FINAL REPORT

Grizzly Bear Denning Ecology in West-Central Alberta

Prepared for
Hinton Woodlands Division of West Fraser Mills

Final Report
fRI Research Grizzly Bear Program

March 10, 2022

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fRI Research
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About the Authors

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REPORT SUMMARY

This report summarizes information on the general den ecology of grizzly bears along with information specific to grizzly bears from the boreal forest of west-central Alberta and includes den dates collected from 1999-2018 on 139 grizzly bears (fRI Unpublished data), den habitats collected from 79 den sites between 2000-2011 (Pigeon et al. 2014) and den site characteristics collected from 42 dens between 2001-2012 (Pigeon et al. 2016a). Management recommendations for forestry workers and planners are also provided.

Many consider grizzly bears as the classic hibernator because they spend months without eating, drinking, defecating, or urinating while in their den. Others believe it is more appropriate to view grizzly bears as experiencing periods of torpor during their winter dormancy (Jansen et al. 2016) and are not "true" hibernators. They can be alert quickly if disturbed and den abandonment can occur. Den abandonment is typically a result of human disturbances near a den. A disturbance that only wakens a bear but happens repeatedly could result in an accelerated loss of fat reserves and reduced fitness. For females with new cubs, this drain could reduce her fitness as well as the quality and/or quantity of milk leading to smaller and/or less healthy cubs. Disturbances that cause the mother to become agitated and move about inside the den could dislodge the cubs from a warm location against the mother or interrupt nursing which could detrimentally impact the cub's growth and survival. Newborn cubs are unable to stand until they are one month old (Tumanov 1998) so if a female abandons her den soon after giving birth, there is little chance that her cub(s) would survive. Therefore, it is important to avoid disturbing a denned grizzly bear.

Grizzly bears in west-central Alberta spent on average 7 and 8 days in the den area (within 500 m of their den) prior to and after den entry and exit respectively but there was much variation with some bears spending up to 31 days prior to den entry and up to 45 days after den exit. During these times they may exhibit physiological lethargy. Ten percent (n=169) of den entries occurred immediately (within the day) after arrival in the fall and 16% (n=127) left their dens immediately after den emergence in the spring. The earliest arrival at the den area occurred on 14 October.

Pregnant females were the first to enter their dens in the fall and the last to exit in the spring. Adult males and subadult grizzly bears were the last to enter a den in the fall and the first to exit in the spring and nonpregnant females and females with yearlings or older fell in between pregnant females and males and subadults. A heavy snowfall has been linked to den entry in some areas but in west-central Alberta there appeared to be other factors influencing the onset of denning such as food availability. Weather factors, specifically warm temperatures, was associated with den exit dates. The mean den entry date for all age and reproductive classes in west-central Alberta was 12 November, with the earliest on 20 Oct and the latest on 19 December. The mean den exit date was 12 April with the earliest on 5 March and the latest on 12 May.

Using remote sensing products along with food models and Geographic Information Systems (GIS) layers, Pigeon et al. (2014) examined grizzly bear den site selection in west-central Alberta. Their results showed that male and female grizzly bears selected similar habitats for their dens (n=79) from 2000-2011. At the broad scale (5-10 km), grizzly bears selected sites on slopes in dry, open conifer stands and in habitats associated with sweet vetch (*Hedysarum*

alpinum), which is an important early spring and late fall food for grizzly bears. Within these stands, dens occurred in areas with low road densities and dense conifer, presumably for concealment and were not within 150 m of habitats associated with Vaccinium spp. or buffaloberry. Dens were typically located at least 300 m from a well site and 150 m from a road. Bears appeared to avoid constructing dens in water saturated areas. The relative probability of den site selection doubled when the terrain slope increased from 10° to 60°. The aspects of dens were variable, likely a result of small-scaled terrain features that maximized protection from the wind and snow accumulation. No dens were in young (0-5 years) harvest blocks. The relative probability of den selection dropped by 30% when road densities increased from 0 to 0.6 km per km^2 and dropped by nearly 70% at road densities of 1.2 km per km^2. At road densities of 2.0 km per km^2, den selection was nearly zero. We found dens ranged in elevation from 795 m in the boreal forest to 2284 m in the mountains with an average of 1705 m.

A Resource Selection Function model was developed for west-central Alberta that predicted the probability of den occurrence on the landscape. This model was provided to the Partners of the fRI Research's Grizzly Bear Program as part of the "Deliverables" package of research findings. Along with the RSF model there were GIS tools that allowed users to incorporate new features such as roads or harvest plans into an area and recalculate the Den RSF layer based on these new features. This is a powerful tool available to predict where grizzly bear denning habitat is likely to be and to mitigate possible disturbances within grizzly bear den habitat during the winter months.

Pigeon et al. (2016a) also visited 42 dens and measured habitat features around the dens and compared these features to random locations within the bear's autumn home range and within 150 m of the den. Greater concealment cover was the most important feature associated with the den sites followed by greater canopy cover and a greater presence of sweet vetch compared with random locations. Dens were located below a tree 62% (n= 42 dens) of the time with the tree species being subalpine fir (42%), spruce spp. (38%), lodgepole pine (12%) and aspen (8%). Logs, roots, and dense vegetation were also frequently located above grizzly bear dens, presumably for added support.

There was no evidence that dens were reused in west-central Alberta, but some grizzly bears dug a new den just metres away from an old den they had previously occupied. On average females in west-central Alberta denned 9 km from a previous den and males denned 15.5 km from a previous den. No dens were found in caves; they were always excavated into the ground.

Grizzly bears in this study area select den sites with little human disturbance. Therefore, before planning roads or harvest blocks or entering an area with limited human presence, we recommend the following steps:

1a. Use the Den RSF map to determine where high value den areas occur for your area of interest. Use the fRI Research den tool to update the map with new anthropogenic features if required.
1b. If the Den RSF map is not available for the area of interest, evaluate the area where winter activities are planned (harvesting / construction) in relation to den characteristics in Table 8.

2. Determine if approved winter activities could begin in early October in high den RSF value areas or areas suitable for a den as listed in Table 8, as this may deter bears from selecting this area for a den site.
3. Conduct ground-based reconnaissance of potential den habitat identified in Step 1 during the SUMMER to look for previous dens. Use the den site details outlined in Table 8 to further focus the surveys. GPS old dens found and areas that match the details outlined in Table 8.
4. Conduct aerial surveys during the early stages of denning in high RSF value den areas, areas where previous dens were found and areas that match the den site details in Table 8.
5. If an active den is found, mitigate actions to prevent den abandonment.
6. Once the bear has left in the spring, den survey data should be collected in a rigorous fashion and stored in a database.

Pigeon (2016a) also recommended keeping road densities in high quality den habitats at or below 0.6 km per km^2. Temporary road closures in these high value RSF areas from early October to mid-May could also be considered as a management strategy to reduce potential disturbances at dens. Keeping snow covered roads unplowed during these months could also be a simple strategy to keep the public from using these roads (Elfstrom and Swenson 2009).

There is still a chance that a grizzly bear will den in areas other than the predicted high quality den habitat based on the current den RSF model. As a result, field workers should be trained to recognize potential den habitat and den sites in any area within grizzly bear range. This will be especially important for winter work because dens become invisible once they are covered with snow. The ability to recognize den habitat might be the only way that field workers will know that they could be encroaching on an active grizzly bear den in the winter.

ACKNOWLEDGEMENTS

We'd like to thank the Foothills Research Institute's Grizzly Bear Program Partners for providing research funds for much of the capture work that allowed us to determine the den locations and dates from collared grizzly bears. We'd also like to send our appreciation to the capture teams through the years, in particular M. Cattet, B. Goski, Dave Hobson, T. Larsen, J. Saunders, John Bell, Nigel Caulkett, T. Winkler, and S Wotton. And to Karine Pigeon and her field crews, who conducted much of the work that is presented in this summary report.

We would like to thank West Fraser Mills for the funds to complete this report and their interest and desire to always look for ways to educate their staff and advance their practices in support of grizzly bear conservation and co-existence.

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Background

The purpose of this report is to

1. To summarize our current knowledge about grizzly bear den behaviour in the boreal forest landscapes of Alberta. This report includes information on den site characteristics, den site reuse, distances between bear dens in concurrent years, and bear den locations in relation to anthropogenic features.
2. Provide the needed information in a pocket guide of photographs to aid forestry workers with the identification of bear dens in the field.

Introduction

Grizzly bears are an iconic species in North America and are often associated with expanses of untouched wilderness, but many grizzly bears also live near humans and have adapted to the resource extraction and recreational activities that have occurred on the landscape. Humans however have proven to be less tolerant of grizzly bears. After the arrival of European settlers into North America, grizzly bear numbers and their range were reduced due to habitat loss and high mortality rates.

In Alberta, as a result of a low population estimate and high mortality rates, a Grizzly Bear Recovery Plan was completed in 2008 (Alberta Grizzly Bear Recovery Team 2008) and the grizzly bear was listed as a Threatened species in 2010 (Festa-Bianchet 2010). Since this time and despite an increase in human activities on the Alberta landscape, grizzly bear numbers have increased in parts of the province (Alberta Environment & Parks 2020). This increase provides further evidence that grizzly bears can successfully live and raise young in a human dominated landscape.

With an increase in grizzly bear numbers, there may be a potential increase in bear/human interactions, some of which could have negative consequences for the bear, the person or both. Strategies to avoid negative encounters between grizzly bears and humans, as suggested by the updated 2020 Grizzly Bear Recovery Plan (Alberta Environmental & Parks 2020), includes educating those who share the land with grizzly bears. Providing Albertans with knowledge on grizzly bear habitats and behaviour is an important first step in increasing tolerance and circumventing negative interactions.

