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Examensarbete i biologi, 30 hp, D-nivå

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Undviker grizzlybjörnen platser för olje- och gasutvinning (s.k. wellsites) i Alberta, Canada?

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Keywords: grizzly bear, Ursus arctos, wellsites, selection, industrial development, human activity, cover, Alberta

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ABSTRACT

In west-central Alberta, wellsites are common features in where oil and gas development is prevalent; yet, little is known about how these sites affect grizzly bears. I examined the wellsite selection and use of cover for ten grizzly bears (2-22 years of age) within 500 m of wellsites, between 2005 and 2010. Selection ratios were calculated for five equally large buffer isopleths. Most bears showed positive selection towards the 224-m wide zone containing the wellsite (WSZ). Important bear food growing on these sites is most likely the factor causing this pattern. Nonetheless, bears generally had higher selection ratios in the WSZ during nighttime compared to daytime, suggesting a temporal avoidance of human activity. The largest differences between day and night selection ratios appeared to generally occur in fall (September), especially for females. In addition, during this time, many bears had more GPS-locations inside the WSZ during night than day, even though there were more day GPS-locations in total within the home ranges, suggesting that some bears spend more time close to wellsites during night than day. These patterns coincide with the start of the big game hunting season in the area, and might therefore be a response to a higher human activity around wellsites and access roads during this time. Regarding the degree of cover, the WSZ selection ratio was not significantly correlated to proportion of forest, shrub or barren land in the WSZ. However, crown closure at bear GPS-location clusters for all available bear locations was not only lower close to inactive wellsites compared to active wellsites, it also varied depending on time of day. Differences between GPS-location density inside wellsite buffers and overall location density in the home range varied among bears and years. I conclude that some bears are attracted to wellsites, but avoid human activity by making temporal adjustments in their behaviour, and by using cover to compensate for being in proximity of human activity. Positive selection for anthropogenic features easily accessible by humans increases the risk of bear-human conflicts, which may in turn lead to increased direct mortality for this threatened bear population, but possibly also increased negative attitudes among people in the area.

SAMMANFATTNING

I väst-centrala Alberta är platser för olje- och gasbrunnar (s.k. wellsites) vanligt förekommande i områden där olje- och gasutvinning råder. I dagsläget finns dock lite kunskap om hur wellsites påverkar grizzlybjörnar. Jag undersökte tio björnars (i åldrarna 2-22 år) val av wellsites, och om de använde täckning i form av vegetation, inom 500 m från wellsites, mellan 2005 och 2010. Selection ratios beräknades i fem lika stora bufferzoner. De flesta björnar visade på positiv selektion för den innersta, 224 m breda zonen som innehöll wellsiten (WSZ). Viktig björnföda som växer på dessa platser är troligtvis en viktig faktor för detta beteende. Björnar hade emellertid högre selection ratios i WSZ nattetid än dagtid, vilket kan tyda på ett temporärt undvikande av mänsklig aktivitet. Den största skillnaden mellan selection ratios under natt och dag förekom generellt på hösten (September), speciellt för honor. Under denna tid hade många björnar också fler GPS-positioner i WSZ nattetid, trots att det totalt sett fanns fler GPS-positioner i hemområdet dagtid än nattetid, vilket tyder på att vissa björnar spenderade mer tid nära wellsites nattetid än dagtid. Dessa beteendemönster sammanfaller med början på storviltsjakten i området, och kan därför vara ett gensvar på en högre mänsklig aktivitet runt wellsites och deras tillfarter under denna period. Selection ratios i WSZ var inte signifikant korrelerade med andelen skog, buskar, eller kalt ödeland.

Krontakets slutningsgrad var lägre vid GPS-kluster runt inaktiva wellsites i jämförelse med aktiva wellsites, och med ytterligare tydliga skillnader i slutningsgrad beroende av tiden på dygnet. Skillnader i densitet av GPS-positioner inuti wellsitebuffrar och övergripande GPS-positionsdensitet i hemområden, varierade mellan björnar och år. Jag drar slutsatsen att somliga björnar selekterar för, och dras mot wellsites, men undviker samtidigt mänsklig aktivitet genom att göra temporära anpassningar i sina beteenden, samt genom att använda en högre grad av täckning i form av vegetation, för att kompensera närheten till mänsklig aktivitet. Positiv selektion för antropogena strukturer som är lättåtkomliga för människor ökar risken för konflikter mellan människa och björn. Detta kan leda till en ökad mortalitet hos denna hotade björnpopulation, men även ökade negativa attityder hos människor i området.

INTRODUCTION

There are always tradeoffs between the exploitation of natural resources and wildlife conservation. The economic value of the natural resource and the affective, scenic, or biological value that often must be traded to enable extraction therefore sets the conditions for resource extraction and wildlife management. Valuable natural resources, such as minerals and hydrocarbons, i.e. natural gas or oil, are often found in wilderness, and therefore the wilderness nature of many landscapes is often sacrificed for the extraction of these non-renewable resources. These tradeoffs may result in negative impacts for wildlife and biodiversity, because extraction normally leads to large deforested areas when oil and gas companies construct access roads, pipeline routes, and drilling platforms. These activities can in turn result in air, water, and soil pollution, noise pollution, littering (Finer at al. 2008) and increased amount of human activity; which all affect different species in varying ways depending on their habitat requirements and behaviour. Both onshore and offshore hydrocarbon exploration and extraction have been shown to significantly affect several species of different taxa. Caribou (*Rangifer tarandus*) have been impacted from decreased or fragmented habitats due to forestry and/or hydrocarbon extraction across their range (Dyer et al. 2001; Dyer et al. 2002; Joly et al. 2006), and other species, like elephants (*Loxondota africana cyclotis*) and apes (Rabanal et al. 2010), sage grouse (*Centrocercus urophasianus*) (Lyon and Anderson 2003), mule deer (*Odocoileus hemionus*)(Sawyer et al. 2006; Sawyer et al. 2009), and various passerines (Ingelfinger et al. 2004) have also been negatively affected by the oil and gas industry. In Australia, gas drilling operations are causing shifts in benthic community structures (Currie and Isaac 2004). The physical footprint of extraction is one direct factor affecting these species, but for higher taxa the functional habitat loss due to avoidance of human activity may be an equally important factor to consider in management and conservation (Dyer et al. 2001). It appears as if it is not anthropogenic corridors, roads, or patches per se that cause the main disturbance responses, but the human presence occurring at these sites (Jalkotzy et al. 1997; Nellemann et al. 2010; Swenson et al. 1996; Vistnes et al. 2008). Given that industrial infrastructure is rapidly expanding in many areas around the world, both physical and functional anthropogenic footprints are important factors that will determine the fate of wildlife populations in affected areas. Canada is one of the major oil-producing countries in the world, with the Western Canada Sedimentary Basin (WCSB) as an important oil and gas-bearing region covering vast areas across four provinces. Alberta, where this study is conducted, lies at the centre of the basin, and the oil and gas development has heavily influenced the landbase (ERCB 2010) especially in western parts of the province (Schneider et al. 2003).

The grizzly bear (*Ursus arctos*), or brown bear, is a holarctic species, occurring on the North American continent and throughout Eurasia. Globally, there are over 200,000 grizzly bears. This species has suffered local extinctions in the past and populations are still decreasing in many areas (McLellan et al. 2008; Servheen 1990). Major threats are e.g. fragmented and isolated populations and bears being killed at unsustainable rates because of control purposes, license hunts, and poaching (Alberta Sustainable Resource Development 2010; McLellan et al. 1999; Servheen 1990; Wakkinen and Kasworm 2004). Negative attitudes among people living in the proximity of bears is another threat for grizzly bears today (Kellert 1994). Bears depredating on domestic animals, injuring hunting dogs and hunters in hunting accidents (primarily in Europe), or bears just being too close to human settlements, are rather frequent events that easily lead to conflicts and strengthen pre-existing negative attitudes (Swenson et al. 1998). However, bear populations are now growing in size or expanding their range in some areas, for example in USA and Scandinavia (Kindberg 2010; McLellan et al. 2008). Because of their globally stable situation, the IUCN classified grizzly/brown bears as “least concern” in 1996, even though some grizzly bear populations still are small and/or decreasing, including on the North American continent.

In June 2010, the provincial government of Alberta, Canada, decided to classify grizzly bears as threatened, following recommendations from the provincial Endangered Species Conservation Committee (ESCC). The grizzly bear was thereby designated as threatened eight years after the initial recommendation to do so (Clark and Slocombe 2010). Currently, the grizzly bear population in the province consists of less than 731 individuals (Alberta Sustainable Resource Development 2010). The grizzly bear license hunt was suspended in 2006 after pronounced concerns over the limited population size (Clark and Slocombe 2010). The low numbers are of great concern for managers in this region, and knowledge about factors influencing the current population size is therefore of outmost importance. Landscape disturbances causing extensive habitat loss and fragmentation, and especially direct mortalities from vehicle collisions and poaching, are believed to be significant threats (McLoughlin et al. 2003; Nielsen et al. 2004a). The western part of Alberta may have one of the highest rates of resource extractions and associated road construction in the world (Gibeau et al. 2000; Gibeau et al. 2002; Schneider et al. 2003). The rate and magnitude of human-caused landscape change are believed to cause long-term, or chronic, stress in bears, which affects their immune system, growth, and reproduction, and may possibly lead to deteriorating populations (Cattet et al. 2007).

