, including regions of both low and high road densities and areas of low to high oil and gas development. Additional human activities in the area include trapping, along with recreational activities such as all terrain vehicle (ATV) use and hunting.

Oil and gas wellsite construction

During oil and gas wellsite development, drilling activities can occur over a timespan ranging from a couple of days to several weeks, depending on the depth and difficulties of reaching the oil or gas reservoir (Energy Resources Conservation Board [ERCB] 2010). There is a high level of human activity at the site during the drilling phase, including heavy equipment, truck traffic, and numerous workers at the site. During wellsite construction, a one to two hectare area is cleared of trees, surface vegetation and topsoil. Wells may either be put into production for a number of years, capped for later extraction, reclaimed (once the well is empty), or abandoned without going into production (T. Churchill pers. comm.). Operationally active wellsites are maintained by oil and gas workers on a regular basis (usually once per day), while abandoned or off-production wellsites are visited approximately once per year (A. Saxena pers. comm.). Wellsite clearings are not usually replanted during operation of the wells; however, early colonizer plant species tend to grow in these open areas. Several important grizzly bear foods have been observed in abundance at wellsites in the Kakwa area, including clover *Trifolium* spp., horsetails *Equisetum* spp. and dandelions *Taraxacum* spp., along with *Vaccinium* species and other berry shrubs in the forest edges surrounding wellsites (McKay unpubl.).

Telemetry data

Telemetry data were collected for grizzly bears in the Kakwa region during 2006–2012. Aerial darting, leg-hold snaring, and culvert traps were used to capture grizzly bears following Canadian Council of Animal Care protocols (animal use protocol number 20010016) (Stenhouse unpubl.). Captured bears were fitted with GPS radio collars programmed to collect hourly locations. Data from collars were collected remotely using monthly Very High Frequency (VHF) data upload equipment during fixed-wing aircraft flights during 2006 to 2012, and/or via satellite transmissions during 2011 to 2012.

Only non-denning locations during May through September were used in our analysis, and we restricted our dataset to bears with $\geq 90\%$ of their annual home range area within our study area boundary. Data were separated by foraging seasons for our area, including hypophagia (spring; 1 May to 15 June), early hyperphagia (summer; 16 June to 31 July), and late hyperphagia (fall; 1 August to 30 September), similar to the periods defined by Nielsen (2004a). For each season, we restricted our analysis to bears with GPS collar locations that included at least half of that season. The final dataset included location data for 23 grizzly bears, including 14 females and 9 males, with 21 847 use locations for the spring season, 31 261 for summer, and 47 462 for fall.

Grizzly bear use of wellsites

We compared grizzly bear collar locations (use) with random (available) locations to assess the probability of habitat selection for wellsites versus the remaining available "non-wellsite" habitat. Annual home ranges were generated as minimum convex polygons (MCPs) using ACCRU tools in ArcInfo (Nielsen 2010). Random locations were generated within each individual home range at a standard density of five locations per km^2.

All use and available locations were classified as being within either 'wellsite' or 'non-wellsite' habitat. Oil and gas wellsite data were obtained as point data from Alberta Energy. Using satellite imagery, we determined that a 100 m radius buffer based at the wellsite centre best incorporated the cleared wellpad area along with the surrounding forest edge (Fig. 2). Therefore, use and available locations were classified as 'wellsite' if they were within 100 m of the centre of a wellsite, and classified as 'non-wellsite' if they fell outside of this distance. For each foraging season, we separated our data by males and females, and calculated a resource selection function (RSF) at the population level, with use and available defined by individual bear ('design III', Manly et al. 2002). We used mixed effects logistic regression in Stata ver. 12.1 with individual bear included as a random effect. Results were reported as odds ratios with 95% confidence intervals, interpreted as the likelihood that grizzly bears used wellsites compared with non-wellsite habitat.

