GRIZZLY BEAR HABITAT MANAGEMENT IN CANADA'S ROCKY MOUNTAIN PARKS: BALANCING VISITOR EXPECTATIONS WITH BEAR HABITAT REQUIREMENTS

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ABSTRACT

Protected area managers are continually challenged to balance ecological integrity with human recreation needs and expectations. In Banff, Yoho, Kootenay, and Jasper National Parks in Canada's Rocky Mountains, part of this challenge is centered on providing grizzly bears with adequate access to high quality habitats while ensuring safe and ample recreation opportunities for millions of annual visitors. Using an interdisciplinary approach, I investigated this complexity through biological and social methods to define a series of management recommendations that maintain grizzly bear habitat security and meet trail user expectations. I conducted field work in the spring, summer and fall from August 2013 to August 2015. I used remote cameras on trails of low, medium, and high human use to quantify grizzly bear and human use of randomly selected trails. I used movement and location data generated from GPS collars on 27 grizzly bears to examine habitat use. I employed an intercept survey to assess trail users expectations and support of various management options pertaining to grizzly bears. Remote cameras captured human activity across the study area in all hours of the day and night across the seasons, although human activity was highest during the day and the summer/fall. Grizzly bears were more likely to be detected by camera on trails during the spring; trail human use level was not a significant predictor of grizzly bear presence. Most grizzly bear camera detections occurred at night or before 8 human events occurred on the trail that day. The GPS data showed that grizzly bears consistently selected for high quality habitat across all seasons. Grizzly bears selected habitat closer to roads in the spring, and closer to roads and trails in the summer than in the fall. I used a Step Selection Function (SSF) analysis to examine grizzly bear movement and

habitat selection in the study area. The results of the SSF showed a high level of individual variation in grizzly bear selected steps in relation to trails of varying levels of human use and roads. Most grizzly bears selected steps close to low human use trails, but only some bears selected steps closer to high human use trails as well. Grizzly bear steps were longer during the day and shorter when in proximity to high use trails during the spring and summer. This suggests that bears were active diurnally and displayed decreased movement rates when near high use trails. The survey showed that trail users were supportive of prioritizing grizzly bear habitat use over their own recreational needs. The most supported management options were to close the trail or put up a warning sign when a bear was in the area; the least supported management options were relocating the bear or applying aversive conditioning. The level of support for management options did differ, however, if it was a lone grizzly bear or a female with cubs in the vicinity of the trail. In the latter scenario, trails users were more support of restrictive management options like closing the trail. Visiting trails users were more supportive of restrictive management options than residents. By integrating biological and social science data, I identified areas of focus in the spring where grizzly bear habitat quality and trail use was high; these areas should have human use restrictions applied during the spring. Resulting management recommendations that combined both biological and social data included: closing the trail when a female grizzly bear with cubs is in the area, implementing trail opening times in high quality grizzly bear habitat during the spring, and improving public education efforts. The interdisciplinary nature of this work helps managers to make decisions founded in biological sciences and to identify when and to what degree those decisions will be supported by trail users.

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CERTIFICATE OF AUTHORSHIP AND ORIGINALITY OF THESIS

The research and discussion presented in this thesis are the original work of the author and have not been submitted at any tertiary institute or University for any other award. Any material that has been presented by any person or institute is duly references, and a complete list of all references is presented in the bibliography.

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Oral Presentations

Elmeligi, S., Nevin, O., & Convery I. (2015). *Trail Use by Grizzly Bears and People in the Rocky Mountain National Parks: We Can All Just Get Along!* Alberta Society of Professional Biologists Annual Conference. Canmore, Alberta.

Elmeligi, S., Nevin, O., & Convery, I. (2015). *Sharing Trails with Grizzly Bears in the Rocky Mountain National Parks.* The Wilderness Society Alberta Chapter Annual Conference. Edmonton, Alberta.

Elmeligi, S., Nevin, O., Stenhouse, G., & Convery, I. (2016). *Grizzly bears and people in space and time – Using an interdisciplinary approach to bear research and management*. International Bear Association Conference. Anchorage, Alaska.

Poster Presentations

Elmeligi, S., Nevin, O., & Convery, I. (2014). *Visitor perspectives regarding grizzly bear management as part of an interdisciplinary approach to addressing grizzly bear habitat security needs.* Society of Conservation Biology North American Section Meeting. Missoula, Montana.

Elmeligi, S., Nevin O., & Convery, I. (2014). *Balancing grizzly bear habitat needs and recreational access in Protected Areas: visitor perspectives of grizzly bear management in the Canadian Rocky Mountain Heritage Area.* IUCN World Parks Congress. Sydney, Australia.

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Elmeligi, S. (2016). Making the most of citizen scientists in brown bear studies in Canada's Rocky Mountain National Parks. International Bear Association Conference, Anchorage, Alaska.

CHAPTER 1 – INTRODUCTION

Grizzly bears (*Ursus arctos*), once globally abundant ranging across Asia, Europe and North America, have been classified as threatened, endangered or vulnerable in most parts of their range (Weilgus, 2002). In Canada, grizzly bears are classified as *special concern* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2015). In the contiguous United States, grizzly bears are listed as *threatened* under the US Fish and Wildlife Service Endangered Species Act (US Fish and Wildlife Service, 2016). From the 1940's to 1960's, habitat loss resulting from expanding human settlements and agriculture (Shelton, 2001) combined with increasing negative altercations between people and bears led to the killing of grizzly bears and dramatic decreases in population sizes (McCracken, 1957). Habitat loss from industrial land use practices and conflict with people continues to impact grizzly bear populations in Canada (Benn & Herrero, 2002; Nielsen, Stenhouse, & Boyce, 2006). The most recent population estimate for the western Canadian province of Alberta was based on a DNA capture-mark-recapture study conducted from 2004-2008. This study estimated a total of 582 (95% confidence interval: 498-732) on provincial lands and portions of the Rocky Mountain National Parks; this was combined with expert opinion pertaining to unsampled areas to create an overall provincial estimate of 691 grizzly bears (Alberta Sustainable Resource Development & Alberta Conservation Association, 2010). In 2012 the Alberta Government classified grizzly bears as *Threatened* under the Alberta Wildlife Act (Alberta Queen's Printer, 2012).

The Rocky Mountain National Parks of Banff, Jasper, Kootenay and Yoho, are Canada's most visited protected areas; Banff National Park (BNP) alone accounts for 25% of all visits to Canadian National Parks (Parks Canada, 2010a). People travel from around the world to experience these iconic mountains, lakes and hikes; they are a cornerstone for tourism in Canada and their management provides leadership in the development and application of protected area policy across Canada (Parks Canada, 2010a). They also contain large amounts of relatively undisturbed grizzly bear habitat. There is potential for the grizzly bear population within these and other Alberta protected areas to serve as a source of animals for the larger, recovering provincial population (Sawaya, Stetz, Clevenger, Gibeau, & Kalinowski, 2012).

Like many protected areas worldwide, the Rocky Mountain National Parks in western Canada are not without environmental issues, and are exposed to habitat degradation or indirect habitat loss from both natural and anthropogenic causes (Rogala et al., 2011). The slowest reproducing grizzly bear population in North America lives in BNP with a population wide reproductive rate of 0.239 (95% CI: 0.185-0.2394; Garshelis, Gibeau, & Herrero, 2005), as opposed to a population reproductive rate of 0.318 (95% CI: 0.277-0.359) in Yellowstone National Park in the United States (Schwartz et al. 2006). Even in these protected landscapes the vast majority of known adult grizzly bear mortalities are human-caused (Nielsen, Cranston & Stenhouse, 2009; Whittington & Sawaya 2015). From 2006 to 2008, the grizzly bear population in the central Bow Valley portions of BNP was recorded to have a slow rate of decline (Sawaya et al., 2012). Increasing human use throughout these protected areas has been directly linked to an unsustainable mortality rate; appropriately managing human use in core grizzly bear habitat is essential for effective population recovery (Gibeau, Herrero, McLellan, & Woods, 2001).

Human use and development, such as roads, communities, industrial development and recreational use, impact grizzly bear habitat both inside and outside of protected areas in western Canada (Nielsen et al. 2006; Sorensen, Stenhouse, Bourbonnais, & Nelson, 2015). Alberta grizzly bears exist in a multi-use landscape with home ranges often overlapping federal and provincial management agency jurisdictions (e.g., Parks Canada, Alberta Environment and Parks, and private land; Bourbonnais, Nelson, Cattet, Darimon, & Stenhouse, 2013). Each of these jurisdictions has different management responses to grizzly bear behaviour and habitat use detailed in their respective management plans. Grizzly bears with home ranges overlapping multiple jurisdictions must navigate a complex variety of human uses and potential management responses. Most research focused on the impacts of human use on grizzly bear habitat use in Alberta have been directed at industrial landscapes on public lands (Boulanger, Cattet, Nielsen, Stenhouse, & Cranston, 2013; Graham, Boulanger, Duval, & Stenhouse, 2010; Nielsen, 2005). While high road densities and motorized recreation have been demonstrated to negatively impact grizzly bear habitat use (Ament, Clevenger, Yu, & Hardy, 2008; Apps, McLellan, Woods, & Proctor, 2004); these impacts may be lessened in federally protected areas where motorized recreation is not permitted and fewer roads exist. The specific impacts of trail users on grizzly bear movement and habitat use still needs to be understood for the application of comprehensive management approaches in these protected areas (Gibeau et al., 2001). With their comparatively low intensity of human use (Garshelis et al., 2005), the Rocky Mountain National Parks can represent a relatively unique perspective regarding impacts of human use on grizzly bear behaviour and habitat selection.

Managing vulnerable and sensitive species, like grizzly bears, while providing for a safe and positive visitor experience in bear-country is the essence of the dynamic management challenge in the Canadian Rocky Mountain National Parks. According to the Canada National Parks Act (2013), the "maintenance and restoration of ecological integrity… is the first priority of the Minister when considering all aspects of the management of parks" (Section 8(2), p. 5). The Parks Canada Charter (2002) defines a more comprehensive mandate for park management, however, and includes elements of "fostering public understanding, appreciation and enjoyment" (p. 1). This mandate complements one of the principal components of the provincial Alberta Grizzly Bear Recovery Plan, which is to reduce human-bear conflict and encourage coexistence between the public and grizzly bears (Government of Alberta, 2008). Understanding public attitudes and support for grizzly bear management in protected areas is, therefore, an important component of meeting management objectives at both the federal and provincial level.

1.1 Interdisciplinary Approach to Research

Ecosystem management embraces both social and ecological dynamics in a flexible and adaptive process (Lackey, 1998). The sociocultural context for wildlife management has changed requiring programs that are acceptable to a diverse array of stakeholders with diverse, often competing stakes in wildlife management (Riley et al., 2003). The goal of management in the Canadian Rocky Mountain National Parks is to balance ecological integrity with the needs and perspectives of visitors, residents, and other stakeholders. Managing human use has always been a central tenet in maintaining the integrity and health of ecosystems, but incorporating other environmental aspects through an integrated and systems approach can improve management effectiveness (Petersen, 2000). There is increasing recognition that ecosystem management is often more about influencing human behaviour and area use than directly influencing animals themselves (St. John, Keane, Jones, & Milner-Gulland, 2014). Due to these complexities and the interconnectedness of human and natural systems, interdisciplinary approaches that bridge the gap between scientific disciplines are becoming increasingly promoted for effective protected area management (van Riper III et al., 2012; Rodger, Moore, & Newsome, 2010).

Two ways of combining scientific disciplines to answer complex research questions are through multidisciplinary or interdisciplinary science. Multidisciplinary science is defined as an additive approach that combines the efforts of more than one discipline (van Riper III et al., 2012); these projects involve different disciplines working in parallel without integration (Pooley, Mendelsohn, & Milner-Gullard, 2013). One distinction between multidisciplinary and interdisciplinary science is that the former focuses on breaking down a problem into unidisciplinary segments, which are then solved individually (van Riper III et al., 2012). For example, multiple research projects have focused on tiger conservation in India using tiger biology and ecology to develop conservation programs, whereas other research efforts have examined policy and political sciences to increase conservation management success (Rastogi, Hickey, Badola, & Hussain, 2012). These research programs focus on the same overall goal of conserving tigers in India, but have not always integrated in to one research effort. In addition, they rarely consider the impacts to communities and as such are challenged by a lack of community acceptance during implementation of research recommendations (Rastogi et al., 2012). Creating research programs that intertwine ecological, political, and community values research could lead to increased conservation effectiveness (Rastogi et al., 2012).

Interdisciplinary research is founded in this concept of intertwining approached; it investigates a research question using an integrative approach that synthesizes the perspectives of several disciplines during all phases of the research (van Riper III et al., 2012). This approach requires researchers to cross disciplinary boundaries to create new knowledge (Granquist & Nilsson, 2016; Pooley et al., 2013). An interdisciplinary, broadened view of science requires various disciplines and stakeholders more directly in hypothesis development, selection of methodological approaches, and the definition of recommendations stemming from results. These approaches help ensure science is more aligned with stakeholder needs and thus increase acceptance of resulting management actions (Allen et al., 2014).

Interdisciplinary approaches have been applied through the creation of scientific centres, like the National Socio-Environmental Synthesis Centre (SESYNC) in the United States (Palmer, Kramer, Boyd, & Hawthorne, 2016). SESYNC uses a set of core practices to develop new interdisciplinary teams of researchers from social and natural science backgrounds to undertake large scale research projects. SESYNC is an example of an entire organization centered around the principles of interdisciplinary research, which involves dozens of researchers from multiple disciplines working on larger scale projects. Not all interdisciplinary research projects are implemented at this scope, however. One project in France involved biologist and sociologists examining the processes behind increasing use of natural areas and the ecological impacts thereof (Claeys, Barthelemy, Tatoni, & Bonhomme, 2011). This projects used data from interviews, telephone surveys, and biodiversity surveys to create recommendations for natural area managers. Interdisciplinary approaches have also been used in wildlife viewing related tourism where ecological data has been used to define impacts to subject species and tourism research has been used to define visitor expectations (Elmeligi, 2008, Granquist & Nilsson, 2016). Within the context of wildlife tourism, interdisciplinary approaches have helped define sustainable balance between using and protecting wild animals as a resource, which likely leads to synergetic and improved outcomes for wildlife and tourists (Granquist & Nilsson, 2016).

Successfully implemented interdisciplinary research comes with significant challenges; linking biological and social science is not easy (Allen et al., 2014). Pooley et al. (2013) define five main categories of conceptual challenges: methodological, value judgements, theories of knowledge, disciplinary prejudices, and interdisciplinary communication. Methodological challenges stem from spatial and temporal scales of research and integrating data and management. One of the key critiques of interdisciplinary science is that the biological and social data are not collected over the same time frames or with the same level of robustness. This can lead to an imbalance of natural and social science where usually more emphasis is placed on ensuring high quality biological information (Christie, 2011); too often social scientists are brought in at later stages of projects and excluded from the planning process (Pooley et al., 2013). To ensure rigor and relevance of interdisciplinary approaches, it is critical for team members representing the different disciplines to work together to explicitly define and apply robust methodological practices that assure all elements of the research will pass appropriate peer review (Allen et al., 2014). Therefore, principal outcomes of the project and the approach to meeting those outcomes need to be agreed upon at the outset (Pooley et al., 2013).

Pooley et al. (2013) also discussed value judgements, theories of knowledge, disciplinary prejudices, and communication as challenges to interdisciplinary research. These challenges are similar in that they may stem from an over-reliance on a particular worldview and science-policy epistemic community (Christie, 2011). While these challenges coming from scientists' personal education and experience are unavoidable, it is essential to realize and acknowledge them throughout the research process. Interdisciplinary researchers should take time to self-reflect and consider how they work with others and how best to include other knowledge systems in their perspective; this can be done through the inclusion of different practitioners, community and Indigenous groups, and other non-traditional partners in the research process (Allen et al., 2014). These kinds of research approaches often involve ambiguity and incomplete knowledge; the field is relatively new and no set protocols have been developed to define intellectual boundaries, the community of participants, and methodological practices (Palmer et al., 2016). It is critical that individual worldviews do not lead to simplified arguments in the explanation of complex problems or the advocacy for particular solutions that are not integrative (Christie, 2011).

Logistical management is also a challenge facing the success of interdisciplinary approaches. These include the effort required to assemble an interdisciplinary team, the time required to learn the necessary components of other disciplines, and the commitment required to develop collectively agreed upon new ideas, concepts, theories, and conclusions (van Riper III et al., 2012). One way to improve the effectiveness of interdisciplinary research is for people to obtain strong training in the principles of ecology or social science research methods and then to work together in teams (St. John et al., 2014). Researchers should define how to work together in an interdisciplinary manner and keep that discussion ongoing throughout the project; one of the project measures of success should be how the team has worked together to strengthen collaborative research initiatives and developed new ways of looking at complex problems (Allen et al., 2014).

Interdisciplinary approaches have been successfully applied in parks and protected areas, despite the above challenges. Van Riper III et al. (2012) describe several efforts where interdisciplinary research has defined trade-offs that park visitors were willing to make between environmental conditions, recreation use levels, and development. These approaches demonstrate how research can successfully span across disciplines to provide more comprehensive management recommendations in parks and protected areas (van Riper III et al., 2012).

