Forest Resource Improvement Association of Alberta

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Project Title: "*Evaluating grizzly bear habitat use and response to new approaches to forest management, harvesting, and access planning in core grizzly bear conservation areas – are new approaches possible to support recovery efforts*?

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Executive Summary

The grizzly bear has been deemed a threated species in Alberta due to lower than expected population size and because of ongoing human recreational and industrial activities occurring within grizzly bear range. Despite a moratorium on hunting (2006) and a recovery plan (2008), grizzly bears along the eastern slopes of Alberta continue to experience high levels of human caused mortality. As human activities continue to grow and expand, particularly within core grizzly bear conservation areas, new approaches to land use management and planning are needed to effectively maintain habitat conditions (security, food supply) in a state that would promote recovery.

This project began in 2013 following discussions between the Foothills Research Institute (fRI) Grizzly Bear Program and Weyerhaeuser (Drayton Valley) regarding planned forest harvesting operations occurring within core grizzly bear conservation areas. Weyerhaeuser was interested in understanding more about the current population status and space use patterns of grizzly bears in a portion (three watershed units) of their Drayton Valley FMA, where new approaches to both harvest design and access management had been proposed. As this work moved forward, West Fraser (Hinton, Edson, and Sundre) and other fRI partners (Alberta Environment and Parks) became interested in this project. Therefore, the 2013 study area expanded to include the entirety of the Yellowhead Population Unit (BMA 3) and the research plan was modified to meet the information needs of our partners

This project moves beyond what is currently known about grizzly bear response to forest harvesting as we aim to investigate changes in response over longer time frames using historic (1999 - 2003) and current data. At this time, the evaluation of newly suggested harvesting prescriptions have not been evaluated relative to bear behavior or numerical response of the population. This research effort provides a valuable opportunity to assist Alberta's forestry sector in understanding how their management activities can be better integrated with the ecological needs of grizzly bears and assist in provincial grizzly bear recovery efforts.

The work presented in this report aims to improve our understanding of grizzly bear distribution and abundance, habitat use, and movement patterns within three watershed units that encompasses core grizzly bear recovery zones, which are managed by Weyerhaeuser and West Fraser forest companies. The findings contained within this is report is based on the first two

years of data collected in this longer term research project and should be seen as an interim report.

In section 6 (***Distribution and abundance of grizzly bears in the Pembina study area***), we assessed change in the distribution and abundance of grizzly bears by comparing the results of DNA hair snag inventory work conducted within BMA 3. Our comparisons included 46 common cells (7 x 7 km) from three projects (2004, 2013, and 2014) that overlapped with the Pembina Study area. The results of our genetic analysis identified 4, 16, and 7 unique bears in 2004, 2013, and 2014, respectively. This finding suggests an increase in the local grizzly bear population from 2004. Comparisons of the 2004 and 2014 data showed of the 46 cells sampled, 63% showed no change in the number of unique bears, 17% increased, and 20% decreased. From 2004 to 2014, there appeared to be an eastward shift in bear distribution. Although the mechanism(s) influencing observed changes in bear distribution and abundance are not known, future modeling work will evaluate correlations associated with changes in habitat conditions (mortality risk, food supply) as well as alternative management actions such as long distance relocations of problem bears.

In section 7 (***Grizzly bear response to roads when using forestry cutblocks: does proximity and density of road types influence habitat selection?***), we evaluated seasonal response of male and female grizzly bears to different road types (main/secondary, tertiary, decommissioned/reclaimed) using a long-term GPS location data set (1999-2014). We compared responses of the population (all bears) to those captured specifically for this project (Pembina bears). Individual and population level resource selection function models revealed similar responses between all bears and the Pembina bears; grizzly bears avoided main/secondary roads, exhibited variable responses (positive and negative) towards tertiary and decommissioned/reclaimed roads, and avoided areas of relatively high road density. Our findings suggest that new approaches to forest management where roads are decommissioned or reclaimed are likely to benefit grizzly bears. Attempts should attempt to increase the distance cutblocks are from roads and minimize road density, particularly tertiary roads that account for the relatively high density of roads observed in this study. Other approaches to access management such as the use of gates could also benefit grizzly bears, but needs to be tested empirically.

In section 8 (***Exploring relationships among roads, forest harvest blocks and grizzly bear movement***), we assessed grizzly bear movements in relation to disturbance features including forestry cutblock and roads. We used GPS location data from male and female grizzly bears collected between 2013 and 2014 to determine specific factors that influence movement (step length) in the vicinity of cutblocks and roads. Step lengths are commonly used in wildlife movement models with short steps indicative of foraging or search behaviour, whereas long steps represent “exploratory” movement behaviour. We used generalised additive models (GAM) to determine the influence of road type, age (years since disturbance), and density as well as forest harvest block age, area (km^2), perimeter length (km), and area to perimeter ratio. Gender, time of day (day vs. night) and season were also included as predictor variables. Our main findings suggested that gender based differences in step length were negligible. Step lengths in relation to roads tended to be longer as road proximity and density increased. Conversely, step lengths in relation to cutblocks tended to be shorter as proximity and density increased. Our findings support our contention that bears are using forestry cutblocks primarily for foraging, whereas roads could be used for both foraging and exploratory movements. Access management is essential to ensure high quality foraging habitat such as forestry cutblocks do not result in mortality events associated with roads.

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1. Project Background

This project began in the summer of 2013 following discussions between Weyerhaeuser Ltd. (Drayton Valley) and the Foothills Research Institute (fRI) Grizzly Bear Program. The Forest Management Agreement (FMA) holder (Weyerhaeuser) was interested in understanding more about the current population status, habitat use and movement patterns of grizzly bears in a portion of their Drayton Valley FMA. In these areas, new approaches to both harvest design and access management would be undertaken in the winter of 2014 in identified core grizzly bear conservation areas. These new approaches had been brought forward by Weyerhaeuser Ltd. to address concerns about forest management operations in designated core grizzly bear recovery zones. As this work proceeded, other FMA holders (West Fraser Ltd.) and fRI partners (Alberta Environment and Sustainable Resource Development) were also interested in and would benefit from this research effort. Therefore, the 2013 original research plan was modified to ensure that the study area boundary would be appropriate and that research questions would meet the information needs of our partners.

The new forest management approaches that are being implemented and evaluated within this project include:

- Cutblocks were designed specifically with grizzly bears as the primary consideration.
- Harvest roads were placed to minimize line of sight using topography and planned in-block retention patches.
- Access was designed to utilize existing footprint and plans were made to decommission and reclaim roads as quickly as operationally feasible.
- Cutblocks were planned in the context of a larger scale landscape to maximize connectivity opportunities between areas of higher value habitat.
- In-block structural retention was pre-planned in some cases and strategically placed to maximize edge relative to the surrounding habitat matrix.
- Shape and placement of harvest blocks was developed in consultation with provincial grizzly bear experts to improve habitat value.

Our research team and project partners recognized that from the outset understanding and documenting grizzly bear response to different forest management strategies might not be possible within a two year time frame. Hence, this project was structured to gather data for one year during the pre-harvest and construction phase (2013) followed by a year of data collection during operations (2014). Data collection would then halt for 3 years and resume in 2018. The first year of this project (2013) was funded by Weyerhaeuser, fRI and Alberta ESRD. With the recognition that DNA data collection would occur within an expanded study area (~50% of Bear Management Area 3) in 2014, the project leader identified an opportunity for the provincial government to conduct a repeat of the 2004 population inventory. As a result a partnership was formed, related to the DNA population inventory work that was supported by FRIAA, Weyerhaeuser, West Fraser, AESRD and fRI for data collection on this topic in the 2014 field season.

2. Introduction

Grizzly bears are a forest resource valued at the provincial, national, and international levels. Often referred to as an umbrella species or indicator of forest ecosystem integrity, maintaining Alberta's grizzly populations is important not only from a conservation stand point, but because of the potential benefits to other species and biodiversity. However, grizzly bears are designated threated in Alberta largely a result of relatively low population size provincially and increased human access and activity within grizzly bear range. Anthropogenic activities, whether industrial or recreational, that occurs within grizzly bear habitat such as development from the energy (mining, oil and gas) and forestry sectors as well as fishing, hunting, and off highway vehicles (OHV) threatens the persistence of Alberta's grizzly bear population . This is because road development may lead to bear human encounters and subsequently higher mortality risk for grizzly bears. Even though a moratorium on hunting was introduced in 2006 and a recovery plan has been in place since 2008, grizzly bears continue to experience high levels of human caused mortality that ultimately hampers recovery efforts.

On the other hand, anthropogenic activities such as forest harvesting also creates early seral habitat that may enhance grizzly bear habitat through the availability of seasonally important bear foods. Research has shown that grizzly bears respond favorably to heterogeneous habitat conditions such as the matrix of different forest seral stages, which creates an abundance of forest edge habitat where food resources are abundant. In most cases opening the forest canopy through timber harvest and having adjacent older (uncut) fire origin stands appears to have positively influenced grizzly bear habitat over time. However, the combination of high resource value associated with food coupled with high mortality risk means that these areas can become ecological traps or sink habitat – habitat that grizzly bears are attracted to, but that they are also likely to die in. However, with effective access and resource management planning, sink habitats can be reduced or eliminated allowing bears to persist within a multi-use landscape. Maintaining grizzly bears in conjunction with the wise and sustained use of other forest resources such as timber growth and production and the development of the energy sector, will demonstrate to the public and stakeholder groups that the use of forest resources in a sustainable manner is being actively pursued through applied management.

Although the focus of land management in these areas has been to maintain open road densities below certain thresholds, this can be a challenge for forestry companies given the socio-economic climatic of Alberta and operational challenges relative to access management and forest harvest planning. Yet, there remains ongoing concern regarding forest harvesting operations and how harvesting can proceed in Alberta's grizzly bear recovery zones. Although maintaining open road densities in provincial core grizzly bear conservation zones below 0.6km/km^2 has been recommended, to date there has been no approved plans concerning access management to meet this target. In addition, there have been no attempts to evaluate if new approaches to forest harvesting, that considers exclusively road construction and cutblock design in terms of maintaining high value habitat while minimizing the risk of human caused grizzly bear mortalities, are possible and how this might influence the movements and habitat use of resident grizzly bears.

This project moves us beyond what is currently known about grizzly bear response to forestry activities as we aim to investigate change in response over longer time frames. The evaluation of new suggested harvesting prescriptions have not been tested or evaluated relative to bear behavior or numerical response of the population. This research effort is focused on assessing new forest management approaches to address access planning and forest harvest design to support continued use by grizzly bears and to reduce human caused grizzly bear mortality risk. Additionally, this work allows the use of historic data (1999-2003) in conjunction with current data sets when comparing different harvesting and road management strategies to the traditional two pass systems with open road networks. The ability to build on existing data sets gathered over a 16 year period (and supported by both FRIAA funding and member companies during this time period) provides a valuable opportunity to assist the forestry sector in Alberta in understanding how their management activities can be better integrated with the ecological needs of grizzly bears and if new approaches can assist in provincial grizzly bear recovery efforts.

The work presented in this report focuses on improving our understanding of current grizzly bear habitat use and movements along with changes in the grizzly bear distribution and abundance in three provincial grizzly bear watershed units. These units are within the Yellowhead Grizzly Bear Management Area (BMA 3) and encompass core grizzly bear recovery zones within Weyerhaeuser's and West Fraser's Forest Management Agreement areas. By supporting this research program, FRIAA and member companies will work towards further integration of forestry practices that consider species-at-risk in an adaptive management framework that will support grizzly bear conservation and recovery in Alberta. In this way, FRIAA and its member companies will continue to show leadership and commitment to sustainable forest management in this province. This report is based on the first two years of data collected in this longer term research project and should be seen as an interim report with the currently available data.

3. Project Objectives:

1. Determine the minimum number of grizzly bears currently using the identified study area where forest harvesting activities are planned and were implemented.
2. Evaluate the current movement paths of a sample of radio collared grizzly bears within the study area.
3. Identify how new forest management practices may affect grizzly bear habitat use.
4. Creation of new landscape condition map products to assist with the evaluation of grizzly bear response to forest management activities and anthropogenic landscape change.

4. Study Area

The 2013/14 study areas comprised the Pembina region (2013) within the Yellowhead grizzly bear management unit (BMA 3). BMA3 is bordered by highways 16 and 11 to the north and south, National Parks (Jasper/Banff) to the west, and areas surrounding Drayton Valley and Rocky Mountain House to the east (Figure 1). It should be noted that provincially recovery plans include national park lands under federal jurisdiction as part of provincial grizzly bear management areas (BMAs).This region includes relatively small protected areas managed under provincial jurisdictions (Whitehorse Wildland and White Goat Wilderness); however, the majority of BMA3 is public land managed for numerous industrial and recreational activities (ATVs, fishing, and hunting). Industrial activities from development of the energy sector and forestry have resulted in anthropogenic footprint associated with open pit coal mines, oil and gas infrastructure and exploration, forestry cutblocks, and access roads. Currently, Weyerhaeuser (Drayton Valley) and West Fraser (Hinton, Edson, and Sundre) actively manage timber for commercial production following Forest Management Agreements established with the province.

Terrain in the study area is variable with rugged mountains to the south and west. This rugged mountain terrain transitions to more gently sloping or rolling hills to the north and east. Elevation across the study area ranges from 800 to 3360 meters, and complex topography creates strong environmental gradients in temperature and precipitation influencing over and under story vegetation associations. Vegetation is characteristic of the Rocky Mountain and Foothills Natural Regions with forests dominated by pure and mixed stands of conifer and deciduous species such as lodgepole pine (*Pinus contorta*) and trembling aspen (*Populus balsamifera*). Natural openings that would have resulted naturally from wildfire are relatively uncommon owing to a long history of fire suppression. In the absence of fire, forest harvesting is the main disturbance mechanism, which in west-central Alberta has occurred since the early 1950's. However, methods of harvest along with design of cutblocks have evolved from a two-pass system to one based on a natural disturbance paradigm, which over time has created a mosaic of early and mid-seral stage stands of variable size and shape.

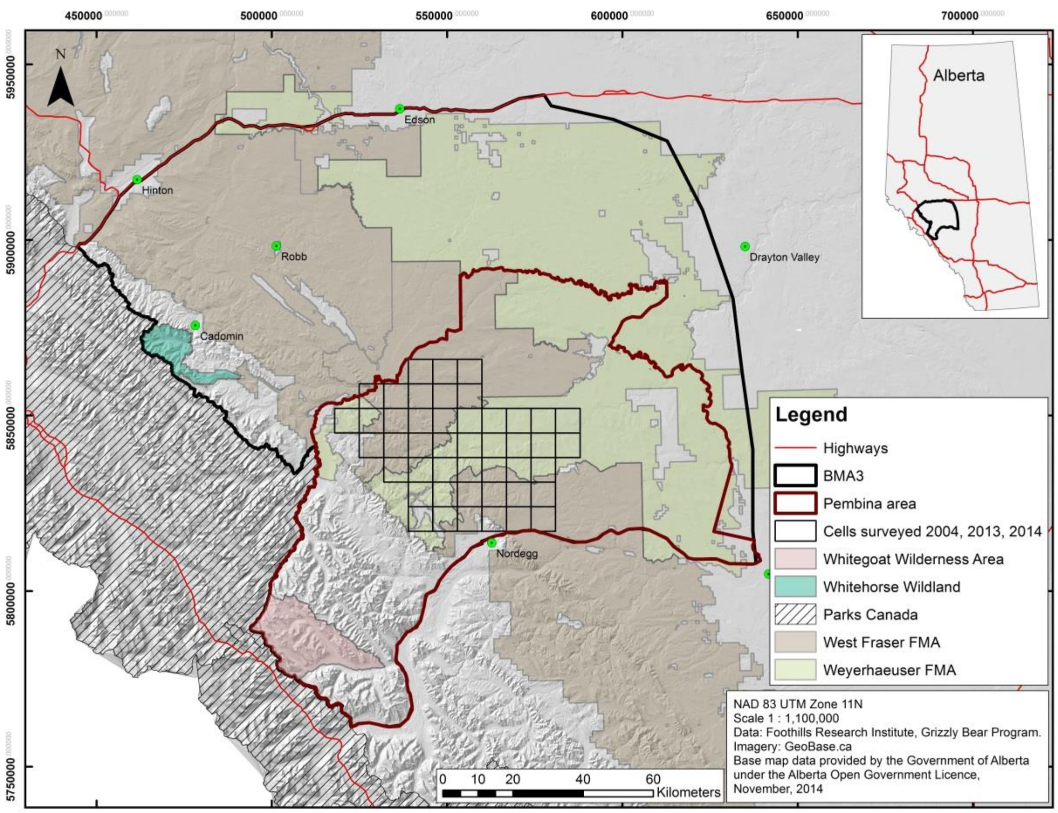

Figure 1: Map depicting Bear Management Area 3 in relation to the Pembina study area. Boundaries of parks and protected areas in relation to Forest Management Agreement holders are shown.