To be able to extract oil, gas, and timber in western Alberta, several hundred thousand kilometres of access roads and pipeline routes have been built, creating a web of travel routes in the forest. This facilitates truck and ATV mobility into and within these remote areas, both for people working there and people out for recreational purposes. Public access (especially when it comes to hunting) has been shown to have negative effects on wildlife in nearby areas because of increased hunting, poaching or traffic collisions (Jalkotzy et al. 1997; Mattson et al. 1996). Therefore, the road and human utilization factor alone greatly increases the mortality risk for bears (Mace et al. 1996a, Nielsen et al. 2004a). Important grizzly bear foods often grow on roadsides in this area, thus increasing mortality risks even further as food may attract bears (Graham et al. 2010; Roever et al. 2008a, b).
Grizzly bears’ behaviour, diet, and activity patterns greatly depend on food availability and plant phenology, and hence vary with season (Munro et al. 2006). Grizzly bears are

omnivores with a diverse diet and, after emerging from dens in early spring, bears primarily feed on roots, e.g. sweet vetch (*Hedyserum* spp.), before starting to eat moose calves (*Alces alces*). As green vegetation emerges in late spring (June), bears start to feed on horsetails (*Equisetum* spp.), clover (*Trifolium* spp.), dandelions (*Taraxacum* spp.), cow parsnip (*Heracleum lanatum*), and various graminoids, along with ants and occasional moose calves (Munro et al. 2006; Nielsen et al. 2004b). This is the time for mating season, and during this time the movement rate is at its peak; it successively decreases towards the fall (Carra 2010). When berries and fruits start to ripen in late summer, these carbohydrate-rich resources, mainly *Vaccinium* spp. and buffaloberries (*Shepherdia canadensis*), quickly become the dominant food sources in the bears' diet (Munro et al. 2006). This pre-denning phase, when immense amount of food is consumed, is referred to as hyperphagia. Bears must accumulate fat reserves rapidly before entering dens in fall to withstand the harsh winter season (Linnell et al. 2000). Indeed, one of the most fascinating features of grizzly bears is their ability to survive the winter without any intake of food or water (Folk et al. 1972). Bears in west-central Alberta normally enter their dens in October/November and emerge in April/May. Females with cubs generally den longer than lone females and males (Stenhouse pers. comm), a pattern also seen in Scandinavia (Friebe et al. 2001). Bears in this area are more active during day and crepuscular hours than during nighttime, both in terms of root-digging, frugivory, and movement (Munro et al. 2006; Carra 2010). Resting most often occurs at night and in forested areas (Munro et al. 2006).

Even though grizzly bears are considered to be wary and elusive animals, anthropogenic disturbances are changing conditions for their present and future existence, and affecting their behaviour. Increased human activity will never be a positive thing for bears, as there are generally only two possible scenarios when human infrastructure is expanding; bears avoid human activity or do not (Swenson et al. 1996). If bears avoid human activity areas, they select habitat without human impacts, but consequently end up with less available habitat than previously. Bears could, on the other hand, continue to dwell in the disturbed habitat and have the same range as before, but would then be subjected to a higher degree of exposure to human activity. This situation promotes conflicts, because of the resulting competition for space and food between humans and bears (Mattson 1990), which may lead to dangerous situations in terms of bear-human encounters and result in habituated bears, negative attitudes among people, nuisance bear management, and increased numbers of illegally shot bears (Mattson 1990). Consequently, whether bears avoid human activity or not, both behavioural patterns lead to negative outcomes for bears (Swenson et al. 1996). Interestingly enough, bears have shown a remarkable individuality in these situations. Some adjust to human activities and appear to endure or even do relatively well during their lifetime, whereas others are distinctly wary (Rode et al. 2006a, b). This highlights the importance of studying behavioural patterns of individuals in behavioural studies.

Hydrocarbon extraction has previously shown little direct negative impacts on grizzly bears in terms of spatial avoidance and displacement (Linke et al. 2005; McLellan 1989; McLellan and Shackleton 1989b). However, wildlife research has revealed that avoidance not only works on a spatial scale (i.e. displacement) and that bears and other large mammals find other ways to avoid human activity, for example by changing their diurnal activity or using denser vegetation and rugged terrain as a compensation for a higher human activity (Boydston et al. 2003; Hebblewhite and Merrill 2008; Lyons et al. 2003; Martin et al. 2010; Nellemann et al. 2007; Ordiz 2010). Altered diurnal activity in bears has been observed in both North America and Scandinavia. Temporal avoidance and changes in diurnal activity in high human activity areas were documented by Olson et al. (1998) in Katmai National Park, Alaska, where grizzly bears decreased their mid-day activity as human activity increased, and increased their activity later in the evening when human activity were lower. McLellan and Shackleton (1988 1989b) showed that particularly use of roads by bears occurred more frequently during night than day. The presence of security cover appears to reduce grizzly bear displacement, presumably because increased cover compensates for a shorter distance to human activity (McLellan and Shackleton 1988; McLellan and Shackleton 1989a; Ordiz 2010). Cover is therefore an important factor to consider when studying disturbance effects on bears.

Wellsites are places where oil or gas is extracted from the earth, and once raised to the surface, conducted through pipelines to compressor stations. In the construction of a wellsite, a 1-hectre square is deforested and the top soil is removed and/or compressed. Drilling for gas is a relatively easy task and usually takes between a couple of days to several weeks, depending on depth and difficulties of reaching the gas reservoir (ERCB 2010). Shallow wells of a few hundred metres depth can be drilled relatively quickly, whereas others, thousands of metres deep, generally take longer. Drilling is usually carried out in winter, but can be conducted at any time of the year. Pipes are drilled down underground and various cisterns, pipes, and small control booths are established to enable gas extraction and the required measurements and maintenance. Structures on the pad are generally not noisy, but they often emit a low humming sound. Some wells are drilled and then “capped” so the gas can be extracted later. When the gas reservoir is empty, the site is capped and reclaimed to government standards, resulting in abandoned wellsites (ERCB 2010). The abandoned sites are often reclaimed by pouring cement into the drilling holes and counteracting soil erosion at and around the site. Trees and shrubs are generally not replanted because of the difficulties of growing trees in compacted soils. Indeed, successful germination and establishment of shrubs and trees appear to be extremely poor on these disturbed sites (Hobson et al. 2008). As new wellsites are created and abandoned ones are not replanted with shrubs and trees, gaps that last over long time spans are left in the forest. However, most wellpads have a ground layer of plant foliage. Grass and legume seed mixes are planted on pads and almost always occurs on some parts of the wellpad, most often around the edges. Other plants frequently occurring on and around wellsites are clover, dandelions, horsetails and various graminoids and sedges. These species are all important foods for grizzly bears in this area (Munro et al. 2006).

GRIZZLIES AND WELLSITES: Setting the questions

As oil and gas development is steadily increasing in western Alberta, wellsites are becoming a more frequent feature in remote, forested areas. The question remains how grizzly bears respond to these sites. Are bears avoiding wellsites and nearby locales to keep away from human activity? To answer this question I developed the following main hypotheses:

1. ***Bears avoid wellsites***

If bears are disturbed by the human activity occurring on wellsites, a possible result could be that they actively avoid wellsites, thereby having fewer GPS locations in the proximities of wellsites than what would be expected based on a random use of the area.

2. ***Bears show a higher selection for wellsites during night time than during day time.***

Because human activity is reduced during night, bears would likely prefer to visit wellsites at these times.

3. ***Bears use areas with a higher average crown closure in the proximity of active wellsites compared to inactive wellsites.***

Because active wellsites have a more frequent human activity, bears are expected to prefer sites with more cover around active wellsites compared to inactive wellsites.

METHODS

Study area

Oil and gas development has occurred since the 1950s in the foothills region of west-central Alberta. This area sits on large reserves of oil and gas, leading to extensive exploration and extraction activities. My study was conducted in the Kakwa study area, situated in the foothills of the Rocky Mountains (Fig 1). The climate is subarctic, with cold winters and mild summers. The peak in monthly ambient temperature generally occurs in July, and lowest temperatures are recorded in December/January (Environment Canada 2010). The landscape is topographically diverse with relatively flat-topped hills, especially in the western part around the Two Lakes Provincial Park area. The forest is typically boreal and dominated by conifers, mainly black spruce (*Picea mariana*) and lodgepole pine (*Pinus contorta*) with interspersed aspen trees (*Populous tremuloides*). Aspen forests dominate in some lowland areas. The standing forest is natural and unthinned to a great extent, shaped by a fire regime where wildfires created patchiness and diversity in the past. Because of fire suppression and development in the area, resource extraction is the main factor causing patchiness today. Because the study area is situated in the heart of an area heavily dominated by oil and gas development, wellsites and deforested areas are constantly reoccurring throughout the landscape. The overall wellsite density is approximately 0.34/km^2, and as high as 1.89/km^2 in denser areas. In total, the study area contains approximately 3000 wellsites (mainly for gas extraction). Relatively large gravel and dirt roads occur throughout the area and numerous smaller access roads lead to clearcuts and wellsites. Other linear objects include cutlines, e.g. seismic lines, pipelines, and power lines.

GIS and data processing

Wellsites are easily distinguishable on the landscape from satellite imagery, because they lack canopy cover and have a relatively invariable size of 1 hectre. Wellsites have been detected and described with Landsat imagery (30 meter resolution) over successive years from 2004. Available wellsite raster data was converted to a point layer with attributes describing which year a specific wellsite appeared on the landscape. From this point layer, I was able to age wellsites. In the analyses I only used wellsites that were present at the time when bears were visiting a specific area. Landsat raster layers of land cover and crown closure were also available for the study area (Table 1). See Figure 2 for further details on characteristics of wellsites and their structures.

Bear captures, telemetry and grizzly bear locations

Bears in this study were captured and fitted with GPS radiocollars (Cattet 2003a, b). Capture types were ground capture with leg snare, ground capture with culvert trap or remote drug delivery from helicopter. All capture procedures were accepted by the Canadian Council on Animal Care for the safe handling of bears. The capture and handling methods were also consistent with the guidelines of the American Society of Mammalogists (Animal Care and Use Committee 1998).