Grizzly bear management is a complex process dependent on several biological and social factors; many of the grizzly bear habitat related management approaches actually target human use. Thus, grizzly bear management lends itself to an interdisciplinary, ecosystem-based management approach based on biological and social data. Successful management plans require a constantly updated knowledge-base and adequate information regarding grizzly bear ecology (Mertzanis et al., 2008), in addition to defining the social context of human needs and expectations associated with grizzly bear management (Kellert, 1994). I selected an interdisciplinary approach in my thesis that integrates biological and social information to create management recommendations.

My overall thesis goal is to use an interdisciplinary approach to improve understanding of grizzly bear and human-use management in protected areas by examining ecological and social aspects (Figure 1.1). By integrating biological and social science data, I define a series of management recommendations that maximize grizzly bear habitat security and meet trail user expectations of bear management in the Canada's Rocky Mountain National Parks. I focused remote camera and survey data collection on hiking trails in grizzly bear habitat during three seasons: spring (May 1 to June 15), summer (June 16 to August 15), and fall (August 16 to October 15). These seasons were defined based on grizzly bear habitat quality characteristics and seasonal forage availability (Smulders et al., 2012). During 2013, all data was collected during the fall season in BNP in areas with GPS collared grizzly bears (essentially between the towns of Banff and Lake Louise). The 2013 field season was approached as a pilot to develop and refine methods for the 2014 and 2015 field seasons. In 2014 and 2015, sampling efforts were expanded to include YNP, KNP, and JNP. Trail user surveys were conducted in all four national parks in the fall of 2013 and the spring and summer of 2014; remote cameras were deployed in BNP, KNP, and YNP in the fall of 2013 (BNP only), spring-fall in 2014, and spring and summer of 2015.

This is one of the first studies to integrate social and biological sciences in protected areas in the hopes of improving grizzly bear management in North America. The management plans for BNP, JNP, YNP, and KNP clearly define management objectives regarding grizzly bear habitat security, increasing park visitation, and addressing the needs of stakeholders (Parks Canada, 2010a-d). A research approach such as mine requires interpretation of broader theory in the context of place-based assessments, including

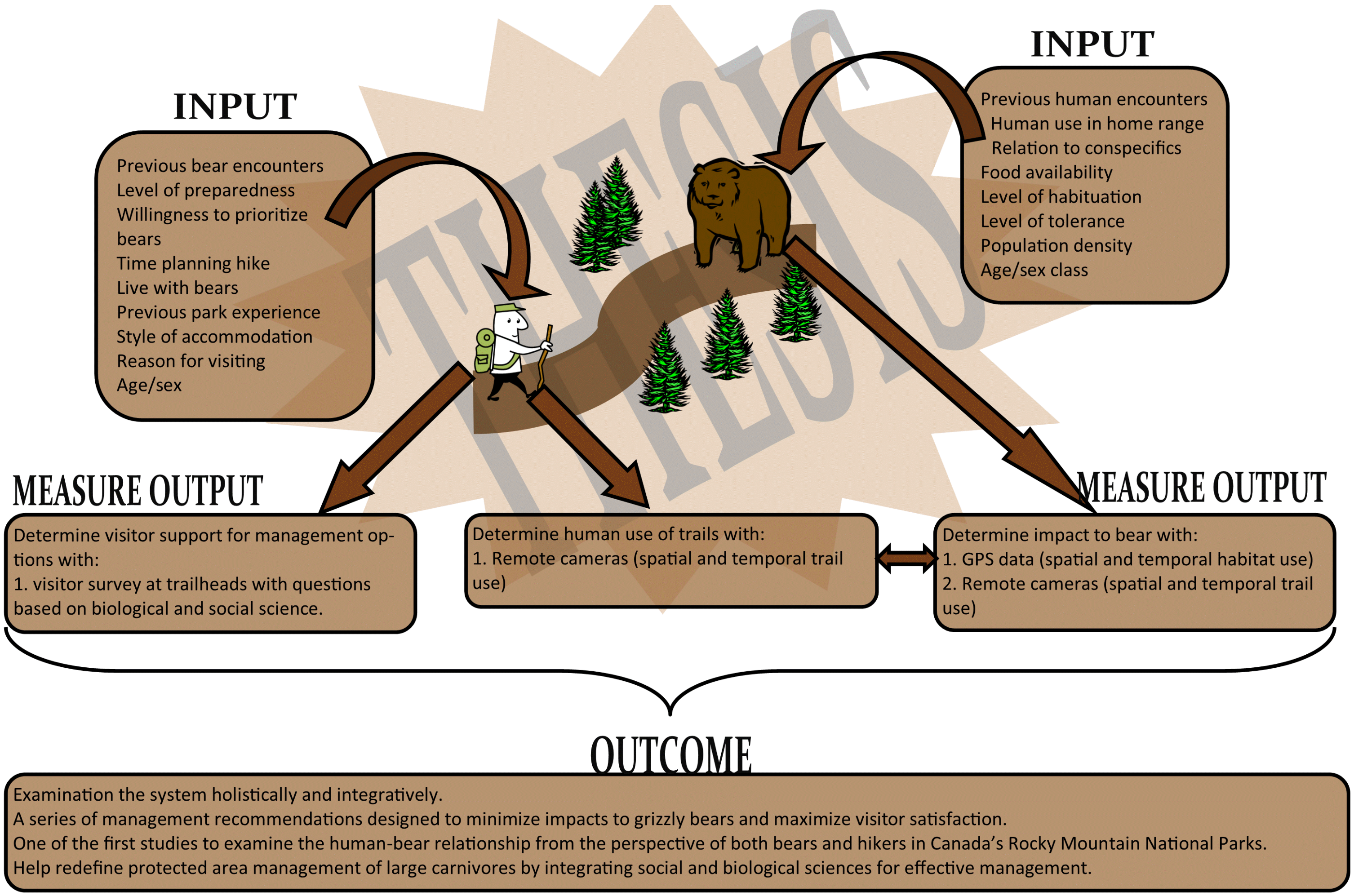


Figure 1.1: Using an interdisciplinary approach to answer a complex question. A bear's habitat use in relation to human presence is based on previous experience with people and other biological factors. The management expectations of trail users are determined by their previous experience and preparedness. I used both biological and social information to create holistic management recommendations as a final thesis outcome. I used data from GPS collars and remote cameras to understand grizzly bear movements and habitat use, and a trail user survey to define visitor expectations of management.

clearly identifying environmental, social, and economic objectives, implementing careful experimental design, and effectively monitoring the application of management options (Moore et al., 2009).

1.2 Research Objectives and Thesis Structure

To ensure a truly interdisciplinary approach, each clearly stated objective and step in the methodology should incorporate biological and social components while considering all other relative factors (e.g., socioeconomic and political contexts). I considered each of my research objectives independently so I could design methodological approaches that would generate robust and defensible data. Biological data focused on understanding grizzly bear habitat use and movement patterns around trails; social data focused on defining human use patterns of trails and understanding expectations associated with management actions.

Research questions and objectives were:

1. *Question:* What impact does methodological approach have on potential inferences made pertaining to grizzly bear habitat and trail use?

   Objective: To compare data and results generated by remote cameras and GPS collars in regards to grizzly bear habitat use (Chapter 2).

   - To compare results regarding grizzly bear habitat selection generated by remote camera data and GPS collar data.
   - To compare and contrast applications of these methodologies in a large, mountainous landscape.

2. *Question:* How does human use of trails influence grizzly bear trail use and habitat use adjacent to trails?

Objective: To quantify the spatial and temporal relationships between grizzly bear habitat use and human trail use (Chapter 3).

- To define human use patterns on trails in the study area through development of a human use model.
- To quantify grizzly bear trail use in relation to intensity of human use of trails.
- To quantify seasonal grizzly bear habitat use in relation to trails in grizzly bear home ranges.
- To quantify grizzly bear movement rates and patterns in response to trails of differing levels of human use.

3. *Questions:* How many human events need to occur before grizzly bear trail use is impacted? Can a potential threshold of human use be defined?

   Objective: To define potential thresholds in spatial or temporal human use that could lead to potentially displacing grizzly bears from high quality habitat in areas of human use (Chapter 3).

   - To identify a potential number of human events after which grizzly bears would be less likely to use trails.
   - To compare grizzly bear activity during the human active (day) and human inactive (night) times around trails of varying levels of human use.

4. *Questions:* What management options are trail users most/least supportive of? Does their support for these options change if a grizzly bear with cubs in the area? Does their support for these options change based on their demographic details?

Objective: To determine trail user support for various management options pertaining to grizzly bears in the vicinity of trails (Chapter 4).

- To test trail user support for management options based on two distinct and hypothetical scenarios: 1) a lone grizzly bear in the vicinity of a trail, and 2) with a female with cubs in the vicinity of a trail.
- To examine how support for management options was impacted by demographic groups, e.g., visitors vs residents and back-country users vs day users.

5. *Overall Synthesis Objective*: To define management recommendations that combine data from all sources (Chapter 5).

1.3 Study Area

My study area was comprised of Banff (BNP), Jasper (JNP), Kootenay (KNP), and Yoho National Parks (YNP) in Alberta and British Columbia, Canada (Figure 1.2). Together, these Parks were listed as a World Heritage Site in 1984 for their exceptional natural beauty, their provision of habitats for rare and endangered species, and their natural landforms (glaciers, lakes, mountains and caves; World Heritage Convention, 2016). In total, this protected area complex covers 20,238 kilometers $(km)^2$ of montane, subalpine, and alpine habitat (Table 1.1). Given their sensitive population status and the potential for human conflict, grizzly bear management is a priority in these parks; management focuses on achieving a balance between grizzly bear habitat security, human safety, and the provision of recreational opportunities for visitors (Parks Canada, 2010a-d).

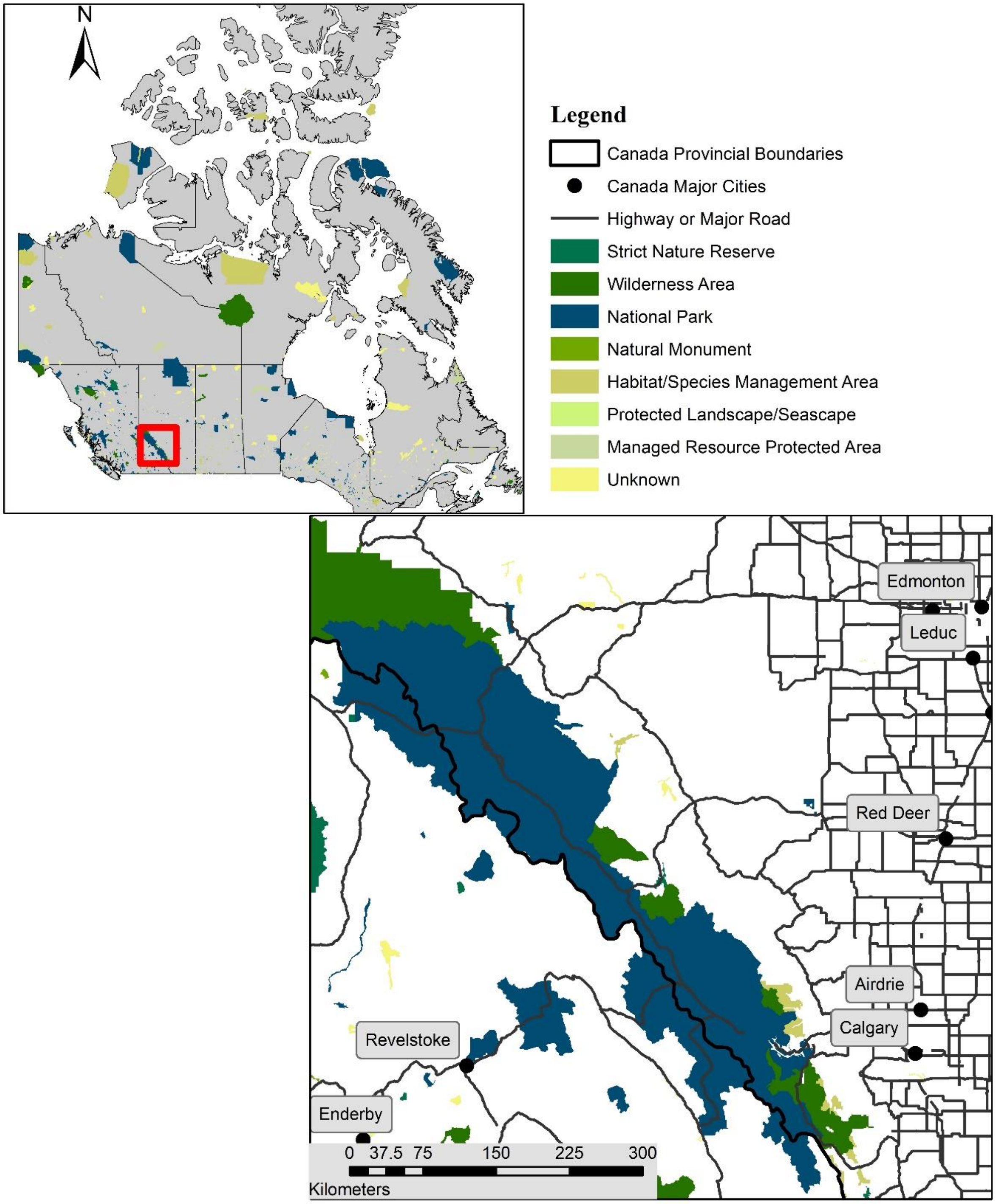


Figure 1.2: Study area in Canada's Rocky Mountain National Parks. Study area is delineated by the dark blue core network of National Parks in inset map, containing Banff, Jasper, Kootenay, and Yoho National Parks. The nearest city in Alberta is Calgary, the nearest city in British Columbia is Revelstoke. Canada's protected areas network from: Canada Centre for Cadastral Management, Geomatics Canada, Natural Resources Canada, 2008. Canadian Provincial boundaries from: ESRI Canada, 2016. Alberta and BC road network from: North American Major Roads, ESRI, Tele Atlas North America, ESRI, 2016.

Table 1.1: National Parks in the study area and their characteristics. All distances and area are in kilometers (km) or square km (km^2). Current population estimates were obtained from updated town websites, referenced in literature cited. Directions of highways are either north-south (N-S) or east-west (E-W).

National Park	Area (km^2)	Annual Visitation	Towns and (population)	Closest major city (population) and distance	Towns and (population) on periphery of park boundary	Major highway and direction	Contains National Railway (Y/N)	Other major development
Banff	6,641	3 million	Banff (7,584), Lake Louise (1,041)	Calgary (1 million), 110km	Canmore, AB (15,000) Kananaskis Village (249)	Hwy 1 (E-W) Hwy 93 (N-S)	Y	Ski resort (3), golf course (1)
Jasper	10,878	2 million	Jasper (5,236)	Edmonton (800,000), 313 km	Hinton, AB (9,640), Edson, AB (8,475), Valemount,BC (1,020)	Hwy 16 (E-W) Hwy 93 (N-S)	Y	Ski resort (1), golf course (1)
Kootenay	1,406	40,000	N/A	Calgary (1 million), 166 km	Radium, BC (777), Invermere, BC (2,955)	Hwy 93 (N-S)	N	
Yoho	1,313	500,000	Field (169)	Calgary (1 million), 208 km	Golden, BC (3,701)	Hwy 1 (E-W)	Y	

The Canadian Rocky Mountain National Parks are Category 2 protected areas as they are managed to protect large scale ecological processes and contain human developments and recreational opportunities (International Union for the Conservation of Nature, 2015). Within Canada's National Park system, the Rocky Mountain National Parks are the oldest and have some atypical features within their boundaries, including towns (Banff, Lake Louise, and Jasper), ski hills, and golf courses; these human use developments are not permitted in newer Canadian National Parks (National Parks Act, Section 36, 2015). Other towns outside of and adjacent to these National Parks also have the potential to impact grizzly bear habitat on a landscape scale. This is likely one of the most developed areas in North America where grizzly bear populations continue to live successfully (Gibeau et al., 2001). Depending on where their individual home ranges are located, grizzly bears in the Canadian Rocky Mountain Parks may not always have the option of staying away from human developments.

Grizzly bear management efforts are integrated between the different Parks in the study area at the landscape level, and all of the Parks list maintaining habitat security for grizzly bears as a key action in their current management plan (Parks Canada, 2010a-d). Common objectives are to maintain grizzly bear habitat access in areas of human use, reduce unnatural causes of grizzly bear mortality, and reduce human-bear conflict.

BNP is a unique protected area whose ecology faces numerous forms of human impact from ski resorts to major transportation thorough fares (Parks Canada, 2010a). Primary considerations in the current BNP management plan is to renew and reinvent visitor experience to increase visitation to the park by 2% annually throughout the term of the management plan and to raise public awareness of grizzly bear behaviour and ecology. Banff also aims to develop new recreational trails that concentrate human traffic away from high-quality grizzly habitat and enable bears use of important habitat areas and movement corridors (Parks Canada, 2010a).

JNP is the largest of the National Parks in the Canadian Rocky Mountains, and is subject to similar human development pressures as BNP, although it experiences less annual visitation. JNP’s current management plan contains similar objectives to that of Banff’s in regards to increasing visitation and grizzly bear habitat security simultaneously, but also includes specific objectives to maintain large tracts of wilderness (Parks Canada, 2010b).

Kootenay and Yoho National Parks are much smaller than Banff and Jasper, see less visitation and contain less development. Kootenay National Park hosts just over 400,000 visitors annually (Parks Canada, 2010c), and Yoho hosts over 500,000 annually (Parks Canada, 2010d). KNP also discusses the need to raise public awareness regarding grizzly bear behaviour and ecology.