5. Field Activities 2013/14

In 2013, the fRI Grizzly Bear Program initiated the field component of the Pembina project which was also repeated in 2014. During these field seasons, there were two main components of data collection. First, grizzly bears were captured and collared (M5, F1) to gather habitat use and movement information. Second, we used barbwire hair snags to collect bear DNA. In 2013, capture and DNA sampling were restricted to the Pembina study area (Figure 1). The following year in 2014, we aimed to distribute collars within the Pembina area and further north to include the Rodney creek drainage. In addition to capture, we undertook DNA population inventory work within BMA3 for the second time since 2004 along with the southern half of Jasper National Park. The project was a collaboration between fRI in partnership with Alberta Environment and Parks, Parks Canada, Weyerhaeuser Drayton Valley and West Fraser Hinton-Edson-Sundre.

6. Distribution and abundance of grizzly bears in the Pembina study area.

Prepared by Anja Sorensen

Intro

Monitoring spatial and temporal trends in species' distribution and abundance is crucial to effective management and conservation efforts (Long, 2008; Kindberg et al., 2011). Traditional DNA hair sampling is ideally suited to monitoring rare or hard-to-capture species because hair can be collected remotely without having to catch or disturb the animal. In the Rocky Mountain eastern slopes of Alberta, the barb wire hair snag technique has proven to be an effective tool to monitor grizzly bear populations, since its first application in bear management area 3 (BMA3) in 2004. With a repeat inventory of BMA3 ten years later, we are now able to evaluate changes in the local grizzly bear population. In this report, our aim was to evaluate change in the distribution and abundance of grizzly bears in relation to changes associated with habitat quality, defined by a resource selection function model, and survival, defined by a mortality risk model, within a portion of BMA3 for 2004 and 2014. We refer to this sampling region as the Pembina study area.

Methods

The sampling design for the collection of DNA samples differed between years (2004, 2013, and 2014). In 2004, the first provincial population inventory of BMA3 established a network of 194 grid cells (7 x 7 km; Figure 1), which encompasses areas where bears were most likely to occur based on a grizzly bear resource selection function (RSF) model (Nielsen et al., 2002), GPS collar locations, remote sensing-based habitat maps, and aerial photographs. In 2013, a smaller portion of BMA3, consisting of 46 grid cells (7 x 7 km), was overlayed with the Pembina study area. In 2014, another complete inventory of BMA3 was undertaken using a grid design similar to that used in 2004, but with 197 cells. Each cell sampled in 2013 was resampled in the 2014 inventory (Figure 1). The 2014 sampling area also took into account the addition of a new project partner (West Fraser) that had their own specific geographic areas of interest relative to data collection. It is important to recognize that the non-invasive genetic sampling done for this FRIAA project was not intended to provide a population estimate for the study area, rather the data would be helpful in identifying the number (minimum count and gender) of grizzly bears that occurred within the study area in each of the two years where sampling occurred. We specifically designed the sampling to allow comparisons between and among the 2004, 2013 and 2014 datasets by only considering those grid cells that were present in each year of sampling.

Distribution and abundance of grizzly bears were sampled using barb wire hair snags (1 per 7×7 km cell) and surveyed over 14 day sampling sessions from June to August (Table 1). Each hair snag station consisted of approximately one 30 m length of barbed wire encircling 4-6 trees at a height of 50 cm above the ground. Each session, 2 L of scent lure, consisting of aged cattle blood and canola oil, was poured on woody debris piled in the center of the barb wire corral. During the 2004 census, hair snags were relocated to new sites after each sampling session to ensure adequate coverage of each cell. 2013 and 2014 surveys used fixed sites throughout the sampling period. Hair samples were collected at each site visit (every 14 days) and stored in paper envelopes. Following collection, we screened and sorted hair samples following previously methods. Samples were then sent for genetic analysis at the Wildlife Genetics Lab in Nelson, BC. Laboratory work that followed used multilocus genotyping of hair samples to 8 loci (7 microsatellites and 1 for gender) to identify individual bears.

Results

Comparisons of the 46 common cells sampled in 2004, 2013, and 2014 revealed changes in grizzly bear distribution and abundance between these snap shots in time. Genetic analysis of the 2004 hair samples identified four unique bears (Table 2, Figure 2A) within the area sampled. In 2013, 16 individuals were detected (Table 2, Figure 2B). Eight of these bears were previously known to researchers through capture efforts; however, none of the 16 bears detected in 2013 had been detected from the 2004 census. In 2014, 7 bears were detected (Table 2, Figure 2C), and all but one male bear had been previously detected in the 2013 census.

When examining changes in bear abundance, comparing individual cells in 2004 and 2014, 63% of the cells had no change in the number of unique bears that were detected; however, 20% of the cells showed a decrease in the number of bears detected (Table 3). When 2014 was compared to the 2013 census, 33% of grid cells had a decrease in bears detected (Table 4). Distribution patterns (bear presence or absence within a given cell) from 2004 to 2013 indicate an increase in the number of previously unoccupied eastern cells detecting bears in 2014 (Figure

3A). The overall decrease in bear detections from 2013 to 2014 obscured any similar observation of this pattern over the short term (Figure 3B).

We used RSF models for BMA3 as our measure of habitat quality for the study area (Nielsen et al., 2002). To represent sampling year that corresponded to a novel landscape, the spatial inputs to derive each RSF model were updated annually. The annual RSF models were then applied to the updated spatial layers to predict RSF values for each DNA census year. The mean RSF values of grid cells changed over time, with 72% of the cells having higher mean RSF values when 2004 was compared to 2014 (Figure 4A). However, over the shorter term, 70% of cells decreased in mean RSF value from 2013 to 2014 (Figure 4B). Similar steps were taken to match mortality risk models with annual DNA censuses. A preliminary evaluation revealed that between 2004 and 2013; mean mortality risk increased in 54% of grid cells.

We used multinomial logistic regression models to determine if observed changes in RSF or mortality risk within grid cells explained variation in bear abundance between 2004 and 2014. We coded cells as increase in individual bears detected (0), no change (1), or a decrease (2). However, this analysis was exploratory, as sample size was relatively low to perform multinomial logistic regression. Regardless, we were interested in the sign of the coefficient, rather than documenting statistically significant effects. Change in bear abundance from 2004 to 2014 was not a function of increasing or decreasing mean RSF values over the same time period (at a 7 x 7 km grid cell level). Coefficient values predicted positive (β=0.480, p=0.68) and negative (β=-0.08, p=0.93) changes in bear numbers that corresponded to an increase and or decrease in mean RSF value. A model predicting change in bear abundance within cells from 2004 to 2014 as a function of increasing or decreasing mortality risk from 2004-2013 was not informative, as coefficient values predicted negative changes in bear numbers with both increasing (β=-0.647, p=0.418)and decreasing (β=-0.647, p=0.378) mortality risk. However, given the low sample size, meaningful interpretation of these results are limited.

Discussion

Since the initial DNA hair snag census work in the Pembina study region in 2004, relative grizzly bear abundance appeared to have increased. This is also a similar conclusion reached by Stenhouse et al (2015) in their repeat population inventory of BMA 3 in 2014. Several factors may have influenced this response. The moratorium on hunting, implemented in

2006, combined with efforts to reduce human-caused mortality following the 208 recovery plan, may have contributed to an increase in the grizzly bear population. In the Northern Continental Divide Ecosystem of Montana, recovery efforts resulted in a mean annual population growth rate of approximately 3% (Mace et al., 2011). Within the Pembina area, an eastern shift in distribution seemed to have occurred, potentially indicating dispersal due to increased population density, however, the role of factors such as landscape change, industrial activity, or mortality risk have not been thoroughly examined. Further investigation is warranted to quantify the effects of past long-distance relocations of management bears, which may have augmented the BMA3 population. Over the past 10 years, 29 grizzly bears have been relocated to BMA3 from other management units, in this case, primarily from southern units.

While our preliminary multinomial logistic regression models where exploratory, the direction of coefficients indicate that the spatial configuration of changes from 2004 to 2014 in population abundance and distribution may be explained by patterns of change in RSF surfaces. The lack of statistical significance is not surprising, given the limited number of cells we were examining in this relatively small study area. Additionally, responses to changes in RSF or risk values were only examined at the scale of 7 km by 7 km grid cells. The influence of landscape change in habitat selection patterns may be more perceptible at the scale of a bear's home range. Following the conclusion of the 2014 census of BMA3, further analyses can now be conducted at a larger scale to evaluate changes in abundance and distribution estimates from 2004 to 2014.

Of the 6 bears detected in the 2014 survey, 5 had already been detected in 2013 hair snag sites, indicating that subsequent surveys on an annual basis are likely not necessary given the high costs of DNA surveys. However, none of the 16 bears detected in 2013 had been detected in the 2004 census. Over a 9 year period, an apparent population increase occurred within BMA3 that can now be examined and interpreted over a broad temporal scale. However, the value of frequent, repeated monitoring stems from additional information to estimate survival rates or detect shorter term responses to environmental or anthropogenic stimuli.

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Tables and Figures

Table 1. Dates of barb wire hair snag sampling sessions from three DNA surveys within the Pembina study area.

		2004		2013		2014	
Session	**Description**	**Start**	**End**	**Start**	**End**	**Start**	**End**
0	Hair snag site set up	25-May	7-Jun	4-Jun	13-Jun	27-May	5-Jun
1	First round of hair collection	8-Jun	21-Jun	18-Jun	27-Jun	10-Jun	17-Jun
2	Second round of hair collection	22-Jun	5-Jul	2-Jul	11-Jul	24-Jun	2-Jul
3	Third round of hair collection	6-Jul	19-Jul	16-Jul	25-Jul	8-Jul	16-Jul
4	Fourth round of hair collection (site take-down 2004 & 2014)	20-Jul	3-Aug	30-Jul	10-Aug	22-Jul	31-Jul
5	Fifth round of hair collection (site take-down 2013)	-	-	13-Aug	22-Aug	-	-

Table 2. Changes in the number of unique bears detected within 46 (7 x 7 km) cells within the Pembina study area.

Census year	Number of unique bears detected	Males	Females
2004	4	3	1
2013	16	11	5
2014	7	4	3

Table 3. Change in bear abundance in DNA census cells (7 x 7 km) within the Pembina study area from 2004 to 2014

Cells within the Pembina study area	Count	Percentage
Cells with a **decrease** in the number of unique bears detected	9	19.57%
Cells with an **increase** in the number of unique bears detected	8	17.39%
Cells with **no change** in the number of unique bears detected	29	63.04%
Total	46	

Table 4. Changes in bear abundance in DNA census cells (7 x 7km) within the Pembina study area from 2013 to 2014

Cells within the Pembina study area	Count	Percentage
Cells with a **decrease** in the number of unique bears detected	15	32.61%
Cells with an **increase** in the number of unique bears detected	5	10.87%
Cells with **no change** in the number of unique bears detected	26	56.52%
Total	46	

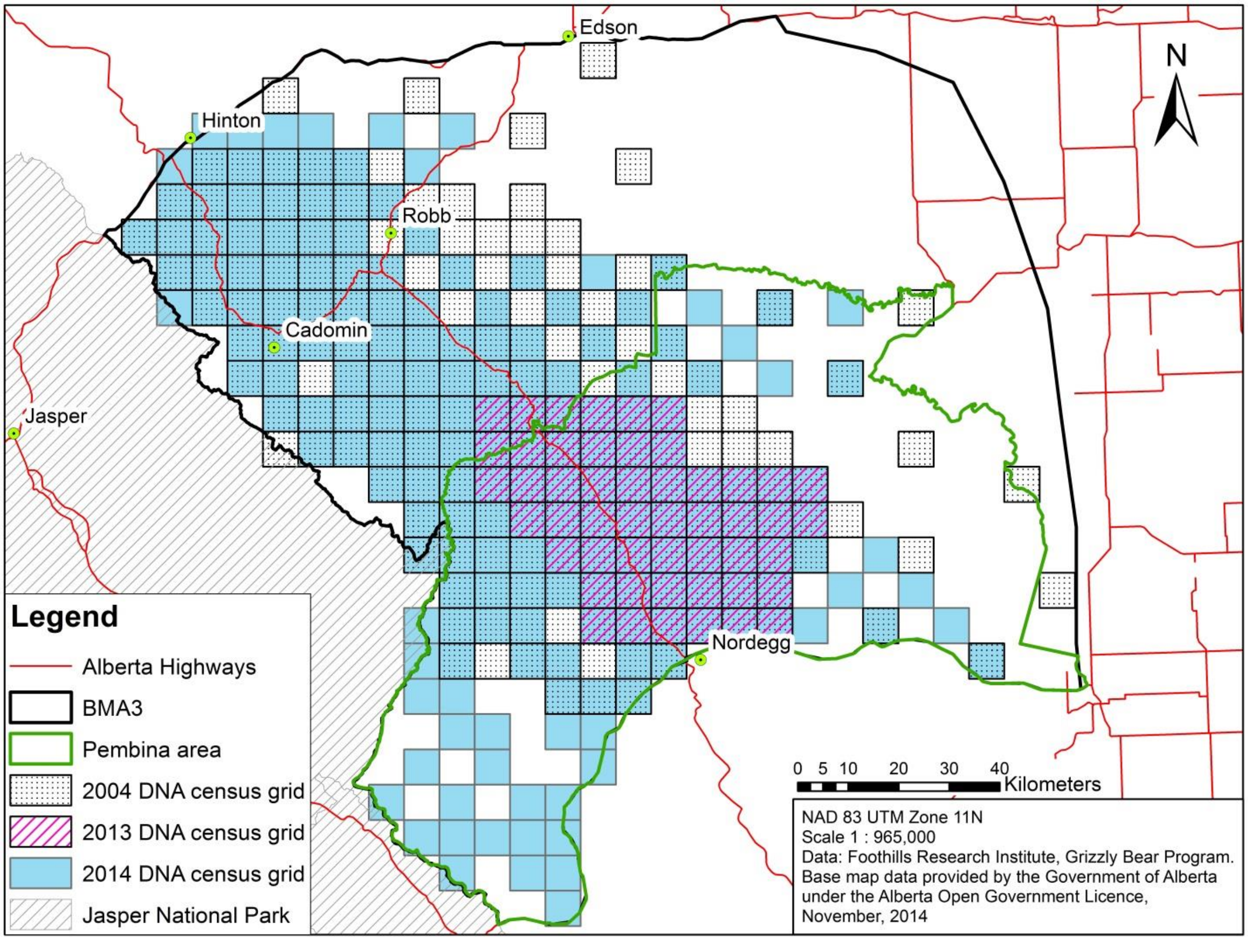

Figure 1. DNA sampling cell design for the 2004, 2013, and 2013 hair snag surveys. 2004 and 2014 efforts were aimed towards surveying primary and secondary grizzly bear habitat across BMA3, whereas the 2013 census focused on the Pembina study area.