Denning is a well-known but less understood bear behaviour that allows bears to avoid a period of time when food resources are scarce (Craighead and Craighead 1972, Watts et al. 1981) and is a time when human caused disturbances can have severe repercussions for the bear and their reproductive performance. A bear’s strategy to get through the 5-6 months of winter is to gain enough body fat prior to denning so that there is no need to eat or drink while in their dens. It is the time and place where female bears give birth to their cubs in a safe and secure environment and produce enough milk to nourish their cubs while in the den. A disturbance to a denned bear can result in an increase in activity and an unnecessary loss of critical body fat which could impact the bear’s health (Miller 1989) and survival of cubs (Swenson et al. 1997). Educating land and resource personnel on grizzly bear den behaviours, along with den characteristics and habitats could reduce human disturbance near active dens through thoughtful planning and avoidance. Allowing bears to den undisturbed would also avoid potentially dangerous interactions between workers and bears, while simultaneously allowing successful cub production that would support provincial recovery efforts.

Many consider grizzly and black bears as the classic hibernator while others believe it is more appropriate to view bears as experiencing periods of torpor during their winter dormancy (Hellgren 1998, Jansen et al. 2016) and are not “true” hibernators. This disparity in definition is partly because a bear’s body temperature, heart rate and breathing do not decrease as drastically as classic hibernators such as ground hogs or ground squirrels. Classic hibernators will also awaken periodically to eat, defecate, and urinate whereas grizzly and black bears will awaken but do not do any of these activities during denning. As well, unlike ground hogs or ground squirrels, grizzly and black bears can be alert when disturbed in their dens. Even aircraft flying overhead has caused an increase in grizzly bear activity while in a den (Reynolds et al. 1986, Schoen et al. 1987). This incongruity in terminology might be best resolved by viewing dormancy or hibernation in mammals as a variety of strategies that have evolved to avoid difficult periods (Moen 1978, Hellgren 1998) and will vary depending on the size of the animal and the conditions it is avoiding.

Whether you consider grizzly bears as hibernators or experiencing winter dormancy, there are periods while in their dens that their body temperature, heart rate, respiration rate and metabolism decrease. The body temperature of a denning grizzly bear can drop by 3-5 C below their normal temperature of 37.0-37.5 C (Hissa 1997), their heart rate can drop to 8-26 beats per minute (bpm) from a normal range of 40-88 bpm (Folk et al. 1980, Reynolds et al. 1986) and their metabolism can be reduced by 70% (Watts and Jonkel 1988). Despite this reduction in metabolism, males can still lose up to 22% of their mass over the winter and females can lose up to 40% (Kingsley et al. 1983). Pregnant females who give birth and nurse their cubs while in their den can lose twice the amount of weight as nonlactating females (Farley and Robbins 1995).

In places where food is available all year, some individuals will not den at all. For example, on Kodiak Island where fish is available all year and the winter climate is relatively temperate, some male grizzly bears do not den (Van Daele et al. 1990).

Study Area and Methods

As part of a long-term ecological study of grizzly bear in Alberta conducted by the fRI Grizzly Bear Program, grizzly bears were captured and affixed with GPS (Global Positioning System) collars from 1999 to 2018. Data used for this report came from grizzly bears within Bear Management Areas (BMA) 2 (Grande Cache) and BMA 3 (Yellowhead) in west-central Alberta (Figure 1). These collars acquired bear locations that were used to determine both denning dates and den locations. Outside the denning season, the collars on these bears collected locations every 4 hours (1999-2005) to every hour or 30 minutes (2006-2018) depending on the collar type and season but during the denning season, the collars were programmed to obtain one location/day when most bears would be inside their dens. We typically used the dates from 1 December to 31 March for this one-a-day program. This was to extend battery life but also to keep the battery active all winter for operational performance of this battery type.

To estimate when the collared bear entered or exited its den, we examined the collar data. When a collar did not have a direct line of sight to the sky, the GPS system had difficulties obtaining a location. When a grizzly bear entered its den, the collar typically was not able to "see" the sky and would miss acquiring many or all the locations it was programmed to obtain. We interpreted a den entry (or exit) date as the date when the collar stopped (or started) to obtain regular locations as scheduled by the collar program.

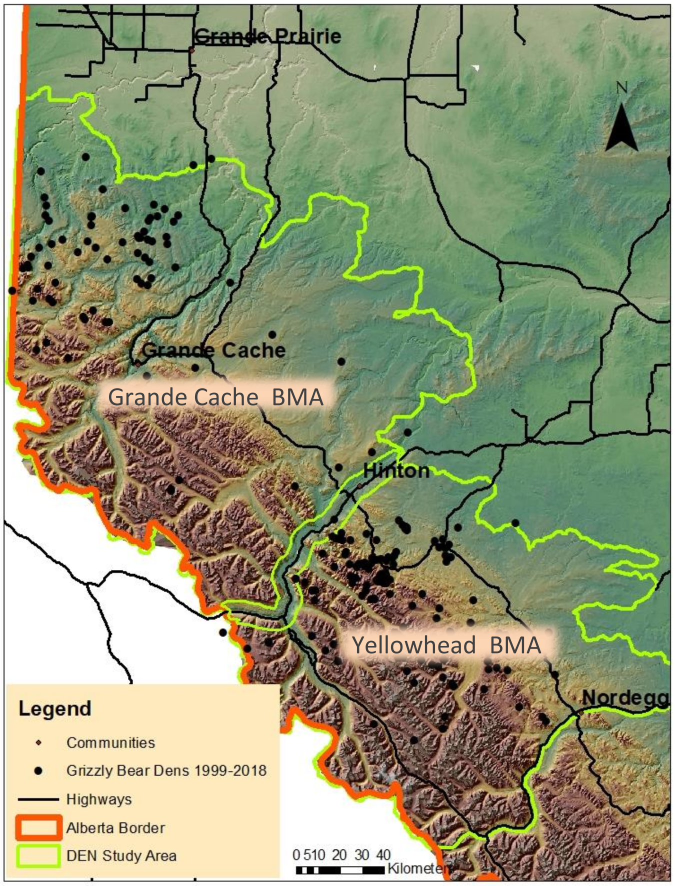

Figure 1. The study area in west-central Alberta which included Bear Management Areas (BMA) 2 (Grande Cache) and 3 (Yellowhead). Den locations from collared grizzly bears from 1999-2018 are also shown.

The den location was determined either using a handheld GPS unit at the den site or the location was estimated using the collar data if the den site was not visited. We used the centre of the cluster of collar locations acquired just before or after the bear entered or exited its den as the estimated den location.

For dens that we visited, the estimated den location using the collar data was typically within a few metres of the true den site.

We used a radius of 500 m from the den location as the **den area** and all locations in this circle that occurred just prior to and after den entry and exit were considered pre- and post-den locations. We used the radius of 500 m because when a bear lingered around its den site before or after den entry and exit, a 500 m radius typically encompassed these locations.

Pre- and Post- Denning Behaviour

Many bears reduce their activity and movements in late fall even before they are near their den site (Folk et al. 1980, Servheen and Klaver 1983, Sahlén et al. 2015) and many will spend days around the den site prior to den entry (Sahlén et al. 2015, Judd et al. 1986, Craighead and Craighead 1972). This reduction in movement and increased lethargy prior to den entry and also after den exit has been termed "walking hibernation" (Nelson et al. 1983). The triggers that cause this metabolic shift are not well understood. Some researchers correlated this lethargy with snow and cold temperatures (Craighead and Craighead 1972) while others believe it could be a combination of factors like photoperiod, food availability and/or nutritional status (Hellgren and Vaughan 1986). Areas where some bears are active all winter and do not exhibit this lethargy are typically in areas with mild temperatures, little snow, and accessible food. The net energy balance likely favoured staying active versus denning for these individuals (Beecham et al. 1983, Hellgren and Vaughan 1986), whereas in harsher environments, the net energy balance favoured bears that slowed their metabolism and denned until conditions improved in the spring.

Sahlén et al. (2015) hypothesized that once a grizzly bear begins to slow its movements and their physiology begins to change in preparation for hibernation, they might be more likely to act aggressively during surprise human encounters. This was because their physiology might not allow their muscles to function as usual for a flight response, leaving a fight response as their only option. This theory could explain why a large proportion of human/bear encounters in Scandinavia, where human injury occurred happened at or near a winter den in the fall, and usually involved surprise encounters with hunters.

The earliest date a grizzly bear arrived at its den area (within 500 m of their den) in our study area in west-central Alberta occurred on 14 October and the latest was on 11 December (Table 1). Grizzly bears of all age, sex and reproductive classes spent on average from 5-9 days near their dens prior to den entry with a mean of 7 days (Table 2). However, there was a great deal of variation, with 10% of den entries occurring immediately (within the day) upon arrival (n=169) and one bear (an adult female) spent 31 days near the den before entry. We do not know if the bears exhibited lethargy during this time. In Yellowstone, grizzly bears spent 8-22 days near their dens prior to den entry (Judd et al. 1986).

Table 1. The dates in which grizzly bears in west-central Alberta arrived at their den area (within 500 m of the den) in the fall by age, sex, and reproductive class.

Age/Sex/Repro. Class	Sample Size	Mean Den Area Arrival	Minimum	Maximum
Adult F	38	2-Nov	21-Oct	22-Nov
Adult F with cubs	28	5-Nov	19-Oct	20-Nov
Adult F - pregnant	24	30-Oct	17-Oct	20-Nov
Adult M	33	8-Nov	14-Oct	6-Dec
Subadult F	24	8-Nov	22-Oct	8-Dec
Subadult M	25	11-Nov	17-Oct	11-Dec
Overall Mean, Min, Max	172	5-Nov	14-Oct	11-Dec

Table 2. The mean number of days spent within 500 m of the den site before den entry in the fall and after den exit in the spring by age, sex, and reproductive class for grizzly bears in west-central Alberta from 1999-2018. Only the maximum number of days spent at the den is shown. The minimum number of days spent at the den either before den entry or after den exit was always zero (i.e., the bear immediately entered the den in the fall or left the den site in the spring).