Factors influencing wellsite use

The analysis of grizzly bear use of wellsites included all use and available locations for each individual bear. From this dataset, any use and available locations classified as 'wellsite' locations were carried forward into the analysis of factors influencing wellsite use by bears. Across all seasons, 3155 bear locations and 5546 available locations were within

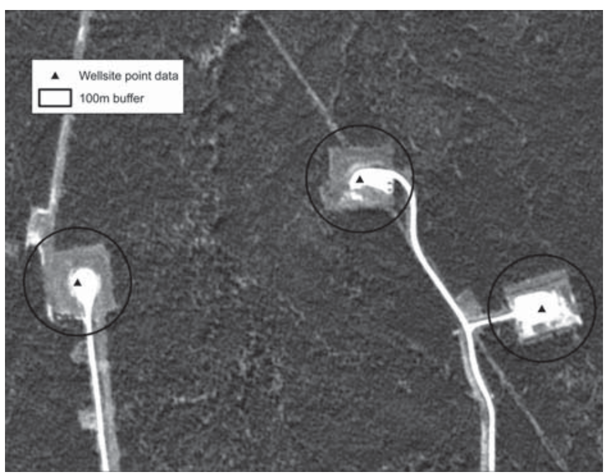

Figure 2. Oil and gas wellsites, wellsite point data, and 100 m buffer distance used for selection analysis.

100 m of a wellsite, and were included in the analysis of factors influencing wellsite use. The final analysis included 22 individual bears in the spring, 23 in summer, and 20 in fall. We investigated the influence of grizzly bear reproductive status, wellsite age, wellsite operational status, surrounding road and wellsite densities, adjacent forest canopy cover, and adjacent habitat (Table 1).

To investigate the effect of grizzly bear reproductive status, we classified bears as males, single females, or females with young. Females were determined to be accompanied by young (cubs of the year or yearlings) based on confirmed sightings. Reproductive status was specific to season (spring, summer, and fall) for each year, as some bears lose their young over the course of the year. Data from female bears with unconfirmed reproductive status were not included in our models.

Wellsite age at the time of bear location data was determined based on the year of initial wellsite clearing and drilling, and was used as an indicator of plant succession and abundance of bear foods at the wellsite. As an index of the level of human activity at a wellsite, wells were also classified as operationally active or inactive. A wellsite was considered to be active during initial drilling and while on production. Wells were classified as inactive either 1) between these two periods of activity, 2) after last production was completed, 3) after a well was discontinued, or 4) if the well did not go onto production.

Within the Kakwa study area there is a wide range in the amount of development and human activities on the landscape. The operational status of each wellsite represents the level of human activity directly at the well, but it does not reflect the level of habitat alteration and human presence in the area surrounding the wellsite. Based on the premise that the surrounding area may influence habitat selection at the wellsite, we applied road densities and wellsite densities as indicators of human activity in the area. Due to the presence of forestry development, not all roads are directly associated with wellsites; therefore, we determined that it was relevant to include roads and wellsite densities as separate indicators. We calculated road density (km road km^{-2}) and wellsite density (wellsites km^{-2}) using a 1 km moving window, similar to Mace et al. (1996). Density values were calculated as a 30×30 m raster grid and subsequently extracted to each use and available location.

Table 1. Summary of variables used in the logistic regression models for grizzly bear wellsite selection in west–central Alberta, Canada, 2006–2012.

Variable	Description of variable
Reproductive status	factor with three levels: females with young, single females, males
Wellsite age	continuous variable; age since the initial clearing of the wellsite, in years
Adjacent canopy cover	continuous variable; average percent canopy overlying the forest floor within a 300 m radius of the use or random location
Surrounding road density	continuous variable; road density (km km^{-2}) within a 1 km radius of the use or random location
Surrounding wellsite density	continuous variable; wellsite density (wellsites km^{-2}) within a 1 km radius of the use or random location