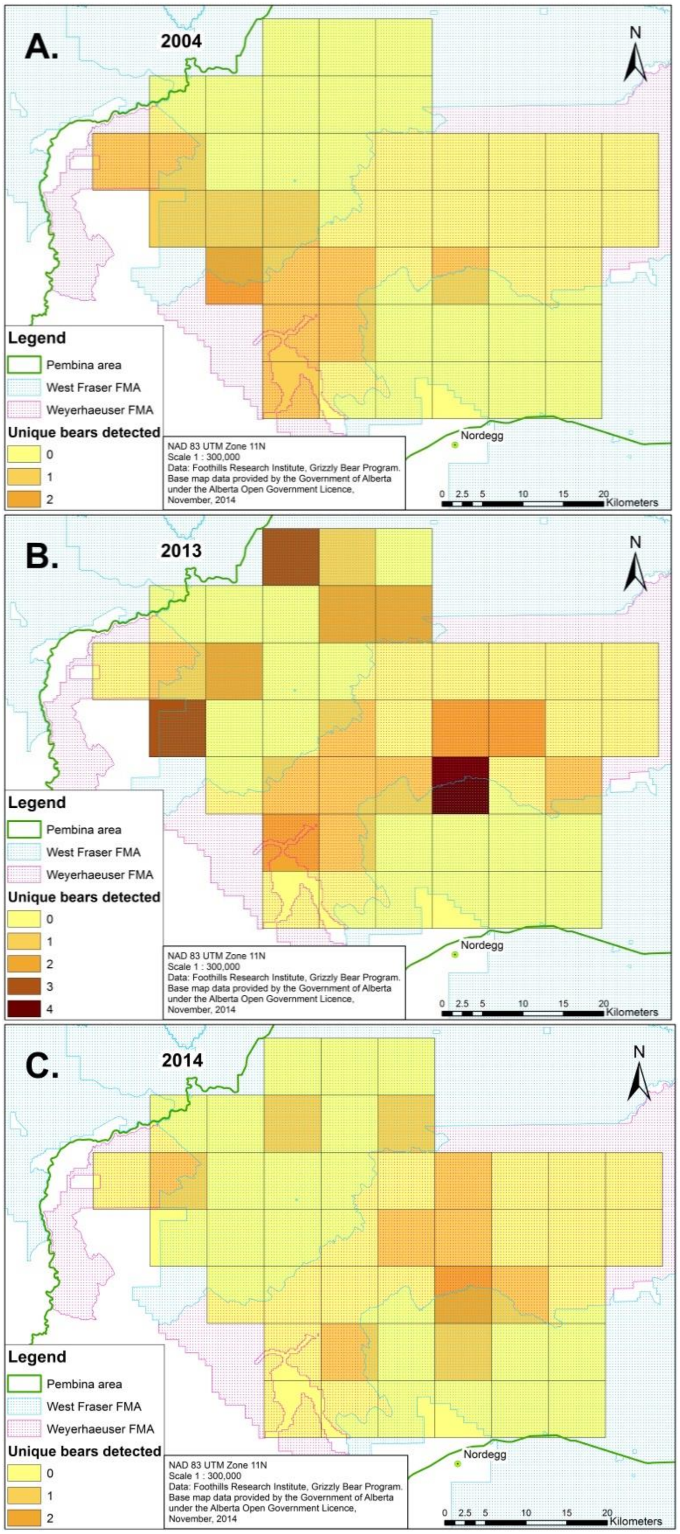

Figure 2. Number of individual bears detected within the cells common to the 2004, 2013, and 2014 DNA census' that occurred within the Pembina study area.

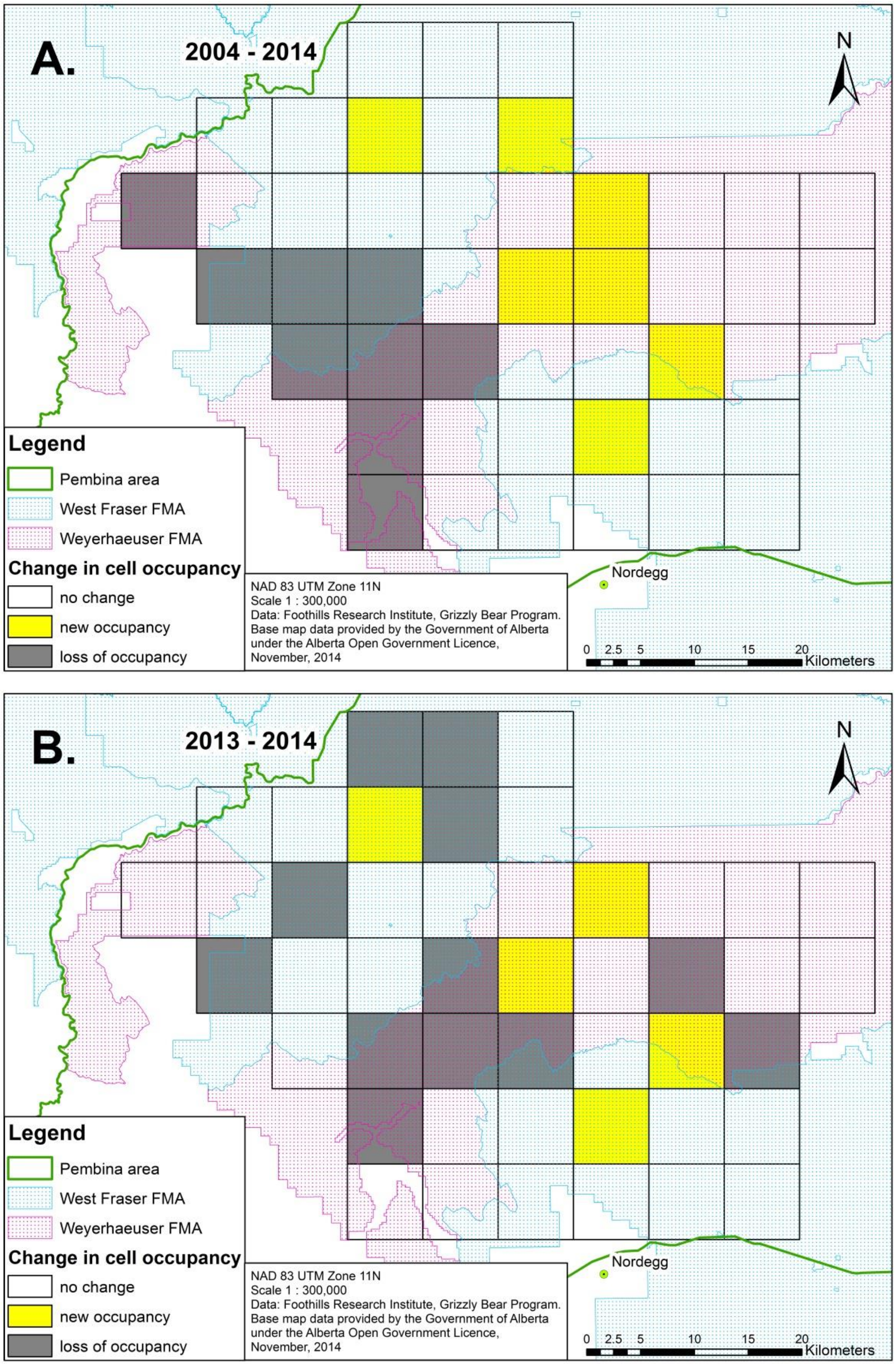

Figure 3. Change in the occupancy of common cells between the 2004 and 2014 DNA surveys (A), and the 2013 and 2014 surveys (B). Occupancy is defined by the detection of one or more grizzly bears within a given cell.

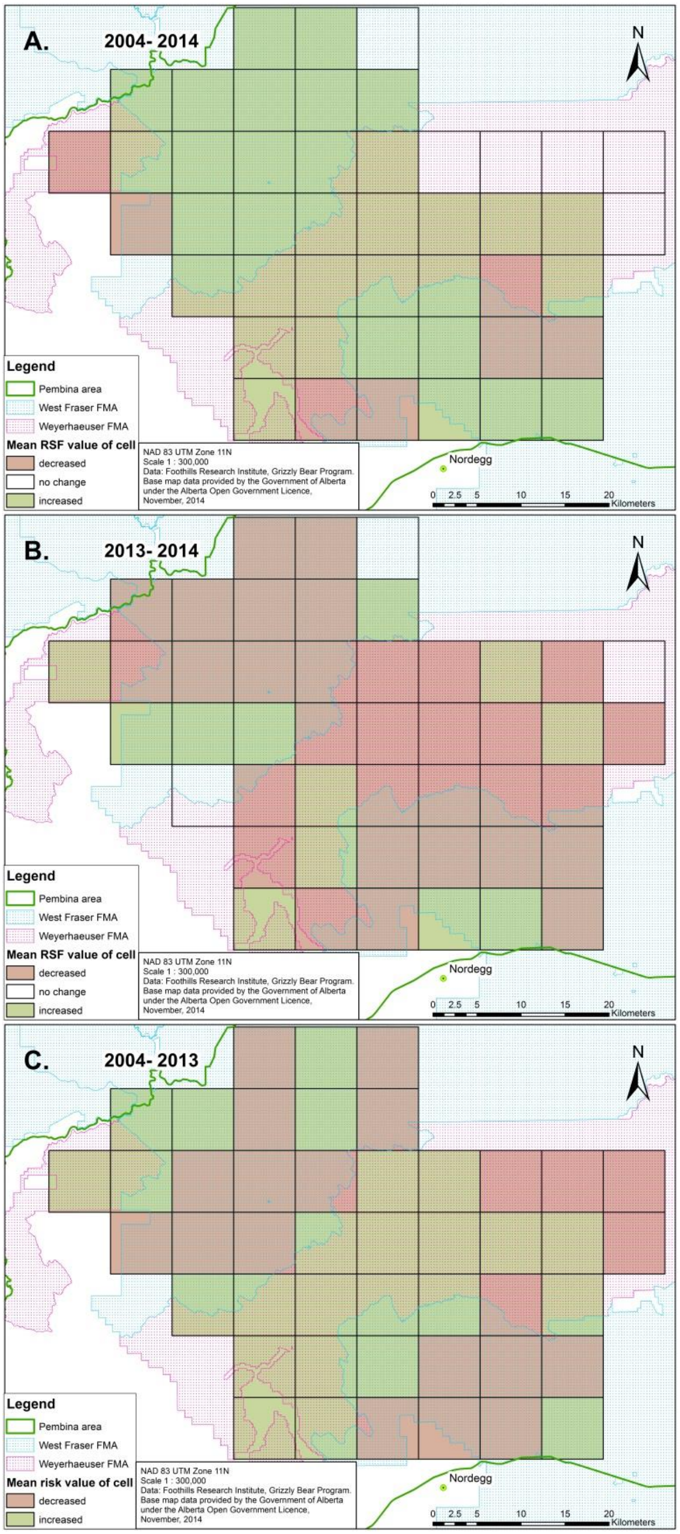

Figure 4. Changes in the values of grid cells (7 x 7km) within the Pembina study area relative to A) Mean RSF value from 2004 to 2014; B) Mean RSF values from 2013 to 2014; and C) Mean mortality risk from 2004 to 2013.

7. Grizzly bear response to roads when using forestry cutblocks: does proximity and density of road types influence habitat selection?

Prepared by Terry Larsen

Introduction

Population recovery of grizzly bears within Alberta's multiple use landscape, like many other North American systems where recovery has been proposed or implemented (Merrill et al., 1999; Boyce and Waller, 2003; Summerfield et al., 2004, Schwartz et al., 2006; Alberta Grizzly Bear Recovery Plan 2008-2013. 2008.), is dependent on reducing human-caused mortalities, particularly females and females with cubs (Boulanger and Stenhouse, 2014), associated management of access features such as roads (Alberta Sustainable Resource Development and Alberta Conservation Association, 2010). Although human attitudes towards bears will also play a fundamental role in reaching conservation and recovery objectives (Boulanger and Stenhouse, 2014), as road networks associated with the energy and forestry sectors continue to increase (White et al., 2011), access management (limit road development, decommissioning roads, establishing gates), particularly within core grizzly bear conservation areas (Nielsen et al., 2009; Boulanger and Stenhouse, 2014), will be critical towards maintaining secure habitat for grizzly bears to ensure population persistence.

The benefit of habitat security associated with access management is not limited to mitigating issues surrounding mortality risk. Grizzly bears that use anthropogenic disturbances such as forestry cutblocks are likely to benefit from seasonally available food resources (Nielsen et al., 2004ab), especially along adjacent uncut edges (Larsen, In prep). Higher levels of food resources available to bears is postulated to be the causal mechanism linking higher body condition indices and lower levels of hair cortisol concentrations, an indicator of stress, to the use of anthropogenic land use features (Bourbonnais et al., 2013, 2014). In fact, bears that use areas of higher road density also tend to have higher body condition indices. Disturbances such as cutblocks in the absence of road networks may improve habitat conditions for bears leading to population growth (Nielsen et al., 2008; Boulanger and Stenhouse, 2014).

Grizzly bears have demonstrated the ability to adjust their habitat selection in response to the spatial and temporal distribution of human activities and roads (Nielsen et al., 2004a; Martin et al., 2010), whereas certain individuals may not perceive roads are risky. On the other hand, grizzly bears might avoid roads all together possibly due to certain road types having higher levels of traffic volume potential (Northrup et al., 2012). The result would be a potential loss in available foraging habitat that could reduce population productivity and hamper recovery efforts. Recently, Weyerhaeuser (Drayton Valley) took steps towards designing cutblocks that reduces grizzly bear mortality risk in core grizzly bear recovery zones by decommissioning roads as soon as is operational feasible. In this case, understanding grizzly bear space use patterns in relation to roads can help guide access management decisions such as where road decommissioning, limiting human access or reducing road density would have the most conservation benefit.

Here we use a long term GPS location dataset from collared male and female grizzly bears within the Yellowhead bear management unit (BMA3) to evaluate behavioural responses of bears to roads relative to their proximity (distance, nearest road) and density when using forestry cutblocks seasonally. At a regional level, the Yellowhead population unit (BMA3) was identified as an important candidate for immediate action relative to reducing mortality levels as other population units (i.e., Grande Cache) might be more stable (Alberta Sustainable Resource Development and Alberta Conservation Association, 2010). Our goal is to understand whether or not bears avoid or select certain types of roads, which we assume correlates with the traffic volume potential associated with anthropogenic land use activities. We hypothesize that bears would not trade-off risk of mortality with rewards of food by selecting roads with lower levels of traffic volume potential and lower road density. In this study, we contrast responses of bears in BMA3 (all bears) to a local group of animals we captured near Nordegg, Alberta, Canada, for this project, which we refer to as the Pembina bears.

Our specific research questions were:

1. Do grizzly bears select or avoid areas of cutblocks in response to road proximity and/or density?
2. Does road type influence the seasonal selection of cutblocks and does this vary seasonally or between male, female, and Pembina bears?

Methods

Grizzly bear capture and monitoring

We captured grizzly bears within the BMA3 study area between 1999 and 2014 using leg-hold snares, culvert traps, or by way of remote drug deliveries from a rotary-winged aircraft (Figure 1). However, we did not use leg-hold snares after 2008 because of the potential negative effects associated with this capture technique (Cattet et al., 2008). During anesthesia, we fit each grizzly bear with a GPS collar programmed to collect locations hourly (after 2004) or every four hours (prior to 2004) over a two year period, and we extracted a pre-molar tooth to determine the age of each animal (Mattson et al., 1993). GPS locations were either downloaded via satellite or by relocating each animal monthly. Following capture and throughout the course of our monitoring, we attempted to identify whether or not females had cubs and if they were subsequently lost.

Road databases

We used databases obtained from the Government of Alberta (GOA), Foothills Research Institute (fRI), and West Fraser and Weyerhaeuser Forest Management Agreement (FMA) holders to spatially represent linear access features (roads) across the study area (Figure 1). More specifically, we amalgamated four spatial databases containing arc representations of the Alberta road network along with attribute information into a single and comprehensive database. We used the Integrate Tool in ArcGIS 10.2.2 to combine road segments that differed spatially, but that appeared to be the same road (10m tolerance), and through a series of spatial joins (1m tolerance) we retained attribute information. Where attribute information was available, we assigned road segments a construction year, otherwise, construction year was estimated from annual satellite imagery (e.g. Landsat and SPOT5). We then used attribute information to classify road segments by type (condition/quality), which was based on the assumption that road type would be correlated with traffic volume from anthropogenic land use activities (Table 1).

Cutblock databases

We used cutblock databases obtained from Weyerhaeuser and West Fraser forest companies to spatially represent harvested areas within FMA boundaries. We assigned each cutblock a harvest year based on associated attribute information (skid clear date). Harvest year was then used to populate the roads database where roads in cutblocks without a construction year were absent. Where in-block retention patches could be discerned, we considered these patches of uncut forest as part of the cutblock. Finally, we calculated the area of each cutblock in hectares.

Road distance and density determination

Corresponding to each year of grizzly bear GPS location data, we calculated the Euclidean distance (30 x 30m pixel) to and density of each road by type. This included the nearest road for distance and all roads for density. For our density calculations, we used a radius of eight and six kilometers for male and female grizzly bears, respectively. These values corresponded to the mean daily movement of bears as measured by step length of successive GPS locations. However, we did not include decommissioned/reclaimed roads in our density calculations.