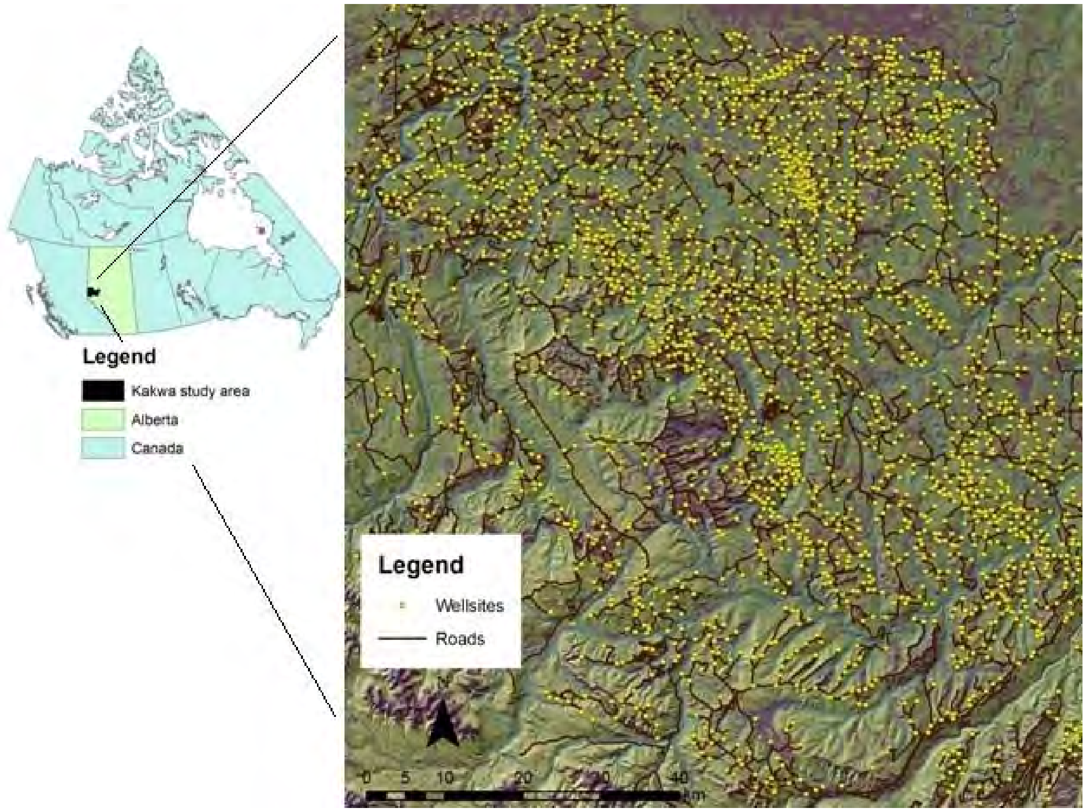

Figure 1.Kakwa study area in Alberta, Canada with its wellsites (yellow dots) and extensive road network (brownish lines).

Table 1.Landcover classes and their definitions in the Kakwa study area, Alberta, Canada (from Landsat raster layer).

Landcover class labels	**Definition**
Upland trees	>5% tree cover by crown closure; mesic or dry moisture regime
Wetland trees	>5% tree cover by crown closure; wet or aquatic moisture regime
Upland herbs	>5% herbaceous cover; mesic or dry moisture regime
Wetland herbs	>5% herbaceous cover; wet or aquatic moisture regime
Shrubs	>5% shrub cover; any moisture regime)
Water	<5% vegetated; aquatic moisture regime
Barren land	<5% vegetated; mesic or dry moisture regime
Snow/Ice	>95% snow or ice cover
Cloud	Ground obscured by cloud
Shadow	Ground obscured by shadow
Crown closure	Percent canopy overlying the forest floor

Figure 2. Satellite image over a few wellsites (top left), a typical wellsite and its structures (top right), wellhead and pipes (bottom left) and bear bed on an abandoned wellsite (bottom right), in the Kakwa study area, western Alberta, Canada.

Radiocollar models mainly included Televilt Simplex and Tellus (Televilt, Lindesberg, Sweden). Collars were mostly programmed to acquire hourly locations. One male had 20-minute intervals between acquired locations, but because this study only considered proportions of locations for individual bears and average cover at GPS-location cluster sites, differences in the interval of locations acquired were accepted. Bear GPS locations during denning periods were excluded from all analyses. Because of lack of cell-phone coverage, bears' GPS locations were downloaded by monthly telemetry flights in the area.

Study design and statistical analyses

Data on type and quantity of activity for most wellsites was lacking, therefore I conducted a large part of my study for all wellsites, with the recognition that they generally are subjected to either frequent or infrequent human activity. Bear GPS-locations within 500 m of a wellsite point were used to analyze wellsite use by the bears. A distance of 500 m has previously been used and identified as a zone of influence around human activity structures

(Berland et al. 2008; Mace et al. 1996b), within which bears have been found to change their spatio-temporal habitat use in relation to anthropogenic features or activities. A larger buffer would probably be less representative of bear selection, because the possibility that bears would be influenced by other structures or features in the landscape increases with increasing distance from the wellsite. The 500-m buffer was divided into five equally large zones, each with an area of 157,000 m^2 (Fig 3). I based my calculations on the relative number of bear locations within these buffer zones and assumed that disturbance associated with wellsites would be reflected in buffer zone selectivity. Selection ratios are the proportions of used/proportion of available buffer zones, analogous to Manly et al. (1993). The innermost buffer zone included the actual wellsite and is hereafter referred to as the wellsite zone (WSZ); <224 m from a wellsite point. I used GPS locations from ten independent bears (five males and five females; 2-22 years of age), between 2005-2010, to analyze wellsite selection on an individual basis during both day and night. Goodness-of-fit tests were used to determine if observed values were significantly different from the expected in the five zones. The resulting selection ratio in the WSZ was further used to examine differences in WSZ selection between day and night for these bears. I used a paired t-test to assess differences in selection ratios between day and night for all ten bears. In addition, selection ratios for the WSZ were plotted for each month between May 1 and October 31 to examine patterns of selection throughout this period. Because selection ratios only show relative proportions of GPS-locations, the number of locations in both the WSZ and in the entire home range was compiled for each bear to get a picture of the extent of their wellsite use. The home range is defined as the area that a bear uses during a year to sustain all necessary resources for survival and successful reproduction (Burt 1943). I used kernel home ranges, instead of minimum convex polygons (MCP), because they give a more representative picture of a bear's utilised area, compared to MCPs that often over-estimate home range size (Berland et al. 2008; Katajisto and Moilanen 2006). In addition to the selection ratio analyses for the ten bears, GPS-location data from a total of 18 female bears during 2006-2010 were used to get a general view of selection ratios patterns for lone females and females with cubs, with locations pooled across individuals for each of these groups.

Landcover is defined as the "physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures" (Ellis et al. 2010). To determine if landcover played a role in bear selection for the WSZ, I used the calculated monthly WSZ selection ratios for each of the ten bears as a response variable, and the three landcover types; Upland trees (forested land), Shrubs and Barren land (Table 1) as explanatory variables, in a generalized linear model (GLM):

Selection ratio ~ Upland trees*Shrubs*Barren land

These landcover types not only dominate in this landscape, they are also meaningful in terms of available cover.

To investigate bear selection on another scale, I compared GPS-location densities in wellsite buffers for each of the ten bears to their overall location densities in their home ranges, for the different years. A Wilcoxon paired t-test was used to test significance in patterns for all ten bears combined.
To determine if bears used less cover closer to inactive wellsites compared to active wellsites and if this depended on time of day, I visited wellsites in the study area in summer 2010 to determine whether they were active. If no structures or merely a wellhead (see Fig 2) were

found at a wellsite, it was classified as an inactive well. Wellsites classified as inactive were thus either completely abandoned or capped wellsites. If structures (pipes, booths or measurement equipment) were found and the wellsite appeared to be operating, it was classified as active. I selected wellsites to visit by randomly selecting wellsites that had more than two bear locations within 150 m from the wellsite point per bear, season, and year. From these visited wellsites, I undertook a cluster analysis of bear locations (from all available individuals) positioned within the 500-m wellsite buffer. Clusters were defined as minimum two subsequent bear locations within 50 m distance from each other. I decided to analyze crown closure at cluster sites instead of using single locations, because a cluster is more likely to reflect a bear's intentional positioning on the landscape. Average crown closure at the locations forming a cluster was analysed in relation to wellsite activity status (active/inactive) and time of day with a Kruskal-Wallis rank sum test. Statistical analyses were performed in R (www.R-project.com) or in Excel. A significance level of 0.05 was accepted.