We used forest canopy cover as an indicator of available cover in the area adjacent to each wellsite. Horizontal cover data were not available for our study area; however, we assume that canopy cover reflects the amount of hiding cover due to the dense growth of coniferous trees in forest stands in the Kakwa. Similarly, Ordiz et al. (2011) showed that both horizontal cover and canopy cover provide brown bears with increased security in Scandinavia. The average hourly travel distance of all grizzly bears in our study area was 300 m; therefore, a 300 m buffer was applied to represent the approximate area available to a grizzly bear at each hourly location. Adjacent cover was then defined as the average percent canopy cover (CC) within a 300 m radius of each use and available location. To describe available adjacent habitat, we used landcover classes originally derived from Landsat 7 imagery (McDermid 2005) along with forest cutblock polygons obtained from local forestry operators. Final landcover classes included herbaceous habitat, shrublands, forest, and regenerating cutblocks classified by age (0 to 20 years, 21 to 40 years, and >40 years since clearing). For each use and available location, adjacent landcover was defined as the dominant landcover within a 300 m radius.

We created a set of a priori logistic regression models by grouping parameters in combinations that we hypothesized to be ecologically relevant for grizzly bears and/or relevant to resource management, including: bear-specific factors, wellsite-specific factors, surrounding level of disturbance, overall surrounding landscape, habitat/food availability, and combinations of these groups (Table 2). Variables were checked for correlation and collinearity using Pearson's correlation coefficients and/or pair-wise regression of independent variables against each other; variables with correlation coefficients of less than 0.6 and non-significant ($p > 0.10$) regression coefficients were included together in analyses. Almost all wellsites have a road for access, and it was expected that wellsite density and road density would be correlated. However, the Kakwa study area also includes regions with higher numbers

Table 2. Candidate models and parameters used in the logistic regression models for grizzly bear wellsite selection in west–central Alberta, Canada, 2006–2012.

	Ecology	Parameters
1	Bear biology	reproductive status (RS)
2	Disturbance/human presence	wellsite density (WD), road density (RD)
3	Surrounding region	wellsite density, road density, canopy cover (CC)
4	Food/habitat at/near wellsite	canopy cover, wellsite age (WA)
5	Biology with disturbance	reproductive status, wellsite density, road density
6	Biology with disturbance, plus interactions	reproductive status, wellsite density, road density, RS × WD, RS × RD
7	Cover/habitat, disturbance, biology	canopy cover, wellsite density, road density, reproductive status
8	Biology with hiding cover	reproductive status, canopy cover
9	Comprehensive	RS, WA, WD, RD, CC, RS × WD, RS × RD, RS × CC

of forestry roads and lower levels of oil and gas development. As a result, these variables were not significantly correlated (r-values of 0.34, 0.39, and 0.41 for spring, summer, and fall data, respectively), and therefore both were included in the set of models. Landcover class is closely related to forest cover; landcover classes in the Kakwa include mature forest (high canopy cover [CC]), shrublands and young cutblocks (intermediate CC), and herbaceous habitat (low CC). As a result, landcover and canopy cover variables were correlated ($r = 0.6$). Preliminary analyses indicated that canopy cover explained more variation than landcover class. Therefore, in order to simplify the final set of candidate models, canopy cover was included and landcover excluded from the analysis. Wellsite status was a significant predictor of wellsite age; inactive wellsites were significantly older than active wellsites ($p < 0.001$). Preliminary analyses indicated that wellsite age explained more variation than wellsite status; therefore, wellsite status was excluded from model selection. We limited interaction terms to combinations of disturbance-related variables and reproductive status of bears, as this was our main topic of interest.