1.4 Working with Citizen Scientists

Citizen science is a form of research collaboration where data gathering is performed by ‘non-expert’ individuals, who are often members of the public (Catlin-Groves, 2012). Typically, this approach is used for large-scale scientific studies (Hart, Stafford, Goodenough, & Morgan, 2012), and projects that encourage the public to participate by acting as voluntary field assistants gathering information to greatly increase datasets (Fowler, Whyatt, Davies, & Ellis, 2013). These projects, however, can also be designed to recognize and incorporate culture and policy contexts surrounding conservation science (Freitag & Pfeffer, 2013), and are thus part of the way in which perceptions of the natural world may change over time.

Citizen science usually incorporates an element of public education (Caitlin-Groves, 2012) and can dramatically improve public scientific literacy encouraging more serious consideration of other relevant complex scientific issues (Hart et al., 2012). Depending on the research project, citizen science can be beneficial to both the scientific community and the participants themselves. The scientific benefits of citizen science include expanding projects across larger spatial or temporal scales, obtaining data from private land, and increased data collection capacity. Social benefits include educating the public in the scientific process and scientific thinking, inspiring a different appreciation of nature and even promoting support for conservation initiatives (Freitag & Pfeffer, 2013). Participants can also provide a solution to the limited funding and capacity to collect data while gaining valuable experience in scientific research as well as educational and health benefits (Fowler et al., 2013).

The main concern from the scientific community centers around the credibility and reliability of data sets gathered by citizen scientists and the validity of associated assessments (Caitlin-Groves 2012; Gollan, Lobry de Bruyn, Reid, & Wilkie, 2012). Most researchers believe this concern can be alleviated through rigorous training of volunteers, targeted volunteer recruitment (Fowler et al., 2013), and a robust methodological approach. The disagreement between estimates and benchmarks among participants can sometimes be explained by the ambiguity in instruction or the differences in the way instructions are interpreted by individual volunteers (Gollan et al., 2012). As with any scientific research, however, the best way to ensure high quality data for analysis is to invest time in developing a robust sampling design and methodology that reduces chances of potential bias and ensures that analyses are shaped by the data not the ability or judgement of the observer (Caitlin-Groves, 2012). Scientific studies are designed to minimize bias, maximize precision, and ensure repeatability (Holt, Rioja-Nieto, MacNeil, Lupton, & Rahbek, 2013); these principles must also be consistently applied in the context of citizen science projects to ensure results are scientifically meaningful and retain cross comparability to other studies. When sound design is combined with rigorous and straightforward volunteer training all outcomes may be enhanced (Gollan et al., 2012; Hunter, Alabri, & Ingen, 2013). Protocols designed for volunteers should attempt to standardize survey efforts while maintaining public interest and involvement (Holt et al., 2013). Training citizen scientist volunteers should be thorough, but also simple. Researchers should clearly and concisely convey the right information (Caitlin-Groves, 2012); it is often helpful if participants attend a pre-research workshop with intensive training regarding, for example, species identification, data collection protocol, and field safety measures (Gallo & Waitt, 2011; Holt et al., 2013). Other training methods have entailed a volunteer accompanying a researcher to a field site and going through the data collection protocol with the opportunity to ask questions and engage in dialogue with the researcher (Gollan et al., 2012).

During data checking and cleaning, it is possible to compare the data generated by volunteers to that of data generated by experts. In these analyses, data generated by citizen scientists has been in strong agreement with those made by trained scientists (Fowler et al., 2013). Quality assurance and quality control measures should be embedded within data processing protocols and should contribute to an overall data quality improvement process (Hunter et al., 2013). This entails identifying the data quality dimensions, performing data quality measures, analysing the results and identifying discrepancies, and implementing tools that provide necessary actions to improve the quality of data (Hunter et al., 2013).

I worked with a total of 97 citizen scientists throughout my thesis research; volunteers assisted with remote camera deployment, visitor survey dissemination, and data entry. These efforts greatly increased my data collection effort (Table 1.2). A total of eight people volunteered all three years of field work, and 21 people volunteered for two years. The large proportion of repeat volunteers helped to ensure a transfer of knowledge from experienced to new volunteers, which contributed to data collection consistency and accuracy.

Involving the local community was key to project success as it was physically impossible for the research team, which consisted of myself and one seasonal volunteer intern, to conduct all data collection in the same time frame. My approach was to select tasks that did not require extensive technical knowledge but increased project capacity, many of these tasks were similar to work conducted by hired technicians on similar research projects. Working with volunteers also helped my thesis contribute to overall Alberta Grizzly Bear Recovery Plan objectives regarding public education and involvement in recovery.

Table 1.2: Summary of data collection effort and citizen scientist involvement. Data was collected from three separate sources: remote cameras, GPS collars on grizzly bears, and trail user surveys at trailheads. Citizen scientists were engaged in data collection pertaining to remote cameras and the trail user survey. In all, over 900 full days were contributed by a volunteer network consisting of 97 individuals over 3 years of field work; this equates to 1.5 full time positions for each 12 months of the project. In addition to these hours, a volunteer intern was hired to assist with volunteer management and data collection for 30 weeks from May to December 2014, and from May to July 2015.

Data Source	Sample Size	Method of citizen science engagement	Contribution of citizen scientists
Remote cameras	55 cameras on rotation. 423 sites sampled on 82 different trail networks.	- Set up and take down of cameras on both day-use and back country trails - Data entry of generated images.	- 506 full days for remote camera set-up and take-down. - An estimated 215 work days for image data entry.
GPS collars	27 individual grizzly bears	None	None
Trail user survey	697 completed surveys at 25 different trailheads	- Dissemination of surveys. - Data entry and checking from surveys.	- 190 full days for survey dissemination. - 7 work days for data entry and checking.

1.4.1 Volunteer Recruitment and Training

Volunteers were recruited through partnerships with local hiking and outdoors clubs, a research blog, and the Parks Canada citizen scientists program. Volunteers were asked to participate in one or more “teams” based on their interest and ability. One team was responsible for setting up and taking down remote cameras, another for disseminating visitor surveys at trailheads, and a third for data entry (classifying images from the remote cameras). Each team involved a different level of physical fitness and time commitment; the variety of work attracted a variety of people. All volunteers attended an annual mandatory day-long training session that described project objectives, safety protocols, and methodological steps required to ensure consistency in data collection and entry (Appendix A). The workshop also discussed a strict protocol for working with remote cameras in the National Park, as required by Parks Canada research permit BAN-2013-14576. The training sessions included a bear safety video and discussed all safety protocols associated with field work. Remote camera training included a hands-on session where volunteers put up and took down cameras as if in the field. Survey training included a session where volunteers practiced survey delivery and the associated preamble to other volunteers as if in the field. Training for data entry volunteers was done one on one for an hour; training focused on the project’s data entry protocol and application of the computer program used. Given that there were many photographs of people, all data entry volunteers were also required to sign a confidentiality agreement to ensure privacy of people captured with remote cameras. To ensure privacy, no images of people’s faces were used in presentations or research materials. All images of people were deleted once all data was entered.

CHAPTER 2 – ASSESSING HABITAT USE WITH REMOTE CAMERAS AND GPS-COLLAR TECHNOLOGY: A COMPARISON OF METHODOLOGICAL APPROACH

DECLARATION OF CO-AUTHORSHIP AND CONTRIBUTION

[This declaration is to be completed for each conjointly authored publication and placed at the beginning of the thesis chapter in which the publication appears]

Title of Paper	Virtual Collecting: camera-trapping and the assembly of population data in twenty-first century biology
Full bibliographic reference for Journal/Book in which the Paper appears	Elmeligi, S., Convery, I., Decker, V., & Nevin. O. (2017). Virtual Collecting: camera-trapping and the assembly of population data in twenty-first-century biology. *In* MacGregor, A (ed) *Naturalists in the Field: Collecting, recording, and preserving the natural world from the fifteenth to the twenty-first century.* Brill, Leiden Netherlands.
Status	X Accepted and In Press Published

Nature of Candidate's Contribution

I, Sarah Elmeligi, PhD Candidate, am the primary author for this book chapter. My role was to draft the primary chapter material, which was then added to by the co-authors. I was also responsible for editing, formatting, and reference checking the final chapter prior to submission to the editor.

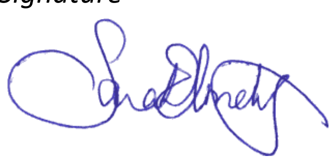
Nature of Co-Authors' Contributions

Co-authors provided additional materials based on their specific work (e.g., the snow leopard case study material). Co-authors also helped with the editing of the chapter drafts and approving the final version sent to the editor for publication.

Candidate's Declaration

I declare that the publication above meets the requirements to be included in the thesis as outlined in the Publication of Research Higher Degree Work for Inclusion in the Thesis Procedures

Signature



Date December 21, 2016

Abstract

One of the challenges facing behavioural ecologists is how to observe animals and their natural behaviour patterns without inadvertently affecting results simply by being present. Technologies used to address this issue include remote cameras and GPS collars; I compared and contrasted these two methodological approaches using data collected from fall 2013 to summer 2014. Remote cameras were deployed on 35 randomly selected trail networks within Banff, Kootenay, and Yoho National Parks from August 16 to October 15, 2013, and from May 1 to August 15, 2014; I compared this data to that from GPS collar data from 14 different grizzly bears over the same time frame. Grizzly bears were more likely to be detected on camera during the spring and summer than fall; habitat quality and weekend/weekday were not significant predictors of detection. The GPS collars, however, showed that grizzly bears continually preferred high quality habitat within their home ranges. Grizzly bears preferred habitats closer to roads and trails in the fall, but farther from roads and trails in the spring. The contrast between the GPS and remote camera data is partially an artefact of home range location and the spatial scale of focus from each data source. The remote camera data provided information whether or not a bear used a trail to move through the study area, whereas the GPS data was more useful in predicting in what kinds of habitat bears spent the majority of their time. The contrast between these two methodologies highlighted the need to define specific research questions and appropriate spatial and temporal scales before selecting one approach over the other.

2.1. Introduction

One of the major issues facing behavioural biologists concerns how to observe animals in their natural environment without inadvertently influencing behaviour (Krebs & Davies, 1996). Several approaches to address this challenge have involved carefully constructed sampling designs, such as those involving scan sampling from a distance (Altmann, 1974), using viewing blinds to obstruct observers, or using spotting scopes or binoculars to view animals from greater distances (Elmeligi & Shultis, 2015; Himmer, 1999; Smith, 2002). These approaches are most useful when direct observation of individual animals is required, animals congregate in specific areas and a researcher can be stationed in one or two locations to make observations. For animals that are more wide ranging or exist in lower densities or for research questions focused at the landscape or home-range scale, radio telemetry collars and Global Positioning System (GPS) collars (Hebblewhite & Haydon, 2010) or remote cameras (Burton et al., 2015) have been deployed. These remote approaches are useful when the research question does not require individual identification (in the case of remote cameras) or when direct observation of the animal is not required. By allowing a researcher to observe animals remotely, the potential impact of researcher presence on animal behaviour can be greatly reduced.

Both remote cameras and GPS collars have the ability to gather data at various spatial and temporal scales depending on how they are applied, therefore defining the spatial and temporal scale of interest must be done prior to engaging in field work. GPS collars provide a spatial location of the given animal at researcher-determined time intervals and can provide data at a fine spatial and/or temporal scales of movement, which is often assumed to increase our ability to understand animal ecology and conservation (Hebblewhite & Haydon, 2010). Remote cameras can be set up to capture an image or video at pre-determined time intervals, or to be motion-triggered. The use of remote cameras can provide discrete information of habitat use or animal presence spatially and temporally at local (Boyer-Ontl & Pruetz, 2014; Fancourt, 2014; Huang et al., 2014) or landscape scales (Clare, Anderson, Macfarland, & Sloss, 2015; Tigner, Bayne, & Boutin, 2014). The specifics of each of these approaches are detailed below.

2.1.1 Using Remote Cameras

The use of remote cameras as a methodological approach within wildlife biology has gained popularity in recent years as they are less intrusive, less costly, require less human capacity to effectively generate an abundance of data (Karanth & Nichols 1998), and can reduce sampling effort in remote and challenging landscapes (Sathyakumar, Bashir, Bhattacharya & Poudyal, 2011; Turpin, 2015). Burton et al. (2015) conducted an extensive literature review and meta-analysis on the use of remote cameras in ecology and found dramatic growth in the number of studies using remote cameras from less than 30 publications in 2008 to just under 70 in 2013; models developed to analyse this data have also increased in complexity and reliability. Remote cameras have been used to measure species abundance or occupancy through population size and density estimates in a particular habitat or geographic area (Baldwin & Bender, 2012; Dougherty & Bowman, 2012; Karanth & Nichols, 1998; Logan, 2015; Tigner et al., 2014), and to measure habitat selection and monitor other behavioural patterns (Boyer & Pruetz, 2014; Clapham, Nevin, Ramsey, and Rosell, 2014; Ohashi et al. 2012; Steenweg, Whittington & Hebblewhite, 2012).

Remote cameras have also been used to monitor understorey and overstorey vegetation within species-specific regions of interest, which allowed for sampling at very dense temporal resolutions and provided researchers with an intimate knowledge of the phenological patterns of food commonly used by grizzly bears in Alberta (Bater et al., 2011). Phenological patterns of vegetation growth were then linked to behaviour and habitat use of grizzly bears from other research efforts through robust statistical models (Bater et al., 2011). The above studies focusing on terrestrial animals have typically fastened cameras to trees or other stationary objects; in marine settings, however, cameras have been mounted to the heads of fur seals to monitor predation success and seal movement patterns (Volpov et al., 2015).

Remote cameras are limited in the kinds of information they can reliably generate about wildlife habitat use. Camera data can sometimes be misinterpreted for several reasons such as biased sampling regimes, failure to sample large enough areas, failure to accurately estimate the effective sampling areas, and applying inappropriate capture-recapture models when data do not meet required model assumptions (Foster & Harmsen, 2012). Another potential source of error in camera-based mark-recapture models occurs when subject animals do not have obvious individual markings, thus leading to unreliable individual identification (Dajun, Sheng, McShea, & Fu, 2006). This is often the case for bears where distinguishing individual pelage patterns is both difficult and frequently unreliable (Foster & Harmsen 2012), but grizzly bear research projects have shown a high level of individual variation in grizzly bear behaviour (Chi & Gilbert, 1999; Elmeligi & Shultis, 2015; Nevin & Gilbert, 2005; Pitts, 2001). These studies, however, relied on close, repeated observations of individuals in person to identify scars or other individual characteristics. In some cases, that information was then used to identify individuals on remote camera images (Clapham et al., 2014). Applied analyses need to consider if individual identification is required and if it can be done reliably with the remote cameras, setting, and species of interest.

Remote camera studies should be reliable, repeatable, and transparent in their approaches to measuring ecological processes (Burton et al., 2015). Two main assumptions typically associated with remote camera data collection are that the target population is considered closed and that all animals inhabiting the study area have equal probability of being detected (Sarmento, Cruz, Eira, & Fonseca, 2009). Traditional analyses with remote camera data have used mark-recapture methods to estimate population size and density, but these may not be applicable for low-density populations as it is difficult to obtain a sufficient sample size of capture-recapture events (Bater et al., 2011; Baldwin & Bender, 2012). Research studies attempting to monitor the presence of species may require a large survey effort and sampling intensity to observe certain species, particularly those living in low densities, and need to remember that absence of a species in photographs is not necessarily reflective of absence from the system (MacKenzie, 2005; Tobler, Carrillo-Percastegui, Pitman, Mares, & Powell, 2008). Sampling design and statistical modeling should account for the likelihood that a species was in the system but was not captured on camera. At the large-scale, cameras should be distributed to meet statistical model assumptions, whereas at the local-scale their locations are usually chosen to maximize capture probability (Foster & Harmsen 2012).

Selecting camera location to optimize capture probability may result in non-random, biased placement and this should be taken into account when extrapolating results to larger areas where the habitat will be of a different quality (Foster & Harmsen, 2012). It is important, therefore, that all habitat types are covered (Tobler et al., 2008) whether in relation to species abundance assessment or to assess a particular species' use of various habitats. Sampling will be biased if the camera locations are only optimal for a subset of the sampled population (Foster & Harmsen, 2012). Refined camera survey techniques did, however, provided researchers with a more efficient and cost-effective survey to generate precise estimates of deer abundance in Maryland (Dougherty & Bowman, 2012). Tobler et al. (2008) found that camera spacing and area covered had little impact on the number of terrestrial rainforest mammals recorded, rather survey effort (i.e., the total number of days cameras were left in the field) was the main factor determining the number of species recorded. The scale of the study area is also important to consider when extrapolating results to populations outside of the study area (Fancourt, 2014).

Statistical models applied to these data also need to address the researcher's ability to find the species on the landscape (detection probability), not necessarily where the species actually occurs on the landscape (MacKenzie, 2005). Detection probability can vary over the course of the study, e.g., seasonally, which should be considered in analysis (Logan, 2015). Accounting for detection probability is critical in regards to statistical models applied and inferences made. A low detection probability results in less confidence in occupancy estimates due to the difficulty associated with differentiating between sites where animals are poorly detected from sites where they are truly absent (O'Connell et al., 2006); this typically leads to underestimating occupancy (Baldwin & Bender, 2012). Researchers should carefully plan for these issues when developing a sampling design to ensure that remote cameras are the right tool to effectively answer the research question, that all associated assumptions are defined, and that any data short comings are explicitly recognized in the discussion of results.