Use-available data and variable coding

We considered male and female (without cubs of the year) grizzly bears that occurred in cutblocks and that had 35 or more GPS locations (use) in each of three seasons as our use dataset. Seasons were defined as spring (May 1 – June 15), 2) summer (June 16 – July 31), and 3) fall (August 1 – October 15), which characterizes broad changes in food resource availability that intern influences bear behaviour and habitat use (Munro et al., 2006; Nielsen et al., 2010). We then defined home ranges for individual bears by 100% minimum convex polygons (MCP’s) that we generated with Geospatial Modelling Environment within ArcGIS 10.2.2 (Beyer, 2012). For our available dataset, we generated random locations within cutblocks for individual grizzly bear home ranges at a point density of 5/km^2.

For our use-available datasets, we created variables to represent cutblock age (yrs.) and area (ha) as well as the distance (m) to and density of each road type. We ensured that our use locations reflected landscape conditions matched to the GPS location year for each bear, whereas our available locations reflected landscape conditions associated with the most recent year for each bear. We used a binary variable to distinguish young (0-20yrs) and old cutblocks (>20yrs) and treated cutblock area as a continuous measure ([log(ha+1)]). Our intent was to control for known factors that influence habitat selection associated with cutblock attributes (Nielsen et al., in prep) and then determine the strength of support for models that include additional variables for road proximity and density. We treated road distance variables as continuous, but transformed to exponential decays of the form $e^{-\alpha d}$ where α was set to 0.002 and d was the distance (m) to each road type (Table 1.). This ensured that the effect of road distance on bear behaviour would not be spurious since responses to linear features such as roads are likely to decline over a relatively short distance of a few hundred meters (Nielsen et al., 2009). After data exploration, we decided to only include the all roads variable as our measure of density since all roads were highly correlated ($r = |>0.9|$) with tertiary roads. We created a categorical variable to also identify the nearest road by type as a means to evaluate what roads tended to be available to bears. Data exploration revealed that the availability of main and secondary roads was low to absent (≤5% availability) for certain individuals (Mysterud and Ims, 1998), so we group main and secondary into a single road type (hereafter main roads).

Resource selection analysis using logistic regression

We used a two staged approach to model grizzly bear habitat selection (Mysterud and Ims, 1998). In the first stage, we used logistic regression to estimate resource selection function (RSF) models for individuals for three seasons where availability of resource units were defined for each animal at the home range level (Manly et al., 2002; Johnson et al., 2006). For each individual, we held availability constant across seasons to ensure regression coefficients reflected changes in bear resource use rather than changes in available resources. Our approach to model selection was three fold and employed the use of Akaike Information Criteria corrected for small sample size (AIC_c) (Burnham and Anderson, 2002). First, we fit models with individual (age or area), additive (age + area), and interactive (age * area) effects of our forest age and area variables. We then retained the model with the lowest AIC_c score that was compared to a null (intercept only) model (Burnham and Anderson, 2002). For bears without both categories of cutblock age (≥5 locations), we only considered the effect of cutblock area on those individuals. Second, we fit individual and additive models considering all possible combinations of our road distance variables and followed the same model selection approach as before. Third, we fit models selected *a priori* and used Akaike weights (w_i) to assess the strength of support for each model, but after eliminating any models with uninformative parameters (Burnham and Anderson, 2002; Arnold, 2010) (Table 2.). Prior to model fitting, we checked for correlation (r<|0.7|) amongst the candidate model set.

In stage two of our RSF analysis, we obtained population level estimates of selection for each variable of interest by taking the models with the highest Akaike weight from stage 1 and averaged the regression coefficients for those animals (male, female, and Pembina bears) that showed a response. Coefficients were then weighted (inverse variance weights) by using the standard errors of the estimates thereby accounting for differences in sample size between individuals and the precision of estimates (Sutton et al., 2000). Our approach appropriately used the individual animal as the sample unit. Negative selection coefficients (<0) would indicate bears select cutblock areas close to roads or where road density was low. When standard errors overlap 0 we assume random use of the landscape – no selection.

Results

We used 9532 GPS locations from male (n=13) and female (n=16) grizzly bears of which Pembina bears (M5, F1) were comprised of to assess seasonal response of bears to road proximity and density at both the individual and population levels. However, in our logistic regression analysis we did not fit age variables for certain male bears, four in the summer and three in the fall, and female bears, one in the spring and two in the fall, because one of the two forest age classes was not available to those animals. Similarly, we did not fit models of RdDist3 for male bears, two in both the summer and fall, because of unrealistically large regression estimates.

The results of our three fold model selection procedure during stage 1 of our analysis suggested that male and female bears did not always respond to our variables of interest, particularly the road distance variable during the summer season (Table 3 and 4). However, when bears responded to road distance or road density variables, variation was more pronounced for road distance with more animals consistently responding to road density. Individual and population levels models provided complimentary information and improved our ability to interpret grizzly bear response where strong relationships could mask potentially opposing effects. Overall, we found support for our top AIC_c selected *a priori* models based on Akaike weights (range 0.7 - 1; mean 0.95) considering the candidate models (Table 3 and 4).

Habitat selection by grizzly bears varied, more so, in response to the types of roads than in relation to road density (Table 5). However, for main roads, responses by male, female, and Pembina bears were consistently positive, meaning that bears tended to be further away compared to random. However, in the summer and fall, there were proportionately more bears closer to main roads (Table 5). Seasonal variability was evident for male and female grizzly bears in response to tertiary and decommissioned road distance. Grizzly bear response to road density was consistently negative (avoidance), meaning that bears tended to select areas of cutblocks where road density was low. Compared to females, male bears tended to have stronger negative responses to road density. For females at the population level, the strength of the negative relationship appeared to decrease from spring to fall (Figure 2).

Discussion

Our study suggests that road proximity and density influence grizzly bear space use patterns. The results of our individual and population level analysis support our hypothesis that when bears use forestry cutblocks, on average, they do not trade off security for food. We found that bears tended to select for areas of cutblocks with low road density, were further away from main roads, and closer to tertiary and decommissioned road. Because of their quality and remoteness, these roads would likely have lower levels of traffic and human activity that may be perceived as risky to bears (Wielgus and Vernier, 2003). Our results are similar to other studies that have found bears using spatial (habitat) and temporal (time of day) strategies to avoid roads and human activity by selecting for secure habitats or habitats with low human activity (Kasworm and Manley 1990; Gibeau et al., 2002; Martin et al., 2010). Even areas of high road density may be used by grizzly bears where traffic levels are comparably low (Northrup et al., 2012). Although we did not assess bear response to the time of day, variability associated with tertiary and decommissioned roads could be explained by bears using cutblocks at night (Nielsen et al., 2004a). Our results also suggest that even though bears appear to be generally risk adverse, bears appear to be trading off risk (mortality) and reward (e.g., food) as certain individuals selected areas of cutblocks in proximity to main roads and where road density was high. These areas would likely have higher levels of human activity and traffic, thus, higher mortality risk. This finding is important and highlights the need to assess both individual and population level responses when drawing inference from habitat selection studies (Gillingham and Parker, 2008).

The results of our study showed that variation in bear response to tertiary and decommissioned roads was seasonally dependent, which suggests that foraging opportunities, ease of locomotion, and/or male avoidance by females could explain this difference (Roever et al., 2008a,b; Roever et al., 2010; Nielsen et al., In prep). While several mechanisms may explain road side selection behaviour of bears, we suspect that food availability is likely a major determinant influencing both the use of roads and habitats that are near roads. Roever et al. (2008a) showed that certain foods were more likely to occur along roads than interior forests. Forbs such as clover which are planted to promote bank stability (e.g., clover) or simply occur because the species in question responds positively to disturbance (e.g., sweet-vetch roots) may attract bears to roads (Nielsen et al., 2004b; Roever et al., 2008a). Because decommissioned roads are likely not planted with forbs, we postulate that food availability associated with specific road types may differ. However, further research is needed to gain a more mechanistic understanding of bear responses observed in this study.

In studies of grizzly bear habitat selection, road density is often an important predictor and responses can be either positive or negative. Our research showed that bears were generally avoiding areas of high road density when using cutblocks. This result is important and consistent with other studies of grizzly bear habitat selection (Mace et al., 1996; Nielsen et al., 2002). Although bears may benefit (body condition) from using cutblocks and in areas of high road density (Boulanger et al., 2013), local habitat value (foraging opportunities) can also be reduced if responses are negative. McKay (2014) showed that the use of oil and gas well-sites by grizzly bears, which are typically used as foraging patches, decreased with increased road density. In addition, road density can also negatively influence other habitat values for bears. Pigeon et al. (2014) found that road density reduced the potential suitability of areas for denning.

Our study, like many others, suggests road density is a conservation and management problem in Alberta. Not only can bears be displaced from high valued habitat, but perhaps more importantly is the potential negative effect of road density on grizzly bear abundance (Apps et al., 2004; Nielsen et al., 2010). Recently, Boulanger and Stenhouse (2014) showed that higher road densities were associated with lower survival probability of subadult bears as well as females and females with cubs (Boulanger and Stenhouse, 2014). Because bear population demographics are sensitive to female mortality (Schwartz, 2006), the effect of roads are perhaps exacerbated in Alberta given that females with young are even at a higher risk of mortality than what was previously thought (Boulanger and Stenhouse, 2014). Our study exemplifies this as male bears responded more negatively than females, particularly in the summer and fall, when certain females were selecting for areas of cutblocks with higher road density

Management Recommendations

It is clear that the trade-off between mortality risk and high quality forage near roads needs to be addressed to ensure that important foraging habitats do not become attractive sinks (Nielsen et la., 2006; Roever et al., 2008b). Access management has the potential to benefit Alberta's grizzly bear population and ensure recovery and long term persistence of the population not only by reducing human caused mortality risk, but by improving habitat conditions for bears, especially females. However, access management is a contentious issue and not easy to manage given that within a multiple use landscape it may be difficult or even cost prohibitive to implement an effective management plan. With this new information, access management strategies can be developed that considers the type of road given what land use activities might be occurring and the value of the surrounding habitat.

The proposed strategy of forest companies in west-central Alberta to design cutblocks such that human caused mortality risk is reduced through road decommissioning once operational activities associated with harvesting have ceased is commendable. However, how to deal with existing roads and roads that require longer-term access such as oil and gas infrastructure certainly is a management challenge. We suggest that with permanent roads (main/secondary) it would be prudent that regular patrols by enforcement officer are conducted, particularly during the fall hunting season when bears may be attracted to roads more so than other times of the year. Although patrolling tertiary roads would also be important, the greatest benefit for grizzly bears would be to decommission tertiary roads. However, if decommissioning is not possible we advocate the use of gates as it can be an effective way to reduce human activity (Summerfield et al., 2004). But, it would be important to test their effectiveness first in Alberta, not only with regards to reducing human activity, but also with regards to bear response. Our research team is now embarking on a new project to answer this question. Access management, if effective, would be a step forward towards population recovery and conservation of grizzly bears in Alberta.

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Table 1. Classification, description, and variable coding of road types used to examine grizzly bear response. Classification of roads by type was hypothetical and based on assumed condition (quality) and traffic volume potential.

Road Type	Quality/Traffic	Traffic	Distance Variable Code	Description
Main	Excellent	High	RdDist1	Paved highways or major gravel roads (i.e., highway 40, forestry trunk road) that typically provides access to secondary roads.
Secondary	Good	Moderate – high		Gravel roads that provide access to areas across the study area, typically tertiary roads or decommissioned/reclaimed.
Tertiary	Fair	Low – moderate	RdDist2	Gravel or dirt roads (i.e., unimproved, truck trail, winter access) that may connect to main or secondary roads.
Decommissioned/Reclaimed	Poor	None - low	RdDist3	Dirt roads generally not passable that may connect to main, secondary, or tertiary roads.

Table 2. Models selected *a priori* to determine strength of support for our working hypotheses in an information theoretic framework.

Model	Model Structure	Description
1	Null (intercept only)	No response to spatial patterns.
2	Age/area	Cutblock attributes predicts grizzly bear response.
3	Age/area + RdDist	Cutblock attributes and road distance predicts grizzly bear response.
4	Age/area + RdDen	Cutblock attributes and road density predicts grizzly bear response.
5	Age/area + RdDist + RdDen	Cutblock attributes, road distance, and road density predicts grizzly bear response.

Table 3. Log likelihood (LL), parameter count (k), Akaike's Information Criteria (AICc) score, Akaike weight (w_i), and model structure of male grizzly bear resource selection function models for three seasons.

Season	Bear	*k*	LL	AIC_c	*wi*	Model Structure
Spring	17	5	-463.8	937.65	0.70	Age * Area + RdDen
	24	2	-221.1	446.13	0.81	RdDist2
	29	6	-384.9	781.9	1.00	Age + Area + RdDist1 + RdDist2 + RdDen
	33	5	-221.4	452.8	1.00	Age * Area + RdDen
	114	6	-267.1	546.32	1.00	Age + RdDist1 + RdDist2 + RdDist3 + RdDen
	130	4	-252.9	513.82	1.00	Age + RdDist1 + RdDist3
Summer	17	3	-350.3	706.51	0.90	Area + RdDen
	24	4	-389.5	787.05	0.92	Age + Area + RdDist2
	29	6	-297.6	607.24	1.00	Age + Area + RdDist1 + RdDist2 + RdDen
	33	3	-212.1	430.27	1.00	RdDist1 + RdDen
	50	6	-137.1	286.25	1.00	Age * Area + RdDist1 + RdDist2
	115	6	-670.5	1353.1	1.00	Age * Area + RdDist2 + RdDen
	127	3	-92.12	190.38	0.96	Area + RdDist3
	150	3	-122.6	251.2	1.00	RdDist1 + RdDist2
	151	4	-143.9	295.97	1.00	RdDist1 + RdDist3 + RdDen
	152	4	-246.6	501.2	1.00	Area + RdDist1 + RdDen
	154	6	-476.2	964.53	1.00	Age * Area + RdDist1 + RdDist2 + RdDist3
Fall	24	5	-440.4	890.87	1.00	Age + RdDist2 + RdDist3 + RdDen
	33	6	-281.7	575.48	1.00	Age * Area + RdDist1 + RdDist3 + RdDen
	53	3	-187	379.93	1.00	Area + RdDen
	115	6	-1013	2038.3	1.00	Age * Area + RdDist1 + RdDist3 + RdDen
	150	3	-653.1	1312.3	1.00	RdDist2 + RdDen
	152	3	-748.4	1502.9	1.00	Area + RdDen
	154	8	-403.1	822.35	1.00	Age * Area + RdDist1 + RdDist2 + RdDist3 + RdDen

Table 4. Log likelihood (LL), parameter count (k), Akaike's Information Criteria (AIC_c) score, Akaike weight (wi), and model structure of female grizzly bear resource selection function models for three seasons.

Season	Bear	*k*	LL	AICc	*wi*	Model Structure
Spring	12	4	-326.7	661.38	0.73	Age + RdDist2 + RdDen
	20	4	-433.6	875.3	0.97	Age + RdDist1 + RdDen
	36	3	-196.3	398.54	1.00	RdDist2 + RdDen
	37	4	-186.8	381.72	0.69	Age * Area
	100	3	-134.6	275.17	0.77	Age + RdDist2
	119	6	-233.6	479.23	1.00	Age + Area + RdDist2 + RdDistD3 + RdDen
Summer	12	5	-305.7	621.4	0.89	Age * Area + RdDen
	20	7	-470	954.11	0.91	Age * Area + RdDist1 + RdDist3 +RdDen
	23	3	-117.6	241.34	1.00	Area + RdDen
	36	2	-210.8	425.66	0.95	RdDen
	37	8	-370.4	756.96	0.91	Age * Area + RdDist1 + RdDist2 + RdDist3 + RdDen
	38	4	-94.69	197.5	0.87	RdDist1 + RdDist2 + RdDen
	40	7	-223.1	460.25	0.85	Age * Area + RdDist1 + RdDist2 +RdDen
	100	7	-141.3	296.74	0.98	Age * Area + RdDist1 + RdDist3 +RdDen
	118	6	-965.2	1942.5	1.00	Age * Area + RdDist1 + RdDen
	119	7	-221.2	456.61	0.95	Age * Area + RdDist1 + RdDist3 +RdDen
	153	4	-132.7	273.36	0.96	Age + Area + RdDist3
	155	4	-453.1	914.32	1.00	Area + RdDist1 + RdDist3
	301	6	-230.8	473.76	0.92	Age * Area + RdDist1 + RdDen
Fall	12	3	-285.2	576.44	0.7	Area + RdDist2
	20	4	-366.9	741.86	0.91	Area + RdDist2 + RdDen
	23	4	-141.3	290.72	0.7	Age + RdDist3 + RdDen
	26	5	-129.9	269.86	0.91	Age + RdDist1 + RdDist2 + RdDen
	36	3	-209.7	425.5	0.99	Area + RdDist1
	37	4	-304.5	617	1.00	Area + RdDist2 + RdDist3
	61	3	-142.9	291.95	0.99	Area + RdDist1
	100	5	-124	258.01	1.00	Area + RdDist1 + RdDist3 +RdDen
	106	5	-303.8	617.7	0.91	Area + RdDist1 + RdDist2 + RdDen
	118	8	-1151	2317.2	1.00	Age * Area + RdDist1 + RdDist2 + RdDist3 +RdDen
	119	6	-630.2	1272.5	1.00	Age * Area + RdDist1 + RdDist2
	153	4	-124.7	257.48	1.00	Age + Area + RdDen
	155	5	-781.2	1572.4	1.00	Area + RdDist1 + RdDist3 + RdDen

Table 5. The number of bears (n), number of coeficients estimated (β) based on AIC_c, number of positive coeficients (β+), and proportion of coeficients (Pp. β) and proportion of positive coeficients (Pp. β+) estimated for variables describing the habitat selection of male, female, and Pembina grizzly bears for three seasons. Proportion of positive coeficients for roads below 0.25 and above 0.75 are in bold.