Mixed effects logistic regression models were run using Stata ver. 12.1 with individual bear included as a random effect. Model selection was based on comparing differences in Akaike's information criterion corrected for small sample sizes (ΔAIC_c). Although AIC is commonly applied for model selection, controversy exists regarding appropriate cutoffs for selecting and/or averaging top models, with recommended ΔAIC values ranging from 2 to 6 and beyond (Burnham and Anderson 2002, Arnold 2010, Richards et al. 2011). However, the addition of a single parameter to a model can result in a model with $\Delta AIC = 2$ even if the additional parameter does not have any explanatory ability (Guthery et al. 2005, Arnold 2010), and excluding models with $\Delta AIC > 2$ may not result in selection of the most parsimonious model (Richards et al. 2011). An alternate approach is to carefully consider ΔAIC values along with a review of the parameters that are retained in each of the top models and a test of model fit. This review assists in determining whether variables added in more complex models truly increase the explanatory power and have meaningful coefficients, versus simply adding 'uninformative parameters' in order to get a slightly lower AIC value (Burnham and Anderson 2002, Guthery et al. 2005, Arnold 2010). For each season, we reviewed the models with the highest AIC_c weights (AIC_cw), verified that a decrease in ΔAIC_c was not the result of a more complicated version of the top model, confirmed that models produced meaningful (i.e. non-zero) coefficients ($p \leq 0.10$), and verified model fit (Boyce et al. 2002, Arnold 2010, Richards et al. 2011). If applicable (i.e. more than one top model), we carried out model averaging to calculate parameter estimates.

For each set of top models we calculated the area under the receiving operating characteristic (ROC) curve (fixed effects only) to check for model fit; a model with no predictive power would have an area under the ROC curve (AUC) of 0.5, whereas a model with perfect predictive power would have a value of 1.0 (Boyce et al. 2002). We considered models with AUC values greater than 0.75 as having good model fit. To gain insight into how much variability in the final models was explained by individual bear (random effects) versus the variability explained by predictor variables (fixed effects), we also calculated and compared marginal and conditional R^2 values for the top models (Nakagawa and Schielzeth 2013). The marginal R^2 includes the variation explained by fixed effects in the model, and the conditional R^2 includes both fixed and random effects (Nakagawa and Schielzeth 2013).

Results

Grizzly bear use of wellsites

For females, odds ratios were significantly greater than 1.00 across all three seasons, indicating that female grizzly bears used wellsites more than expected based on availability in spring, summer, and fall (Table 3). Use of wellsites by males was not different than expected during spring, but males used wellsites more than expected during summer and fall.

Factors influencing wellsite use

In the spring, the top two models accounted for 0.63 and 0.36 of the total AIC_c weight (Table 4). Both models fit the data well, as estimated by AUC-values (0.84), and predictive variables accounted for the majority of the variation explained by the model, as indicated by marginal and conditional R^2-values (0.21 and 0.34, respectively). The top model retained the variables of reproductive status, wellsite density, and road density. The second to top model included reproductive status, wellsite density, road density, and canopy cover; this model had a delta AIC-value of 1.11 (Table 4). The second model was a more complex version of the top model, but had a similar model fit (AUC) to the top model, and coefficients were meaningful ($p = 0.09$ for canopy cover). Therefore, both of the top models were used for inference; model averaged estimates and 95% confidence intervals are included in Table 5. Females with young were more likely to select for wellsites than single females, whereas males were less likely to use wellsites than both females with and without young. Wellsite density and road density within the surrounding area (1 km radius) had a negative effect on wellsite selection; bears were less likely to use wellsites in areas of higher wellsite and road densities (Fig. 3). Bears were also less likely to use wellsites as the surrounding canopy cover increased.

Analysis of summer data resulted in two models with AIC_cw-values of 0.85 and 0.14 (Table 4). However, the delta AIC_c for the second model was 3.55, it was a more complex version of the top model, and coefficients in the second model were not significant. Therefore, only the top model

Table 3. Probability of grizzly bear use of wellsites versus non-wellsite habitat. Odds ratios and 95% confidence intervals, by season and sex class in the RSF for grizzly bear wellsite selection in west–central Alberta, Canada, 2006–2012.