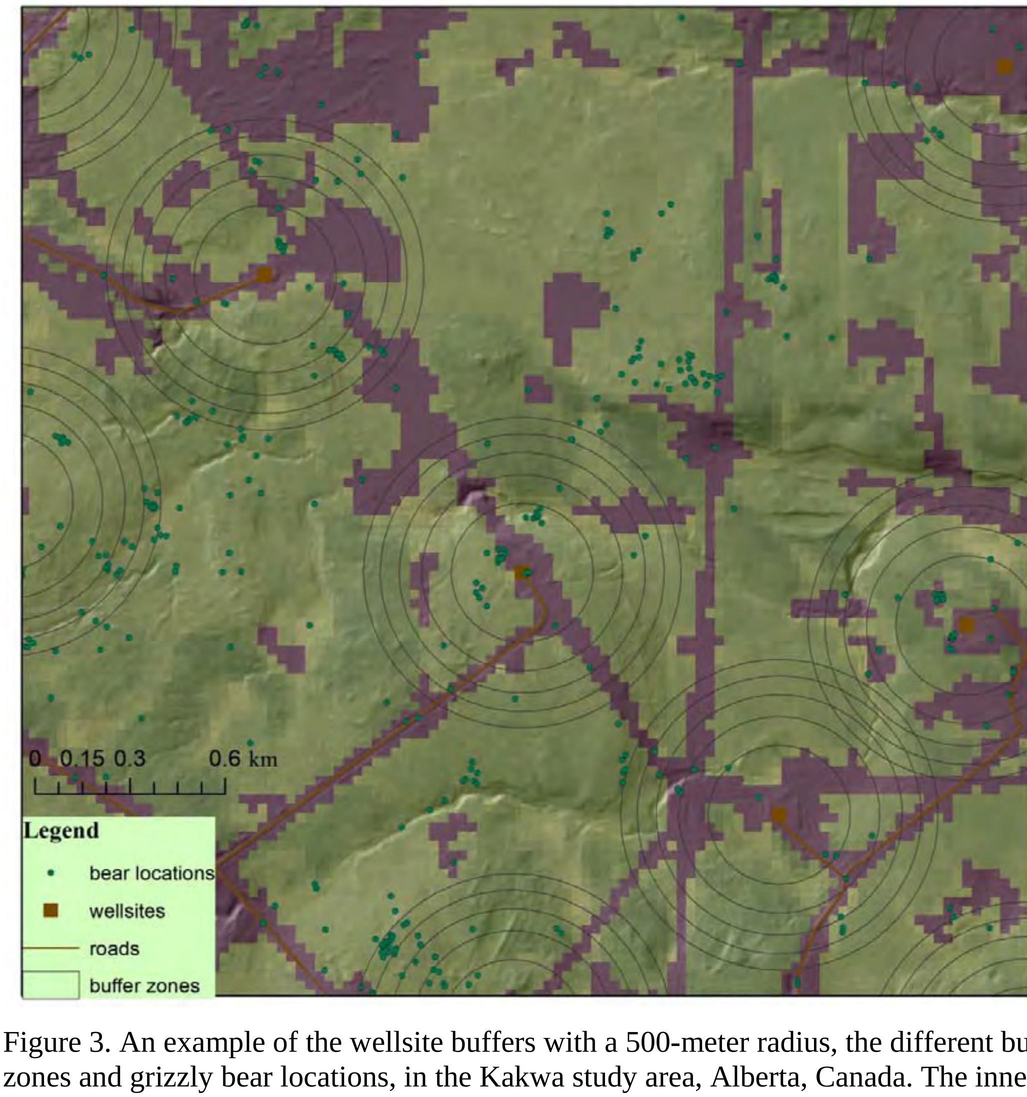

Figure 3. An example of the wellsite buffers with a 500-meter radius, the different buffer zones and grizzly bear locations, in the Kakwa study area, Alberta, Canada. The innermost zone is called the wellsite zone (WSZ) in this thesis.

RESULTS

Most of the bears did not avoid the WSZ more than the other buffer zones, but had higher WSZ selection ratios than expected during both day and night (Table 2). Eight of the ten individuals, had a higher selection ratio in the WSZ during night than day. Difference between day and night selection ratio, with all ten bears combined, was significant in a paired t-test ($t = -2.6597$, $df = 9$, $p = 0.026$).

Table 2. Selection ratios for male and female grizzly bears during day and night within the five wellsite buffer zones (<500 meter of wellsites), during 2005-2010, in the Kakwa study area, Alberta, Canada (^{d}=day, ^{n}=night and *= 20 minute interval in acquired GPS-locations). Significance for individual bears was determined with Goodness-of-fit tests based on location numbers in each buffer zone.

		Wellsite buffer zone					
Sex	Bear	1(WSZ)	2	3	4	5	p
Females	$G260_d$	1.806	1.106	0.723	0.825	0.540	0.000
	$G260_n$	1.676	1.091	0.721	0.868	0.644	0.000
	$G223_d$	0.798	1.166	0.876	1.135	1.025	0.000
	$G223_n$	0.873	1.447	0.953	0.833	0.893	0.000
	$G224_d$	1.613	1.040	0.903	0.677	0.766	0.000
	$G224_n$	1.556	1.130	0.889	0.796	0.630	0.000
	$G238_d$	0.774	1.425	1.044	0.848	0.909	0.000
	$G238_n$	1.360	1.420	0.880	0.580	0.760	0.000
	$G265_d$	1.120	1.120	1.266	0.830	0.664	0.020
	$G265_n$	1.456	1.392	0.549	0.949	0.654	0.000
Males	$G229_d$*	1.938	0.807	0.863	0.802	0.590	0.000
	$G229_n$	2.958	0.771	0.493	0.412	0.365	0.000
	$G266_d$	1.773	0.898	0.705	0.786	0.838	0.000
	$G266_n$	1.830	0.746	0.653	0.758	1.014	0.000
	$G264_d$	1.216	0.811	1.126	0.766	1.081	0.470
	$G264_n$	1.842	0.855	0.921	0.921	0.461	0.003
	$G262_d$	1.275	1.057	0.909	0.949	0.810	0.013
	$G262_n$	1.367	0.952	0.623	0.571	0.588	0.000
	$G257_d$	0.815	1.630	1.185	0.519	0.852	0.000
	$G257_n$	1.279	0.349	0.698	1.395	1.279	0.130
	All $mean_d$	1.313	1.106	0.960	0.814	0.808	0.000
	SE_d	0.141	0.082	0.060	0.051	0.055	
	All $mean_n$	1.620	1.015	0.738	0.808	0.729	0.000
	SE_n	0.174	0.111	0.052	0.085	0.086	

When plotting mean WSZ selection ratios for the ten bears for each month between May and October, I found large differences in selection ratios between day and night in July and September (Fig 4). Selection ratios increased until August during both day and night, but diverged in September as the day selection ratio decreased. Selection ratios during day were relatively uniform throughout the whole period however. Females were generally uniform in their patterns, with increasing WSZ selection ratios until August for both day and night, but then diverged in their selection ratios for day and night in September (Fig 5a). Selection ratios decreased in October. However, males were very individual, and also had varying duration of available data. Two males showed great differences in selection ratios between day and night in July, thus amplifying the difference between day and night selection ratios during this month (Fig 5b). The individual patterns of all ten bears can be found in the Appendix.

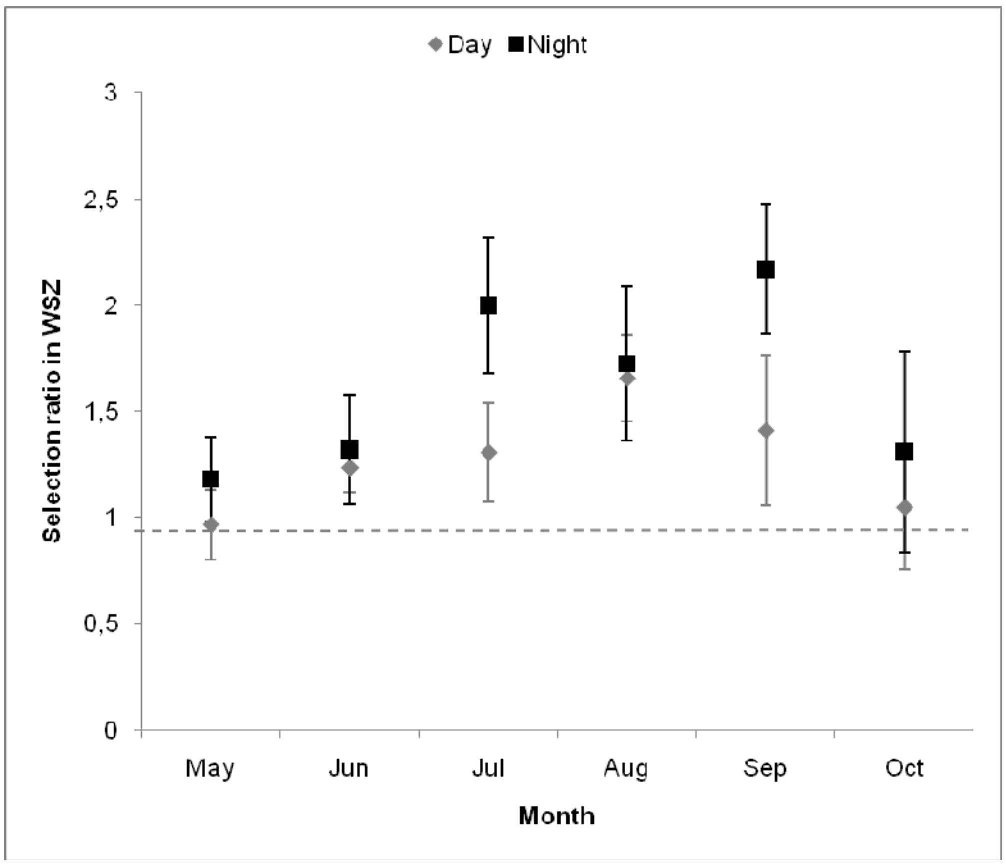

Figure 4. Mean selection ratios in the wellsite zone (WSZ) in day and night periods from May to October for ten grizzly bears (five males and five females) in Kakwa study area, Alberta, Canada, during 2005-2010.