		Spring					Summer					Fall				
Group	Variable	n	β	Pp. β	β+	Pp. β+	n	β	Pp. β	β+	Pp. β+	n	β	Pp. β	β+	Pp. β+
Male	Age	6	5	0.83	4	0.80	7	5	0.71	3	0.60	4	4	1.00	1	0.25
	Area	6	3	0.50	0	0.00	11	8	0.73	4	0.50	7	5	0.71	3	0.60
	Age X Area	6	2	0.33	1	0.50	11	3	0.27	1	0.33	7	3	0.43	2	0.67
	RdDist1	6	3	0.50	3	**1.00**	11	7	0.64	6	**0.86**	7	3	0.43	2	0.67
	RdDist2	6	2	0.33	1	0.50	11	6	0.55	3	0.50	7	3	0.43	2	0.67
	RdDist3	6	2	0.33	1	0.50	9	3	0.33	1	0.33	5	4	0.80	1	**0.25**
	RdDen	6	4	0.67	0	**0.00**	11	6	0.55	0	**0.00**	7	7	1.00	0	**0.00**
Female	Age	5	5	1.00	4	0.80	13	9	0.69	8	0.89	11	5	0.45	2	0.40
	Area	6	2	0.33	1	0.50	13	11	0.85	7	0.64	13	11	0.85	3	0.27
	Age X Area	6	1	0.17	0	0.00	13	8	0.62	1	0.13	13	2	0.15	0	0.00
	RdDist1	6	1	0.17	1	**1.00**	13	8	0.62	5	0.63	13	8	0.62	7	**0.88**
	RdDist2	6	4	0.67	2	0.50	13	3	0.23	0	**0.00**	13	7	0.54	3	0.43
	RdDist3	6	1	0.17	0	**0.00**	13	6	0.46	3	0.50	13	5	0.38	3	0.60
	RdDen	6	4	0.67	0	**0.00**	13	11	0.85	2	**0.18**	13	8	0.62	3	0.38
Pembina	Age						4	2	0.50	1	0.50	3	2	0.67	1	0.50
	Area						6	3	0.50	1	0.33	5	4	0.80	1	0.25
	Age X Area						6	1	0.17	1	1.00	5	1	0.20	1	
	RdDist1						6	4	0.67	4	**1.00**	5	2	0.40	2	**1.00**
	RdDist2						6	2	0.33	1	0.50	5	2	0.40	1	0.50
	RdDist3						4	4	1.00	1	**0.25**	3	2	0.67	0	0.00
	RdDen						6	2	0.33	0	**0.00**	5	5	1.00	1	**0.2**0

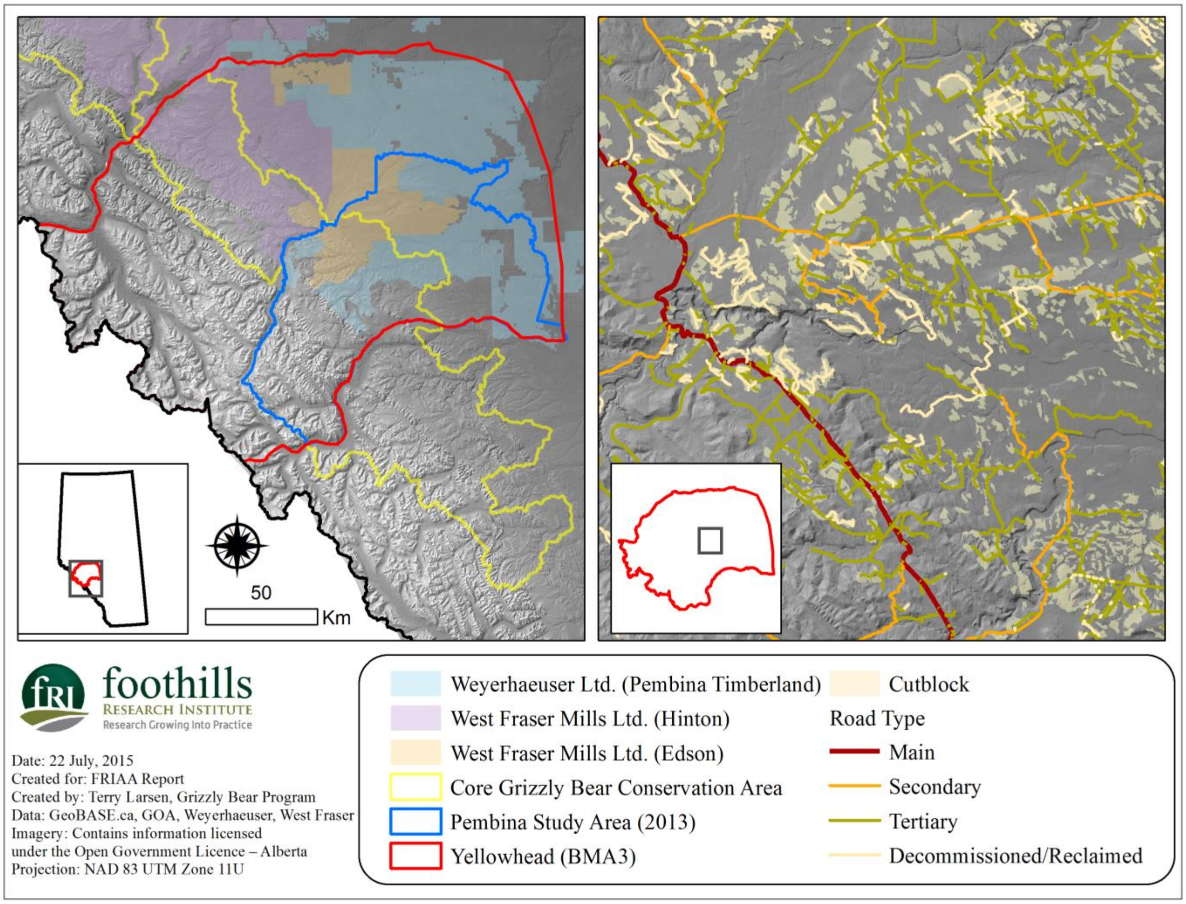

Figure 1. Study area map depicting the boundaries of the 2013 Pembina study area in relation to Forest Management Agreement holder areas and core grizzly bear conservation areas within the Yellowhead bear management unit (BMA3). An example of roads classified by type and relative to cutblocks is shown (right map).

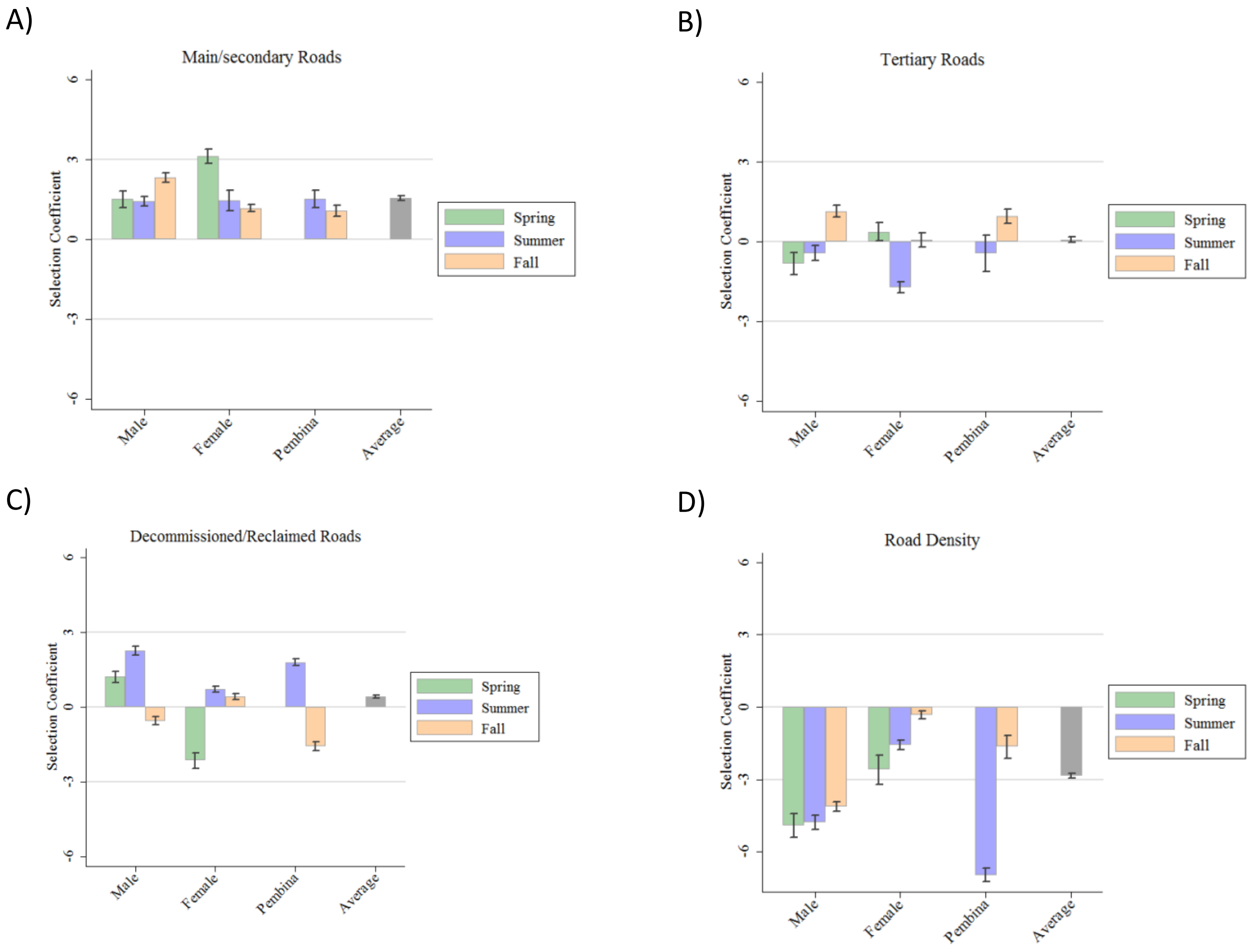

Figure 2. Grizzly bear response to A) main/secondary road distance, B) tertiary road distance, C) decommissioned/reclaimed road distance, and D) road density for three seasons and averaged across seasons. Selection coefficients (inverse variance weights) with standard errors represent the population averaged response of male, female, and pembina bears.

8. Exploring relationships among roads, forest harvest blocks and grizzly bear movement

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Introduction

The availability of wildlife telemetry data with high spatial and temporal resolution acquired using Global Positioning Systems (GPS) has expanded our ability to understand animal movement and refine existing hypotheses regarding how individuals move through the landscape and select habitat (Nathan et al., 2008; Cagnacci et al., 2010). Of primary interest is quantifying how wildlife movement is influenced and/or altered by human features, including roads and forest disturbance features (e.g., forest harvest blocks, oil and gas well-sites), and by human activities (e.g., resource extraction, backcountry recreation, tourism) (Kramer-Schadt et al. 2004; Rode et al., 2006; Fahrig and Rytwinski, 2009; Graham et al., 2010; Martin et al., 2013; McKay et al., 2014).

The grizzly bear population of Alberta, Canada occupies a landscape influenced by resource extraction and human activities. Human disturbance features such as roads contribute significantly to grizzly bear mortality (Nielsen et al., 2004a; Boulanger and Stenhouse, 2014), and there is growing evidence that human features influence the health of individuals (Bourbonnais et al., 2013; Bourbonnais et al., 2014). In contrast, human disturbances also contribute to the availability of resources (Nielsen et al. 2004b; Munro et al. 2006; Roever et al. 2008), and grizzly bears alter their selection of habitat dependent on the age, configuration, and density of human disturbance (Nielsen et al. 2004c; Linke et al. 2005; Berland et al. 2008; Stewart et al. 2012; Stewart et al. 2013). Individuals may also mitigate risk and increase resource selection by varying daily movement patterns around human features (Munro et al. 2006; Graham et al. 2010; Roever et al. 2010).

However, while several studies have examined habitat selection in relation to human disturbance features, our understanding of movement in relation to these features are still limited. By combining GPS positional data with new methodological approaches we can now begin to refine hypotheses regarding movement relative to roads and forest harvest blocks. In many cases, statistical attributes of GPS telemetry datasets related to movement are linked with behavioural patterns of the animal. For example, given a standardized fix rate (e.g., one GPS location per hour), variance in the linear distance between sequential locations (termed step lengths that correlate with turning angles and movement velocity) can be used to distinguish foraging or search behaviour (e.g., short step lengths) from transitory or exploratory (e.g., long step lengths) movements (Morales et al. 2004). The goal of this analysis was to quantify how movement parameters calculated from grizzly bear GPS telemetry data are influenced by roads and forest harvest blocks in the Yellowhead grizzly bear management unit.

Methods and Materials

Grizzly bear movement

We quantified movement parameters using GPS telemetry data collected during 2013 and 2014 from 24 male (n = 13) and female (n = 11) grizzly bears in the Yellowhead bear management unit. Telemetry data were collected at a temporal resolution of one hour. GPS locations were removed from the dataset if either the positional dilution of precision was greater than 10 or if the time between one hour fixes exceeded a ±10 minute moving window. This procedure screened consecutive locations that would have resulted in erroneous small or large movement parameters (Hurford, 2009). We calculated step length and turning angle statistics to characterize the movement trajectories of each of the 24 individuals. These metrics are commonly used as proxies to represent behavioural phases of movement trajectories and are fundamental components of more complex movement models (Calenge et al. 2009; McClintock et al. 2014). Step lengths represent the linear distance between consecutive locations (Figure 1). Turning angles are calculated based on the relative angle of the current step and the previous step, thereby characterizing the directional persistence between GPS locations (Figure 1). The relationship between step lengths and turning angles is non-linear (Figure 2). Given a consistent temporal interval between locations, turning angles close to zero are associated with longer step lengths, and as such are commonly used to represent “exploratory” movements (Morales et al. 2004; Fryxell et al. 2008). As turning angles increase, step lengths become shorter indicating a shift towards more restricted movement pattern and behaviours (e.g.,"encamped") (Morales et al.

2004; Nelson et al. 2015). For the purposes of this analysis, we focused on step lengths as the dependent variable to describe grizzly bear movements.

Road and forest harvest block data

Road and forest harvest block GIS data were provided by West Fraser, Weyerhaeuser, and Alberta Environment and Sustainable Resource Development. Attributes associated with each road included the type of road (e.g., main, secondary, or tertiary highway and decommissioned roads) as well as the approximate year of construction. Forest harvest block data included details regarding the harvest year, the harvested area, and the total perimeter of the harvested area, the ratio of the area and perimeter, and (when available) the potential inclusion of retention patches within each block. These attributes were associated with the origin of each step based on proximity of the step to the nearest road and forest harvest block. We also calculated annual and cumulative densities (km/km^2) of all-weather roads, forest harvest block area, and forest harvest block perimeter which were associated with the origin of each movement step.