Age	Sex	Repro. Class	Pre-Entry Mean # Days	# Of Bears	Max # Days	Post-Exit Mean # Days	# Of Bears	Max # Days
Adult	F	Pregnant	4.8	24	20	15.0	18	45
Adult	F	Alone/Unknown	6.9	38	31	6.7	29	18
Adult	F	With Cubs	9.2	26	24	7.2	21	20
Adult	M	NA	6.3	32	23	4.9	25	21
Sub-adult	F	NA	7.4	24	21	10.6	16	27
Sub-adult	M	NA	7.4	25	20	5.3	18	13
Overall Means and Totals			6.9	169	31	7.9	127	45

As with pre-denning behaviour, post-denning behaviour in west-central Alberta was also quite variable. The latest a grizzly bear remained in the den area (within 500 m of its den) was 24 May and was a female with newborn cubs (Table 3). On average, grizzly bears spent 8 days in the den area after den emergence but 16% (n=127) of bears left their dens immediately (within the day) after emergence and one bear spent 45 days in the den area. Adult males spent the least amount of time in the den area after emergence (mean = 5 days; maximum = 21 days; Table 2) while females with new cubs spent the longest amount of time (mean = 16 days; maximum = 45 days; Table 2). This behaviour of staying at the den with young cubs might serve to keep the cubs safe from predation (Libal et al. 2011, Miller 1989) because after leaving a den, most grizzly bears will move to snow-free areas (Berman et al. 2019), away from areas where females with new cubs often remain. Waiting near the den might also allow for easier travel when they do decide to leave the den area. This is because warm spring days and cool nights will cause a snow crust to form making it easier for the young cubs to travel (Craighead and Craighead 1972). Females with newborn cubs will often make day beds near their den and spend part of the day outside resting on the day bed and return to the den for the night. The cubs will actively explore the area but remain close to the mother (Vroom et al. 1980).

Table 3. The dates in which grizzly bears in west-central Alberta left the den area (within 500 m of the den) in the spring by age, sex, and reproductive class.

Age/Sex/Repro. Class	Sample Size	Mean Den Area Departure Date	Minimum Date	Maximum Date
Adult F	30	23-Apr	26-Mar	15-May
Adult F with cubs	21	18-Apr	8-Apr	2-May
Adult F - pregnant	18	6-May	18-Apr	24-May
Adult M	25	8-Apr	20-Mar	3-May
Subadult F	16	14-Apr	28-Mar	1-May
Subadult M	18	13-Apr	28-Mar	28-Apr
Overall Mean, Min, Max	128	19-Apr	20-Mar	24-May

Grizzly bears do not eat immediately after den emergence. It can be up to 3 weeks after den exit before they will start to eat and drink at normal levels (Nelson et al. 1983) which suggests that it takes time for their physiology to change to a more normal and active state following hibernation.

Den Creation

The time it takes to dig a den and the quality of the den likely varies with a bear's experience (Craighead and Craighead 1972) but a den can be dug in under 10 hours (fRI Research Grizzly Bear Program, Unpublished data) or can take up to 7 days (Craighead and Craighead 1972). There was no evidence that a bear dug its den well in advance of den entry in west-central Alberta but in Yellowstone, one grizzly bear dug its den in early September and returned to it later in the fall to den (Craighead and Craighead 1972).

In west-central Alberta, Pigeon et al (2016a) sometimes found partial excavations near dens used by collared grizzly bears (Figure 2). These were thought to be attempts at digging a den but were abandoned for unknown reasons. Some partial dens in Banff ended with large boulders blocking further excavations (Vroom et al. 1980) while in Yellowstone, partial dens were abandoned as a result of large rocks or roots limiting the size of the entry (Craighead and Craighead 1972).

Figure 2. Partial excavations that were found within meters of a used grizzly bear den in west-central Alberta.

Often grizzly bears will line the floor of their dens with vegetation. In west-central Alberta, Pigeon et al. (2016a) found conifer bough as well as moss and grasses used as bedding materials. Sometimes this bedding material was found outside the entrance to the den and had presumably been pulled out by the bear (Figure 3). The bedding material used was what was available near the den site. Presumably, the bed would insulate the bear from the cold ground and keep the bear dry if melt conditions occurred. In Yellowstone, grizzly bears used spruce or fir boughs but pregnant females used softer vegetation like moss and grass (Craighead and Craighead 1972).

Figure 3. Bedding material presumably pulled out by the bear after den emergence

Den Entry and Exit

In Yellowstone, a heavy snowfall and cold temperatures appeared to trigger grizzly bears to enter their dens in the fall (Craighead and Craighead 1972, Servheen and Klaver 1990). In west-central Alberta, not all bears entered their dens at the same time so there were other factors used by bears to decide when to enter their dens (Pigeon et al. 2016b). Berry availability had an influence with good berry crop years associated with later den entry dates in our study area (Pigeon et al. 2016*b*). Similarly, poor berry crop years were associated with early den entry in Alaska (Schoen et al 1987, Miller 1989).

Throughout their range, there is an order in which grizzly bears typically enter and exit their dens and grizzly bears in west-central Alberta were no exception. Pregnant females entered their dens the earliest (mean = 3 Nov) and males and subadults the latest (mean = 14-18 Nov) and lone females and females with cubs fell in between (mean = 9-14 Nov). The mean den entry date for all age/sex classes combined was 12 November. The earliest den entry occurred on 20 October by a pregnant female and the latest was on 19 December by an adult male and a subadult female (Figure 4).

Similarly, the mean den exit date for grizzly bears in west-central Alberta followed the typical emergent pattern. Females with new cubs exited the latest (mean = 24 April), adult males and subadults the earliest (mean = 5-7 April) and lone females and females with yearlings or older fell in between (mean = 11-16 April). The mean den exit date for all age/sex classes combined was 12 April. The earliest exit occurred on 5 March by a subadult female and the latest on 12 May by a female with new cubs (Figure 4).

Den entry and exit dates are known to vary by geographic latitude with bears living at higher latitudes entering their dens earlier and exiting later compared with lower latitude populations. Although the sample size is small, it appears that grizzly bears in southern Alberta (between Hwy 3 and the USA border), in the Castle Bear Management Area (BMA 6) denned around the same time as grizzly bears in west-central Alberta but exited their dens earlier (Table 4; unpublished data).

Table 4. A comparison of den entry and exit dates between Bear Management Areas (BMA). BMA 2 and 3 are the Grande Cache and Yellowhead BMAs and occur in west-central Alberta (Figure 1). BMA 2 is the Castle BMA and occurs in southern Alberta (Highway 3 to USA border).

BMA	Alberta Location	Sample Size	Mean Den Entry	Sample Size	Mean Den Exit
2 (Grande Cache)	West-central AB	65	14-Nov	49	11-Apr
3 (Yellowhead)	West-central AB	114	11-Nov	98	13-Apr
6 (Castle)	Southern AB	9	17-Nov	7	29-Mar

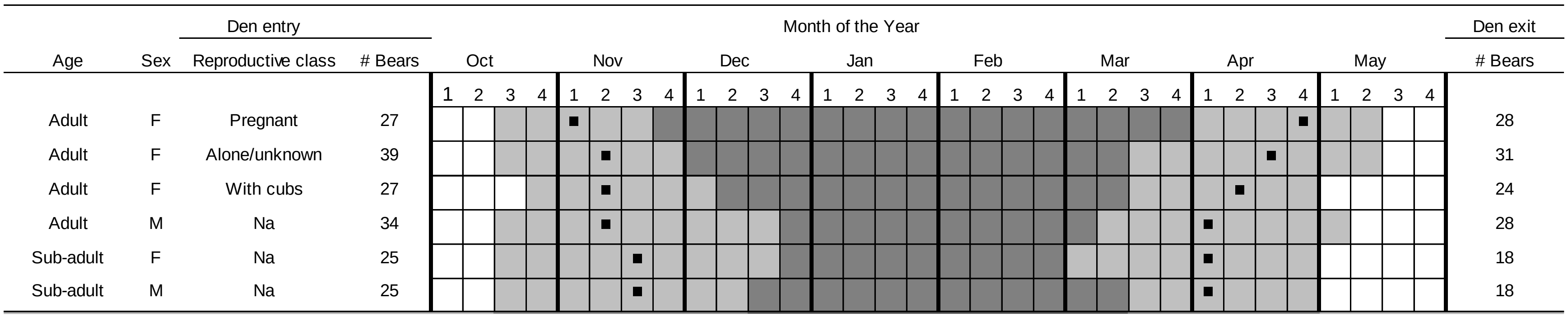

Figure 4. The denning chronology for grizzly bears in the Grande Cache and Yellowhead Bear Management Areas combined from 1999-2018 by age and reproductive class. Black squares indicate the mean date when grizzly bears entered and exited their dens shown within monthly quarters. The light shading indicates the range of den entry and exit dates within monthly quarters and the dark shading indicates when all bears were in their dens. Monthly quarters are defined as 1 = day 1-8; 2 = day 9-15; 3 = day 16-23 and 4 = day 24-31 within a specified month.

Den exit may be related to weather, with warmer temperatures and reduced snow cover associated with earlier den exit (Pigeon et al. 2016*b*). This could be a result of water melting and seeping into their dens (Schoen et al. 1987) or could be because the ambient temperature outside is actually warmer than the temperature inside their den (Craighead and Craighead 1972).

Den Duration

In west-central Alberta, grizzly bears typically spent from 98-198 days (mean = 150 days, n=136 den events) in their dens (Table 5). Females with new cubs tended to stay in their dens the longest (mean = 171 days) while subadults and adult males had the shortest duration (mean = 137-141 days) and lone females and females with older cubs spent a mean of 148-159 days. Table 6 provides mean den durations for various grizzly bear population throughout their circumpolar range. Grizzly bears in west-central Alberta spent less time in their dens compared with Sweden and Alaska bears but more time than bears in Yellowstone which illustrates a latitudinal effect.

While in their den, the entrance is typically covered with snow and acts as a "seal" to keep the cold air out and the bear's body heat in (Craighead and Craighead 1972). We have no evidence to suggest that grizzly bears exit their dens on warm days during the winter in our study area (fRI Unpublished data).

Table 5. The mean den duration in days for grizzly bears in west-central Alberta from 1999-2018 by age, sex, and reproductive class. The sample size and the minimum and maximum durations are also shown for each age, sex, and reproductive class.