Season	Females (n = 14) Odds ratio (95% CI)	Males (n = 9) Odds ratio (95% CI)
Spring	2.51 (2.19 – 2.85)	1.07 (0.82 – 1.41)
Summer	5.59 (5.07 – 6.18)	2.59 (2.24 – 3.00)
Fall	2.69 (2.43 – 2.99)	1.93 (1.62 – 2.31)

Table 4. Top models, log likelihood values (LL), AIC_c weights, and model goodness of fit as indicated by area under receiver operating characteristic (ROC) curve (AUC) in the logistic regression analysis for grizzly bear wellsite selection in west–central Alberta, Canada, 2006–2012.

Season	Model(s)	Parameters	LL	K	AIC_c	ΔAIC_c	AIC_c weight	AUC
Spring	5	reproductive status, well density, road density	−776.07	5	1565.90	0	0.63	0.8143
	7	reproductive status, well density, road density, canopy cover	−774.71	6	1567.01	1.11	0.36	0.8103
Summer	5	reproductive status, well density, road density	−1478.38	5	2970.29	0.00	0.85	0.76
Fall	comprehensive	reproductive status, well density, road density, canopy cover, wellsite age, interactions between reproductive status and wellsite and road densities	−1138.08	11	2331.15	0.00	0.62	0.76
	7	reproductive status, well density, road density, canopy cover	−1156.85	6	2332.16	1.00	0.37	0.76

was used for inference. Similar to results from spring, the top model retained the parameters of reproductive status, wellsite density, and road density. The AUC-value indicated a good model fit, and predictive variables accounted for the majority of the variation explained by the model. Again, males were less likely to use wellsites than all females, and females with young were more likely to select for wellsites than single females (Table 5). Wellsite density and road density continued to have a negative effect on wellsite selection.

In the fall, the comprehensive model was the highest ranked model ($AIC_cw = 0.61$), and the second model included reproductive status, wellsite density, road density, and canopy cover ($AIC_cw = 0.37$) (Table 4). The AUC-values (0.76) indicated an acceptable model fit; however, random effects (i.e. variation between individual bears) accounted for the majority of the variation explained by the models (conditional $R^2 = 0.29$, marginal $R^2 = 0.14$). The second model was not simply a more complex version of the top model; therefore, both of the top models were used for inference, and coefficients were based on model averaging. Coefficients for wellsite density, road density, and canopy cover indicated the same patterns as in spring and summer; all had a negative effect on selection (Table 5). Females with young were more likely to use wellsites than females without, but differences between males and females were less pronounced. Wellsite age had a positive effect on wellsite selection; older wellsites were more likely to be selected than newly cleared wellsites. Bears were also more likely to select inactive wellsites versus active wellsites. Patterns of interaction factors are more complex; females with young tended to select for wellsites with higher surrounding wellsite densities than single females and males, but males appeared to select for wells with higher road densities in the surrounding region.

Discussion

Both males and female bears in our study showed selection for wellsites. 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). However, other research in Alberta (Labaree et al. 2014) indicated that grizzly bears were generally closer than expected to wellsites during spring, and that the response in other seasons depended on age–sex class. Grizzly bears have also been reported to select for other anthropogenic disturbances. 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, and bears in the Kakwa area used forest disturbances more than expected (Stewart et al. 2012). 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 200 m of roads more than expected in spring. Berland et al. (2008) also reported that grizzly bears in the foothills of Alberta were not avoiding

Table 5. Estimated seasonal model coefficients with upper and lower 95% confidence limits for grizzly bear wellsite selection in west–central Alberta, Canada, 2006–2012. Coefficients in bold indicate p-values ≤ 0.10. Coefficients for reference categories are presented as zeroes.