Statistical analysis

Within this ongoing project we considered a number of exploratory methods to compare potential inter-annual or gender based differences in movements. As the step length distributions are substantially right skewed, we used a bootstrap Harrel-Davis estimator to compare the central tendency (50th percentile) and the upper (75th percentile) and lower (25th percentile) quantiles of the step length distributions (Wilcox et al. 2013). The statistic allowed us to assess significant differences in short and long movements between genders and across years.

As observed relationships between animal movements and landscape features are commonly observed to be non-linear (Johnson et al. 2002; Preisler et al. 2006; Mayor et al. 2009), we used generalized additive models (GAM) to quantify the relationship among step lengths, roads, and forest harvest blocks. GAMs incorporate non-linear relationships using non-parametric smoothing functions (Wood 2006). We fit separate GAMs for roads and forest harvest blocks by year. Smoothed approximations of continuous variables were modelled using thin plate regression splines with the degree of smoothing selected automatically by cross-validation (Wood 2006). We also considered the influence of gender, time of day (movements were classified as “day” or “night” based on sunrise and sunset times, e.g., Munro et al., (2006)), and season (movements were classified as “mating” from den emergence to July 31 and “post-mating” from August 1 to denning, e.g., Stenhouse et al., (2005)) on observed step lengths. Because we were interested in movements relative to roads and forest harvest blocks, we only considered step lengths within a 1 km radius of these features.

Results

Step length distributions of male and female grizzly bears in 2013 and 2014 were strongly right skewed showing a tendency towards short step lengths (e.g., < 100 m) with infrequent long movements (Figure 3 & Figure 4). Turning angle distributions were approximately uniform with slight increases in steps with a turning angle near zero (e.g., directional persistence) and in the tails of the distribution (e.g., encamped) (Figure 5 and Figure 6). Inter-annual and gender based comparison of the central tendency and tails of the step length distributions revealed a number of statistically significant differences. While the inter-annual distribution of short step lengths was not statistically different ($p = 0.06$) for males, median step lengths were longer ($p = 0.00$) in 2013 (93.37 m) compared to 2014 (72.15 m) and 75th percentile step lengths were shorter ($p = 0.00$) in 2013 (424.30 m) compared to 2014 (616.33 m) (Figure 7A). Female step lengths were shorter ($p = 0.00$) in 2013 compared to 2014 in all three quantiles considered (Figure 7B). Comparing genders, in 2013 female step lengths were shorter ($p = 0.00$) than male step lengths in all three quantiles considered (Figure 8A). In 2014, female and male step lengths were similar ($p = 0.06$) in the 25th quantile and female step lengths were shorter in the 50th and 75th quantiles (Figure 8B).

The results of the road and forest harvest block GAMs revealed a number of significant relationships among attributes describing roads and forest harvest blocks, densities of these features on the landscape, and grizzly bear step length parameters. The GAM road model for 2013 explained 8.2% of the deviance in step lengths. Step proximity to the nearest road ($p < 0.001$), 2013 road density ($p < 0.001$), cumulative road density ($p < 0.001$), and road category ($p = 0.002$), were all significantly related to step lengths. Time of day ($p < 0.001$) and season ($p < 0.001$) were also significantly related to step lengths. Gender ($p = 0.122$) was not statistically significant. Generally, step lengths were longer in close proximity to roads (Figure 9A), and increased in relation to 2013 road density (Figure 9B) and cumulative road density (Figure 9C). Step lengths tended to be longer around roads classified as secondary or reclaimed compared to main roads (Figure 9D). Longer step lengths in relation to roads were observed during the day compared to the overnight period (Figure 9F) and during the mating season compared to the non-mating season (Figure 9G).

The GAM road model for 2014 explained 4.75% of the deviance in step lengths. Step proximity to the nearest road ($p < 0.001$), cumulative road density ($p = 0.006$), road category ($p < 0.001$), gender ($p = 0.034$), and time of day ($p < 0.001$), were significantly related to step lengths. The 2014 road density ($p = 0.13$) and season ($p = 0.82$) variables were not statistically significant. Similar to the 2013 road model, step lengths were substantially longer in close proximity to roads (Figure 10A), were inversely related to cumulative road density (Figure 10C), and were shorter in relation to main roads compared to other road classes (Figure 10D). Unlike the 2013 road model, male step lengths were longer in relation to roads compared to females (Figure 10E). Similar to the 2013 road model, longer step lengths were observed during the day compared to the overnight period (Figure 10F).

The GAM forest harvest block model for 2013 explained 10.50% of the deviance in step lengths. Step proximity to the nearest harvest block ($p = 0.003$), block age ($p < 0.001$), block area ($p < 0.001$), block perimeter ($p < 0.001$), area to perimeter ratio ($p < 0.001$), 2013 block density ($p < 0.001$) and perimeter density ($p < 0.001$), cumulative perimeter density ($p < 0.001$), time of day ($p < 0.001$), and season ($p < 0.001$), were all significantly related to step lengths. Similar to the 2013 road model, gender ($p = 0.83$) was not significantly related to step lengths. Cumulative forest harvest block density ($p = 1.0$) was not significantly related to step lengths. Step lengths tended to be longer in very close proximity to blocks (Figure 11A), and shorter in relation to younger blocks up until approximately 20 years after which they increased (Figure 11B). Generally, harvest block areas (Figure 11C) and perimeter lengths (Figure 11D) were right skewed and step lengths were inversely related to these variables. Step lengths were longer in relation to low area to perimeter ratio and decreased abruptly (Figure 11E). Step lengths increased as 2013 block density (Figure 11F) and 2013 perimeter density (Figure 11H) increased. However, step lengths were shorter in areas with greater cumulative perimeter density (Figure 11I). Similar to the road models, step lengths were longer during the day compared to the overnight period (Figure 11K), and shorter during the mating season compared to the non-mating season (Figure 11L).

The GAM forest harvest block model for 2014 explained 10.80% of the deviance in step lengths. Step proximity to the nearest block ($p < 0.001$), block area ($p < 0.001$), block perimeter ($p < 0.001$), the ratio of block area to perimeter ($p < 0.001$), 2014 block perimeter density ($p < 0.001$), cumulative block density ($p = 0.046$) and perimeter density ($p = 0.002$), and time of day ($p < 0.001$), were significantly related to step lengths. Unlike the 2013 forest harvest block model, block age ($p = 0.76$), 2014 block density ($p = 0.08$), and season ($p = 0.26$), were not significantly related to step length. Gender ($p = 0.44$) was also not significant. The relationship between step length and step proximity to the nearest block (Figure 12A) was the opposite of the 2013 model as step lengths were shorter in close proximity to blocks. Step length increased as block area approached 2 km^2 (Figure 12C), and were generally shorter in relation to increasing block perimeter (Figure 12D), increasing ratio of area to perimeter (Figure 2E), and cumulative block density (Figure 12G). Similar to the 2013 forest harvest block model, step lengths tended to increase in accordance with 2014 perimeter density (Figure 12H) and step lengths tended to decrease in relation to increasing cumulative perimeter density (Figure 12I). Again, step lengths were longer during the day compared to the overnight period in the 2014 forest harvest block model (Figure 12K).

Discussion

Step length and turning angle distributions quantified using GPS telemetry data can help reveal behavioural components of grizzly bear movement patterns. The majority of male and female grizzly bear movements in 2013 and 2014 tended to be short (e.g., < 100 m step length over approximately a 1 hour period) with infrequent longer movements. Comparing the two genders, long movements tended to be of greater duration among males (Graham & Stenhouse, 2014). As short step lengths are generally associated with higher turning angles indicating a more tortuous trajectory, these movements could be interpreted as foraging or search behaviour (Giuggioli & Bartumeus, 2010; Nelson et al., 2015), while longer movements with low turning angles could indicate transitory movements (e.g., between habitat patches or in pursuit of mates). It is important to note that trajectory segmentation (e.g., Benhamou, 2004; Barraquand & Benhamou, 2008; Gurarie, Andrews, & Laidre, 2009) and modelling approaches (e.g., Morales et al., 2004; Jonsen et al., 2005; Patterson et al., 2008) do exist that may help statistically define periods of homogeneous movement in future analyses and this work is ongoing.

Despite the gender based differences in step length distributions observed in the GPS data, we found limited evidence in the models that male and female movements differed in close proximity to roads and forest harvest blocks and associated attributes (e.g., harvest area, road type etc.). However, when we only considered movements in relation to road and forest harvest block density (results not shown), male movements were significantly longer than female movements as cumulative road and block densities increased. This suggests that the density of road and harvest blocks, rather than the nature of these features, may have a greater influence on gender based differences in movement and will be examined further during this project..

Movements of both males and females were shorter in close proximity to forest harvest blocks compared to roads. Based on our interpretation of short concentrated movements representing search behaviours, these patterns may reflect increased forage opportunities and/or greater security offered by forest harvest blocks compared to roads (Nielsen et al., 2004b; Nielsen et al., 2004a). Movements were always longer during the day compared to the overnight period, regardless of the feature type. This could indicate that individuals are more likely to forage in habitat associated with roads and forest harvest blocks between sunset and sunrise (Munro et al., 2006). Conversely, longer movements with increased directional persistence during the day in the vicinity of roads and forest harvest blocks, and also in areas with high cumulative densities of these features, may allow individuals to minimize their exposure to human contact (Graham et al., 2010; Roever et al., 2010) as road densities in particular influence survival (Boulanger & Stenhouse, 2014). Movements were also slightly shorter during the mating season compared to the non-mating season in relation to roads and forest harvest blocks reflecting seasonal shifts in food availability associated with these features.

While movements were longer around roads (in agreement with Roever et al., (2010)), the type of road also influenced individual movement patterns. Movements tended to be shorter in the vicinity of main roads compared to secondary, reclaimed, and decommissioned roads. Individuals may be foraging in habitat adjacent to main roads, however they may also be increasingly cautious in the vicinity of roads with greater human activity. Future analyses will examine whether step lengths change as the bears approach main road compared to other road types, and what potential distances behavioural shifts occur.

Movement patterns related to forest harvest block attributes (e.g., harvest area, perimeter length etc.) were highly variable. Previous studies have shown that individuals will select harvest blocks dependent on the age and spatial configuration of the blocks (Nielsen et al., 2004c; Stewart et al., 2012). The age and density of forest harvest blocks may also affect the health of individuals (Bourbonnais et al., 2013, 2014). In this analysis, movement patterns were only influenced by harvest block age in 2013 and not in 2014. Furthermore, the movement response to the ratio of harvest block area to perimeter length changed from 2013 to 2014. Understanding the influence of disturbance age and disturbance characteristics on movement patterns may require a longer study period (as indicated in our FRIAA research proposal) in order to obtain a consistent response in a dynamic environment. Movement patterns were influenced by forest harvest block area and perimeter length. Similar to cumulative densities, movements tended to be shorter in the vicinity of smaller harvest blocks with lower perimeter length suggesting these smaller disturbance features may provide suitable (or preferred) habitat. Other analyses have shown that individuals were more likely to select disturbed habitat where forest cover was prevalent and easily accessible (Roever et al., 2010; Stewart et al., 2013), which may be the case in smaller forest harvest blocks.

Conclusion

Movement patterns of grizzly bears observed in 2013 and 2014 were influenced by the proximity to roads and forest harvest blocks, the density of these features, and to some extent by associated attributes. Based on changes in step lengths, there is evidence that individuals are engaging in foraging or search behaviour in the vicinity of roads and harvest blocks and that these behaviours become less prevalent depending on the road type, the harvest block area and perimeter length, and the cumulative density of roads and harvest blocks. These movement patterns are also more likely to occur between the hours of sunset and sunrise allowing individuals to mitigate the risk of human exposure.

For the purposes of this analysis we considered the influence of roads and forest harvest blocks separately in order to understand the movement response to these features. However, the presence and density of these features are often linked and subsequent analyses will consider how their cumulative effects influence grizzly bear movements. Finally, the fit of the models presented here could be improved by including other variables associated with roads and forest harvest blocks, including land cover (Nijland et al., 2015), food availability (Nielsen et al. 2010), and habitat productivity (Bourbonnais et al., 2014), that are known to influence grizzly bear behaviour.

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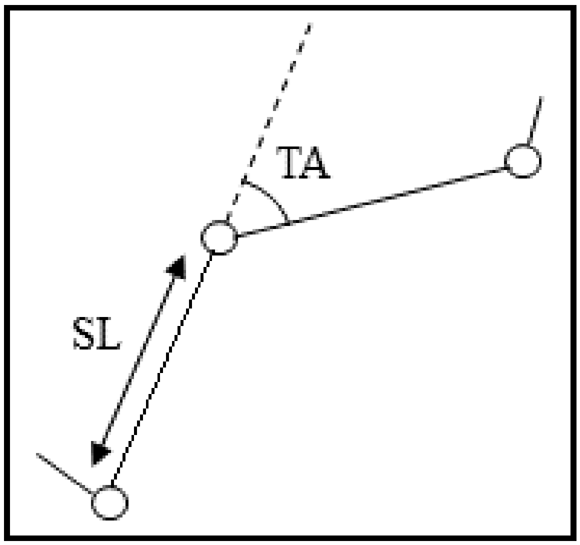

Figure 1. Metrics calculated from a sample movement trajectory (adapted from Calenge et al. 2009). The distance between two consecutive locations (e.g., a step) is termed the step length (SL). The angle of a step relative to that of the previous step is given by the turning angle (TA). Given a constant temporal step interval, the distribution of step lengths and turning angles are commonly used as proxies for behavioural states (e.g., "transitory" and "encamped")

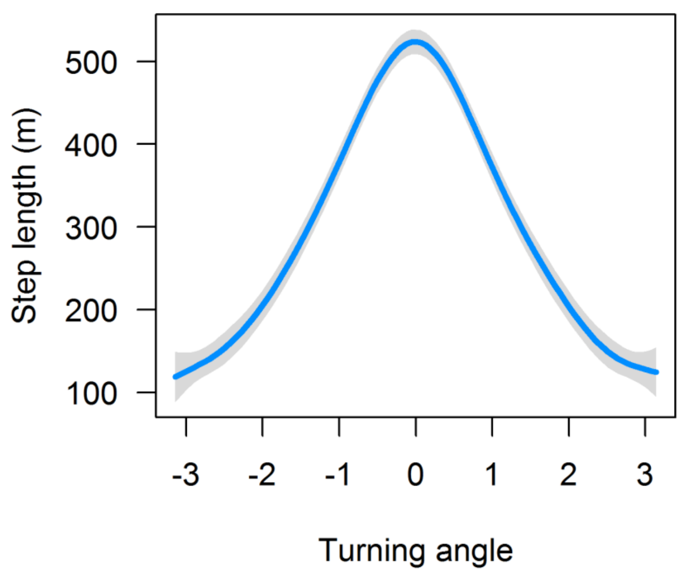

Figure 2. Non-linear relationship between grizzly bear step lengths and turning angles. Turning angles centered near zero represent increased directional persistence resulting in longer step lengths. As turning angles increase towards the tails, directional persistence and step lengths decrease.

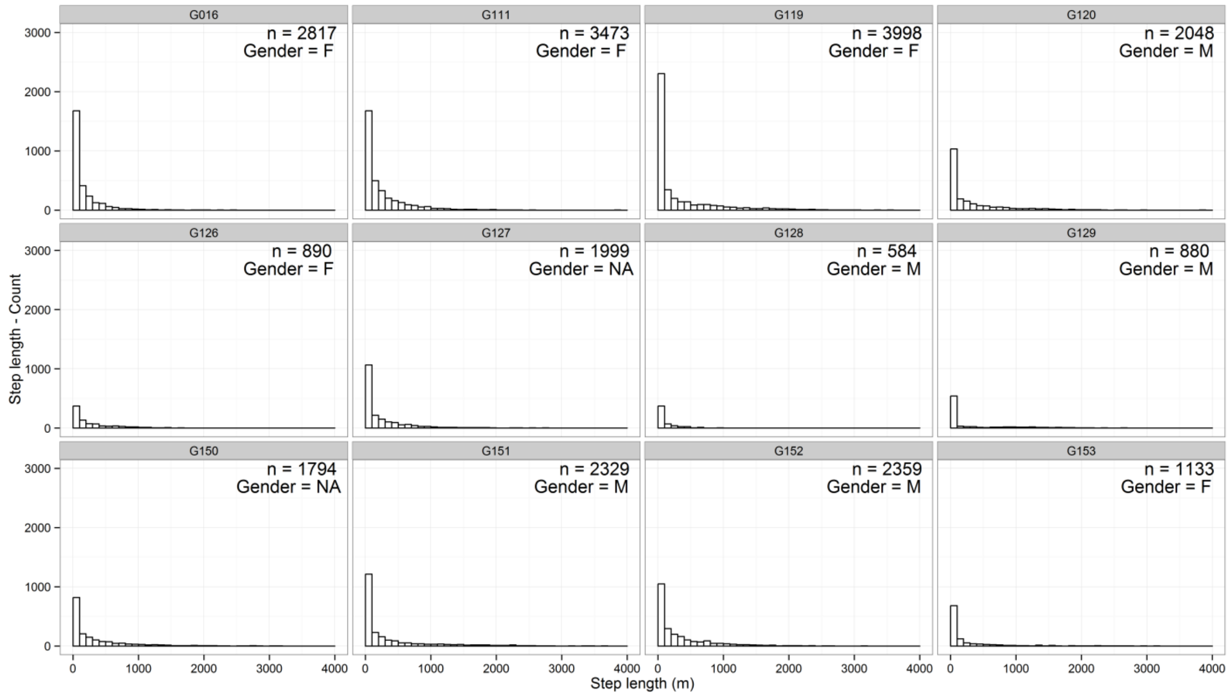

Figure 3. Step length distributions for individuals tracked in 2013. Regardless of individual and gender, distributions are strongly right skewed favouring short movements with infrequent long movements.