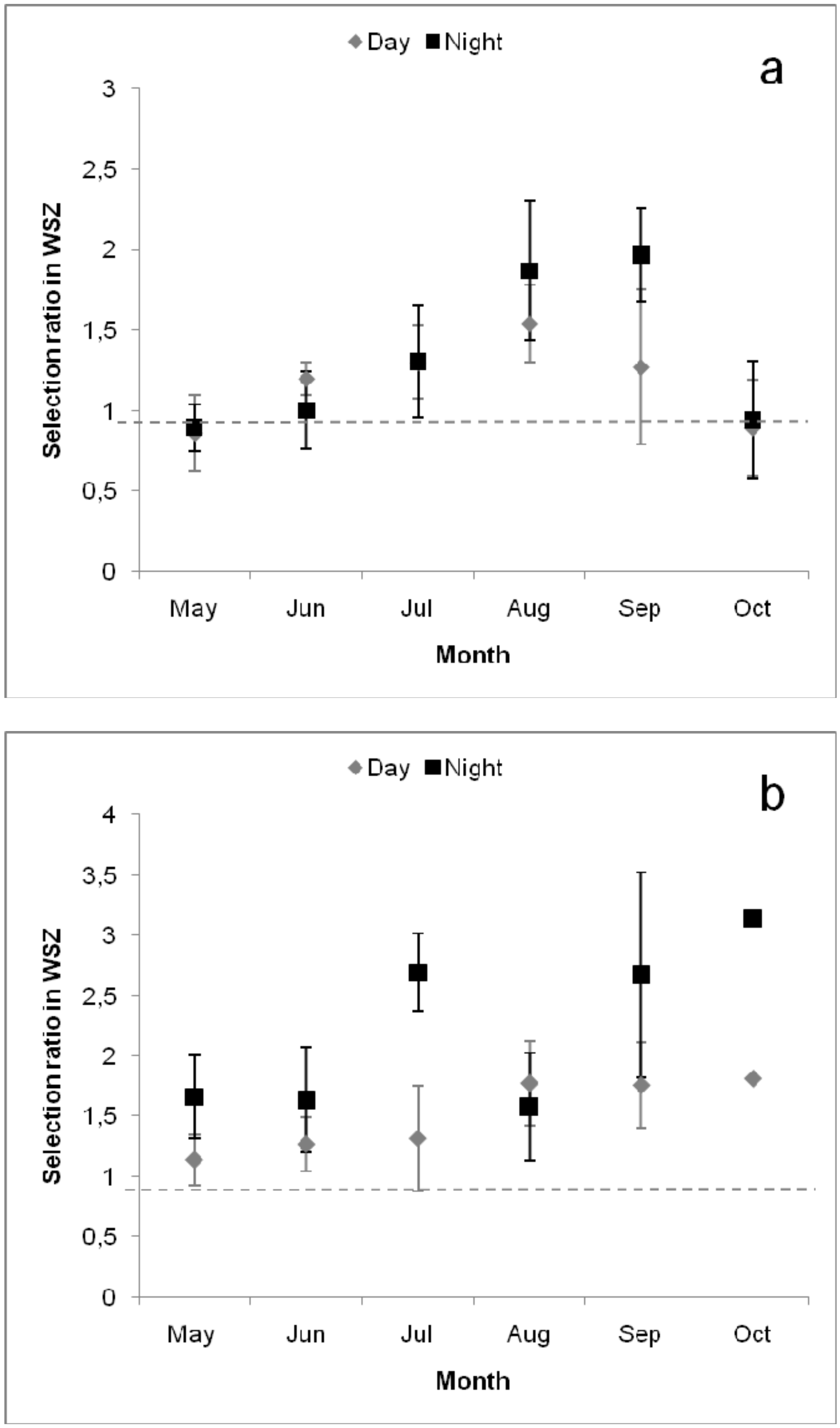

Figure 5. Mean selection ratios in the wellsite zone (WSZ) in day and night periods from May to October for five female grizzly bears a), and five male grizzly bears b) in the Kakwa study area, Alberta, Canada, during 2005-2010. Notice the difference in y-axis scale.

Based on number of GPS-locations, day locations were variable throughout the period, whereas night locations for many bears exceeded day numbers in September and October, even though overall numbers of locations in the home ranges were higher during the day at that time (Table 3). Amount of locations were low for many bears in October, implying a lower WSZ use. Females with cubs appeared to have higher selection ratios during night than day in August and especially September, whereas lone females did not show this pattern (Fig 6).

The proportion of forest, shrub or barren areas in the WSZ did not appear to have an effect on WSZ selection ratios (Fig 7a, b and c, respectively; see Table 4 for statistical results). However, selection ratios were generally lower when proportion of forested areas was low.

Wellsite activity and time of day affected crown closure at clusters of GPS-locations (X^2= 11.0848, df = 1, p-value = 0.001, Fig 8). Clusters of bear locations within inactive wellsite buffers had a significantly lower percent of crown closure than clusters within active wellsite buffers. Crown closure at clusters during night was similar for both wellsite activity levels, but crown closure at clusters during daytime was lower for inactive wellsites.

Observed GPS-location density within the wellsite buffers varied among bears and years (Table 5). There were no significant difference between home range location density and wellsite buffer location density, indicating no preference or avoidance of wellsites and their proximities at this scale (V=139 and p=0.988). General information for the ten individual bears is summarised in Table 6.

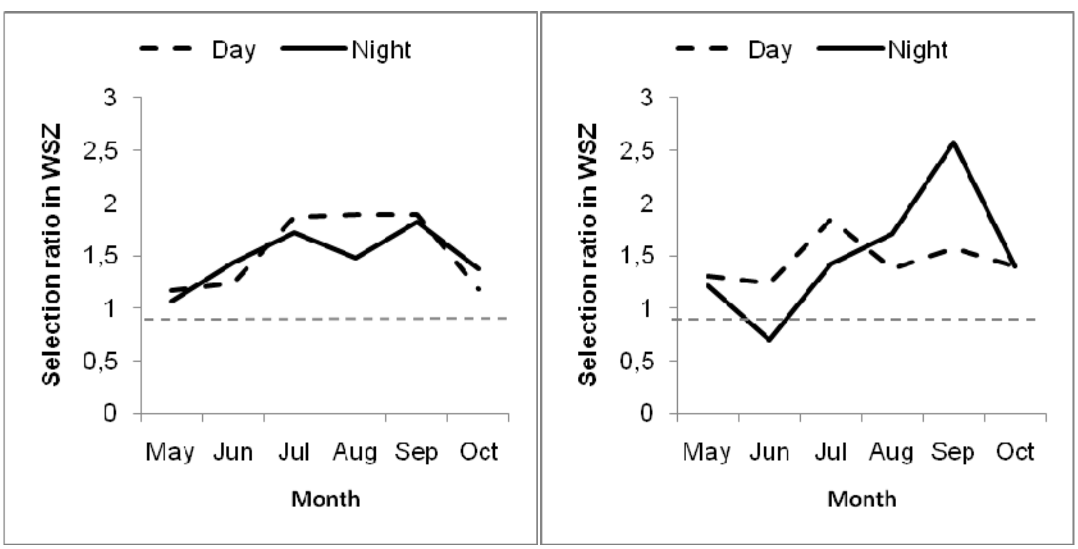

Figure 6.Monthly selection ratios in the wellsite zone (WSZ) between May and October for lone female grizzly bears(left) and females with cubs (right) in the Kakwa study area, Alberta, Canada, during 2005-2010.

Table 3.Number of grizzly bear GPS-locations in the wellsite zone (WSZ) for day (d) and night (n), during 2005-2009 in Kakwa study area, Alberta, Canada. Overall location numbers in the home ranges (HR) for each bear and month is presented as a reference (*denotes 20 minute GPS-location interval).

Bear	Range	Time of day	May	Jun	Jul	Aug	Sep	Oct
Females								
G260	HR	d	496	1029	911	745	791	594
		n	151	331	314	495	680	627
	WSZ	d	99	123	159	69	78	68
		n	29	24	45	62	121	65
G223	HR	d	981	859	666	569	611	539
		n	357	251	215	307	438	606
	WSZ	d	61	56	20	30	17	16
		n	11	11	10	36	30	24
G224	HR	d	395	604	546	353	347	134
		n	138	162	179	163	257	115
	WSZ	d	16	42	76	36	28	2
		n	4	7	31	25	16	1
G265	HR	d	310	268	346	259	284	143
		n	119	114	142	163	232	157
	WSZ	d	1	21	14	12	5	1
		n	1	25	27	5	11	0
G238	HR	d	528	514	310	190	100	179
		n	183	151	108	138	171	196
	WSZ	d	23	11	12	3	0	5
		n	19	5	2	5	18	17
Males								
G229*	HR	d	427	2208	2844	2581	2197	400
		n	169	584	805	1173	1538	396
	WSZ	d	16	38	107	157	128	1
		n	12	15	35	139	309	0
G262	HR	d	124	800	849	553	92	0
		n	49	259	298	319	64	0
	WSZ	d	4	88	34	3	0	0
		n	7	27	35	62	0	0
G264	HR	d	8	330	255	193	78	0
		n	2	113	81	137	47	0
	WSZ	d	0	14	3	10	0	0
		n	0	6	9	13	0	0
G266	HR	d	257	322	864	734	616	351
		n	120	111	301	354	466	407
	WSZ	d	1	16	54	115	28	6
		n	5	18	31	58	31	9
G257	HR	d	12	185	370	118	11	0
		n	7	49	123	58	11	0
	WSZ	d	0	7	8	7	0	0
		n	0	2	9	0	0	0