Variables			Spring			Summer			Fall		
			β	95% CI		β	95% CI		β	95% CI	
Reproductive status		FSingle	0	–	–	0	–	–	0	–	–
		FYoung	**1.498**	1.025	1.970	**0.720**	0.361	1.078	**0.569**	0.036	1.102
		Males	−1.059	−2.592	0.474	−1.045	−2.265	0.175	−0.430	−1.76	1.462
Canopy cover (CC)			**−0.007**	−0.015	0.001	–	–	–	**−0.029**	−0.036	−0.022
Road density (RD)			**−0.423**	−0.731	−0.114	**−0.589**	−0.825	−0.353	**−0.739**	−1.049	−0.429
Wellsite age			–	–	–	–	–	–	**0.022**	0.012	0.032
Wellsite density (WD)			**−0.298**	−0.545	−0.052	**−0.182**	−0.346	−0.017	**−0.752**	−1.008	−0.496
Interactions	RS × RD	FSingle	0	–	–	0	–	–	0	–	–
		FYoung	–	–	–	–	–	–	−0.165	−0.826	0.496
		Males	–	–	–	–	–	–	**0.989**	0.443	1.535
	RS × WD	FSingle	0	–	–	0	–	–	0	–	–
		FYoung	–	–	–	–	–	–	**0.468**	−0.059	0.996
		Males	–	–	–	–	–	–	0.184	−0.329	0.679

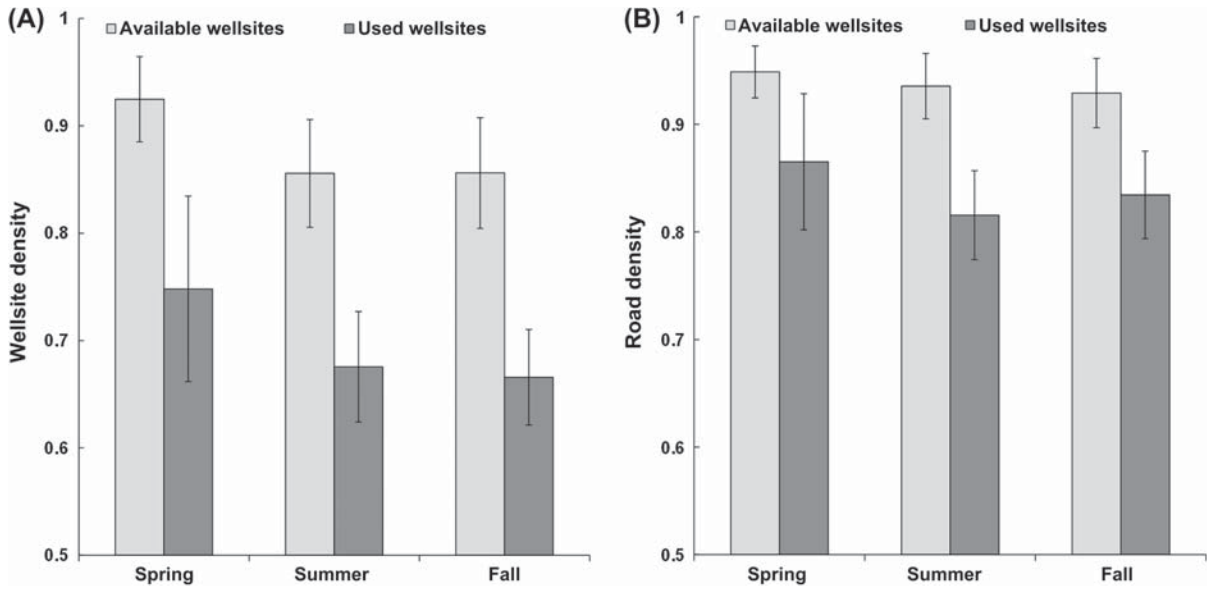

Figure 3. (A) Mean surrounding wellsite density (wellsites km^{-2}), and (B) mean surrounding road density (km road km^{-2}) for available versus used wellsites, by season in west–central Alberta, Canada, 2006–2012. Error bars represent standard error (SE).

disturbed areas, and research in BC suggested that grizzly bears were not displaced by seismic and logging activities (McLellan and Shackleton 1989a). Grizzly bear use of the edge habitat created by cutblocks, roads, and pipelines has also been observed in the Kakwa area (Stewart et al. 2013).