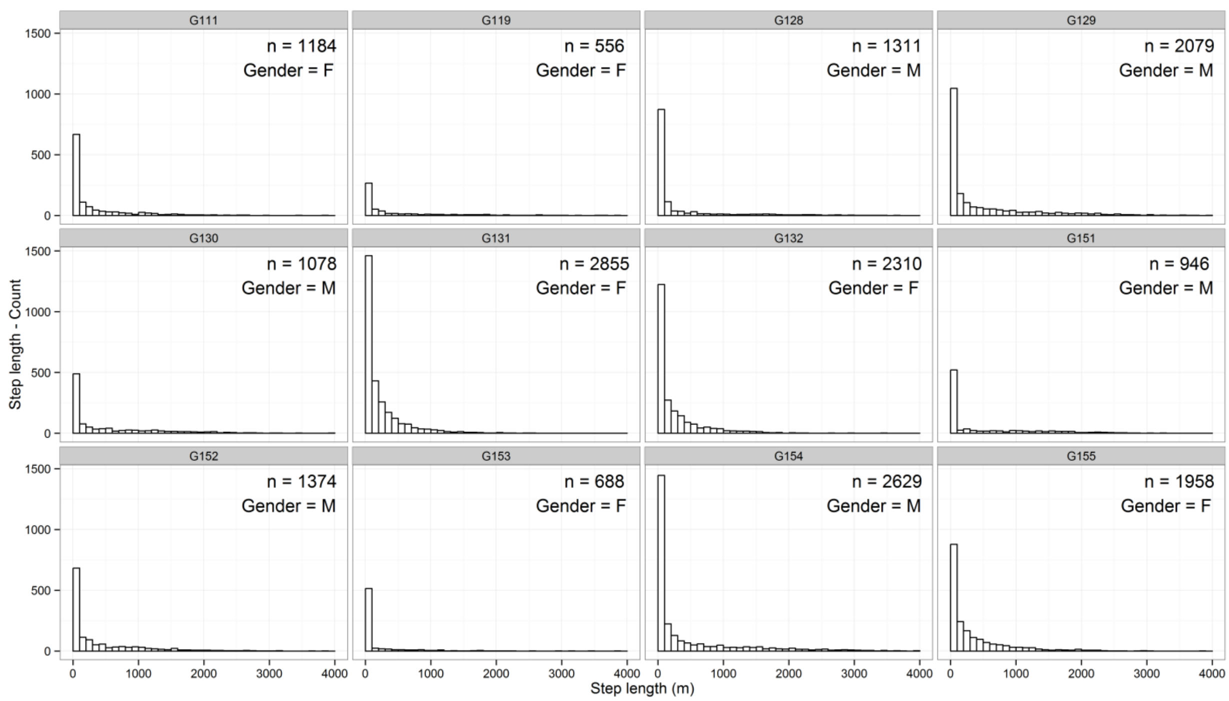

Figure 4. Step length distributions for individuals tracked in 2014. Regardless of individual and gender, distributions are strongly right skewed favouring short movements with infrequent long movements.

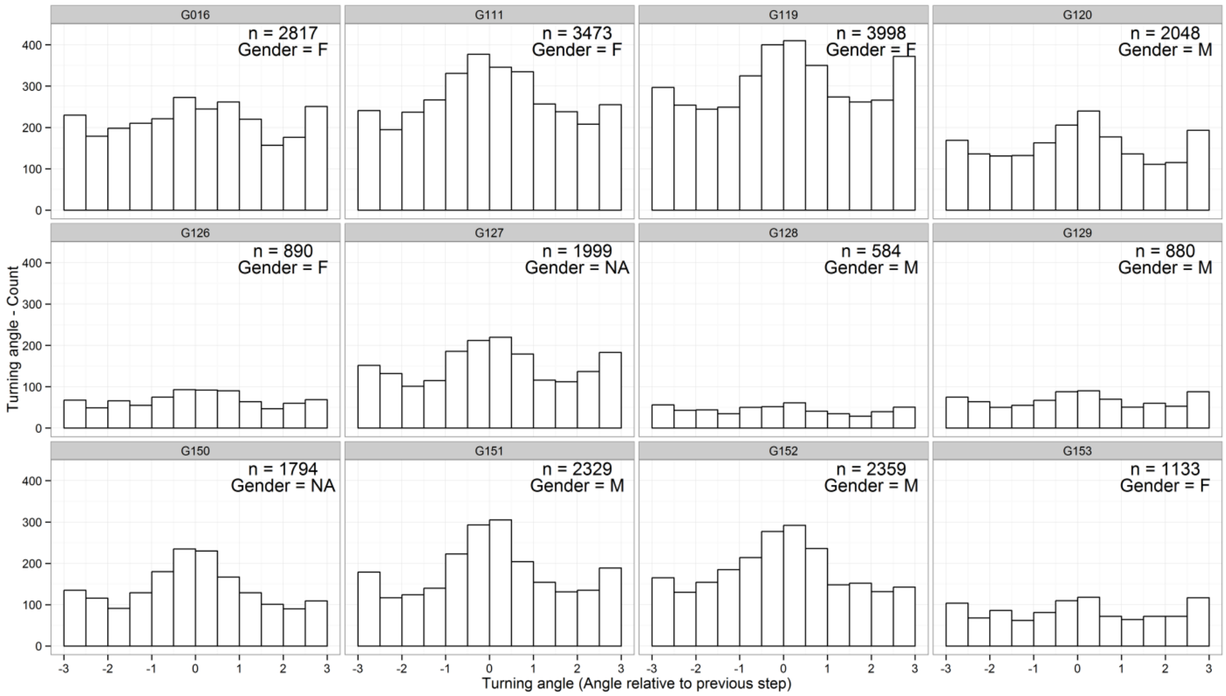

Figure 5. Turning angle distributions for individuals tracked in 2013. Turning angle distributions are approximately uniform with slight peaks near zero and in the tails.

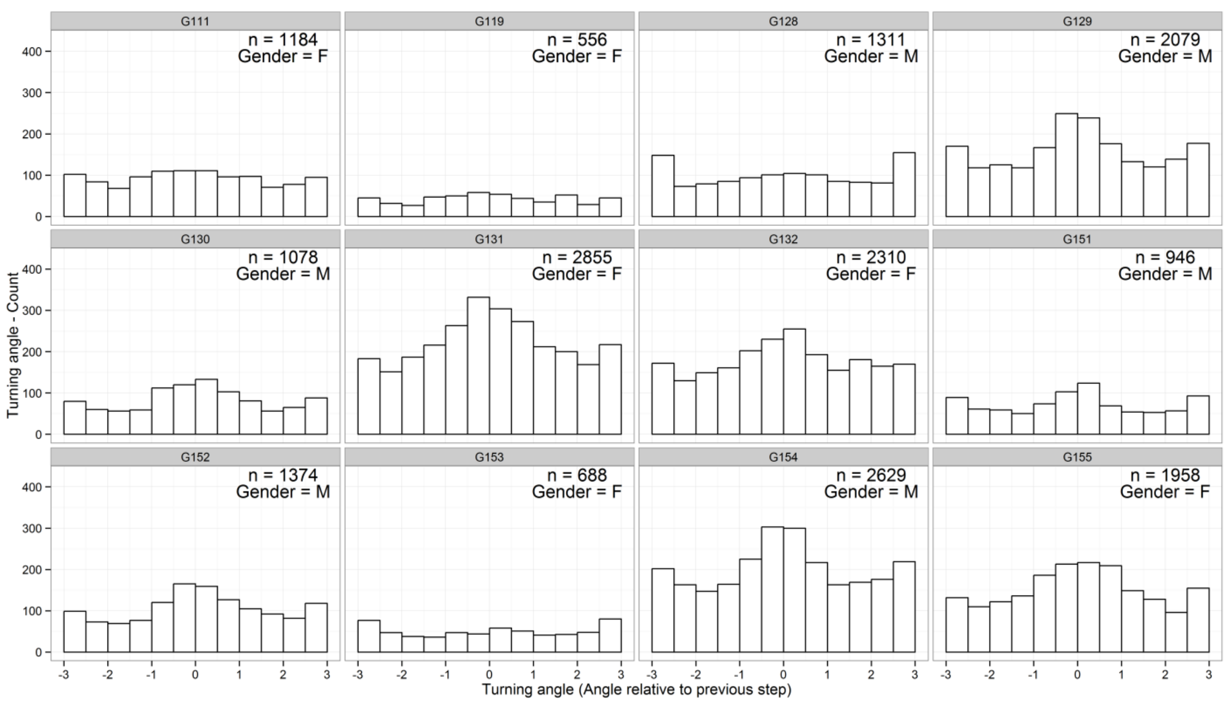

Figure 6. Turning angle distributions for individuals tracked in 2014. Turning angle distributions are approximately uniform with slight peaks near zero and in the tails.

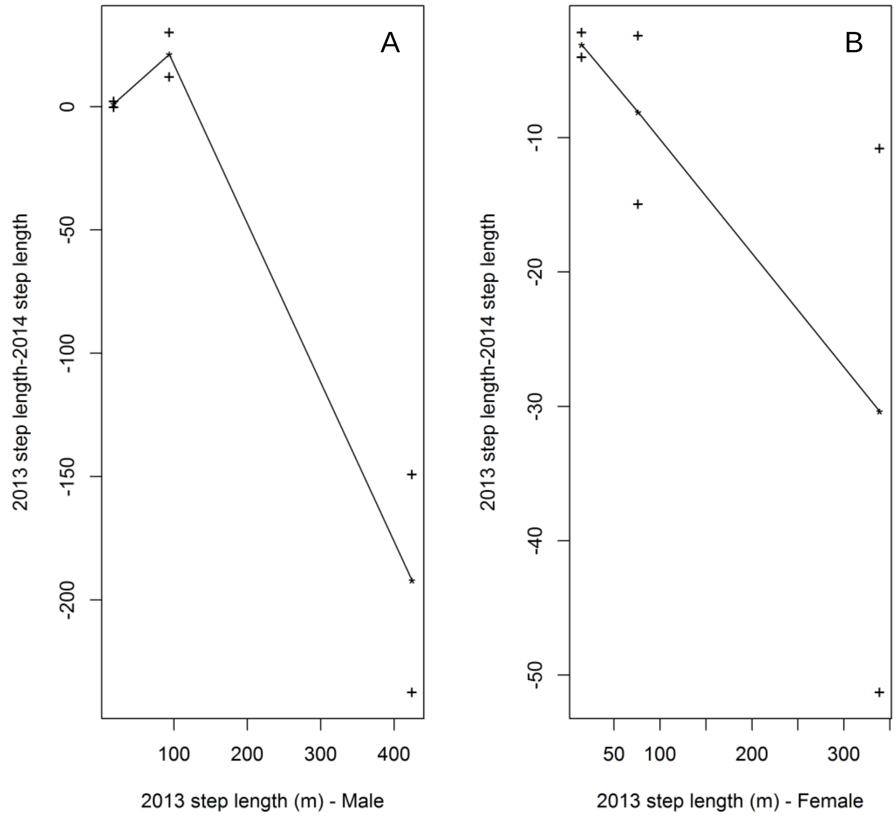

Figure 7. Statistical comparison of male (A) and female (B) step length distributions in the 25th, 50th, and 75th percentiles. The x-axis is the reference year for the comparison. The y-axis gives the difference in the bootstrap quantile samples from the two distributions for the reference distribution on the x-axis. The 95th percentile confidence interval of the difference estimate is given by the outer marks.

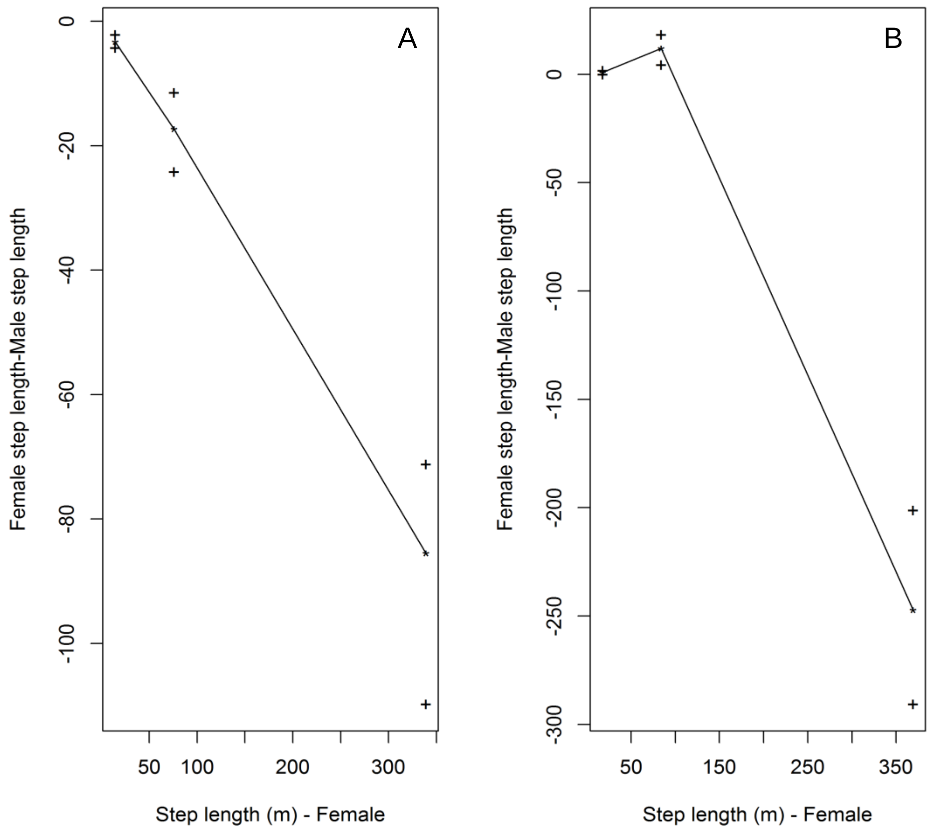

Figure 8. Statistical comparison of male and female step length distributions from 2013 (A) and 2014 (B) in the 25th, 50th, and 75th percentiles. The x-axis is the reference gender for the comparison. The y-axis gives the difference in the bootstrap quantile samples from the two distributions for the reference distribution on the x-axis. The 95th percentile confidence interval of the difference estimate is given by the outer marks.