Age	Sex	Repro. Class	# Days	# Bears	Min.	Max.
Adult	F	Pregnant	171	22	140	198
Adult	F	Alone/Unknown	159	30	112	191
Adult	F	With Cubs	148	22	112	182
Adult	M	NA	141	27	98	191
Sub-adult	F	NA	137	17	104	182
Sub-adult	M	NA	140	18	110	169

Table 6. A comparison of den duration days from different grizzly bear populations throughout their range.

Sex Class	WC Alberta	Sweden[1]	Yellowstone[2]	Alaska[3]
Pregnant Females	171	195-226	170	211
Males	141	161-206	113	165
Females[4]	148-159	166-209	132	194

[1] Friebe et al. 1998, Manchi and Swenson 2005
[2] Judd et al. 1986
[3] Schoen et al. 1987
[4] Includes lone females and females with yearlings or older

Pregnant Females

Although breeding season for grizzly bears in west-central Alberta occurs from late May to early July (Stenhouse et al. 2005), female grizzly bears do not become pregnant until the egg or eggs become implanted on the wall of the uterus which will occur sometime in the late fall. This form of pregnancy is called “delayed implantation” and is a way for females to give birth to cubs only if they have enough fat reserves to get themselves and their offspring through to the spring. Females require no less than 20% body fat prior to denning before the egg will implant (Robbins et al. 2012). Only 2 months after implantation, they will give birth in their dens in late January to early February (Friebe et al. 2014). They rely solely on their fat stores for milk production and will nurse their offspring for the remaining 2-3 months before den emergence and throughout the first summer (Tumanov 1998). Females with greater fat stores will typically give birth earlier and produce richer milk and larger cubs than females with less fat stores (Friebe et al. 2014). Any disturbance while in their den can be detrimental to the survival of these tiny cubs who only weigh 400-650 g (0.9-1.4 pounds)(Farley and Robbins 1995, Tumanov 1998, Robbins et al. 2012) and are born blind and covered with very fine hair (Tumanov 1998). They rely on their mother to provide protection, warmth, and food, so disturbances that stress the female and cause her to move around inside the den could dislodge the cubs from a warm location against the mother or interrupt nursing which could detrimentally impact the cubs’ growth and survival. Cubs are unable to support themselves on their feet until they are at least one month of age (Tumanov 1998) so if a female were to abandoned her den soon after giving birth, there is little chance that her cubs would survive.

Climate Change

Climate change will undoubtable impact grizzly bears with possible benefits and consequences, but it is difficult to know what the net effect will be. Because den exit was associated with warm spring days, Pigeon et al. (2016b) predicted that with climate change scenarios tending toward warmer spring temperatures and reduced snow (Bush and Lemmen 2019), grizzly bears could exhibit earlier exit dates in the future. Earlier exit dates by females with new cubs could result in the cubs being less mobile, smaller, and more vulnerable when they leave the den which could reduce cub survival. However, climate change could also lead to earlier foraging opportunities and a longer growing season for bears which could benefit their body condition and reproductive performance. The possible down side of a longer growing season with a correspondingly shortened den period could result in more opportunity for grizzly bears and humans to interact which could lead to higher grizzly bear mortality rates and perhaps less tolerance toward bears if negative interactions increase.

DEN SITE HABITATS

Den site selection of grizzly bears in our study area was investigated by Pigeon (2015) for her PhD between 2000-2012 and comprises much of the information presented in these next three sections of this report. First Pigeon et al. (2014) used various remote sensing products, models and anthropogenetic maps to successfully described grizzly bear den site locations. The results are presented in this section. A Resource Selection Function (RSF) Model was developed from this work (Pigeon et al. 2014) and is described in the next section called "Den Resource Selection Function Model". Lastly, some of the dens were visited by Pigeon and her field staff and the den and the environmental characteristics around the dens were quantified (Pigeon et al. 2016a). This field data was also used to describe den site locations and results were compared with their 2014 paper and is presented in the "Den Characteristics" section of this report.

Seventy-nine grizzly bear den locations from 15 males and 35 females (with or without cubs) along with random locations within each bear's fall home range were combined with data derived from remote sensing products (slope, elevation land cover etc.), food models (spring and fall food; Nielsen et al. 2010), and various Geographic Information Systems (GIS) layers of anthropomorphic features (roads, well sites and harvest blocks) to examined den site selection for grizzly bears in west-central Alberta (Pigeon et al. 2014). They found that males and females selected similar landscapes for their dens with selection occurred at two spatial scales with variables linked to den insulation, remoteness, and spring foods.

At the broad scale (5-10 km), grizzly bears avoided wetlands and denned in dry conifer stands with abundant spring food. Within these stands, at a 600 m scale, dens occurred in areas with low road density and dense conifers, presumably for concealment, and avoided landscape features associated with fall foods at the 150 m scale. Den sites were not in water saturated areas (Figure 5). They denned on slopes with the relative probability of den site selection doubling when the slope increased from 10° to 60° (Figure 5). Slopes along riparian drainages and depressions were used. Deciduous stands were avoided. No dens were in young (0-5 years) harvest blocks. In addition, we found no evidence of dens in slash piles (fri Unpublished data).

The food probability models developed by Nielsen et al. (2010) considered sweet vetch (*Hedysarum alpinum*) as the important spring (May) food for grizzly bears. Grizzly bears dig and consume the roots of sweet vetch both in early spring and late fall, when most other grizzly bear foods are unavailable (Munro et al. 2006). Habitat features associated with sweet vetch included mountain slopes but also riparian habitats, open conifer forests and low elevation disturbed sites (Nielsen et al. 2010). It wasn't clear if dens were within 9.6 km of habitat features associated with sweet vetch or if it was the presence of the plant itself that the bears were selecting (Pigeon et al. 2014). However, their analysis using habitat data collected at den sites (see "Den Characterisitcs" section) confirmed that it was likely the presence of sweet vetch that the bears were selecting (Pigeon et al. 2016a).

The important fall foods used by Nielsen et al. (2010) were huckleberry (*Vaccinium membranaceum*) and buffaloberry (*Shepherdia canadensis*). Huckleberry was associated with closed conifer stands at moderate to high elevations with abundant precipitation, while buffaloberry was associated with intermediate aged forests with high solar radiation and lower elevations (Nielsen et al. 2010). Den sites were typically > 150 m from these fall foods but as with the relationship with spring bear food in this analysis, it was unclear if bears were selecting habitats associated with little to no huckleberries or buffaloberries or if it was the absence of the shrubs themselves in the den area that the bears were selecting.

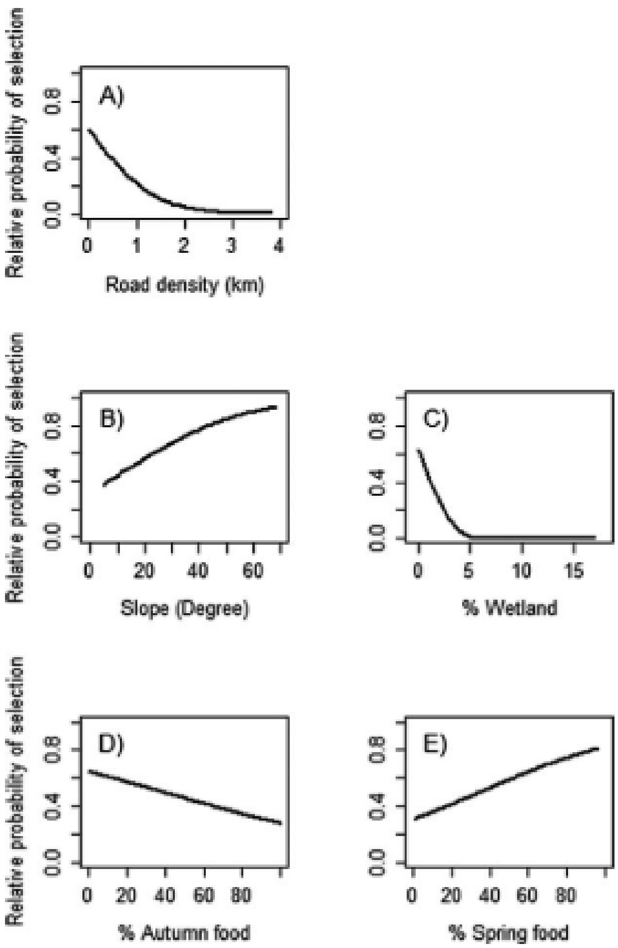

Figure 5. Relative probability of den selection by male and female grizzly bears in the boreal forest and Rocky Mountains of Alberta, Canada between 2000 and 2011. A) Road density (km^2) at the 0.6-km scale, B) slope (degree), C) percent wetland at the 9.6-km scale, D) percent autumn food at the 0.15-km scale, and E) percent spring food at the 9.6-km scale. Each predictor variable is plotted within its observed range while other variables are held constant at their respective mean (Figure from Pigeon et al. 2014).

Pigeon et al. (2014) found that grizzly bears did not select for deciduous forests, possibly because these stands occurred at low elevations which would have less snow cover for insulation and more freeze/thaw events, all of which could negatively impact den insulation and water leakage (Schoen et al. 1987). Similarly, grizzly bears avoided water-saturated areas which would have provided poor insulation qualities. Figure 5 shows that within a 9.6 km radius of a den, if 6% of the landcover was classified as a wetland, the probability of a den dropped to zero.

Bears with access to high elevation areas seemed to prefer these areas for dens but these areas were also more remote so avoiding humans and human disturbances could also have been the driving force for these remote sites rather than habitat and snow conditions (Figure 6). Including dens used by Pigeon et al (2014) and dens from the fRI database, we found dens ranged in elevation from 795 m in the boreal forest to 2284 m in the mountains with an average of 1705 m (n=223 dens; fRI unpublished data).

Although no specific mineral soil was preferred, no den was excavated in organic soils, likely because these soils may not be as well drained and cohesive as more loamy soils (Pigeon et al. 2014). In Banff, Vroom et al. (1980) found that if a den was dug into less stable soils, it was often dug beneath a tree or shrubs where the roots would provide additional stability. Because there was no obvious choice in mineral soils selected by grizzly bears in west-central Alberta, it is likely that much of this region is composed of soils suitable for digging a den.