When forests are cleared to construct oil and gas wellsites, the existing vegetation and top soil is removed. For reclaimed wellsites, guidelines include planting species that are representative for the sub-region, ecosite, and plant community to obtain "equivalent land capability" (Alberta Environment unpubl.). However, during production (usually over a 20-year period), these areas are usually not replanted. After initial clearing, early colonizing plant species begin to grow, and edge habitat is created where the openings meet the surrounding forest. Dandelion, clover, and *Equisetum* spp. are frequent colonizers of disturbed areas, and these species were abundant at wellsites in our study area (McKay unpubl.). Similarly, Roever et al. (2008b) reported that roadsides had a higher frequency of *Equisetum* spp., dandelions and clover 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). Ungulates are also known to forage in cleared areas, providing an additional food source for bears. Berry species were relatively abundant along the wellsite edges in our study area, 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). It is likely that wellsites in our study area provide a concentrated source of bear foods, and these food resources could be an important factor driving grizzly bear wellsite use.

Our regression models indicated that females with young were more likely to use wellsites than both males and single females, and males used wellsites less than all females. Similarly, Steyaert et al. (2013) found that females with cubs in Scandinavia selected areas closer to certain human-activity areas than males during mating season. Graham et al. (2010) reported that female bears in Alberta crossed roads more often than males, and McLellan and Shackleton (1988) found that males used habitat near roads less than other age–sex classes, while some females with cubs used these areas more than any other age–sex class. In Scandinavia, females with cubs were also reported to move in areas with substantially less vegetation cover than males (Steyaert et al. 2013). Males may be more wary of human activity and/or more able to avoid human features, as they are more mobile than females with dependent young. Other authors have reported sexual segregation of habitat use by grizzly bears, including the presence of females with cubs in areas with substantially less vegetation cover than males (Steyaert et al. 2013), and displacement of females by adult males into lower quality or less secure habitats (Mattson et al. 1987, Wielgus and Bunnell 1995, Steyaert et al. 2013). Females with young in our study area may prefer the risks posed by higher human-activity areas over the risks associated with encountering males (Rode et al. 2006). Alternately, the accessibility and abundance of food growing at wellsites may simply outweigh the increased risk of encountering humans.

Across seasons, a consistent pattern was observed between probability of wellsite use and the level of human activity in the surrounding region. With decreasing wellsite and road densities in the surrounding area, the likelihood of grizzly bear use of a wellsite increased. In a working landscape such as the Kakwa, wellsite density and road density reflect the level of resource extraction and human activity in the area. Although bears appear to be selecting for wellsites, these results suggest that bears may still prefer areas of lower overall human disturbance. Similarly, although some research indicates that bears use areas around roads (Roever et al. 2008a, Graham et al. 2010), research has also suggested that bears may select for areas with lower road densities (Mace et al. 1996, Apps et al. 2004). These results imply that patterns of habitat use around anthropogenic features may be more complicated than direct avoidance or displacement from the features themselves. Grizzly bears have been reported to adjust their daily activity patterns according to levels of human activity (Olson et al. 1998, Martin et al. 2010, Northrup et al. 2012), and changes in the level of human activity in an area can also result in changes in grizzly bear habitat use or movement patterns (Rode et al. 2006, Ordiz et al. 2012). While grizzly bears in our area were not displaced by the wellsites themselves, it appears that they may avoid areas with a higher risk of encountering humans. There may be a threshold for wellsite density above which bears may avoid wellsites, and this avoidance could result in displacement from certain areas within a bear's home range.

Adjacent canopy cover had an influence on wellsite selection in our study, and bears were more likely to use wellsites next to areas with lower canopy cover. Forest cover not only provides concealment for bears (and other wildlife), it also provides shelter during hot or cold temperatures, and areas with dense canopy cover may be less likely to be used by humans because of low accessibility to such areas. Canopy cover also reflects habitat type; in the Kakwa region, areas with lower canopy cover correspond to regenerating cutblocks, meadows, and shrublands. Grizzly bears in our study area have been reported to select for regenerating cutblocks in summer, and bear foods are known to grow more in areas with an open forest canopy (Nielsen et al. 2004c, Roever et al. 2008b). It appears that the increased food availability in open areas may be more important than the presence of cover adjacent to these anthropogenic features. The influence of adjacent habitat on wellsite use may also reflect larger scale habitat selection patterns; regardless, knowledge of which habitats are most likely to have wellsite use could have applications for mitigation strategies.