2.1.2 Using Geographic Information and Positioning Systems

Geographic Information Systems (GIS) are computer-based systems designed for storing, manipulating, analysing, and visualizing spatially referenced data; they are also useful for analysing distributions of organisms in relation to the landscapes in which they are found (Gough & Rushton, 2000; Webb & Merrill, 2012). Within this context, researchers can use location data obtained from animals with GPS (Global Positioning System) collars to compare animal locations and movement patterns with natural habitat features (e.g., topography, hydrology, and vegetation) and human use features (e.g., roads, towns, and transportation corridors) on the landscape. GPS data provides a representation of spatial data that can be visually displayed to show spatial patterns. Animal location data can be correlated with topography and other natural features to determine spatial relationships in the landscape providing valuable conservation related information (Hebblewhite & Haydon 2010). GIS systems can be used to manage and analyse large datasets of complex, geographically referenced data (Boyce et al., 2010; Nielsen, Stenhouse & Boyce, 2006,); further they can be used to evaluate temporal patterns by representing environmental information and animal location data over time (Atkinson & Canter, 2011; Cohen, Kushla, Ripple, & Garman, 1996).

GIS layers can be used to represent habitat loss and fragmentation (Atkinson & Canter, 2011; Hirsch & Chiarello, 2012; Nielsen et al., 2006), or the degree to which ecosystems are being disturbed or degraded and the effects of these changes on ecosystem function (Latombe et al., 2014; Rose et al., 2015). Animal response to these changes may become evident through changes in their movement or habitat use patterns measured with GPS collars, which can then be measured and modeled over time across the landscape (Kite, Nelson, Stenhouse, & Darimont, 2016; Nielsen et al., 2006). Using GIS has become increasingly common in ecology related research; it has been used to assess wetland conditions and function over time, and to analyse the spatial distribution of land uses, soil erosion and other surface information (Atkinson & Canter, 2011). This technology has advanced as a means of assembling and analysing diverse data pertaining to specific geographic areas, with spatial locations serving as the organizational basis for the information systems (Northrup, Hooten, Anderson & Wittenmyer, 2013; Proctor et al., 2015).

Modelling applications, which are essentially simplifications of reality that to help us understand complex systems, are often used to predict animal habitat use over large spatial or temporal scales. Models are also used to test our ideas and generate new hypotheses about the mechanisms underlying observed space use patterns by performing experiments that would not be possible in the field (Gough & Rushton, 2000). This has helped researchers develop Habitat Suitability Indices (HSI models) or Resource Selection Functions (RSFs) where animal habitat use is modeled across the landscape based on variables such as slope, elevation, and vegetation type (Boyce et al., 2006; Gillies et al., 2006; Nielsen et al., 2006; Nielsen, Cranston, & Stenhouse, 2009). There are 4 hierarchical orders of habitat selection: the geographic range of the species (first order), an individual animal's home range (second order), selection of resource patches within that home range (third order), and selection of food items within resource patches (fourth order; Johnson, 1980). The scale of research interest guides the GIS methodological processes and analyses applied.

GIS layers and GPS data from animals are often used for use-availability analyses (Gough & Rushton, 2000), which contribute to RSF and other models to refine our understanding of a species' habitat use. Similar to presence-absence analysis, RSF modeling compares used and available resources to estimate selection for or against specific variables to provide quantitative, spatially detailed, predictive models of animal occurrence and habitat use (Gillies et al., 2006). Use-availability analyses typically employ a series of randomly generated points (representing available habitat) compared to used (GPS generated) locations. In an RSF, available units are those that could potentially be encountered by an animal; the distribution of available units defines the proportion of different environmental attributes across the study area (e.g., animal's home range, species landscape distribution; Lele et al., 2013). Used units are those resources that are encountered, selected, and are part of a set of resource units that have received some investment by an animal during a sampling period (Lele et al., 2013). Habitats are then defined as selected if there is a higher density of used locations than would be expected based on the random availability within the landscape scale of analysis (Stewart, Nelson, Wulder, Nielsen & Stenhouse, 2012). Use-availability analyses typically involve data from more than one individual in a population. Individual animal identification is not a variable controlled explicitly by the researcher but is still randomly selected from the population, therefore, adding individual as a random effect ensures the analysis addresses unbalanced samples and variation in the individual responses to covariates (GIllies et al., 2006). Gillies et al. (2006) demonstrated the necessity of this approach when they compared two RSFs - one that used individual identification as a random effect and one that did not. In their original RSF, grizzly bears use of open habitats was higher in low elevations and declined at higher elevations. The addition of a random effect improved model fit and changed the magnitude of the coefficients, even changing the significance of some variables. Addition of individual as a random factor also allowed the researchers to evaluate individual variation in selection for elevation and allowed for an unbalanced sampling among bears (Gillies et al., 2006).

GPS data from collared grizzly bears has been used to identify selected habitats and spatial-temporal patterns of habitat use based on topography and water availability (Mertzanis et al., 2008), greenness and human development (Ciarniello, Boyce, Seip, & Heard 2007b), forest disturbances (Stewart et al., 2012), and landscape disturbance over time (Berland et al., 2008). Although grizzly bears display individual responses to stimuli and resulting habitat selection, some variables are consistently selected (greenness) or avoided (intense human development) across scales (Ciarniello et al., 2007b).

Location data has also been used to model source and sink habitats for grizzly bears in Alberta based on habitat occupancy and mortality risk maps created using various environmental and human use predictor variables (Nielsen et al., 2006). Creating these models can be challenging for wide ranging species as there is no way to analyse relationships or variables that occur outside of the study area boundaries; for example research may focus on specific jurisdictional boundaries but an animal may have locations outside of that boundary. Study area boundaries can be set as an area of interest (Berland et al., 2008; Hirsch & Chiarello, 2012), as a jurisdictional area of interest (e.g., a protected area or County; Fortin et al., 2005), or may be predetermined by the extent of available habitat layers (e.g., a GIS vegetation layer for a province cannot provide habitat information for individual animals that cross provincial boundaries). Alternatively, as in Nielsen et al. (2006), animal locations can be used to set the study area not geography details.

GIS technology has been used to improve habitat modeling and conservation objectives for animals through its increased potential for unbiased, high-quality data; this has led to significant advances in our knowledge of basic ecology of species foraging (Gough & Rushton, 2000), movement, and distribution patterns (Hebblewhite & Haydon, 2010). GPS technology provides highly precise spatial and temporal location data about animal movements at researcher-determined time intervals. The habitat use that occurs between location points should also be considered in analysis and when presenting results. Use as reflected by GPS locations does not always represent habitat occupancy. An area is *occupied* if the species is always present somewhere within that area over a set period of time (e.g., season); as used GPS locations include traveling, the fraction of spaces *used* by the species is generally larger than the spaces that were *occupied* by the species (MacKenzie, 2005).

Like all research methodologies, GIS-based models can be limited by unknown or unaccounted for confounding variables. Concerns with GIS technology are largely focused on methodological approaches and analysis challenges. The absence of any representation of indirect effects or cumulative effects of variables pertaining to the research question can limit models rendered through GIS analyses (Atkinson & Canter, 2011). Of particular interest is the difference in spatial or temporal scales at which GIS data has been collected for various habitat or environmental data. While it is possible to obtain very fine scale data of an animal's movements (every 20 minutes for example), habitat data may be gathered at much larger scales than the subject animal can actually cover in 20 minutes. For example, the micro-scale habitat selection of an animal that covers 100 meters (m) in 20 minutes will not be analysed effectively if the habitat data has been collected in 500m sampling intervals. It can therefore be challenging to determine the biological drivers for an animal's particular movement patterns (Boyce et al., 2010). Potential discrepancies in scale need to be addressed in study design – if micro-habitat selection of the subject species is being researched, GIS layers will also need to be created at fine spatial scales.

Careful biological measurements of resource availability and behavior are required to complement GPS technology (Hebblewhite & Haydon, 2010). Grizzly bear research from northern British Columbia found that scale-dependent habitat selection occurs (Ciarniello et al., 2007b); statistical models are more reliable if they are created across different spatial (e.g., site, home range and landscape) and temporal (e.g., seasonal and annual) scales with the same data. Ecologists should better attempt to match temporal varying estimates of resource availability at the same time scale as animal movements (Boyce et al., 2010; Thurfjell, Ciuti & Boyce, 2014). Scales chosen for inclusion in statistical models should be reflective of the data's details. Although grizzly bear habitat selection is scale dependent, the appropriate scale on which to base management decisions depends on the management question.

One of the greatest challenges facing analysis of GPS data is reconciling the relationship between movement and resource selection (Turchin, 2015). Failure to incorporate movement into statistical analyses can lead to autocorrelation between GPS locations, which is another significant challenge with this data source (Nielsen et al., 2002; Boyce et al., 2010). Spatial autocorrelation implies that the value of a variable at any particular location is dependent upon its value at neighboring sites, or the value at one site increases with its value at neighboring sites leading to a clustering of organisms spatially (Gough & Rushton, 2000). This is relevant to our understanding of how an animal uses habitat, particularly where a series of locations may be clustered if the animal is feeding or resting in one location over a period of time. Northrup et al. (2013) suggest that in such cases where autocorrelation is a factor, the term "preference" is more appropriate than "selection" when describing habitat use. Spatial autocorrelation can exacerbate error in availability sampling by creating bias for some landscape characteristics, leading to an imbalance between truly available and used locations (Northrup et al., 2013). Sequential observations that are not independent spatially or temporally may violate assumptions for statistical inference (Boyce et al., 2010); statistical models should address these potential sources of autocorrelation (Gough & Rushton, 2000; Nielsen et al., 2002). Including landscape features as predictor covariates and then examining residuals for spatial autocorrelation is one solution (Boyce, 2006), however, residual autocorrelation may exist due to animal behavior or another unmeasured ecological variable, thus confusing the analysis (Boyce et al., 2010).

Addressing autocorrelations requires analytical tools that use the researcher-defined time interval of location fixes to determine biologically relevant movement behavior. One approach is to plot autocorrelation in step lengths as a function of time lag yield patterns (Fortin et al., 2005). Pairing autocorrelation functions with models of habitat use and movement, and knowledge of a species provides a more complete view of the behavioural patterns exhibited by animals (Boyce et al., 2010). These types of analyses are referred to as Step Selection Function (SSF) modeling (discussed and applied in Chapter 3 of this thesis). Over the longer term, similar approaches can be used to analyse movement of home ranges over times (STAMP – Spatial Temporal Analysis of Moving Polygons), which has been used to demonstrate shifting boundaries of home ranges over several years based on age-sex class as grizzly bears mature (Smulders et al., 2012; Sorenson et al., 2015).

Another limitation to GIS analysis and GPS collars is associated with budgetary constraints. GPS collars and often GIS software are costly (Atkinson & Canter, 2011; Rose et al., 2015), which can lead to a trade-off between the overall sample size and project cost (Hebblewhite & Haydon, 2010). The ability to incorporate these technologies into decision making is also dependent on the cost and availability of the data to feed into the models (Rose et al., 2014). Researchers are frequently faced with balancing a fine scale level of data with the cost associated with obtaining a reasonable sample size. While the number of GPS collars required depends on the research question, Hebblewhite and Haydon (2010) recommend that a minimum of 20 GPS collars be mounted on individuals of a species to obtain sufficient data to make inferences at the local population scale. GPS collars are also invasive as they require trapping, chemically immobilizing (for some species), and handing an animal in order to attach the collar. Some research has attempted to address these shortcomings by combining GPS data with other data sources. Mertzanis et al. (2008)

combined GPS generated bear locations with location data from bear signs to increase sample size of used-habitat locations. There were biases with this approach, however, as the individual sample size from GPS collars was small and data could not be analysed seasonally. While combining datasets in this way is not always advised because of this and other potential biases, this approach allowed researchers to consider habitat use beyond the few bears they had been able to fit with GPS collars and expand the spatial coverage of the study area.

2.1.3 The Resource Selection Function (RSF) Model Used

My research relied heavily on a Resource Selection Function model developed by Nielsen (2005) for grizzly bear habitat in west-central Alberta. Data 21 GPS collared grizzly bears from 1999 to 2002 were used to create the model. The RSF was developed for habitat selection in three seasons: spring, summer, and fall. For each season, an RSF at the population level was calculated; individual areas of the landscape were scored based on their use in proportion to their availability. Use in concordance with availability was represented as 1.0, selection (use is greater than availability) was represented by a score >1.0 and avoidance by a score of <1.0. Nielsen (2005) used these availability scores to define 10 quantile bins that ranked habitat with low relative probability of use (1) to habitats with a high probability of use (10). The RSF model represents habitat selection at the 3rd (patches/stands) and 4th (within patch/stand variation) order scales likely to be most relevant for resource management.

This RSF was developed to assess grizzly bear habitat selection in a landscape that included protected areas, commercial forestry operations, and oil and gas operations. The predictor variables used to define habitat selection included: age of clearcut (in years), size of clearcut (km^2), and silviculture data. These predictor variables were added to other landscape metrics of distance-to-clearcut edge (km), and area (km^2)-to-perimeter (km) ratio. The model also included a 26.7 digital elevation model (DEM) to estimate elevation and terrain ruggedness for each used or available grizzly bear location. Nielsen (2005) added soil wetness (or compound topographic index – CTI) and estimated direct incoming solar radiation as predictors to the RSF model based on the DEM. The model also included land cover (vegetation type) and forest age (Nielsen et al., 2006). This RSF model was expanded across western Alberta by Foothills Research Institute Grizzly Bear Program to cover 100,000 km^2 and to use additional data from grizzly bear GPS collar data from 2004-2007.

2.1.4 Chapter Objectives and Hypotheses

One objective of my thesis is to quantify grizzly bear habitat use near trails and to quantify human use of these same trails. To address this objective, I used both GPS collars on grizzly bears and remote cameras to examine spatial and temporal grizzly bear habitat preference in relation to human use trails. As such, my research presents a unique opportunity to compare and contrast data generated from both sources to answer similar research questions. This comparison will help further discussions regarding appropriate methods to answer habitat use related research questions. This chapter examines data generated from the remote cameras and the GPS collars for the first year of data collection (fall 2013, spring 2014, and summer 2014). I chose to use a sub-set of the data to keep the dates of collection between the two sources consistent for effective comparison. Another objective of this chapter was to validate the RSF model for my study area. The overall purpose of this chapter is to compare the results and inferences generated from these two methodologies. The discussion portion of this chapter will compare the limitations from each data source and the implications on potential conclusions. Chapter hypotheses were:

H_1: Areas defined as high quality habitat in the RSF model will be characterized by increased grizzly bear use.

H_2: Grizzly bear trail detection with remote cameras will increase with decreased human use of the trail and increased distance to road.

H_3: Grizzly bear habitat preference, as measured with GPS collar data, will be positively correlated with distance to linear features (i.e., roads and trails).

H_4: Remote camera data will perform better for predicting grizzly bear trail use, whereas GPS collar data will perform better for predicting habitat use in relation to habitat quality.

2.2. Methods

Previous research efforts examining grizzly bear habitat use in Alberta separated the year into three distinct seasons: hypophagia/spring (May 1 to June 15), early hyperphagia/summer (June 16 to August 15), and late hyperphagia/fall (August 15 to October 15; Nielsen, Johnson, Heard, & Boyce, 2005). I used these same dates and seasons for both the remote camera and GPS sampling design and analysis. All of my research was approved and conducted under Parks Canada Research Permit BAN-2013-14576 (Appendix B).

2.2.1 Remote Camera Sampling Design

Remote cameras were used to record human use patterns for comparison with grizzly bear trail use or presence-absence information. Cameras were placed on trails throughout the study area to ensure all grizzly bears and people using human use trails in the study area had an equal opportunity of being detected. Grizzly bears could violate this assumption by walking on part of the trail not covered by a camera and people could violate this assumption by walking behind a camera to avoid it or by not following a trail. Grizzly bears not being captured by camera should be addressed by considering the camera's detection probability, and the majority of people using trails in the study area follow designated trails. Cameras were deployed in a variety of habitats at varying distances from human developments, such as towns and roads (Figure 2.1a-c show camera locations in relation to grizzly bear GPS locations for each season).