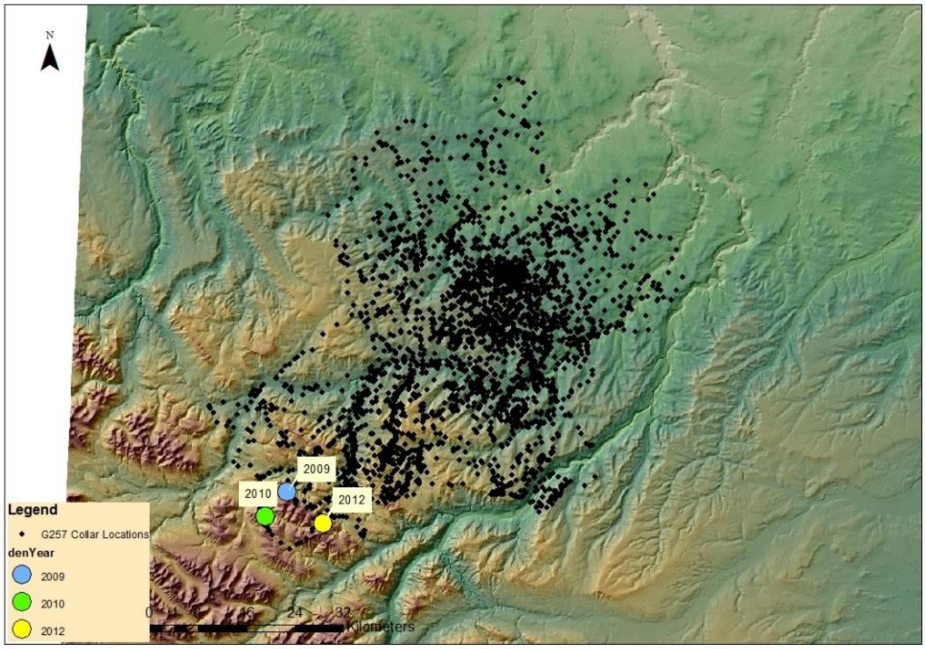

Figure 6. The den sites for G257 and all his GPS collar locations showing how he travelled to the east slopes of the Rocky Mountains each fall to den.

The aspect of a den varied but was likely situated to maximize protection from the wind and snow accumulation. Pigeon et al. (2014) found aspects of grizzly bear dens in west-central Alberta to range from NE to NW with a mean of SE. This large variation in aspect was likely a result of small-scaled terrain features that caused the wind to shift from the prevailing west wind direction. In Banff National Park most dens were NE to ESE facing which tended to be leeward slopes where snow would be expected to accumulate (Vroom et al. 1980). Further research on snow conditions at den sites is required to better understand how wind and snow impacts den site selection in west-central Alberta.

Dens were typically 300 m away from oil/gas well sites and 150 m from a road. The relative probability of den selection dropped by 30% when road densities increased from 0 to 0.6 km per km^2 and dropped by nearly 70% at road densities of 1.2 km per km^2 (Figure 5). At road densities of 2.0 km per km^2, selection was nearly zero. Grizzly bears in Scandinavia, especially adult males were also sensitive to active roads and avoided these areas for denning (Elfstrom et al. 2008).

We have no evidence that dens were reused in west-central Alberta, but some grizzly bears excavated another den within metres of one of their previous dens (Figure 7). Clusters of dens in an area were also found in Banff National Park (Vroom et al. 1980). On average, females in the study area denned 9 km from a previous den and males denned 15.5 km from a previous den. Reuse of dens has been documented in other areas; most of which occurred in caves (Schoen et al. 1987, Judd et al. 1986). We found no evidence of cave use by denning grizzly bears in our study area.

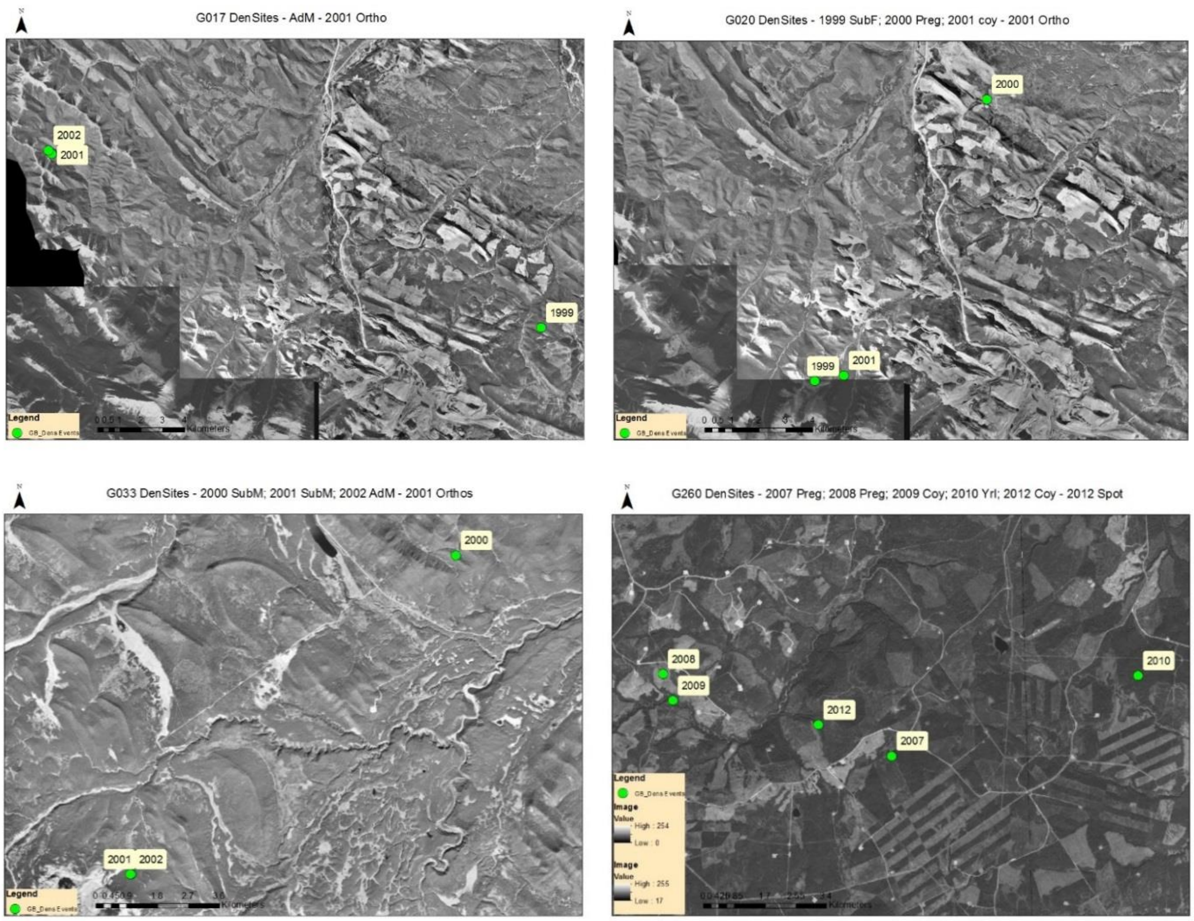

Figure 7. Locations of den sites over multiple years for individual grizzly bears in west-central Alberta showing the surrounding landscapes.

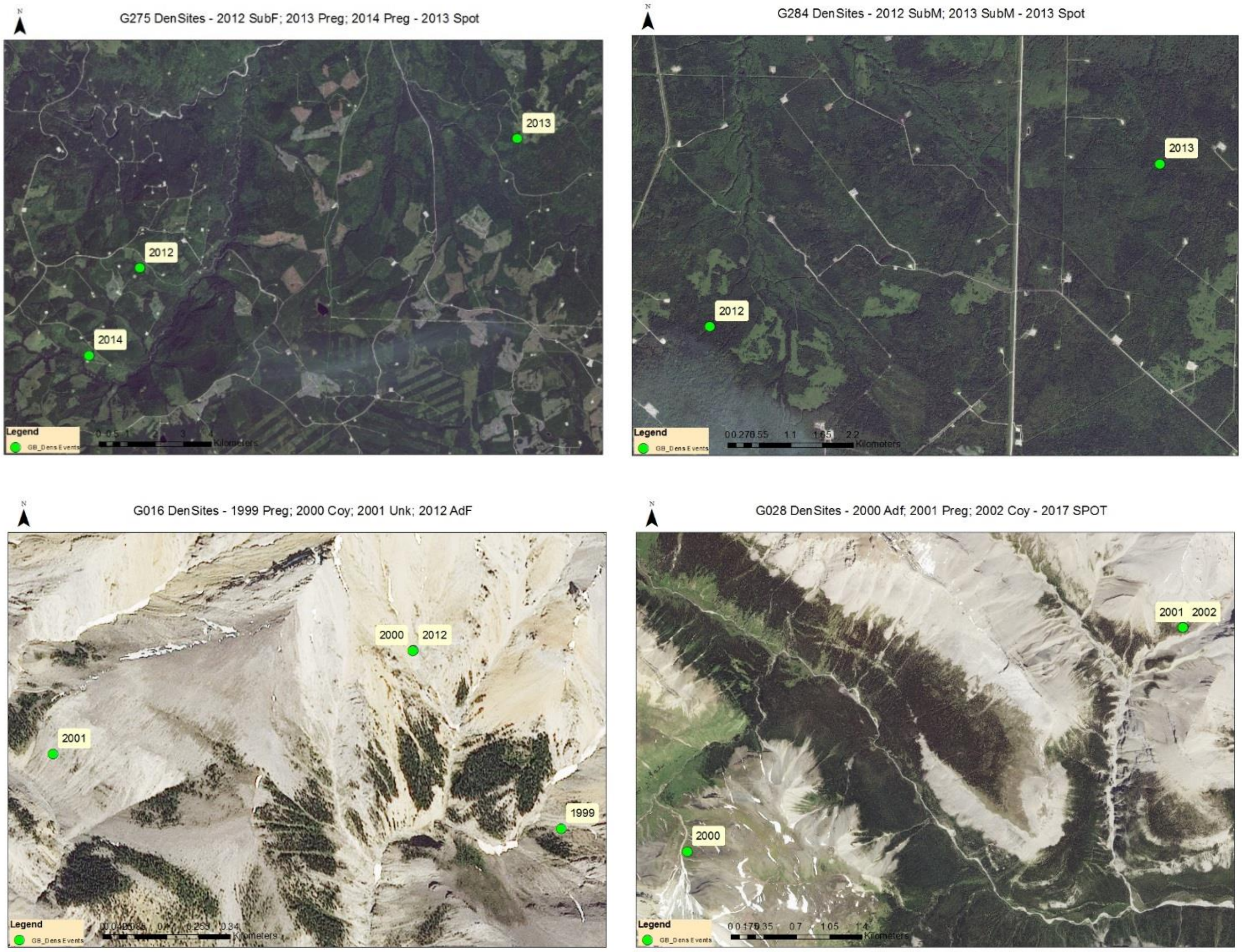

Figure 7 (continued). Locations of den sites over multiple years for individual grizzly bears in west-central Alberta showing the surrounding landscapes.