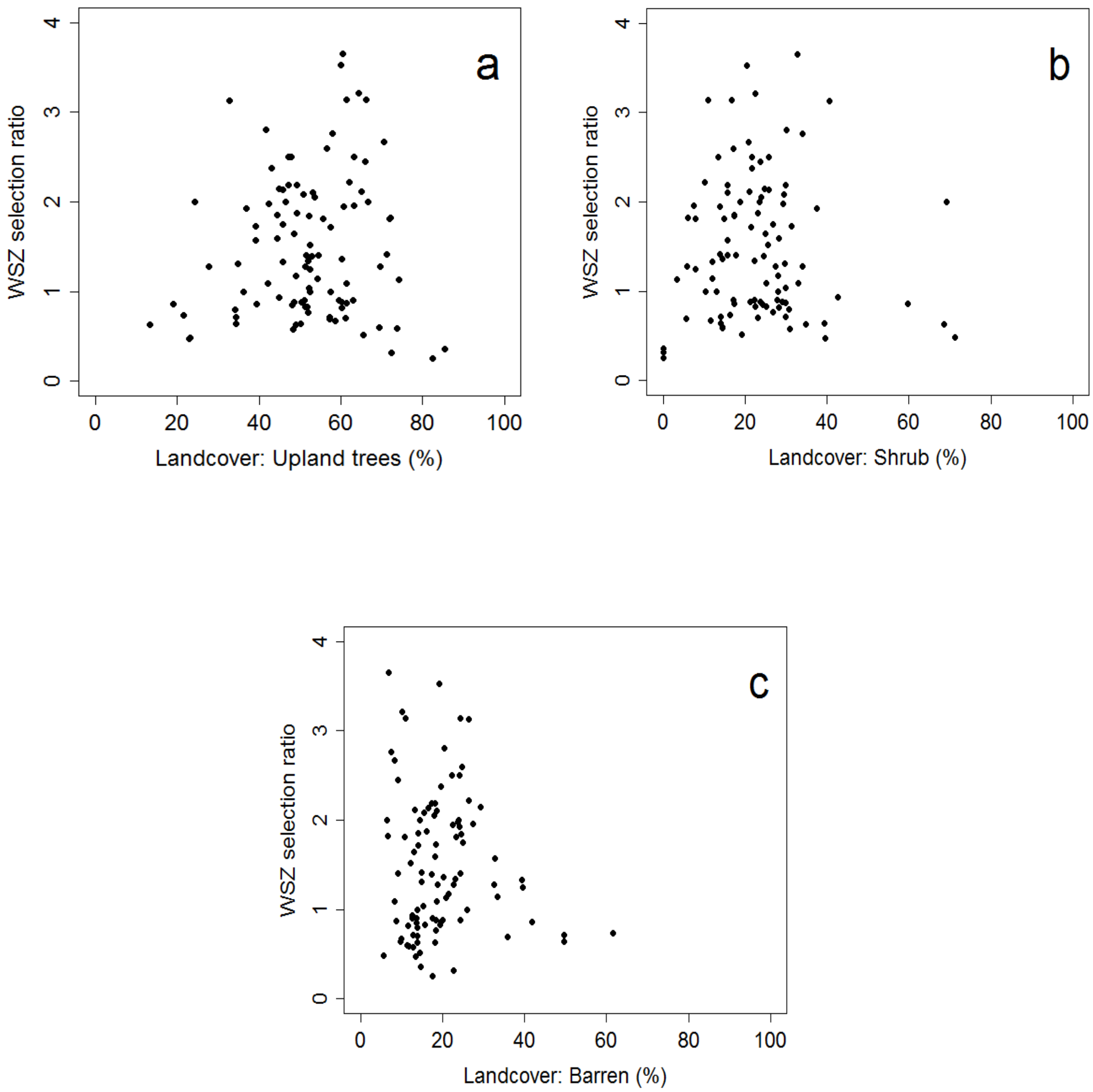

Figure 7. Grizzly bear selection ratios in wellsite zones (WSZ) in relation to proportion of the landcover classes a) Upland trees, b) Shrub and c) Barren during 2005-2010, in the Kakwa study area, Alberta, Canada.

Table 4.Results of a generalized linear model with landcover variables tested in relation to grizzly bear selection ratios in the wellsite zone (WSZ), in the Kakwa study area, Alberta, Canada. The selection ratio (response variable) was log transformed.

	B	SE	t-statistic	p
(Intercept)	1.305e+00	5.918e-01	2.205	0.030
Uptreed	-6.863e-03	9.474e-03	-0.724	0.471
Barren	-1.598e-02	1.760e-02	-0.908	0.366
Shrub	-1.248e-02	1.378e-02	-0.905	0.368
Uptreed:Barren	1.169e-04	3.960e-04	0.295	0.769
Uptreed:Shrub	1.205e-04	3.460e-04	0.348	0.728
Barren:Shrub	3.702e-05	7.739e-04	0.048	0.962
Uptreed:Barren:Shrub	1.373e-05	2.106e-05	0.652	0.516

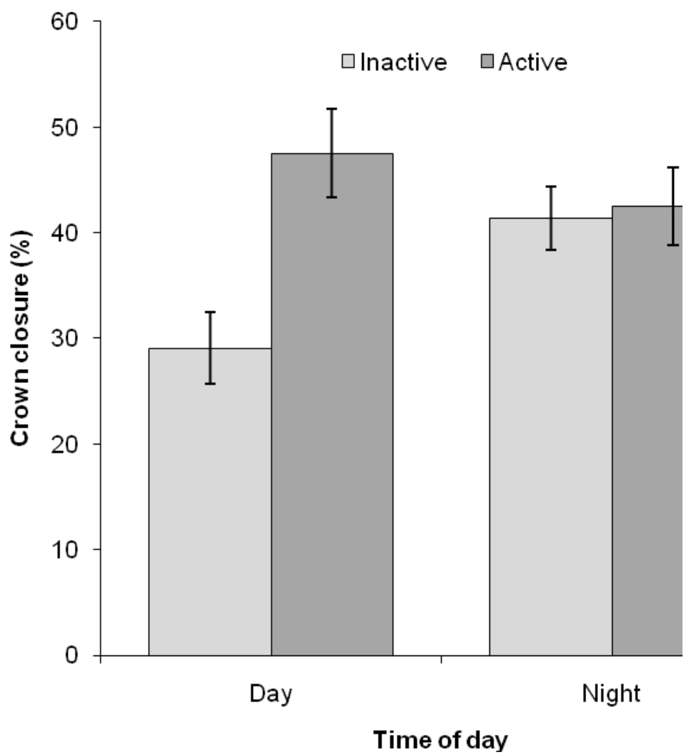

Figure 8. Mean crown closure for grizzly bear GPS-location clusters in relation to time of day and wellsite activity within wellsite buffers (<500 m from a wellsite point) during 2005-2010, in the Kakwa study area, Alberta, Canada.

Table 5. GPS-location density in grizzly bear home ranges and in wellsite buffers (<500 m from a wellsite point) in the Kakwa study area, Alberta, Canada, during 2005-2009 (*denotes 20 minute location interval).

		Females				Males	
		Density				Density	
Bear	Year	Home range	Buffer	Bear	Year	Home range	Buffer
G260	2007	5.506	4.416	G229*	2005	11.426	20.733
	2008	14.274	16.558		2006	18.907	33.891
	2009	13.739	12.928				
				G266	2007	3.474	2.805
G223	2007	9.354	8.594		2008	1.179	1.315
	2008	12.221	8.538		2009	1.881	2.346
	2009	16.277	14.230				
				G264	2007	1.688	2.288
G224	2007	3.713	4.537		2008	0.266	0.290
	2008	11.133	16.637				
				G262	2007	0.528	0.664
G238	2007	3.646	2.880		2008	1.267	0.692
	2008	1.683	1.405		2009	1.920	0.953
G265	2007	11.315	22.504	G257	2009	0.834	0.640
	2008	3.490	1.326				

Table 6. Home range (HR) and wellsite information for ten grizzly bears during 2005-2009, in the Kakwa study area, Alberta, Canada.

Sex	Bear	Year	No. of wellsites	HR area (km^2)	Visited wellsites (locs inside WSZ)	Total area occupied by wellsites (km^2)*	Wellsite density (wellsite/km^2)
Females	G260	2007	182	420.3	54	1.82	0.43
		2008	99	187.9	56	0.99	0.53
		2009	89	177.3	53	0.89	0.50
	G223	2007	133	280.3	46	1.33	0.47
		2008	94	278.2	27	0.94	0.34
		2009	29	47.0	11	0.29	0.62
	G224	2007	113	490.0	39	1.13	0.23
		2008	42	157.6	31	0.42	0.27
	G265	2007	27	183.3	14	0.27	0.15
		2008	42	172.2	7	0.42	0.24
	G238	2007	171	636.3	33	1.71	0.27
		2008	191	534.2	19	1.91	0.36
Males	G229	2005	15	659.8	4	0.15	0.02
		2006	62	423.5	30	0.62	0.15
	G266	2007	227	679.0	40	2.27	0.33
		2008	78	669.2	15	0.78	0.12
		2009	259	1067.7	46	2.59	0.24
	G264	2007	78	586.0	11	0.78	0.13
		2008	253	1273.9	9	2.53	0.20
	G262	2007	551	1262.5	24	5.51	0.44
		2008	640	1283.7	48	6.4	0.50
		2009	336	690.2	27	3.36	0.49
	G257	2009	378	1205.6	18	3.78	0.31

*with the assumption that each wellsite is approximately 1 hectre (100*100 m).

DISCUSSION

Based on my results I reject the hypothesis that bears in my study spatially avoided wellsites. Instead, most of the bears appeared to select the zone containing the wellsite significantly more than what would be expected during these years. But why are bears selecting human activity areas? I did not study potential causes of this pattern; however, it is reasonable to speculate that bears may be attracted to the food resources occurring on, or near wellsites. Nielsen et al. (2004b) found that bears in the same area readily used clear cuts and roads, apparently because valuable food sources are associated with these anthropogenic structures. Bears in this study area inhabit a landscape with a high density of wellsites and other anthropogenic disturbances and have been seen foraging on or around wellsites (Stenhouse, pers. comm). Food availability has previously been shown to be a good predictor of grizzly bear occurrence (Nielsen et al. 2010), and it is therefore likely that some bears are attracted to industrial features, like wellsites, if a strong enough attractant is prevalent. Other species also appear to use wellsites for resource utilization. For example, white-tailed deer (*Odocoileus virginianus*), in West Virginia, USA, regularly move outside of their core-area home ranges to visit gas wells to assimilate high saline seepage occurring in connection to these sites (Campbell et al. 2004).