Placing cameras specifically on trails or in areas known to be frequented by wildlife has been used to increase camera capture success (Karanth & Nichols, 1998; Gil-Sánchez et al., 2011; Ohashi et al., 2012; Sathyakumar et al., 2011). To capture grizzly bear and human use on trails, I placed cameras on human use trails used for hiking, mountain biking, and horseback riding. Although three trails in the study area are accessed by maintenance vehicles, no public motorized use is permitted on any trail in the study area. This is the defining difference between roads and trails in the study area; roads are accessible to public vehicular traffic and were only considered in the analysis of GPS collar data. This sampling design assumes that grizzly bears have the same probability of being captured walking on

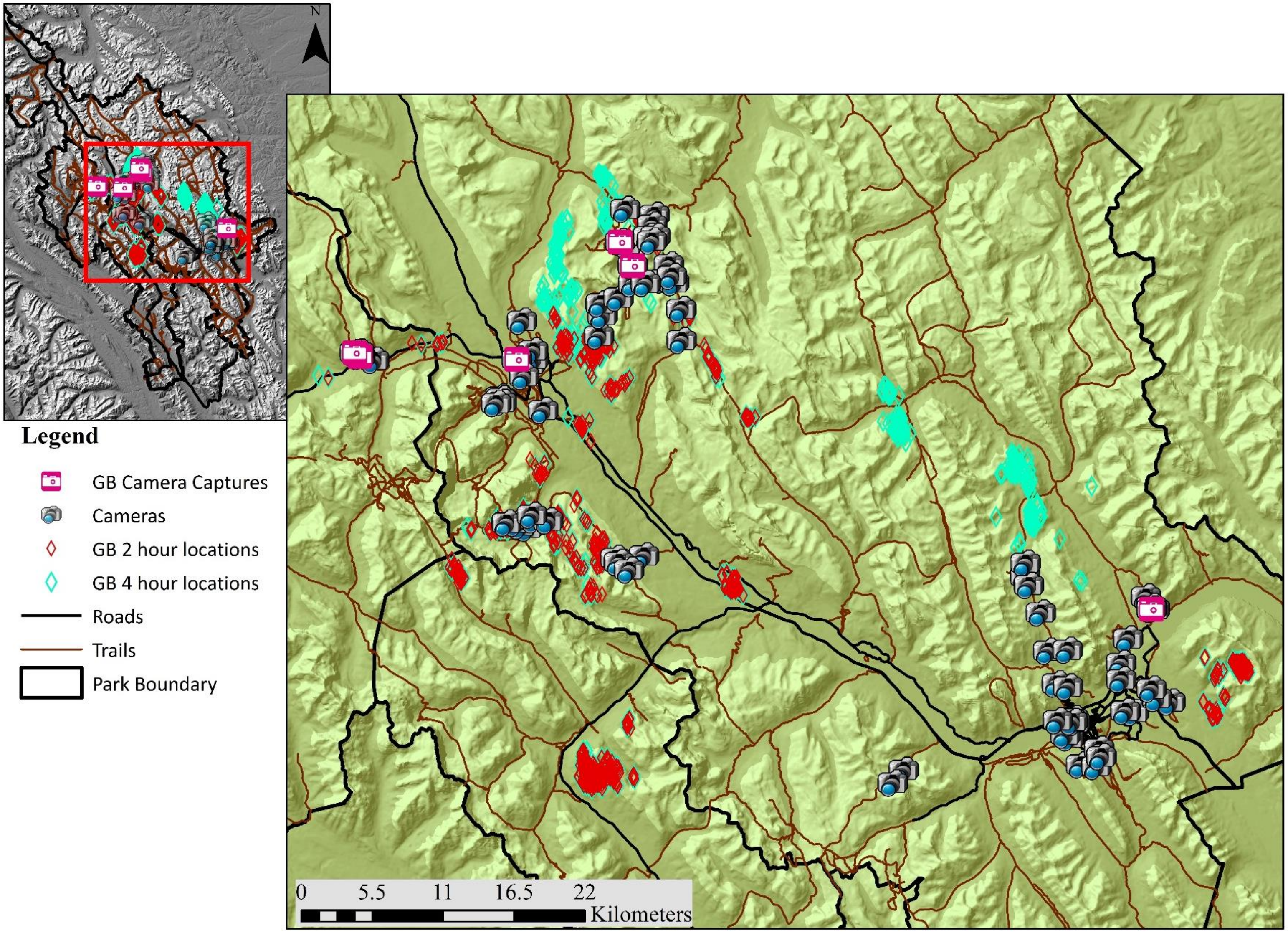


Figure 2.1a: Camera locations and grizzly bear locations during Fall 2013. Two hour grizzly bear locations are indicated with red diamonds; 4 hour locations with blue diamonds. Cameras that detected a grizzly bear are pink; other cameras did not detect bears.

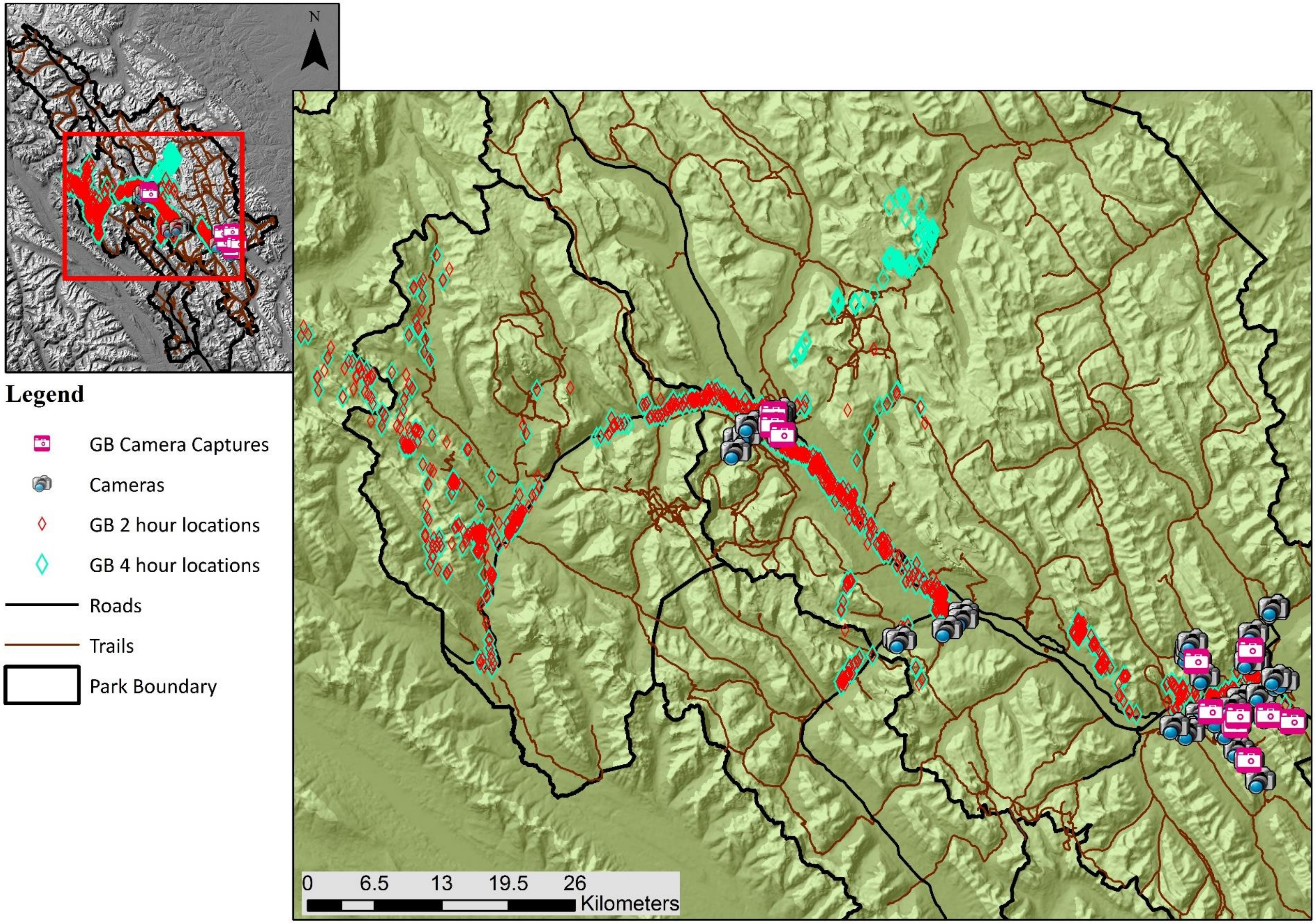


Figure 2.1b: Camera locations and grizzly bear locations during spring 2014. Two hour grizzly bear locations are indicated with red diamonds; 4 hour locations with blue diamonds. Cameras that detected a grizzly bear are in pink.

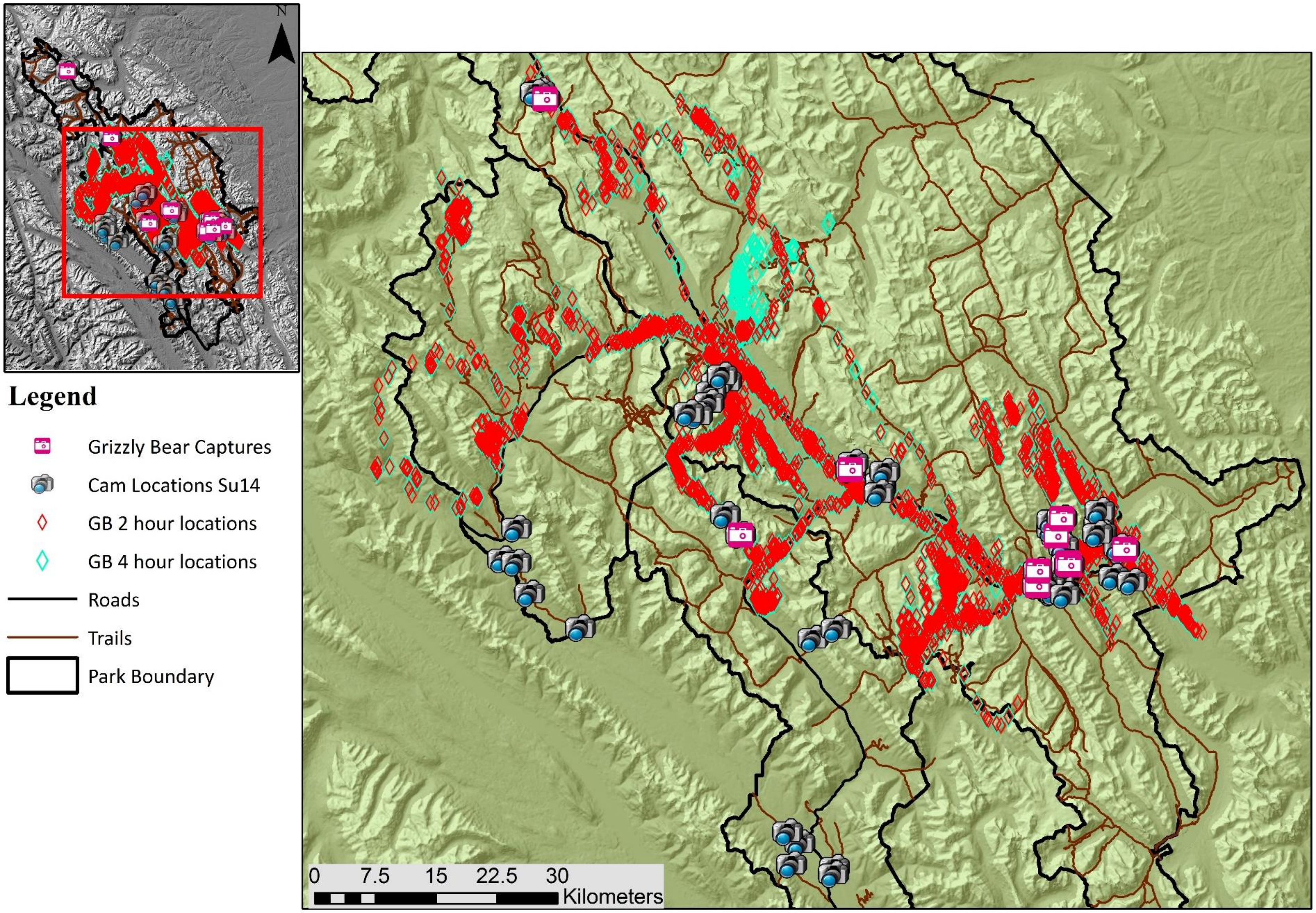


Figure 2.1c: Camera locations and grizzly bear locations during the summer of 2014. Two hour locations are indicated with red diamonds; 4 hour locations with blue diamonds. Cameras that detected a grizzly bear are in pink.

human use trails as they do walking in randomly selected locations within their home range. This may not be case for all bears or all areas of the study area, although previous work did find grizzly bears use established human use trails to navigate the landscape (Steenweg, Whittington & Hebblewhite, 2015). My research question was focused on grizzly bear use of human use trails. Therefore, violating this assumption is not as relevant as if I was attempting to measure grizzly bear occupancy or population density. I assumed there were occasions when bears would use other wildlife trails or non-trails, but on these occasions bears and people are not utilizing the same trail system. These exceptions should not affect my analysis or results.

A list of trails within the study area was compiled based on Parks Canada's database of designated official hiking and walking trails (Parks Canada Agency unpublished data, 2016). Human use was categorized based on three levels: low (<100 people/month; Gibeau et al., 2001; Hood &Parker, 2001), medium (101-1439 people/month), and high (>1440 people/month). All previous research on grizzly bear habitat use in response to people has used two categories of human use (low and high) based on a threshold of 100 people/month; however, several trails in the National Parks see several thousand hikers per month. Thus, I created a third level of human use based on extrapolating data from Rogala et al. (2011) who found that 2 people per hour could displace elk and wolves from hiking trails. This was a more current measure of a low human use level and its impact on other species. To establish a medium level of human use, I extrapolated the minimum hourly estimate from Rogala et al. (2011) to a monthly human use estimate and then doubled it to define the threshold between medium and high levels of human use. I used a categorical measure of human use rather than a numerical variable (number of people captured on camera) because cameras could capture multiple pictures of the people in one group. It was important to avoid double-counting trail users. Categorizing human events eliminated this issue and is discussed in more detail in the data analysis section of this chapter.

To create the sampling design, each trail was categorized as low, medium, or high human use based on the most recent trail use estimates from the Parks Canada Master Trail database (Parks Canada Agency unpublished data, 2016); for trails that did not have a quantitative estimate of use, I estimated which category they would fit based on discussion with Parks Canada staff familiar with the trail (K. Rogala, personal communication, 2013). Trails were then grouped into trail networks, which included a main trail and all its offshoots as well as any smaller trails within 500m. For random sampling, the human use level associated with the main trail was used as the human use level for all trails in the network as most offshoot smaller trails did not have trail counts of their own and the main trail is where the majority of human use at the network scale is focused.

I used stratified random sampling to select trail networks first by the level of human use and then to create the order of sampling. This was done independently for each season; a trail network could not be sampled more than once per season. In each season (spring, summer, fall), an equal number of trail networks from low, medium, and high use levels were randomly selected and ordered to create the sampling schedule. Precise dates of camera set-up and take-down were affected by logistical factors such as the amount of time required to hike certain trails (Dajun et al., 2006) and capacity of field staff and volunteers, therefore the exact date of sampling was not randomly assigned.

All remote camera photos were classified using the program TimeLapse Image Analyzer (Greenberg Consulting Inc., 2015). TimeLapse is a computer program designed to facilitate data entry from remote cameras, which can be difficult and onerous when thousands of images are generated. TimeLapse uploads all camera images; it then displays photos individually and a custom interface for entering data specific to the researcher's requirements. The researcher is responsible for defining the data fields to be filled in during data entry. The program automatically saves data from the camera's images to a .csv file, which can be used in statistical analysis programs. A team of volunteers assisted with remote camera data entry and set-up/take-down. In 2013, 18 volunteers and in 2014, 35 volunteers assisted with camera set-up or take-down; over this same time frame, 25 volunteers assisted with the data entry.

Recent work in Banff National Park found grizzly bears were significantly more likely to be detected by remote cameras set on human-use trails than they were on non-human-use (wildlife) trails when no lures were used (Steenweg et al., 2012). This research had also suggested that detection probability did not increase when cameras were left up beyond 14 days (Baldwin & Bender, 2012; Steenweg et al., 2012); in fall 2013, I left cameras on trails for 14 days. The following year, however, this research was updated with an increased sample size and suggested that longer periods of time of at least 50 days were required to achieve maximum detection success (Steenweg et al., 2015). Using an intensive sampling design, I wanted to test as many sites as possible in each season and only had 55 cameras in operation. Starting in 2014, I left cameras out for 21 days at a time to increase detection probability but still sample as many sites as possible in a season.

A general strategy for rare species is that landscape units, small regions of an arbitrarily defined size or naturally occurring discrete habitat patches, should be sampled at least 3 times over a relatively short period of time (MacKenzie, 2005). I defined trail networks as the landscape unit and sampled a minimum of 3 low, medium, and high use trails per season. Cameras were placed at trail junctions and mid-way points between junctions on all trails that were part of any sampled trail network. In situations where junctions were closer than 500m to each other, one camera was placed on each trail branch of the network but not at the junction itself. Therefore, the number of cameras placed on a trail varied not by trail length but by trail complexity. This approach provided an accurate measure of human and grizzly bear use on each trail within a network.

I placed cameras on a variety of hiking trail networks ranging from short (<5 Km) day use trails to longer (>30 Km) back country trails of varying levels of human use. Cameras therefore covered a range of habitat, elevation, human use levels, and distances from towns and roads. While grizzly bears will select habitats of higher quality based on various factors, such as vegetation, preliminary visual examination of the grizzly bear GPS locations used in my research showed that all collared grizzly bears had at least one hiking trail within their annual home range.

Images of grizzly bears and people on hiking trails were recorded using the Bushnell Trophy Cam 8HD. These cameras are equipped with motion and heat sensors thereby reducing the number of images captured due to vegetation movement in the wind (Wawerla, Marshall, Mori, Rothley, & Sabzmeydani; 2008); the cameras have a built-in infrared LED flash motion sensor to capture images in low light and overnight. Cameras were set to take one photo every 6 seconds whenever heat and motion were detected in front of the camera.