Wellsite age was not an important predictor in spring or summer, but appeared to have an effect on wellsite selection in the fall. Older wellsites were more likely to be selected by bears, which may be a result of vegetation succession, with a larger amount of valuable food resources growing on or adjacent to these wells compared to more recently cleared wellsites. Data collected in 2011 indicated that abundance of bear foods increased with wellsite age (McKay unpubl.).

Wellsites are relatively small patches in the forest compared to other anthropogenic disturbances (e.g. regenerating cutblocks), and in our study it appears that these features are not causing significant displacement of grizzly bears. However, the primary limiting factor for grizzly bears in Alberta is human-caused mortality (Festa-Bianchet 2010). Areas with a higher level of human access in Alberta are associated with an increased risk of human-caused grizzly bear mortalities; bears near roads are more likely to be shot or hit by vehicles (Benn and Herrero 2002, Nielsen et al. 2004b, Roever et al. 2008a). An open canopy allows more bear foods to grow on the forest floor, potentially attracting bears (Nielsen et al. 2004c, Roever et al. 2008a). While wellsite clearings could provide good grizzly bear foraging habitat, the potential increase in mortality risk could result in wellsites functioning as attractive sinks (Delibes et al. 2001, Nielsen et al. 2006). Current research has not established a direct link between grizzly bear use of wellsites and mortality rates; however, during 2013, two human-caused grizzly bear mortalities occurred within 100m of wellsites in the Kakwa area. Both mortalities involved illegal hunting, and one incident included a female grizzly bear with yearlings (Stenhouse unpubl.). Previous research has investigated the relationship between grizzly bear demographics and other human disturbances. In east–central BC, Ciarniello et al. (2009) compared birth and death rates of grizzly bears in an area of extensive forestry development versus the adjacent undeveloped mountain region. The authors reported that forest harvest did not appear to have negative effects on reproductive parameters of female bears, but the area with extensive development had a higher rate of mortality than the adjacent mountains. McLellan (1989a, b) studied reproductive rates, survival, and population growth rates in southeastern BC in an area with forestry activities, gas exploration, and recreation. Eight out of nine known grizzly bear mortalities were human-caused, although the deaths could not be directly linked to industrial activities (McLellan 1989a), and no direct impacts of disturbance on reproduction were observed (McLellan 1989b). Schwartz et al. (2010) reported that grizzly bear survival in the Greater Yellowstone Ecosystem was directly related to the level of human development on the landscape within a grizzly bear's home range; survival rates decreased as road density, number of homes, and development increased. To assess the sensitivity of grizzly bear population growth to road densities, Boulanger and Stenhouse (unpubl.) modeled the effect of road density on survival rates for grizzly bear range in Alberta. The authors reported that grizzly bear survival was directly related to road density, and they identified threshold levels at which population levels would decline. Our data indicate that females with young are more likely to use wellsites; this highlights the importance of investigating thresholds and developing wellsite mitigation measures with the specific goal of reducing human caused mortality risk for reproducing females.

Reducing or limiting human use of linear access to grizzly bear habitat and/or reducing sightability of grizzly bears adjacent to wellsites could decrease human-caused grizzly bear mortalities. Possible mitigations for our study area include installing gates or berms at linear access features associated with wellsites, reclamation of roads leading to abandoned wellsites, or reduction of visibility at wellsites. Mitigation measures could be focused on those wellsites more likely to be used by grizzly bears, based on the results of our model. These mitigative actions during and following oil and gas wellsite activities could play an important role in improving survival rates of grizzly bears in areas of energy sector development in Alberta.

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