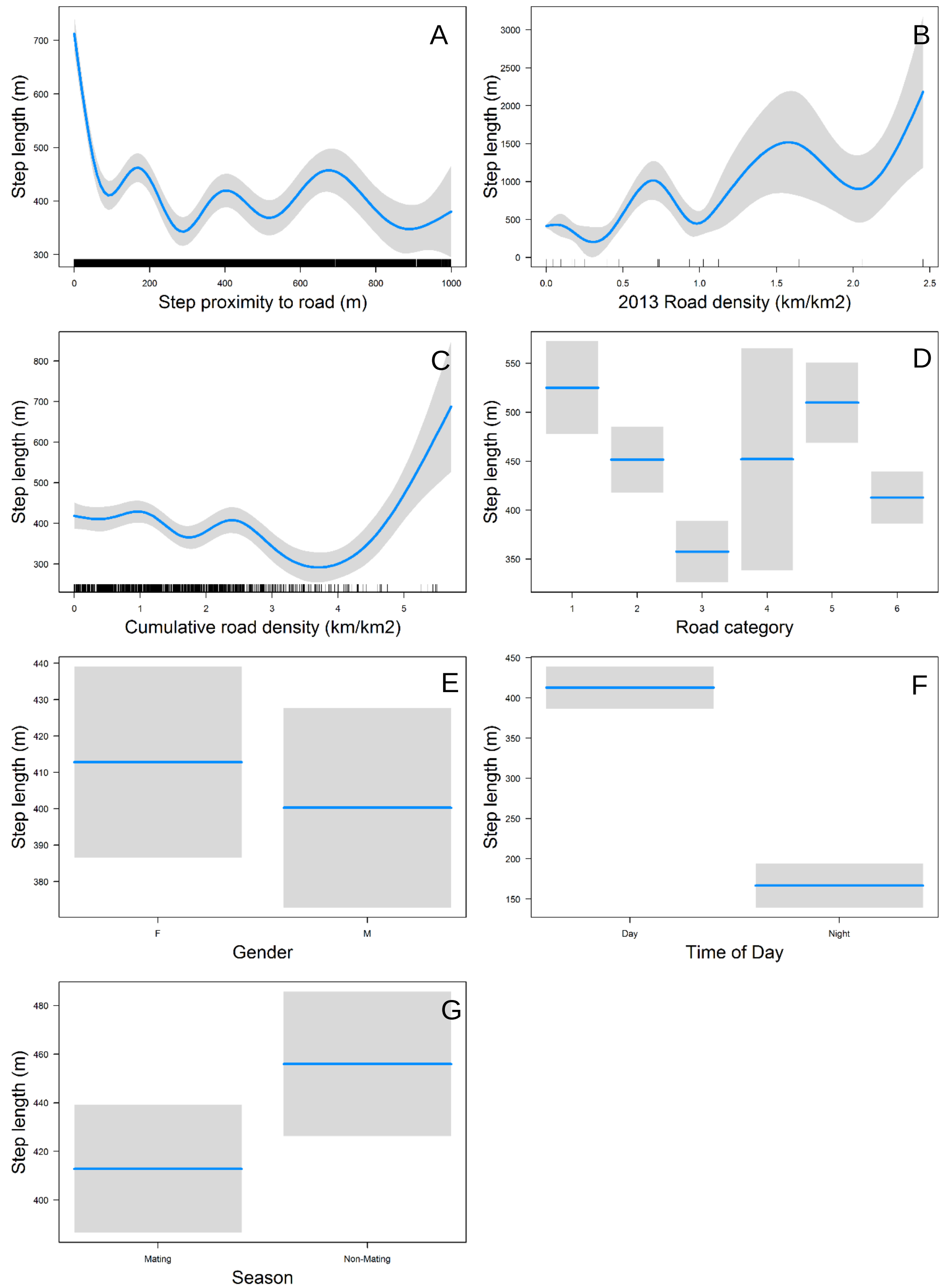

Figure 9. Estimated effects of variables considered in the 2013 road generalized additive model. Smoothed partial effects (blue line) and 95% confidence interval (grey band) are given for step proximity to the nearest road (A), 2013 road density (B), and cumulative road density (C). Categorical variables, road category (D), gender (E), time of day (F), and season (G) are represented using boxplots showing the median values (blue line) and 25th and 75th percentiles (grey box) of the step lengths. Road categories are 1) FMA Secondary; 2) Forestry decommissioned; 3) Main road; 4) Other secondary; 5) Reclaimed; 6) Tertiary.

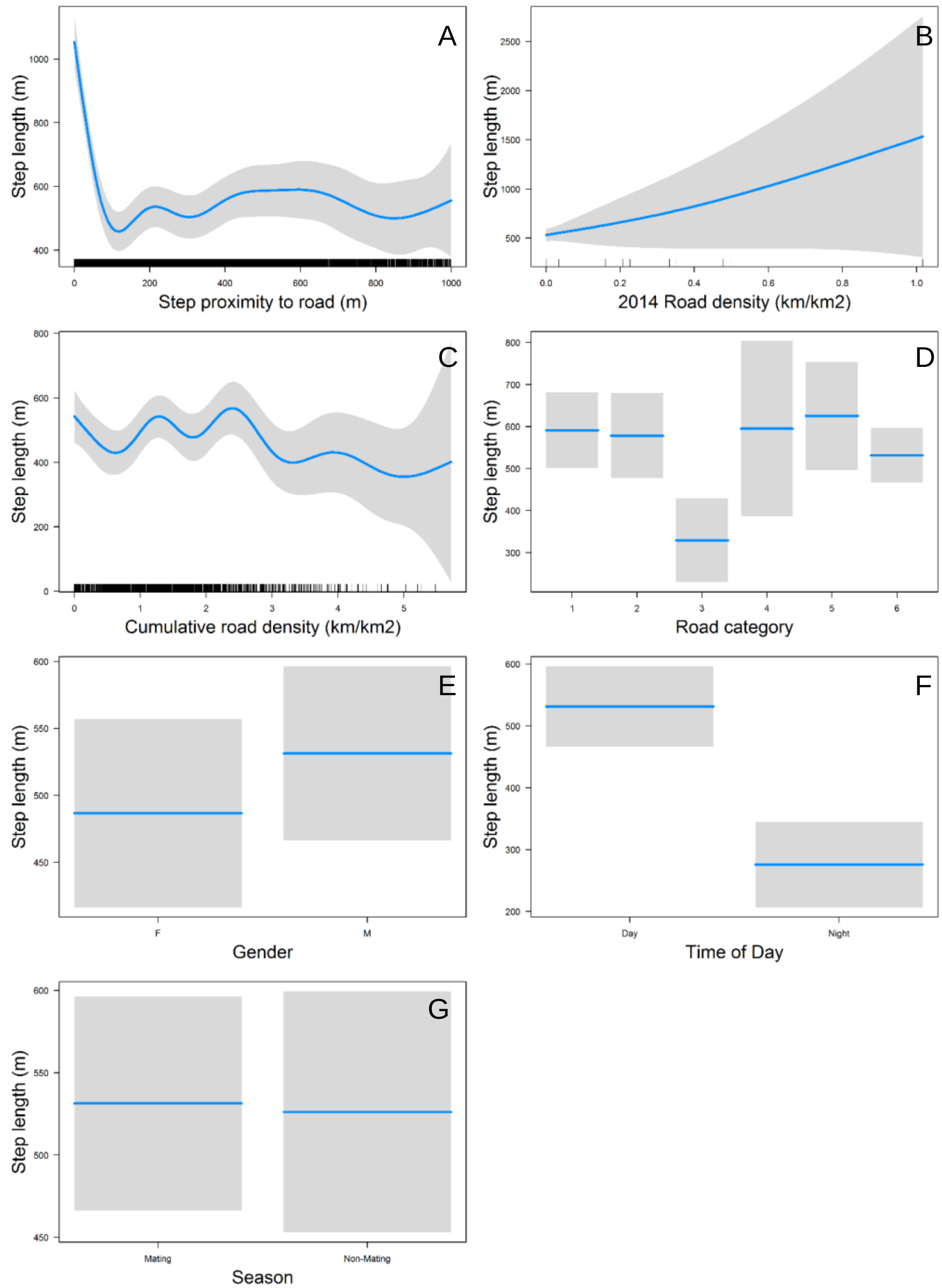

Figure 10. Estimated effects of variables considered in the 2014 road generalized additive model. Smoothed partial effects (blue line) and 95% confidence interval (grey band) are given for step proximity to the nearest road (A), 2013 road density (B), and cumulative road density (C). Categorical variables, road category (D), gender (E), time of day (F), and season (G) are represented using boxplots showing the median values (blue line) and 25th and 75th percentiles (grey box) of the step lengths. Road categories are 1) FMA Secondary; 2) Forestry decommissioned; 3) Main road; 4) Other secondary; 5) Reclaimed; 6) Tertiary.

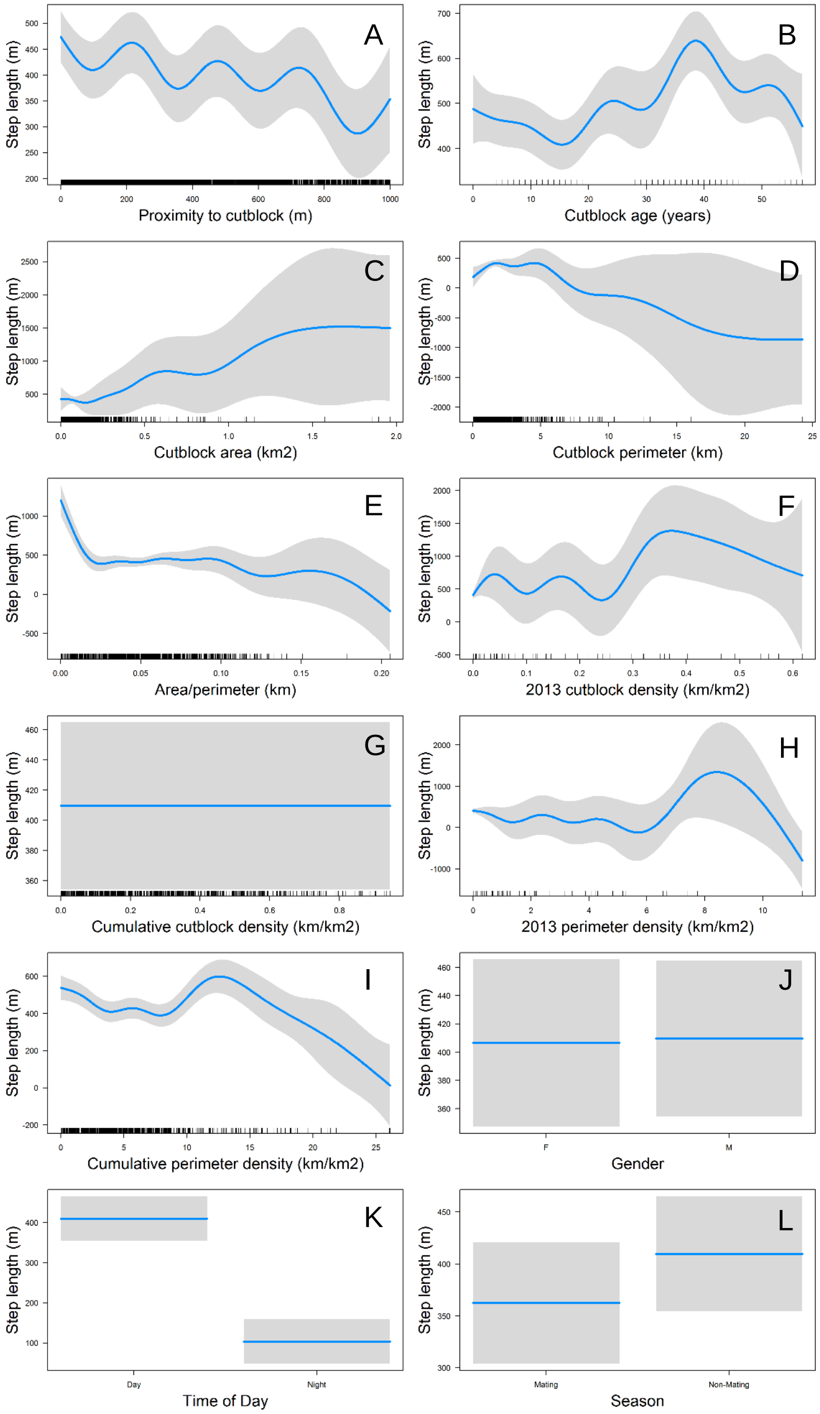

Figure 11. Estimated effects of variables considered in the 2013 forest harvest block generalized additive model. Smoothed partial effects (blue line) and 95% confidence interval (grey band) are given for step proximity to the nearest block (A), block age (B), block area (C), block perimeter (D), ratio of area to perimeter (E), 2013 block density (F), cumulative block density (G), 2013 perimeter density (H), and cumulative perimeter density (I). Gender (J), time of day (K), and season (L) are represented using boxplots showing the median values (blue line) and 25th and 75th percentiles (grey box) of the step lengths.

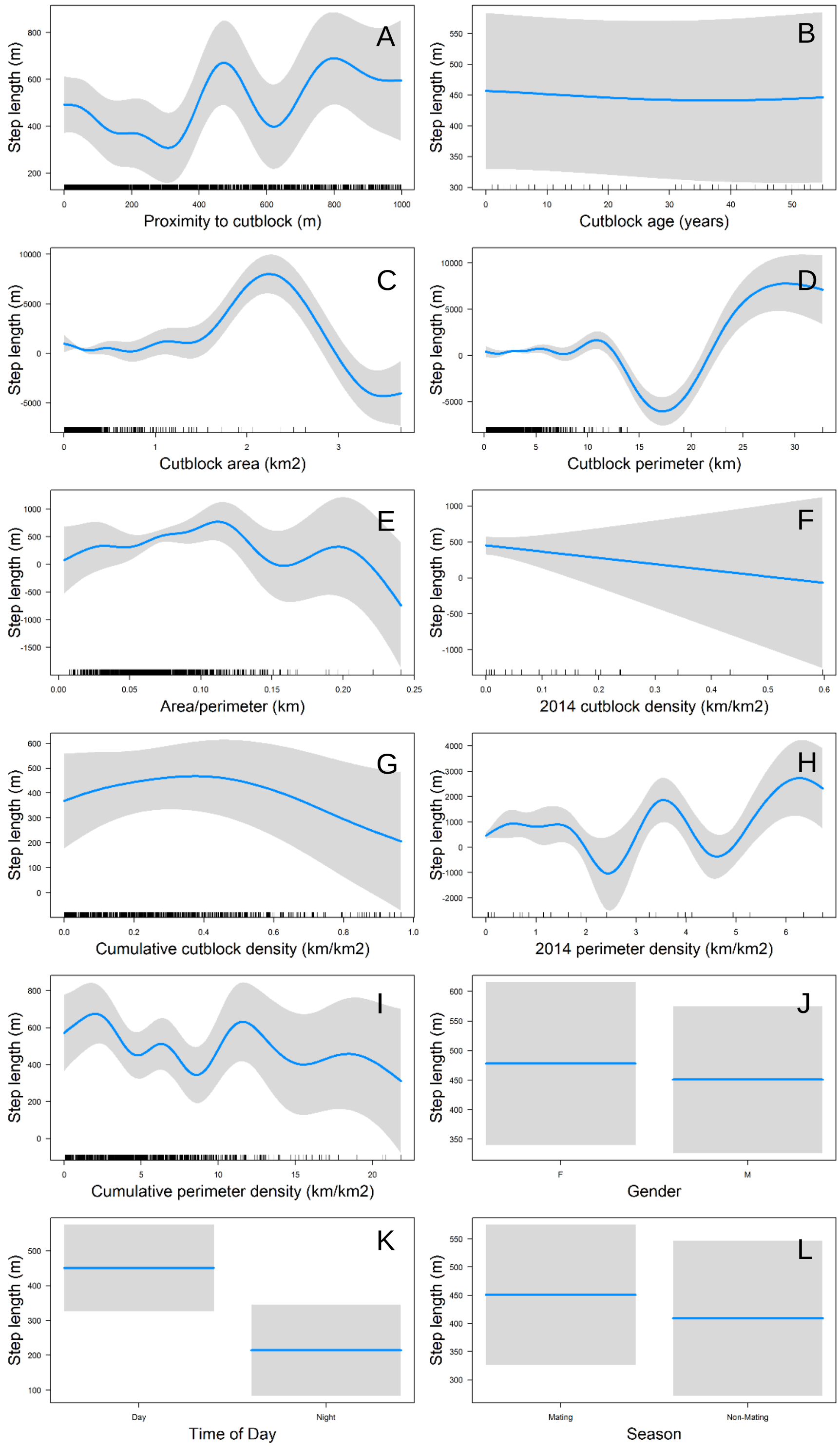

Figure 12. Estimated effects of variables considered in the 2014 forest harvest block generalized additive model. Smoothed partial effects (blue line) and 95% confidence interval (grey band) are given for step proximity to the nearest block (A), block age (B), block area (C), block perimeter (D), ratio of area to perimeter (E), 2013 block density (F), cumulative block density (G), 2013 perimeter density (H), and cumulative perimeter density (I). Gender (J), time of day (K), and season (L) are represented using boxplots showing the median values (blue line) and 25th and 75th percentiles (grey box) of the step lengths.