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DEN RESOURCE SELECTION FUNCTION MODEL (RSF)

By combining the food models, GIS layers of anthropogenic features and remote sensing-based habitat features associated with grizzly bear dens outlined in the previous section, Pigeon et al (2014) developed an RSF model to predict where grizzly bear dens were most likely to occur within the area shown in Figure 1. Originally, Pigeon had created a separate model for mountain grizzly bears and one for boreal grizzly bears, but the models were similar, so a single RSF model was created. The model showed that dens were 11 times more likely to be in the highest RSF value (bin 6) than in areas ranked at the lowest bin (bin1). This model is provided to the Partners of the fRI Research's Grizzly Bear Program as part of the "Deliverables" package of research findings. Along with the RSF model there are GIS tools that allowed users to incorporate new features such as roads or harvest plans into an area and recalculate the Den RSF layer based on these new features. This is a powerful tool available to predict where grizzly bear denning habitat is likely to be found and to also mitigate possible disturbances within grizzly bear den habitat during the winter months. Figure 8 shows output from the RSF den model and how it compared with actual grizzly bear dens on the landscape.

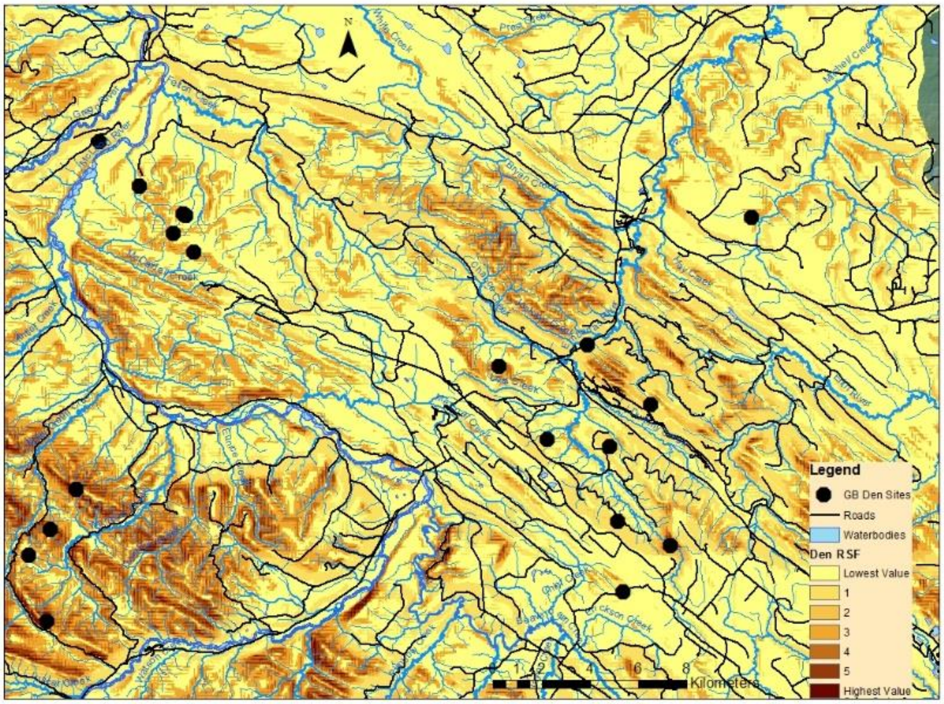

Figure 8. An example of the RSF model output showing where high quality grizzly bear den habitat occurs on the landscape. The darker the colour the better the den potential. The black dots show where actual collared grizzly bear dens occurred.

DEN CHARACTERISTICS

Pigeon (2016a) visited 42 grizzly bear dens in west-central Alberta from 10 adult males and 21 adult females and compared habitat features, including the cover of sweet vetch and Vaccinium spp., within a 20 m x 20 m plot centred at the den site, with random plots located within the bear's fall home range and within 150 m of the den. Den measurements were also taken. They found that grizzly bears selected dens in areas with denser concealment cover, denser canopy cover and abundant sweet vetch compared with random locations within the home ranges. There was also denser canopy cover compared with plots within 150 m of the den.

These findings from field data corroborated with much of their earlier work (Pigeon et al. 2014) using remote sensing-based data, GIS layers and food models. However, they noted that field data provided fine-scaled information that the remote-sensing based results did not. Therefore, their recommendation **to minimize grizzly bear den disruption was to locate high quality den habitat using the RSF model and within those areas conduct ground surveys to find locations with high concealment cover and abundant sweet vetch**. Restricting activities in these areas would serve to reduce grizzly bear-human interactions and conserve optimal grizzly bear den habitat.

They found that all grizzly bear dens were excavated into 12–50 degree slopes. Excavated dens were the most common den type used by grizzly bears throughout their circumpolar range. However, grizzly bears in other areas (British Columbia, Alaska, Yellowstone and Scandinavia) also used natural caves, ant hills, hollow trees, or rock caves (Judd et al. 1986, Schoen et al. 1987, Van Daele et al. 1990, Ciarniello et al. 2005, Elfstrom and Swenson 2009). Some grizzly bears in Sweden even spent the winter months in open ground "nests" or in a hollow out area dug into the snow i.e. snow caves (Schoen et al. 1987, Elfstrom and Swenson 2009).

Excavated grizzly bear dens typically consist of a porch, entrance, tunnel, chamber and bed (Figure 9 from Faure et al. 2020). Pigeon et al. (2016*a*) found that 81% (n=27) of dens looked like Figure 9 with a tunnel that opened into a larger chamber. The remainder had the entrance opening directly into the chamber or had collapsed and the structure could not be determined. There was no difference in the dimensions and characteristics of dens excavated by males and females even though male bears have a larger body size compared with females (Table 7). In contrast, Judd et al. (1986) in Alaska showed that the chamber and tunnel length of dens used by male grizzly bears were longer than those used by females with cubs.

In west-central Alberta, Pigeon et al. (2014a) found dens were excavated below a tree 62% (n= 42 dens) of the time with the tree species being white/Engelmann spruce (38%), subalpine fir (42%), lodgepole pine (12%) and aspen (8%). Logs, roots, and dense vegetation were also frequently above excavated grizzly bear dens, presumably for added support (Figure 10). Some dens were easy to see because of the large amount of excavated soil and rocks that rolled down the slope (Figure 11) however, others were more difficult to discern (Figure 12). Dens could be heavily concealed in dense shrubs or trees (Figure 13). Of the 29 dens visited the same year as used by the bear, 11 (38%) were found collapsed (Figure 14).

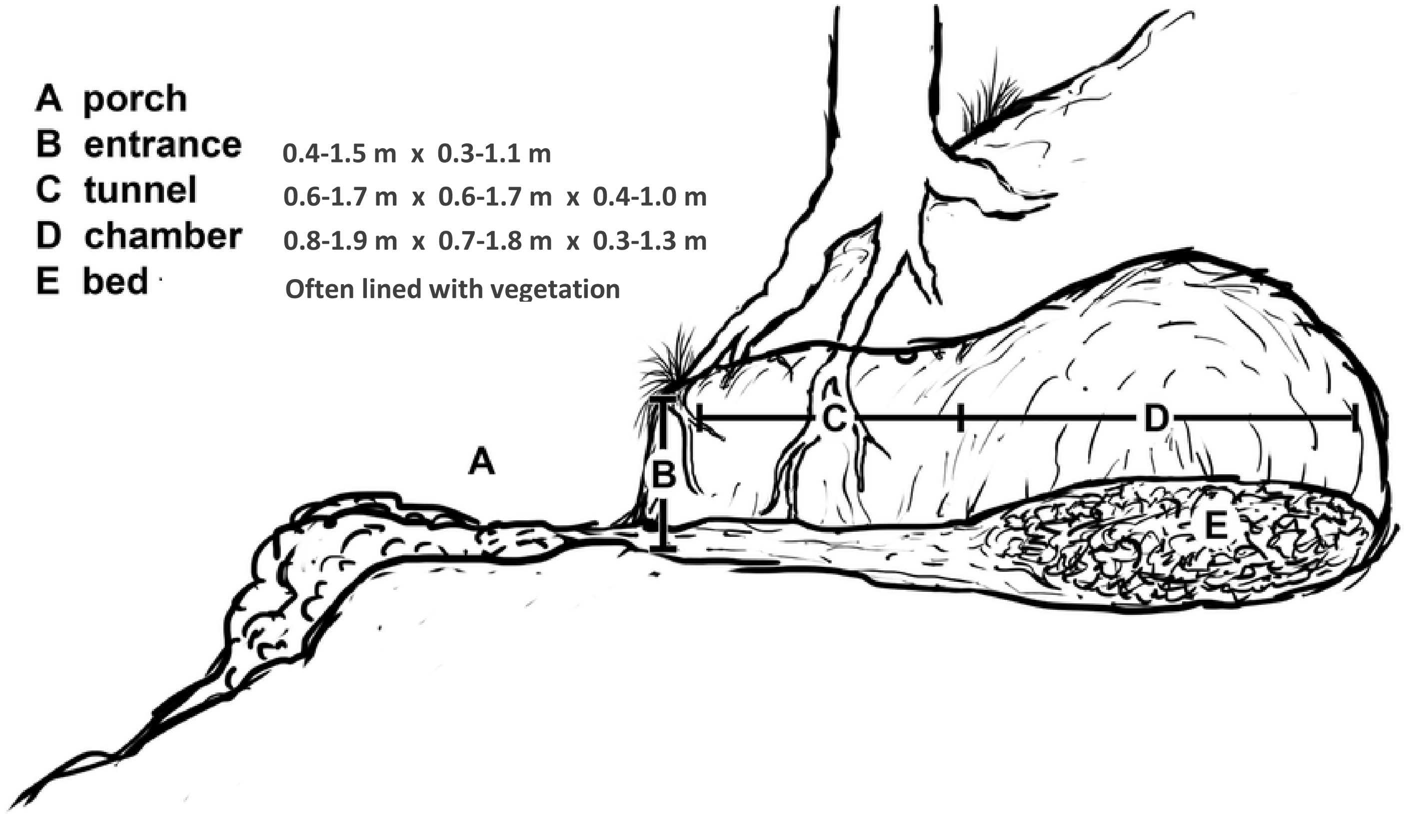

Figure 9. A typical grizzly bear den. Measurements are from (Pigeon et al. 2016a) and image is from (Faure et al. 2020). Measurements are width x height for the entrance and length x width x height for the tunnel and chamber. The range of sizes are provided.