Cameras were wire-locked to trees in an effort to meet as many of the following requirements as trail conditions and topography would allow:

1. At an intersection between a wildlife trail and a human use trail;
2. A clear view of the trail without branches, shrubs, or grasses obstructing the picture frame;
3. On a tree sturdy enough to withstand strong winds (diameter of 15cm or more);
4. At a horizontal angle to capture at least 5 meters (m) of the human use trail;
5. At a height and vertical angle where the ground of the trail was captured in the bottom half of the photo frame. This ensured the camera's ability to photograph a bear's feet to aid in species identification and to minimize the number of photos of people's faces;
6. Facing in a northerly direction to avoid direct sunlight from overexposing photos;
7. With minimal damage to the tree itself and other surrounding vegetation.

Each time a camera was mounted, the trail name, GPS location (in a handheld GPS unit), camera name and identification (based on the camera's location and trail name), and a general description of where the camera was mounted were recorded.

A pilot season was conducted from July 30 to August 15, 2013 to test camera functionality and to refine placement and positioning. Data used in this chapter were generated from 35 trail networks over 3,329 capture days, which were defined as the number of 24-hour periods from camera set-up to take-down (Table 2.1).

Table 2.1: Number of trail networks sampled from fall 2013 to summer 2014. Camera capture days refer to the number of 24-hour days that cameras were deployed on trails.

Season and Year	Trail Networks Sampled	Camera sites	Camera capture days	Total number of images
Fall 2013	12	79	1,055	93,307
Spring 2014	9	49	1,012	50,318
Summer 2014	14	63	1,262	28,126
Total	35	191	3,329	171,151

2.2.2 GPS Data Sampling Design

As data from the GPS collars were being used on multiple research projects, grizzly bears were captured and collared by Parks Canada. GPS collars were fitted to bears following capture and handling protocols approved by the Parks Canada Animal Care Committee (Garrow et al., 2015). Parks Canada's objective was to maintain 10-12 grizzly bears with GPS collars each year from 2012 to 2015 between the east boundary of Banff National Park and the west boundary of Yoho National Park. In 2013, 6 bears were fitted with GPS collars and 9 bears retained their collars from 2012. In 2014, 9 bears were fitted with GPS collars. In 2013, a total of 16,071 GPS points were recorded from 2 adult females, 2 females with offspring, 1 adult male, and 1 subadult male; in 2014, a total of 17,170 locations were recorded from 3 adult females, 3 subadult females, 4 adult males, and 2 subadult males (Garrow et al., 2015). Data from 6 grizzly bears in the fall of 2013, 9 from the spring of 2014, and 11 from the summer of 2014 were included in this analysis; only one adult female and one adult male had data from both 2013 and 2014.

GPS units were programmed to attempt a GPS fix every 20 minutes, 2 hours, or 4 hours depending on the bear's proximity to the major railway bisecting the National Parks, which was part of the sampling design associated with another research project. Due to collar malfunctions, 20 minute fixes were ceased after 2013 (Garrow et al., 2015). When to adjust a bear's GPS fix intervals was decided by Parks Canada staff; 2- hour fixes were obtained when bears were using habitat in or near the Bow River valley bottom and the transportation corridor, and 4-hour fixes when the bear was clearly into the backcountry (also shown in previous Figure 2.1a-c). Changing from 2-hour to 4-hour locations helped save battery power and extend the life of the collars.

I obtained the following GIS baselayers from Parks Canada for analyses: National Park boundaries for Banff, Kootenay, and Yoho National Parks, designated trails (included hiking, biking, and ski trails), and roads (Parks Canada Agency, unpublished data, 2016). The roads layer included all paved roads from the TransCanada highway to residential roads; I considered all roads equal regardless of size or traffic volume in my analyses. The geographic reference system of all base layers was Universal Transversal of Mercator (UTM Zone 11U); I used the same coordinate reference system for my remote camera locations.

The RSF model used did not include any lands in the province of British Columbia and could therefore not be used for Kootenay and Yoho National Parks. I used three individual RSF models for spring, summer, and fall. For all analyses, except validating the RSF model, I classified RSF habitat layers into 3 categories: low quality (RSF category 0-4), secondary habitat (RSF category 5-7), and primary habitat (RSF category 8-10).

These RSF models were created with GPS collar data from 2004-2007. To test H_1, I validated the RSF model by testing the GPS data from grizzly bears in this study against the existing seasonal RSF models by extracting the number of locations for each individual bear in each RSF habitat quality bin (ranging from 1 to 10). I then calculated the percent area of each habitat quality bin in Banff National Park. I defined a bear's percent use by dividing the number of locations by the total area of that habitat quality bin. I then ran a Spearman Rank correlation analysis on each season separately examining correlations between percent use and RSF bin;

the percent use was averaged among bears for model validation. If the model is performing well then use should increase with habitat quality bin.

2.2.3 Remote Camera Data Analysis

Data from remote cameras were cleaned prior to analysis to delete images that were not of people or grizzly bears. I identified multiple images of the same subjects (whether grizzly bears or people) over a period of time and classified them as "consecutive events", which were defined as an image containing at least one common subject (e.g., person, dog, bear, or horse) as the image preceding it and being separated by less than 10 seconds. A series of consecutive images of people or bears were classified as 1 human event or 1 grizzly bear event respectively. Human events or grizzly bear events were therefore defined as a new person(s)/bear entering the photo frame preceded by at least 6 seconds (trigger speed of the camera) of no activity on the trail. The total number of human and grizzly bear events were calculated for each camera. There were no instances of a grizzly bear and person being captured in the same sequence of photographs.

During data preparation for analysis, the following variables were calculated for each camera:

- Total Time – the length of time for each consecutive event;
- Event Timing – the length of time between all human and grizzly bear trail use events;
- Total Events – the total number of human and bear events;
- Total People – a sum of the number of people in each human event. This was a minimum estimate of trail use as the equation only used the number of people

captured in the first image of any consecutive sequence and non-consecutive images;

- Total horse and dog events – the total number of horse events and dogs that were captured;
- Time of Day – dawn/dusk (5:00-7:59; 18:00-20:59), day (8:00-17:59), night (21:00-4:59). Gibeau, Clevenger, Herrero, and Wierzcowski (2002) defined human active time as 8:00-17:00 and human inactive as 17:00-8:00, which I used as a guideline to create the time periods;
- Distance to road – using GIS data of the existing road and trail network, the straight distance of the camera to the nearest road was calculated; and
- Habitat quality – each camera was assigned a habitat quality value based on the relevant seasonal RSF layer described above. Habitat quality was calculated using the Values to Points tool in ArcGIS and was interpolated by averaging habitat quality from all 30m x 30m cells adjacent to the camera and the cell the camera was in.

In each image, human activities were recorded as: hiking, running, biking, horse riding, or vehicle. This was used to classify trails as either hiking only, hiking with biking/horses, and all activities including vehicles. I calculated an estimate of monthly human use on each camera by taking the average number of human events/trap day/camera and multiplying that by 30; I used the result to classify the camera as being on a low, medium, or high use trail segment.

I used a presence/absence analysis for camera data. Presence/absence data are modelled using logistic regression, which is based on a binomial probability distribution; the simplest of these models assume that the incidence of presence is dependent on a series of habitat variables (Gough & Rushton, 2000). Data from cameras were analysed with a series of backwards stepwise regressions. In each instance the dependent variable was the presence/absence of a grizzly bear; predictor variables entered into the equation were the camera's distance to road, human use category (low, medium, high), trail activity type, and habitat quality (low quality, secondary habitat, primary habitat). Each season was analysed separately to account for seasonal differences. This analysis measured grizzly bear trail use in relation to human use (H_2). The RSF habitat quality layers included a measure of distance to edge, which could be a road or a clearcut in its estimate of habitat quality. Although the potential for autocorrelation bias was small, I ran two separate regressions – one using habitat quality as one of the predictor variables and the other using distance to road as a variable. Separating out habitat quality from distance to road for these remote camera analyses increased confidence in defining potential impacts from the two variables separately.

2.2.4 GPS Data Analysis

To match data time frames from the remote cameras, I only used grizzly bear locations from fall 2013, spring 2014, and summer 2014 in this chapter's analyses. Grizzly bear locations were processed post-collection to remove locations that were aberrant or had low spatial accuracy (Stewart et al., 2012). Grizzly bears respond seasonally to habitat and topographic variables in addition to human use variables (Mace & Waller, 1996), I therefore created seasonal home ranges for each bear using both a minimum convex polygon (MCP) and a kernel density estimator (KDE; Worton 1989). As per previous research, I only used data from bears with a minimum of 50 telemetry points to create home ranges (Smulders et al., 2012); this eliminated two bears in the creation of home ranges (bear 148 in the spring, and bear 140 in the summer). These seasonal home ranges were used in use-availability analyses. I also calculated descriptive characteristics of seasonal home ranges for bears with locations within 10 days of a season start and end date, these included size, trail density and road density. Several bears did not have locations throughout a season and were not included in this descriptive home range summary. Bears not included from the fall were: 131 and 135 (both females with cubs); from the spring were: 138 and 72 (adult females), 140 and 141 (adult males), and 142, 143, 144 (subadults); and from the summer were: 130 (adult female), 126 (adult male), and 142, 144, and 149 (subadults).

A MCP home range encircles all of the bear's locations in a single polygon. MCP's have been criticized for over estimating home range size because they include all unused areas between the outermost locations (Berland et al., 2008), but can still be useful for gaining an understanding of the area that an animal may pass through on its way to higher density use clusters. I only used MCPs to generate a descriptive understanding of the largest potential area a grizzly bear used. Other similar studies in Alberta have chosen KDE as the home range for analysis because it does not over-estimate area as much as the MCP method and can account for multiple centres of activity (Stewart et al., 2012). I used 95% of a grizzly bear's locations in each season to generate KDE home ranges. The KDE smoothing parameter was estimated using a least-cross squares validation and implemented on a Gaussian kernel (Stewart et al., 2012). Gibeau (1998) described a zone of influence (ZOI) as the distance measured horizontally where grizzly bears could be affected by human activity; this ZOI in Banff and Yoho National Parks for linear non-motorized features (i.e., trails) was 400m. Kite et al. (2016) refined this estimate for

ZOI as it pertained to roads and found it varied by season, age, and sex ranging from 25m for subadult females in the non-breeding season to 90m in the breeding season; male grizzly bears displayed a more consistent response to roads and had a ZOI around 70m. I chose to use the more conservative ZOI defined by Gibeau at al. (1998) as it was calculated for non-motorized trails, rather than roads, and was applied to my study area (Banff and Yoho National Parks); for each bear I calculated the number of locations within a 400m ZOI around trails in each season and used it as another descriptive measure of home range habitat use.

Similar to Stewart et al. (2012), once a KDE was created using 95% of the used locations, I created a set of 1:1 used:random locations to ensure an identical density of observed locations within the KDE. MCP polygons were created using ArcGIS 10.2 (Environmental Systems Research Institute, 2013), seasonal KDE polygons were created using the package AdeHabitat in R (version 3.1.3, R Foundation for Statistical Computing, 2015), and random points were generated in Geospatial Modeling Environment (Spatial Ecology LLC, 2014). Statistical analyses for both the remote camera and GPS data were done in SPSS (version 21, IBM, 2011).

For each location (both random and used), I calculated the straight line distance to the nearest road, straight line distance to the nearest trail and habitat quality category. I only included bears with a minimum of 10 locations in each habitat quality category in both the used and available scenarios in this analysis. This eliminated several bears from analysis: bears 138 and 141 in the spring, and bears 141 and 144 in the summer. For statistical analyses, only bear locations within the boundaries of BNP were used as the RSF layers did not include YNP and KNP; this excluded 916/2818 locations in the fall, 623/2552 locations in the spring, and

1402/4109 locations in the summer. Bear 140 had locations entirely outside of Banff National Park and so was not included.

To address H_3, which centered on grizzly bear habitat preference, I used a backwards stepwise regression analyses to compare the available and used locations for each bear in each season. In each case, the dependent variable was grizzly bear use/availability and the predictor variables were habitat quality, distance to road, distance to trail, and an interaction term between distance to road*distance to trail. Similar to other research (Gillies et al., 2006), I used Bear ID as a random factor to account for individual variation. I also tested the level of correlation between habitat quality and distance to road for each individual bear's locations; the variables all had correlation scores lower than 0.7 so I included both variables in the same use-availability regression analyses. I retained the separated analyses for the remote camera presence-absence analyses mainly because the RSF identifies where bears are likely to spend more time, but cameras capture movement pathways through the study area and I was interested in isolating how distance to road impacted travel corridors. I ran a series of one-way ANOVAs on the data from each season to compare the mean distance to trail and mean distance to road for each bear; variances between bears were not homogeneous so I ran a Tamhane's T2 test post-hoc to determine where the differences between bears lie.

2.3 Results

2.3.1 RSF Model Validation

The RSF showed a range in area associated with each habitat quality category with the majority of BNP falling into Category 1, low quality habitat (Table 2.2). The RSF performed well overall and use did increase with habitat quality (Figure 2.2). The RSF did not perform as well in the spring (r_s = 0.221, p=0.066), particularly for adult females and subadults. The model was reliable in the summer (r_s = 0.714, p<0.001) and fall (r_s = 0.699, p<0.001) for all age/sex classes.

2.3.2 Remote Cameras

From fall 2013 to summer 2014, most cameras were categorized as being from a medium human use trail; 68 camera sites were classified as low human use, 97 sites were medium human use, and 26 sites were high human use. The observed difference in deployment rates is due to general human use patterns on a trail network where most people use a central main trail that leads to a viewpoint or destination and fewer people use trail offshoots. The mean number of camera trap days was 17.4 for a total of 3,341 trap days. The number of human events captured on low, medium, and high human use trails were 1,391, 30,143, and 53,843 respectively. The number of grizzly bear events were not markedly different from low to medium use trails (23 and 19 respectively), but did decrease on high human use trails (12). The total number of grizzly bear events was 1.62 bear events/100 camera trap days. The number of horse events totaled 16,124 and were most common on medium use trails; the total number of dogs captured was 7,865 mostly from medium and high human use trails. It was not possible to reliably distinguish age, sexes, or individual identity of bears caught on cameras; only one adult female with cubs was captured on camera (Figure 2.3). It was possible to categorize grizzly bear images as being consecutive pictures of the same individual, however, based on the camera's time stamp and bear behaviour in the images (e.g., a bear approaching and investigating the camera would be captured in several images within seconds of each other).

Table 2.2: Distribution of habitat quality categories across Banff National Park (BNP) based on the RSF. Categories ranged from 1 to 10 with 1 being low quality habitat and 10 being high quality habitat.

Habitat Quality	Category	Area within BNP (km^2)
Low	1	3231.59
	2	461.87
	3	359.58
	4	398.54
	5	362.32
	6	380.13
	7	585.99
	8	313.17
	9	277.17
High	10	454.06

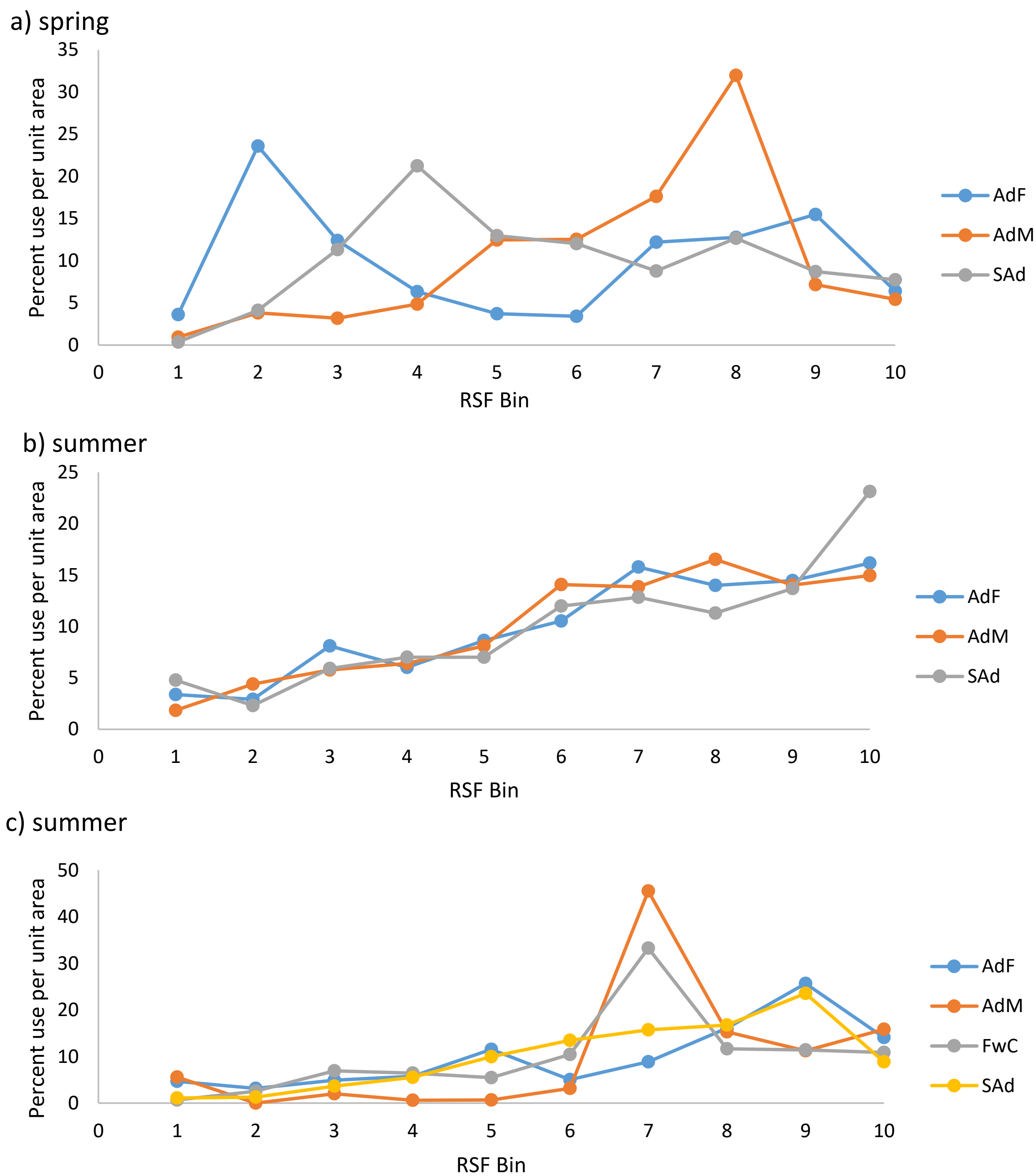


Figure 2.2: RSF model validation. I compared the percent use per unit area in each level of habitat quality ranging from 1 (low) to 10 (high) in each season. Similar to all other analyses in this chapter, only grizzly bear GPS data from fall 2013 (6 bears), spring 2014 (9 bears) to summer 2014 (10 bears) was used in model validation. Spearman rank correlation coefficients showed the model performed best in the summer ($r_s(8)=0.714$, $p<0.001$) and fall ($r_s(8)=0.699$, $p<0.001$). Data presented in the above figures are mean values in each age/sex class.