An interesting aspect of my results is the generally higher selection ratio in the WSZ during night compared to day. What is important to emphasize is that this does not mean that these bears necessarily spend more time in wellsite proximities during the night compared to during the day, only that the selection is stronger, more "directional" towards the wellsite (hence reflecting when bears are more prone to visit the wellsite if they are in the area). Considering the fact that bears in west-central Alberta are more active during the day and that movement rates are reduced during nighttime (Carra 2010), it would be interesting to know if bears using wellsites would adjust their temporal activity to avoid human activity. Such patterns have been seen earlier in many studies investigating human activity impacts on bear use and activity (Martin et al. 2010; McLellan and Shackleton 1989a; Olson et al. 1998). It is possible that shifts in activity patterns ultimately may have an impact on bears' overall health and survival. In the Kakwa study area there are normally many wellsites within the home range of a bear, making it rather unlikely for bears not to have to adjust themselves to the "risk" associated with these. Similar to my results of a generally higher wellsite selection during night, Nielsen et al. (2004b) showed that bears preferred clearcuts to a greater extent during night than day. Proposed reasons included that deforested areas reach high temperatures during daytime in the summer, so bears were thought to use these areas during night to avoid high temperatures. The authors also suggested that bears were wary and preferred these areas during night because of lower human activity. When looking on differences in monthly WSZ selection ratio between May 1 and October 31 in my study, it appears that WSZ selection ratio during night is predominately high in July and September. In this area, the peak in monthly ambient temperatures normally occurs in July, and that is also the time period when day temperature is the highest and the greatest temperature differences between day and night occur. Predominantly males had higher selection ratios during night than day in July, highly affecting the values for this month. However, their behaviour could depend on this factor. During the same month there was no difference between selection ratios for females. It is possible that females limit their use of wellsites during night in July, because these are used more frequently by males. The results suggest that males are greatly individualistic in their wellsite use, making discussion on a population level difficult. In addition, it is difficult to draw conclusions from the results for June/July, because bear movement and locations can be greatly influenced by breeding behaviour (Stenhouse et al. 2005). It is also possible that social structure within the population has an influence on selection in high risk areas. Not only did the night selection ratio in the WSZ increase in the fall (in August and especially September) for many bears, but the bears also appeared to spend more time in the WSZ during night than day. Large differences in selection ratios for day and night in the fall are not likely a result of high temperatures, as temperatures generally decrease towards fall. Thus, the higher selection during night for these areas is not likely related to climate factors, but likely the result of adjustments to human activity. The pattern seen for September may be a response to an increase in recreational human activity in the forest, as the general big-game hunting season starts in September ('Archery Only' season starts in late August). Because all wellsites have travel routes connected to them, it is likely that these routes are used by people for recreational purposes, thus increasing the human activity and the potential for associated bear/human conflicts. There were no evident differences in selection ratios between day and night in October; however, many bears had fewer or no points in the WSZ during this month, indicating a low use of wellsites. During this time, there was a change in the distribution of available food resources, as valuable plants and berries became scarce, and

some bears concurrently started to enter their denning phase. Furthermore, it is possible that the hunt, and level of human activity, was at its most intensive peak during the first few weeks and therefore did not affect bears as much in October.
The pooled locations of lone females showed that they, in general, did not have an apparent difference in day and night selection throughout the period, compared to females with cubs, whose pattern greatly resembled the pattern of the five females analyzed individually. This may imply a lower wariness of lone females to human activities compared to females with cubs. This could be because lone females generally are younger and subordinate and/or that females with cubs are more careful in exposing themselves and their cubs to these areas when human activity is readily prevalent. Further, females with cubs had relatively low selection ratios during night in June and July, which could suggest a restricted use of wellsites at the time when two males showed very high ratios.

The degree of wellsite use is presumably higher when food availability in the matrix (the surrounding forest) is poor. Food sources vary in availability from year to year, and between seasons (Nielsen et al. 2010). This variation could have a large effect on grizzly bear selection of wellsites. It is possible that bears use wellsites to feed on certain plants or roots during hyperphagia if the berry season is poor. Potential presence of buffalo berries around wellsites and ants on wellsite banks might also be the attractant on wellsites in the fall.

The WSZ selection ratio did not appear to be influenced by the amount of forest, shrub or barren land in the WSZ. It was however apparent that selection ratios were generally low when proportion of forest was low. The reason for these findings may be related to two important factors; (1) that forest cover on this scale is not the most important factor influencing bears' use of wellsites and that other factors, e.g. food abundance, are more essential for WSZ use, and/or (2) that the selection ratio in the WSZ is derived from proportion of landcover types prevailing in the other buffer zones, hence not only related to the WSZ itself. Wellsites, although they are very uniform in many respects, can be completely different from each other in their bear food availability. Whereas some wellsites are completely covered in clover, dandelions and horsetails, others are completely barren. The fact that some wellsites were operating (i.e. active), some were capped, and some were completely abandoned, made it difficult to determine the extent of human activity around these sites. Active wellsites are operating facilities which require regular site maintenance and inspections. In general, an operator would check the well and its devices once per day, leading to a fairly high and constant frequency of human activity. Inactive wellsites are a more difficult group to classify in terms of human activity however. Because access roads and other travel routes, e.g. pipelines, facilitate movement in the area up to the wellpad, these wellsites could also receive irregular human activity. Further, inactive and active wellsites are intermixed in this area, which means that operators may drive past an inactive wellsite on their way to a more remote active wellsite. Many abandoned wellpads are open patches in the forest, looking more like meadows and sometimes with fallen trees blocking their access roads. Some wellsites are therefore probably readily visited by bears, whereas others are never used. There is a need to collect data on bear food availability on wellpads and in the immediate vicinity to be able to incorporate this effect when analyzing selection.

Analysis of the GPS-location density within the wellsite buffer for each of the ten bears showed no preference or avoidance of this area when compared to the general density throughout their home ranges. Because most bears had a higher selection ratio towards the WSZ, this suggests that bears only use a relatively few "favourite" wellsites in their home ranges to a greater extent. The information in Table 6 further suggests this pattern.

Cover has previously been shown to be a factor in determining bear distance to human activity (McLellan and Shackleton, 1989a). This behavioural pattern was supported in my study, because bears spending time in the proximity of wellsites used significantly less cover during day at inactive wellsites. The most likely reason for this is the lower human activity occurring at these sites. During night, when the human activity decreases at active wellsites and becomes more similar to inactive wellsites, bears may require less cover. It is questionable to assign wellsites an activity level one year and combine these data with bear location data from a few years before. Many wellsites I visited and assigned the value of "inactive", were abandoned wellsites that had not been operating since long before 2005. In addition, the general period that a wellsite is active is presumably most often longer than 5 years. However, activity information for single wellsites is being collected from oil and gas wellsite operators at the time of writing. That information will increase our understanding of wellsite activity effects on grizzly bears. Because many studies have found that it is the human presence and not the actual development itself that leads to disturbance effects on bears (Jalkotzy et al. 1997; Swenson et al. 1996), activity-level studies is important for future bear conservation.

Wellsites are relatively small patches in the forest compared to other forest harvesting cutblocks (e.g. clearcuts). The main challanges in landuse planning regarding wellsite construction are not wellsites per se, but their accompanying access roads. All roads constructed for oil and gas extraction facilitate human access to remote forested areas that previously were relatively safe refuges for bears. Because oil and gas extraction activities are increasing in bear habitat, with old access roads and abandoned wellsites left, increased amount of areas are becoming more accessible. Some specific wildlife-management areas are closed with barriers on some access roads, which is a relatively efficient way to impede access for people without permission. Such mitigative measures are probably important to decrease human activity in the forest. Roever et al. (2008a), raised concerns about bears being attracted to roads, because of the abundance of food occurring along roadsides. Bears attracted to roads are concurrently attracted to high-risk areas, where they are more likely to perish, either by being shot or hit by vehicles (Jalkotzy et al. 1997, Roever et al. 2008a). The increased mortality risks in human activity areas may go unnoticed for bears, and result in a maladaptive habitat selection. Roads in this sense might be attractive sinks for bears. Unfortunately, a small increase in the proportion of attractive sink habitats may have disproportionate effects on the persistence of a population (Delibes et al. 2001). For small and threatened populations, like the grizzly bear population in west-central Alberta, attractive sinks may be an important factor determining population growth. It is not a desirable situation when wild bears dwelling in remote forested areas are attracted to anthropogenic development, because the proximity to wellsites and roads greatly increases the risk of bear-human conflicts. When I was out in the field during summer 2010, I came across people who work daily on wellsites within the oil and gas development. It appears as if some of them are afraid of bears, and some even carry weapons, e.g. knives, in fear of a bear attack.

It is important to stress that this study did not include bears that were outside the wellsite buffer areas. Although, all marked bears had GPS-locations within wellsite buffer areas; but some bears had very few, and were therefore not possible to analyze in terms of meaningful selection ratios. Similarly, only wellsites that had bear locations within its 500-m buffer were analyzed in terms of WSZ landcover characteristics. For example, bears might readily use a few wellsites with specific characteristics that differ from unused wellsites within their home ranges. Consequently, these ten bears do provide a picture of how some bears behave around wellsites, but it is clear that there is a great individual variation in bear habitat selection. Future studies should strive to incorporate the effects of wellsite food availability, activity status at wellsites, and landcover parameters, to evaluate which wellsites are selected for and readily used. Other important questions are how well drilling affects denning bears during winter and/or home range displacement during the non-denning period.

Conclusions

Grizzly bears in this study were shown to use wellsites and/or their proximities more than expected, presumably because of the occurrence of important grizzly bear food. Bears appeared to prefer to use wellsites more during night than day, and especially at times when human activity was hypothetically higher around wellsites. In the proximity of wellsites, average crown closure at bear GPS-location clusters was shown to vary depending on time of day and wellsite activity. The diurnal patterns of grizzly bears are therefore very important scales to consider in behavioural studies, as shown by Moe et al. (2007). When wellsites attract grizzly bears there is a risk of bears becoming habituated to human developments, and therefore also more likely for bears to come into conflicts with humans and be killed.