Table 7. Dimensions (in metres) of grizzly bear dens in west-central Alberta from Pigeon et al (2016a).

Location	Mean (m); Male - Female	Minimum (m)	Maximum (m)
Entrance width (bottom)	0.8-0.8	0.4	1.5
Entrance width (mid height)	0.7-0.8	0.4	1.4
Entrance width (top)	0.6-0.6	0.2	1.4
Entrance height	0.6-0.6	0.3	1.1
Tunnel length	0.7-0.8	0.6	1.7
Tunnel width	1.0-0.9	0.6	1.7
Tunnel height	0.6-0.6	0.4	1.0
Chamber length	1.3-1.3	0.8	1.9
Chamber width	1.3-1.3	0.7	1.8
Chamber height (min)	0.7-0.7	0.3	1.3
Chamber height (max)	0.9-0.9	0.5	1.3

Figure 10. Typical grizzly bear dens dug beneath a tree, roots, rock, and/or log in west-central Alberta.

Figure 11. Showing the excavated rock and soil debris below the entrance of some dens.

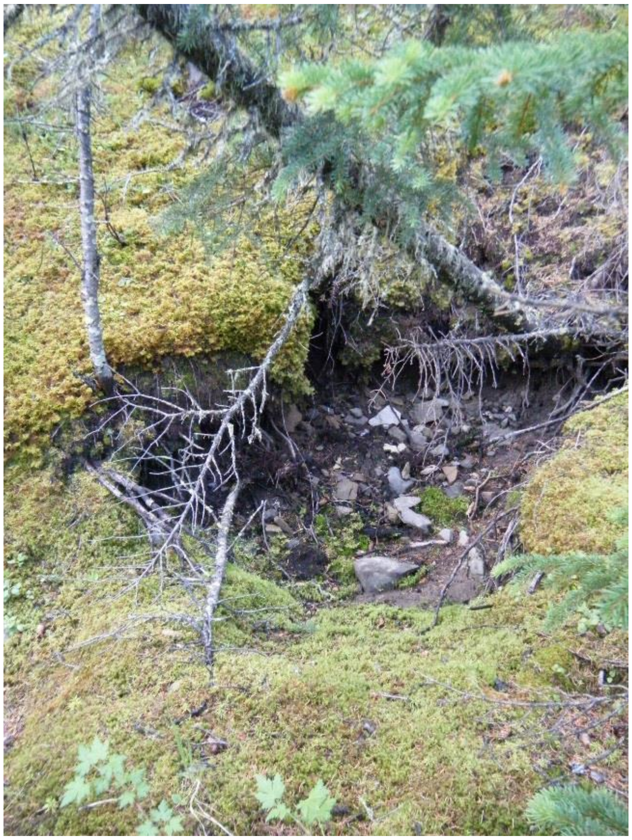

Figure 12. Some den openings can be quite narrow and difficult to discern, others can look like erosion on a slope and others can be hidden beneath vegetation.

Figure 13. Examples of den concealment.

Figure 14. A collapsed grizzly bear den in west-central Alberta.

Den Abandonment

Swenson et al. (1997) found den abandonment by grizzly bears in Sweden was typically caused by human disturbances that had occurred within 100 m of the den. Disturbances included hunters (Sahlén et al. 2015), forest surveyors, skiers, and ice fishermen. After abandoning the den, the bears in Sweden typically moved a mean of 5.1 km away with 56% moving 2 km or less and one bear moved up to 30 km away. The bears either dug a new den or laid on the ground on a “nest” of branches. One bear returned to the original den. Den abandonment tended to happen more often in the first half of winter but this also could be because more people were on the landscape at that time (i.e. hunting occurs in early winter)(Swenson et al. 1997, Sahlén et al. 2015). However, other researchers also found den abandonment more likely if the disturbance happened within the first month after den entry (Beecham et al. 1983, Smith 1986). Den abandonment can also be caused by weather events. In Alaska, den abandonment in February was suspected to be caused by unusually heavy rains and thawing that likely caused water to drip into the dens (Schoen et al. 1987).

Linnell et al. (2000) described how disturbances could impact a denned bear. A disturbance that causes the smallest impact would result in a bear waking with a slight increase in body temperature or heart rate. The next level would progress to movement inside the den and the body temperature rising to normal levels accompanied with an increase in metabolism. The last and most detrimental to a bear’s survival would be the actual abandonment of the den. Abandonment of a den has been reported to cause an additional 56% loss of mass compared to an undisturbed bear (Tietje and Ruff 1980). The type and frequency of disturbance and the individual bear’s tolerance to disturbance would dictate what level of impact the bear would experience. Even a disturbance that only wakes the bear but happens repeatedly could result in an accelerated loss of fat reserves and reduced fitness. For females with newborn cubs, this drain on their fat reserves could reduce their fitness as well as the quality and/or quantity of milk leading to smaller and/or less healthy cubs. In addition, female bears must keep newborn cubs in constant body contact as the cubs cannot thermoregulate and can quickly loose body heat and die if this contact with their mother is not maintained. A disturbance that causes a nursing female to become agitated and move about while inside the den could displace newborn cubs from a warm location or from nursing which would be detrimental to the cubs' growth or survival. If a pregnant female does abandon a den before giving birth, there is a high probability that one or more cubs will not survive (Swenson et al. 1997) and abandoning a den after giving birth would almost certainly result in cub mortality.

In west-central Alberta, there were three radio collared grizzly bears that abandoned their dens and made new dens during the winters from 1999-2018. The actual reasons for these abandonments are unknown, however the habitat and land use characteristics around these den sites follows.

The first was G012 (Figure 15) in 2002. She entered her den around 2 Dec and moved on 14 Dec to her new location 2.3 km away. She was with her yearling cub before and after her move. Her first den was 16 m from the edge of a harvest block. There was a forestry road connecting two harvest blocks within 60 m of her first den, but we do not know if any traffic occurred on this road at the time of den abandonment.

The second bear was G238 in 2009 (Figure 16). She entered her first den around 18 November and moved 4.25 km to a new den on 27 November. We are unsure of her reproductive status at that time. A new harvest block appeared on the 2009 SPOT imagery within 750 m of her den and an established road that accessed the block was within 750 m of her den, but we do not know the exact date when this block was harvested or if there was traffic on the road. There was also a well site within 1 km and a seismic line within 50 m of the den which would have provided easy access for people to approach close to her den.

The last bear was G254 in 2008 and she was known to be pregnant (Figure 17). She went into her first den on 4 November and moved 700 m on 30 November to a new den location. It is unclear why she moved as there was no obvious habitat disturbances nearby. There was a seismic line within 50 m of her den. She successfully produced cubs and emerged from the den in 2009.

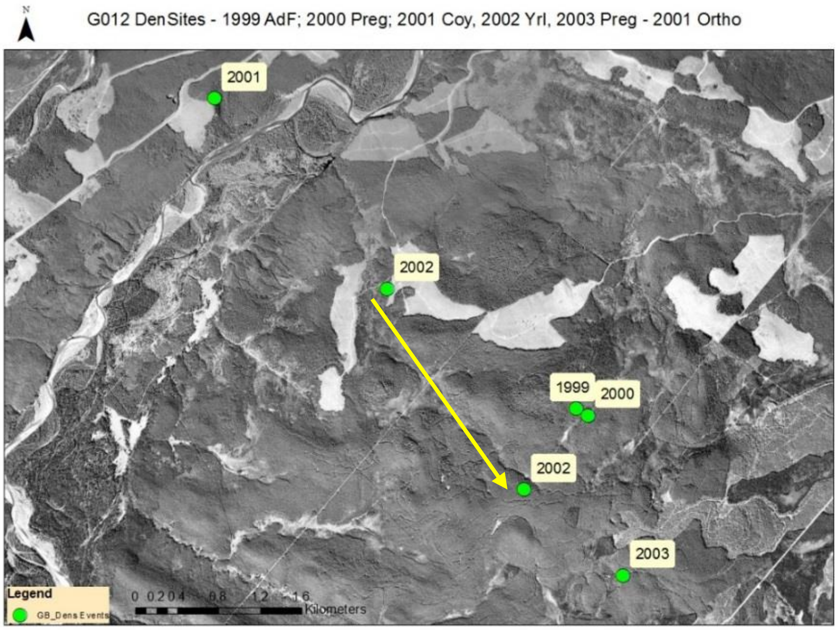

Figure 15. Den abandonment by G012 showing all her dens that we documented along with the two dens in 2002. The arrow shows her movement from the first den to the second den in 2002.