Figure 2.3. Examples of grizzly bear remote camera detections. It was not possible to identify individuals in photographs for various reasons, including low light, the position of the grizzly bear in the photograph, or vegetation obscuring a portion of the bear. In some instances, consecutive grizzly bear events were distinguishable by two photos of one bear taken within 7 seconds of each other (a and b). The only female with cubs captured in the summer of 2014 is shown in photo e. On some occasions, the identification of a GPS collar was easy (as in photo f) but this was not reliably detected in all photographs.

Regression analyses showed that more grizzly bears were detected on camera during the summer (β=1.322, p=0.016) than fall, in the model containing distance to road as a covariate (as opposed to habitat quality); this trend was also observed in the spring (β=1.894, p= 0.012) in the model that used habitat quality as a covariate (Table 2.3). Both models also showed a significant decrease in grizzly bear presence on trails that were used by bikes and horses (β=-1.174, p= 0.007); the model containing habitat quality as a covariate also showed a significant decrease in grizzly bear presence on trails limited to hiking (β= -1.051, p= 0.029) compared to trails with vehicle traffic. This result was opposite to H_2, which expected bear camera detection to increase with decreasing human use. This result was skewed by a series of trails near the town of Banff that have better vehicle access and very high levels of human use and grizzly bears use. Once these cameras were removed from analysis, these trends were no longer significant. This is further explored in Chapter 3 using the full data set from all years. Distance to road was negatively correlated with grizzly bear presence meaning that more bears were captured on trails closer to roads than expected, again rejecting to H_2. Human use level and weekday/weekend were not significant contributors to either model predicting grizzly bear presence. Habitat quality was also eliminated from the model in the stepwise process, thus habitat quality was not a significant predictor of grizzly bear trail presence. This supported H_4, which predicted that remote cameras would perform better in predicting grizzly bear trail use.

2.3.3 GPS

Only two of the collared bears had data from all 3 seasons included in use-availability analyses (bear 72 an adult female, and bear 126 an adult male); all other bears included in these analyses had data from 1 or 2 seasons only. For those bears with locations within 10 days

Table 2.3: Backward stepwise regression results of grizzly bear presence/absence. I used grizzly bear presence/absence on cameras as the dependent variable and various habitat attributes as the predictor variables. As Habitat Quality contained a measure of road density, two series of models were run. I ran one model with Distance to Road as a predictor variable and another using Habitat Quality as a predictor variable. All other predictor variables were the same in both models. In the final model using distance to road as a predictor variable, human use category and weekday/weekend were eliminated. In the final model that used habitat quality as a predictor variable, habitat quality and weekday/weekend were eliminated. Two regression analyses were completed to avoid inherent autocorrelation between habitat quality and distance to road (as road density is part of the measurement of habitat quality). In both of these models, the following reference categories were used for indicator variables: human use level – high use, season – fall, trail type – vehicles, weekday/weekend – weekday, habitat quality - low. Coefficients presented are from the final models; * denotes significance at p<0.05.

Input		**Coefficients**		
Dependent Variable	**Independent Variables**	**Unstandardized *B***	**Standard Error**	**p-value**
Grizzly Bear (presence/absence) Distance to Road used as predictor variable.	Distance to Road Category	-0.001	0.000	0.001*
	Season	Spring: 0.955 Summer: 1.322	0.567 0.548	0.092 0.016*
	Trail Type	Hike: -0.236 Bike/horse: -1.174	0.451 0.436	0.600 0.007*
Grizzly Bear (presence/absence) Habitat Quality used as predictor variable.	Human Use category	Low: 0.021 Medium:-0.738	0.496 0.459	0.967 0.108
	Season	Spring: 1.894 Summer:2.266	0.756 0.746	0.012* 0.002*
	Trail Type	Hike: -1.051 Bike/Horse: -1.078	0.482 0.448	0.029* 0.016*

of the season start and end date, there was variation in seasonal home range size (Table 2.4). The smallest home range was that of Bear 130 in the spring, an adult female. Grizzly bear home ranges changed location and size seasonally (Figure 2.4). The largest home ranges for all bears were observed in the summer, with Bear 72, an adult female, having the largest seasonal home range and Bear 138, an adult female occupying the smallest. Fall home ranges were located in higher elevations away from the Bow River Valley bottom, whereas spring and summer home ranges were more focused in the lower elevations.

All bears had very low road and trail densities in their home ranges; one adult female (Bear 138) and a female with cubs (Bear 72) occupied home ranges with no roads in the fall. There were no data available for females with cubs in 2014. In the other seasons, only Bears 130 and 138 had no trails or roads in their KDE home ranges respectively. Most bears had fewer locations within 400m of trails in the fall than the spring or summer, with the exception of Bear 72 who had half of her locations within a 400m ZOI in the fall.

The main difference between the GPS analysis and the remote camera analysis was in the relationship between bear presence to habitat quality. The regression analyses comparing used and random locations from the GPS data showed that areas of higher habitat quality were consistently preferred, supporting H_4 (Table 2.5). The remote camera data, however, showed no significant relationship to habitat quality. Regardless of season and Bear ID, the positive relationships between used locations and primary habitat preference were the strongest, suggesting this to be the most important predictor of whether a grizzly bear would use an area more than expected.

Table 2.4: Descriptive statistics of grizzly bear seasonal home ranges from fall 2013 to summer 2014. Home ranges were calculated as Minimum Convex Polygons (MCP) and 95 % Kernel Density Estimates (KDE) in Km^2. Trail density and road density in each home range varied between individuals and seasons. Age-sex class: AdM = adult male, AdF = adult female, SAd= subadult, FwC = female with offspring. Only bears with a minimum of 50 locations in their 95%KDE and locations within 10 days of the season start and end date are included in this table.

Season	Bear ID	Age/Sex Class	Area of MCP (km^2)	Trail Density in MCP ($*10^{-4}$ km/km^2)	Road Density in MCP ($^*10^{-4}$ km/km^2)	# of Locations in 95% KDE	Area of KDE (km^2)	Trail Density in KDE ($^*10^4$ km/km^2)	Road Density in KDE ($^*10^{-4}$ km/km^2)	Locations in 400m ZOI	% Locations in 400m ZOI
Fall	126	AdM	485.81	3.13	1.01	715	196.45	4.53	0.74	189/734	25.7
Fall	138	AdF	90.46	5.85	0	327	67.52	4.71	0	91/332	27.4
Fall	72	FwC	89.95	5.38	0	462	55.86	7.47	0	247/462	53.5
Fall	128	SAd	956.37	4.99	1.14	1607	182.66	4.61	3.22	437/1639	26.7
Spring	126	AdM	440.97	5.49	1.97	758	106.71	8.13	5.97	265/774	34.2
Spring	130	AdF	45.55	2.46	1.22	604	3.37	0	3.60	3/659	0.5
Summer	132	AdM	181.99	3.24	2.50	511	21.81	0.63	1.71	65/648	10.0
Summer	138	AdF	103.77	6.69	0.67	315	18.29	4.65	4.20	150/352	42.6
Summer	141	AdM	661.68	2.16	0.31	626	85.17	3.90	0.71	251/715	35.1
Summer	72	AdF	424.61	4.08	1.74	683	192.33	4.78	2.29	306/714	42.9
Summer	143	SAd	381.71	5.91	1.89	652	74.59	10.60	2.89	526/728	72.3
Summer	148	SAd	332.26	5.83	4.15	650	57.53	8.48	13.60	305/718	42.5

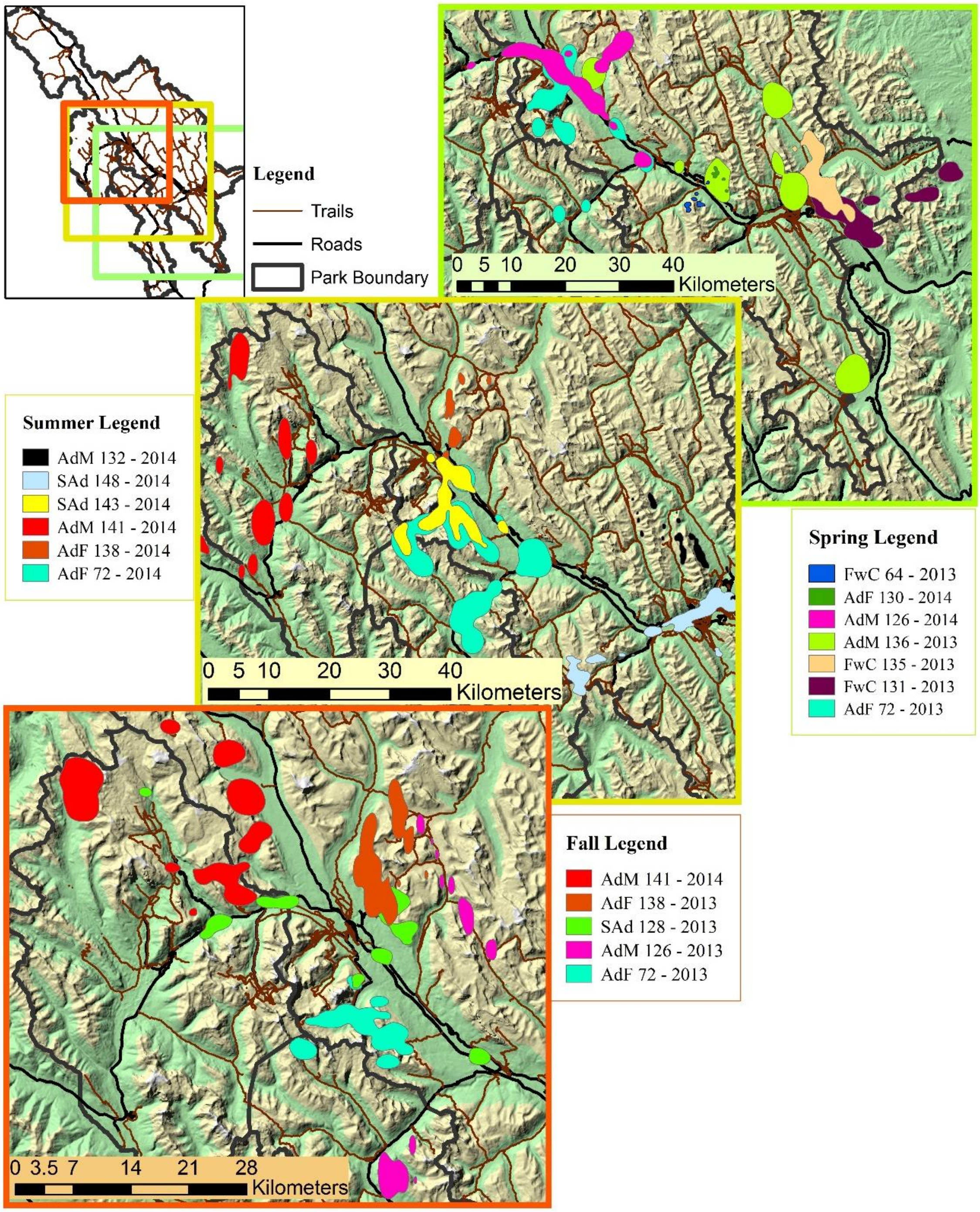


Figure 2.4: Grizzly bear 95% KDE seasonal home ranges from 2013 and 2014. Individual grizzly bear ID, age-sex, and year is indicated in each seasonal legend (AdM = adult male, AdF = adult female, SAd = subadult, FwC = female with offspring). Home ranges contained a minimum of 50 locations and data from within 10 days of season start and end dates. This map is meant to provide an example of how grizzly bear home ranges changed over the seasons; statistical analyses were conducted on this data.

Table 2.5: Binary logistic regression results comparing used and available locations within grizzly bear 95%KDE home ranges. Individual Bear ID was entered as a random effect. Primary habitat was consistently selected across seasons. Analysis was conducted using Bear ID as a random factor. * denotes significance at p<0.05.

Season	Parameter	Estimate	p-Value
Fall	Habitat Quality – Secondary	0.336	p<0.001*
Residual estimate =	Habitat Quality – Primary	0.344	p<0.001*
0.222; Wald Z Statistic =	Distance to Road (km)	-0.008	p<0.001*
53.37; P< 0.001	Distance to Trail (km)	-0.067	p<0.001*
	Distance to Road*Distance to Trail	0.007	p<0.001*
Spring	Habitat Quality – Secondary	0.027	p= 0.147
Residual estimate =	Habitat Quality – Primary	0.179	p<0.001*
0.241; Wald Z Statistic =	Distance to Road (km)	0.028	p<0.001*
47.624; P<0.001	Distance to Trail (km)	0.026	p= 0.035*
	Distance to Road*Distance to Trail	-0.039	p< 0.001*
Summer	Habitat Quality – Secondary	0.091	p<0.001*
Residual estimate =	Habitat Quality – Primary	0.240	p<0.001*
0.239; Wald Z Statistic =	Distance to Road (km)	-0.004	p= 0.069
64.195; P< 0.001	Distance to Trail (km)	-0.015	p= 0.064
	Distance to Road*Distance to Trail	0.001	p= 0.334

Within their home ranges, bears preferred habitats closer to roads and trails than random in the fall ($p < 0.001$). Although a similar relationship with roads and trails was observed in the summer, this was not significant. In the spring, however, grizzly bear preferred locations farther from roads and trails ($p<0.001$ and $p= 0.035$ respectively). The ANOVA results examining trail and road density in individual grizzly bear seasonal home ranges showed a high level of variation between bears ($p<0.001$), particularly in the spring (Figure 2.5). In the spring, subadult bears were closer to roads than other age/sex classes. Overall, bears kept higher distances to roads than trails, especially in the fall.

The use-availability and ANOVA results examining bear habitat use in relation to trails and roads support the remote camera analyses that showed bears were more likely to be captured on cameras during the spring and summer but not in the fall. The differences between seasonal results demonstrate the need to examine habitat relationships based on the seasonal home range scale. Spring home ranges of bears are smaller and focused more in the valley bottoms, where road density and trail density are higher. The use-availability analyses suggest that during spring bears are more likely to prefer habitat that is both far from roads and trails within their home ranges. Fall home ranges are larger and in higher elevations with lower road and trail densities, thus while bears prefer habitats closer to roads than random this does not necessarily imply they are physically closer to trails and roads than in the spring. This is also supported by the number of locations within a 400m ZOI, which was higher in the spring and summer than the fall for most bears.