Implications for management

To reduce soil erosion on wellpads, herbaceous plants are sometimes used in site remediation. In these cases, it is important to make sure that these plants do not hinder the establishment of shrubs and trees (e.g. like some fast-growing legumes, which has a negative impact on tree growth in their vicinity) (Burger et al. 2005). Fire suppression is presumably one factor that has an impact on how attractive wellsites are for bears, because it impedes natural gap dynamics in these forests (Nielsen et al. 2004b). The abandoned cleared openings for oil and gas well-drilling operations offer the potential for excellent bear habitat, provided that wellsites and roads are reclaimed with vegetation beneficial to bears. Because wellsites lead to a loss in pristine grizzly bear habitat, bear foods growing on wellpads and their banks are likely beneficial to bears in terms of increased amount of food at these sites. However, the fact that mortality rates are higher in areas with higher open road densities probably counteracts the direct positive effect of high food abundances. A way out of the attractive-sink situation would be to ban grizzly bear food from wellsites or maybe even fence some of them off. Offshore models (helicopter only) in some areas would also reduce possibilities for people other than licensed companies to access wellsites, even if this would be quite drastic actions (Kolowski and Alonso 2010; Rosenfeld et al. 2001). As a minimum, more roads should be closed to public access with various types of access control measures; gates, berms etc., and roads leading to abandoned wellsites should be reclaimed or otherwise made impassable. These are expensive management actions, but may be crucial for long-term grizzly bear persistence in this area. It is also very important to educate people about grizzly bear behaviour and how to prevent bear-human conflicts. These human dimension aspects are important to consider to decrease negative attitudes towards bears, but also to diminish human-caused bear mortality. People working in remote areas where grizzly bears dwell should preferably carry bear spray, instead of other weapons that could lead to even more dangerous situations in case of a bear attack. The occurring landcover change leads to a reduction in secure areas for bears, with bears making adjustments in their behavior in ways that may not be ideal. But something as abstract as functional, or secondary, habitat loss due to avoidance behaviour might be difficult to deal with in management, and an even more complicated aspect to impose upon the oil and gas industry in their establishment of exploration and extraction plans. This is a first step to improve our understanding of wellsite use by grizzly bears. The knowledge will enhance our ability to understand and predict bear responses to industrial disturbance. When wellsites are constantly increasing in numbers and making up relatively large proportions of available bear habitat, basic knowledge is fundamental to be able to accomplish successful bear management and conservation, but also to help planning future studies on this important topic.

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APPENDIX

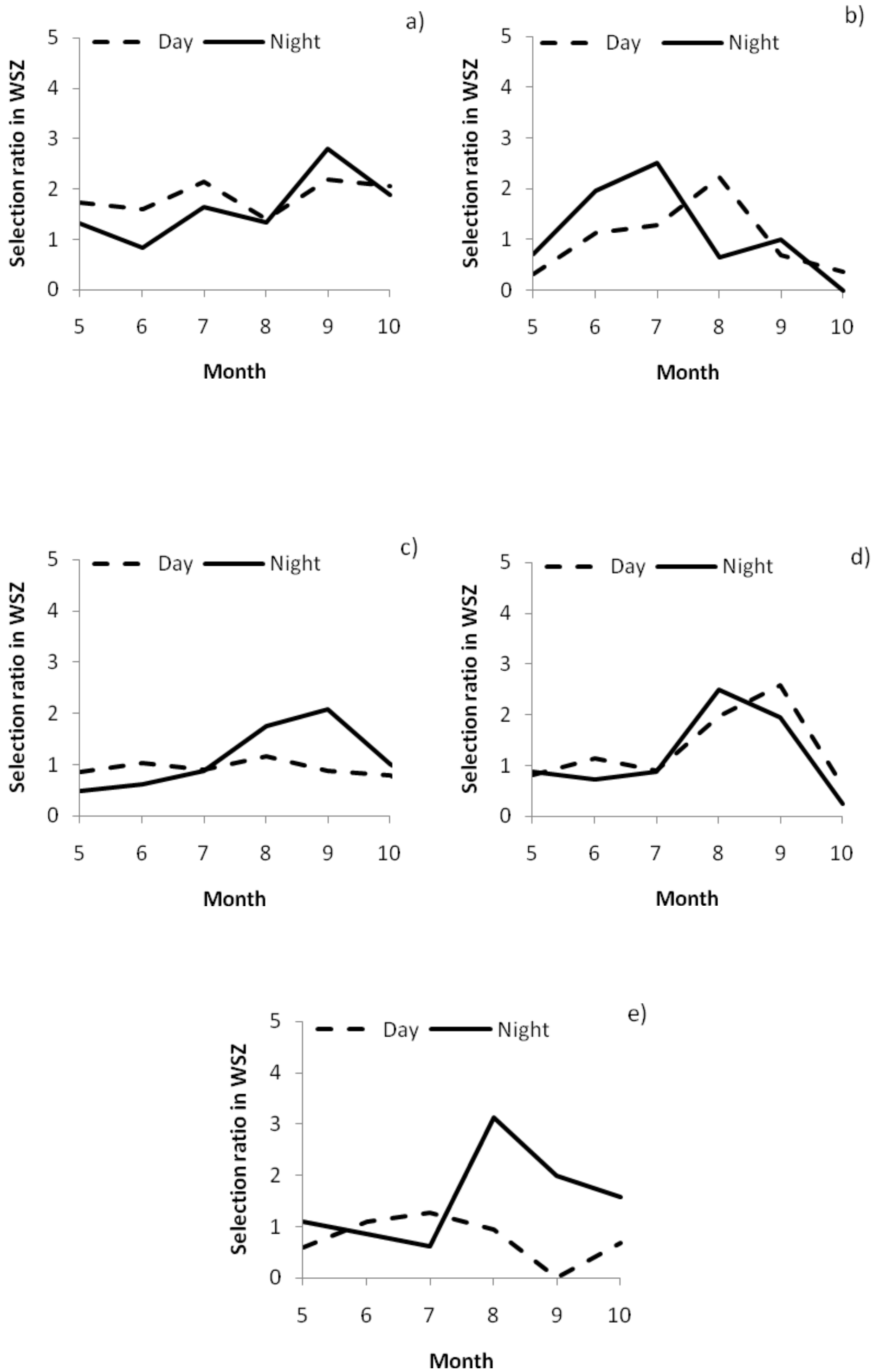

Figure 9. Selection ratios in the WSZ between May and October for five individual female grizzly bears in the Kakwa study area, Alberta, Canadaduring 2006-2010 a) G260, b) G265, c) G223, d) G224 and e) G238.

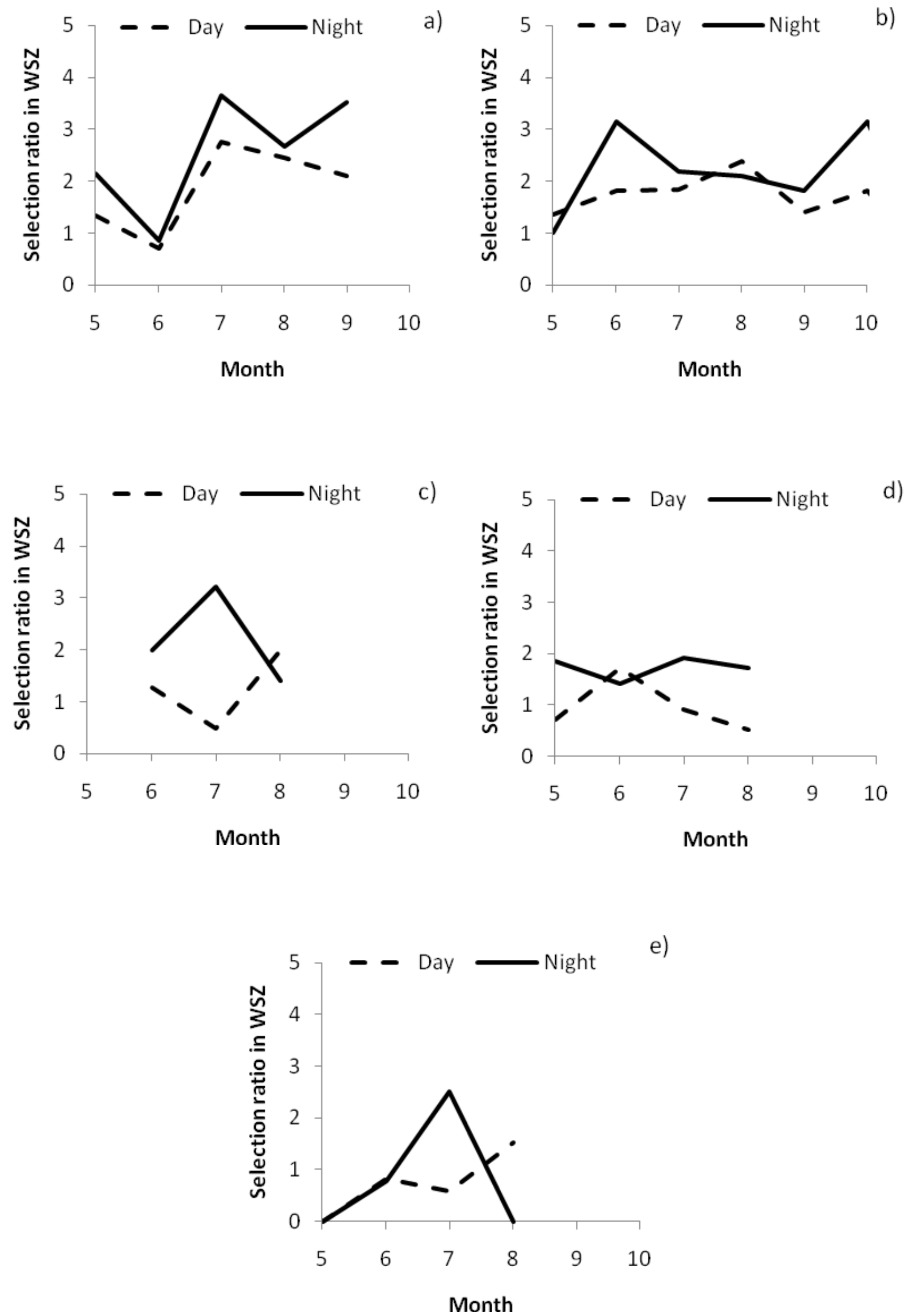

Figure 10. Selection ratios in the WSZ between May and October for five individual male grizzly bears in the Kakwa study area, Alberta, Canada,during 2005-2010 a) G229, b) G266, c) G264, d) G262 and e) G257.

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