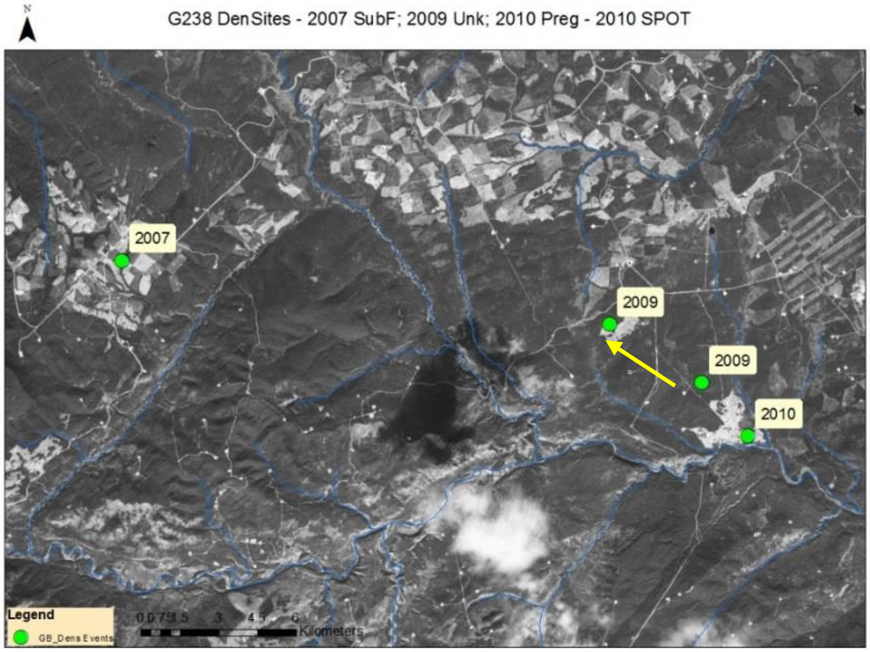

Figure 16. Den abandonment by G238 showing all her dens that we documented along with the two dens in 2009. The arrow shows her movement from the first den to the second den in 2009.

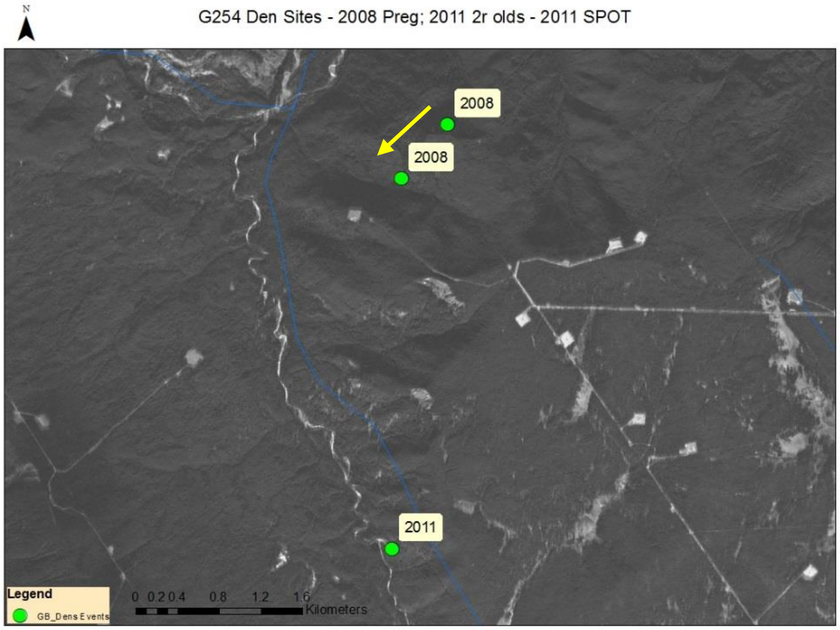

Figure 17. Den abandonment by G254 showing all her dens that we documented along with the two dens in 2008. The arrow shows her movement from the first den to the second den in 2008.

Grizzly vs Black Bear Denning

We do not have data on black bear den dates or den site characteristics for our study area as black bears captured within our research program were not radio-collared. However, other regions have compared the denning ecology of sympatric black and grizzly bears and there were similarities and differences.

In Alaska, black bears entered their dens earlier than grizzly bears but emerged about the same time (Miller 1990). In the front ranges of the Montana Rocky Mountains, den entry and emergence dates were similar between the two species (Aune 1994).

Black bears tended to den at lower elevations and lower slopes compared with grizzly bears (Miller 1990, Aune 1994) and were more likely to den in hollow logs, tree cavities, or under rocks, logs or stumps (i.e., not excavated) compared with grizzly bears (Jonkel and Cowan 1971, Lecount 1982). As well, black bears more commonly reused a den (Lecount 1982, Miller 1990)

Black bear dens in Idaho had smaller entrance heights compared with grizzly bear dens in Montana but no difference in entrance widths (Servheen and Klaver 1983). However, Miller (1990) found no difference between the den entrance size between black and grizzly bears.

Black bears showed little aggression when disturbed at their dens (Smith 1986) while grizzly bears can be aggressive and dangerous (Sahlén et al. 2015).

Management Recommendations

Grizzly bears throughout their range choose areas with little human disturbance for denning. Therefore, before planning roads or harvest blocks, or entering an area with limited human presence, we recommend the following steps:

1a. Use the Den RSF map to determine where high value den areas occur for your area of interest. Use the fRI Research den tool to update the map with new anthropogenic features if required.

The Den RSF map is provided as part of the fRI Research Grizzly Bear Program Deliverables package and will have the most recent anthropogenic footprint already incorporated in the product but if new roads or harvest blocks have occurred, then the denning tool allows users to incorporate new disturbances. Once the RSF maps are updated if required, examine the output to locate the areas with high den RSF values. These should be the focus of denning survey efforts before the construction/harvesting activities begin.

1b. If the Den RSF map is not available for the area of interest, evaluate the area where winter activities are planned (harvesting / construction) in relation to den characteristics in Table 8.

Table 8. Attributes associated with grizzly bear dens in west-central Alberta from Pigeon et al. (2014) and Pigeon et al. (2016a).

Attribute	Den Site Details
Concealment	Dense canopy / lateral cover
Roads/Truck Trail	>150 m
Well Sites	>300 m
Forest	Dry conifer stands
Spring Food	Sweet vetch within 150 m
Soils	Not saturated and not organic
Slope	Mean=34°; range=12-50°
Aspect	Likely to accumulate snow
Elevation	795 m -2284 m

2. Determine if approved winter activities could begin in early October in high den RSF value areas or areas suitable for a den as listed in Table 8, as this may deter bears from selecting this area for a den site.

If a new disturbance that involves heavy machinery must occur in a high den RSF value area, try to time the disturbance to begin in early October. Because grizzly bears prefer to den in undisturbed habitats, loud equipment in an area starting in early October could deter a grizzly bear from using this area for denning that year. A minor disturbance such as a person flagging a harvest block is likely not enough to deter a bear and could also be dangerous for the worker so only disturbances where workers are inside heavy machinery is appropriate for this recommendation. We should also point out that our data does not suggest that denning habitat is limited in the areas we studied.

3. Conduct ground-based reconnaissance of potential den habitat identified in Step 1 during the SUMMER to look for previous dens. Use the den site details outlined in Table 8 to further focus the surveys. GPS old dens found and areas that match the details outlined in Table 8.

Even though grizzly bears in west-central Alberta do not typically reuse a den, they will sometimes den near one of their old den sites. To avoid possible bear encounters, these surveys should occur before 14 October in west-central Alberta, which is the earliest we found a bear in the den area in the fall (i.e., within 500 m of its den site). We recommend experienced and knowledgeable staff, working in pairs with appropriate safety equipment and training, undertake these surveys.

4. Conduct aerial surveys during the early stages of denning in high RSF value den areas, areas where previous dens were found and areas that match the den site details in Table 8.

Conduct aerial surveys in mid-October into November, preferably following a fresh snow fall so tracks are visible but den entrances are not yet covered with snow. If no snow is on the ground, look for the excavated soil and rock debris that can occur below den entrances. Be aware that during this time, some bears could already be in their dens, other might be outside a den but in the general den area (within 500 m of their den) and others could still be many kilometers from where they will eventually den. Also know that den entrances can be concealed behind dense vegetation. Aerial surveys should be conducted quickly to minimize the time near signs of bear activity as evidence suggests that aerial flights are enough to cause distress in some grizzly bears; with some abandoning their den if a disturbance occurs within the first half of the den period. Depending on the circumstances (snow cover etc.), these flights may need to be repeated every 10 days or so during the den establishment period (up to 19 December in our study area).

5. If an active den is found, mitigate actions to prevent den abandonment.

If an active den is detected, this location should be mapped and avoided until late May. We found that most pre- and post- den behavior occurred within 500 m of the den site. We recommend keeping disturbances at least 1 km from a known den site which will provide an additional 500 m buffer around the den area. Similarly, other researchers have also recommended that disturbances should be kept at least 1 km away from active dens (Swenson et al. 1997, Linnell et al. 2000).

6. Once the bear has left in the spring, den survey data should be collected in a rigorous fashion and stored in a database.

All den survey data (dens found or no dens found) should be stored in a database and these data used to test and update/improve the current den RSF model. In cases where a den was discovered, or thought to occur, these sites should be investigated the following spring (June) to determine den status and collect any important biological samples (hair/scat and feces)

Pigeon (2016a) also recommended keeping road densities in high quality den habitats at or below 0.6 km per km^2. These are the same open road density thresholds provided in the 2016 Alberta Grizzly Bear Recovery Plan for core habitat areas (Alberta Environment & Parks 2016). Temporary road closures in these high value RSF areas from mid-October to late May could be a management strategy to reduce potential disturbances at dens. Keeping snow covered roads unplowed during these months could also be a simple strategy to reduce public traffic on these roads (Elfstrom and Swenson 2009).

There is still a chance that a grizzly bear will den in areas other than the predicted high quality den habitat based on the current den RSF model. As a result, field workers should be trained to recognize potential den habitat, and den sites in any area within grizzly bear range. This will be especially important for winter work because dens become invisible once they are covered with snow. The ability to recognize den habitat might be the only way that field workers will know that they could be encroaching on an active grizzly bear den in the winter.

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