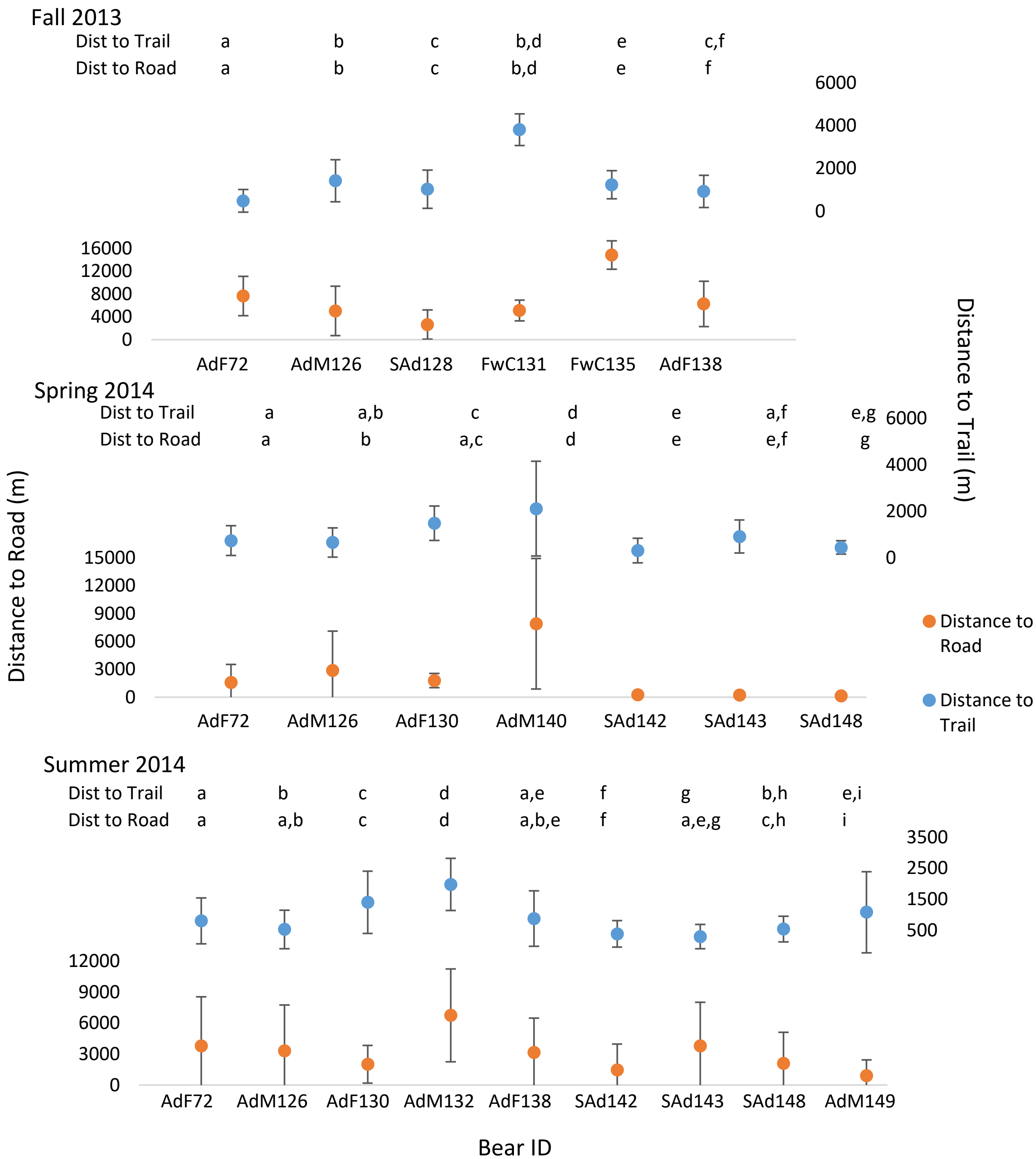


Figure 2.5: Mean bear distance to roads and trails by season. Error bars represent standard variation; variance was not consistent between bears and some bears displayed a wide variation in means. Text above Bear ID numbers represent which individual bears were significantly different from others based on ANOVA results; bears with the common letters above bars were not significantly different from each other (P<0.001). Individual grizzly bears identified by their age/sex class and number on the x-axis (AdF= adult female, AdM= adult male, FwC= female with cubs, SAd= subadult).

2.4 Discussion

2.4.1 The RSF model

My study was the first to validate the RSF model for Alberta in Banff National Park. The model performed well overall, which was reflected in the highly significant results showing grizzly bear preference for higher quality habitat throughout the seasons. The model was not designed for my study area, however, and this may be important when considering habitat quality as it relates to trail use. Mace and Waller (1996) found that the highest RSF habitat quality scores were achieved when the distance to trails exceeded 2,130m. The RSF used by Mace and Waller (1996) was developed in their study area, but trails were not included in the RSF I used to measure habitat quality. Therefore, this particular threshold may not apply in my study area. Only one bear during the fall had a mean distance from trails greater than 2,130m. I observed the highest levels of variation around mean distance from trails during the summer. The GPS analyses showed bears preferred habitat closer to trails in the spring and fall, which suggests that distance to trails is not as large a factor in bear habitat use in the summer as it is in the spring and fall.

2.4.2 Camera and GPS Results Pertaining to Habitat Quality

By using similar statistical approaches with two different data sources, I am able to compare and contrast results. I identified that the biggest difference in results lay in grizzly bear response to habitat quality when applying a GPS-based use-availability analysis compared to a remote camera based presence-absence analysis. This trend supports H_4, which predicted that remote cameras would perform better in predicting bear trail use, whereas GPS collar data would perform better in predicting habitat use. Grizzly bear detections on remote cameras were not related to habitat quality, whereas the GPS data showed a strong positive relationship between grizzly bear habitat use and habitat quality. This reflects the kinds of information that the two different data sources provide. The remote camera data provided information regarding whether or not a bear used a particular section of a particular trail, whereas the GPS data identified grizzly bear habitat use at a larger spatial scale (i.e., a bear in the area of a trail). A bear that is moving through an area may be doing so because of the trail, not necessarily because of the habitat quality nearby. Conversely, the GPS data and the use-availability analyses provide information regarding where bears are spending the majority of their time; exactly how bears move from location to location is not incorporated in the model. The use-availability analyses show that bears prefer high quality habitat, but the remote camera analyses suggest they are not preferring or selecting for high quality habitat when using trails to move through the study area. This distinction is important and can impact implications of the research if misinterpreted. For remote cameras to be used for assessing habitat use as it relates to quality, the sampling design would necessitate mounting cameras in various locations based on habitat attributes, not trail attributes.

Understanding life history traits and habitat characteristics outside of habitat quality is essential as occurrence or abundance estimates may relate to factors other than habitat quality (Nielsen et al., 2006). These could include proximity to various human developments, such as road, trails, parking lots, or towns. Grizzly bears are known to have increased mortality related to human vehicle access (Nielsen, Munro, Bainbridge, Stenhouse, & Boyce, 2004) and most grizzly bear mortalities are human-caused (Benn &

Herrero, 2002). The RSF model of habitat quality as used in this thesis included distance to roads but did not account for trails. The remote camera regression showed that bear detection probability increased on trails closer to roads during the spring and summer, but detections in the fall were significantly reduced. In contrast, the GPS data showed that bears selected for habitats closer to roads and trails in the fall. This could either be an artefact of cameras not accurately documenting bear presence in these areas during the fall, or could be a reflection of home range characteristics. In the spring, high quality habitat is less abundant as much of the higher elevations are snow bound. Grizzly bears consistently select for green vegetation (Ciarniello et al., 2007b), thus their spring home ranges are likely influenced by food availability in areas where plant phenology is earliest to advance (e.g. road-side). In the spring, I found home ranges were smaller, with higher road and trail densities, and centered in the valley bottoms. While the GPS data showed bears selected for habitat farther from roads and trails within their spring home ranges, the number of locations within a 400m ZOI were higher.

As the year progressed most bears expanded their home ranges into higher elevations and road and trail density decreased. Although bears displayed a preference for habitat closer to roads and farther from trails in the fall, this does not necessarily mean a bear is physically closer to roads and trails because of home range location. This is also reflected in the reduction of remote camera detections. This concurs with previous work that found bears more likely to select for alpine landscapes and high-elevation habitats (Ciarnello, Boyce, Heard, & Seip, 2007a), and farther away from trails in the summer months (Mace & Waller, 1996).

Combining data sources enables a more comprehensive understanding of bear habitat and trail use. Grizzly bears did change their seasonal habitat use in relation to proximity to trails, which suggests that most bears have a threshold distance from roads and trails after which point habitat use is not influenced by human traffic. Other research has also shown that bear age-sex classes may respond differently to roads, settlements (Gibeau et al., 2002), and varying levels of human use (Elfström, Zendrosser, Støen, & Swenson, 2013). The threshold distance from roads and trails beyond which habitat use is not influenced by human use is likely individually variable and potentially influenced by home range characteristics and age-sex class, not necessarily season.

2.4.3 Camera and GPS Results Pertaining to Movement and Trail Use

The remote cameras can provide certainty of trail use that the GPS data cannot. If a bear is detected on remote camera, the bear definitely walked on that human use trail. GPS locations have an error of approximately 10m and therefore cannot determine that a bear used a particular human use trail or was simply close to the trail. GPS data can be used to count the number of times a bear crossed a trail. In contrast, the absence of a bear on camera is not evidence of its absence from the vicinity of the trail or other locations on the trail. In this case, the GPS provides certainty of use at a larger spatial scale. In addition, the two approaches were able to examine different variables and their relationship to bear presence or use. Importantly, the remote cameras are able to provide an accurate measure of human use (both volume and activity type) for all sampled trails in a network; this information can be used to create a model of human use across hiking trails in the study area. Additional analyses could compare a bear's GPS movements in proximity to hiking trails of defined levels of human use (low, medium, high) not just its proximity to a trail in general (e.g., using the step selection function analysis in Chapter 3).

The GPS data provides detailed information regarding the movements and habitat use of an individual bear at the home range scale, but the fact that bear has its home range where it does is already indicative of habitat section (Johnson, 1980). Using a KDE approach to examine use versus availability is only examining third-order selection (habitat patches within the home range; Johnson, 1980). Grizzly bears display individual variation in their selection and size of home range. Similar to Mace and Waller's (1996) research in Montana, most grizzly bears in this study area had some level of human use in their home range whether in the form of trails, roads, or both. Individual bears may develop tolerance towards humans (Elfström et al., 2013), thus potentially reducing the negative effects they may experience from occupying habitat closer to towns or roads. Resulting management implications pertain to how individual bears are managed to reduce negative human-bear encounters and potential conflict in areas of high human use. These bears would have a higher likelihood of being detected by cameras on trails close to roads, but individual bears are not commonly distinguishable. Cameras can therefore be more appropriate to make inferences at a population level and landscape scale, like the geographic range of the species (first order of selection) depending on the size of the study area (Johnson, 1980). This can then be used to create overarching population level management tactics. This approach would require a different sampling design across all areas of the landscape, not only on trails. While GPS data can also be used to make inferences at the population level, when it comes to wide-ranging, low density carnivores like grizzly bears, it requires a high sample size of individuals being collared across the landscape over several years.

2.4.4 Data Limitations and Challenges

GPS data is generated in set time fixes usually determined by the researcher. My data set contained locations generated at various time fixes (20 minutes, 2 hours, or 4 hours), but the analytical approach I used in this chapter treated all points equally. If I selected only those locations 4 hours apart, some important information in the data set may be lost. In addition, the rate these time fixes were altered is different between bears. How these different time fixes are addressed could change the shape and size of the home ranges, which could fundamentally impact the analysis and results. A more robust analysis would control for this by standardizing GPS fixes to specific time intervals. The Step Selection Function (SSF) models used in Chapter 3 take this approach and are more appropriate for addressing limitations created due to autocorrelation between location points. Pairing autocorrelation analyses with models of habitat use and movement over time provides a more complete view of the behavioural patterns exhibited by animals (Boyce et al., 2010).

Addressing detection probability of the remote cameras is important to increase robustness of analyses. Unless detection probability is specifically accounted for, results will pertain to a combination of biological and sampling processes (MacKenzie, 2005). Essentially, any potential biases in the sampling approach may skew results and lead to misinterpretation. Similar work with remote cameras in my study area examined occupancy of grizzly bears and found that accounting for detection probability resulted in an increase in occupancy by 13% from 0.70 to 0.79 (Steenweg et al., 2015), which would potentially increase my grizzly bear detections from 54 to 61 in total from fall 2013 to summer 2014 . Steenweg et al. (2015) operated cameras on wildlife and human use trails for a 6 month period, whereas I only operated cameras for 21 days or less. Thus, I could not calculate detection probability as robustly but it is likely that doing so would have little impact on my overall results. Detection should be accounted for on two spatial scales: the camera trigger zone scale (e.g., a grizzly passes by behind the camera), and the site scale (e.g., a grizzly bear is in the area and may even walk on the human use trail but does not walk right in front of the camera; Burton et al., 2015). I did take steps in my sampling design to maximize detection. Cameras were set to have a sensitivity level that would capture grizzly bears and people 24 hours per day, so there is confidence that if a bear walked into the trigger zone of the camera it would be photographed. Detectability can also change with seasons, times of day, between individual camera stations, and across the landscape, as a result statistical analysis should model these variables as well (Burton et al., 2015; MacKenzie, 2005). Cameras were set to capture as much of the trail as possible, take pictures in all weather and times of day in three different seasons, and on randomly selected trails thus minimizing these errors. The stratified random sampling approach did allow for a representative sample size of cameras on low, medium, and high human use trails in all seasons across the study area at varying distances from roads, towns and other human features. These efforts reduced detection bias (MacKenzie, 2005). Still there were a few occasions where GPS data showed a grizzly bear in the area of cameras and no bears were captured on camera. It is not possible to say those grizzly bears did not use human trails. One potential solution to addressing this bias is to compare detection rate between sites (Burton et al., 2015), particularly in areas where collared grizzly bears were active while remote cameras were deployed. Another option is to use a maximum likelihood function with Bayesian methods of analysis to estimate the per-visit probability of non-detection (MacKenzie, 2005; Manley, Schlesinger, Roth & Van Horne, 2005). This analysis defines the probability of species presence based on the probability of species detection at a specific time, the number of sampling occasions, the number of sites with detections at that time, and the number of sites in which the species is detected at least once. I did not execute these analyses with this thesis because I also used GPS data to garner information regarding grizzly bear habitat use and I did not leave cameras in operation for a sufficient number of trap days. If remote cameras were the only data source, I would suggest leaving cameras mounted for a longer period of time and accounting for detection with these analyses.

The current RSF model used in this analysis is only available for Banff National Park, but several bears have locations in Yoho and Kootenay National Parks. Only one bear in one season had locations entirely outside of Banff National Park and so was eliminated from analysis (bear 140 in the summer). In these cases, the habitat quality of locations (both used and random) were left blank in analysis. So while these points could still be used in comparing distances to roads and trails between used and available points, they could not be used to compare selection for habitat quality. To remedy this, RSF models could be developed for surrounding areas in Yoho and Kootenay National Parks.

2.4.5 Other Considerations

It has been suggested that remote cameras are a good alternative to GPS data in some situations because they are less costly and less invasive for the study animals. Both points are true, though warrant further consideration. The remote cameras in this analysis cost this project several thousand dollars (just over $5,000), a much smaller initial investment compared to the large investment in conducting bear captures and GPS collaring (approximately $1 million over 5 years). The human resources required to work with these data sources is an important aspect of this discussion. Human capacity and technical expertise is required to put a collar on and potentially remove from a grizzly bear, but less human effort is required to gather the data or maintain the collar. Remote cameras, on the other hand, require limited expertise to mount in the field but do require an on-going investment of human capacity to relocate on the landscape, change batteries, and check SD data storage cards. In addition, data entry for the thousands of photos generated require a high level of time investment. I estimate that gathering and processing the one year of data discussed in this chapter, required 219 volunteer days for camera placement and removal and approximately 100 days of data entry. This contribution is the equivalent of more than one full time position for one year. While the initial costs of GPS collars is substantially greater, the maintenance and data entry costs of remote cameras should also be considered in project planning and management.

2.5 Conclusion and Management Implications

As with most methodological approaches aimed an answering similar research questions, there are advantages and disadvantages to both remote cameras and data generated from GPS collars. Based on the results of this Chapter, I do not think that remote cameras are a replacement for GPS collars and should not be treated as such. With either technology, the most important thing is to select a methodological approach that will answer the management objective requirement. Accurately defining the spatial and temporal scales required to address the objective should then lead to creating specific research questions, which will guide the selection of an appropriate methodology. Creating a robust sampling design that will ensure data meets the assumptions of any statistical modeling analysis is also essential. Remote cameras can be used at varying spatial and temporal scales to provide an abundance of information, but are subject to varying rates of detection and cannot be used to reliably identify individual grizzly bears. They can, however, be used to collect data pertaining to human use and grizzly bear use simultaneously. This can be extremely useful for research aiming to understand spatial and temporal human and grizzly bear use. Remote cameras can also provide reliable temporal information regarding trail use and can be focused on particular landscape features of interest. Depending on the research question, remote cameras can be applied broadly across the landscape for a long period of time and collect data pertaining to potentially all members of a population. Depending on the sampling design, remote cameras can also be used to intensively sample at the microsite scale since the area of inferences is really constrained to the immediate view of the cameras. Due to grizzly bears' inherently high level of individual variation, cameras may provide better data for population level studies. This implies they should be mounted at a large landscape scale to encompass a population, which may be more logistically prohibitive or challenging.

GPS collars can be used to generate an abundance of information at the individual grizzly bear home range scale and if a sufficient sample of collars can be deployed, population inferences can be made. The GPS collars provide good temporal and spatial information that is repeatable and individuals are identified. GPS collars provide an abundance of data that cannot be generated with remote cameras, such as movement rates, selection in relation to habitat attributes that are not equally distributed across the landscape, and specific activity patterns. GPS collars cannot provide information pertaining to variables that are not related to the bear, such as human use in an area, vegetation types, and relation to non-collared conspecifics.

Ultimately, the selection of methodological approach will depend on the specific research question and variables being compared. Remote cameras can provide data pertaining to multiple variables but the sampling design will have a large impact on the validity of inferences made across the landscape. GPS collars provide details information pertaining to individuals and can be used to make inferences at the population scale. GPS data is best if complimented with other robust data sources detailing habitat attributes and human use levels. Other important factors to consider in choosing a methodological approach are budgetary constraints and staff capacity.

CHAPTER 3: GRIZZLY BEAR HABITAT USE IN AREAS OF RECREATIONAL USE

Abstract

Human recreation can impact grizzly bears directly through increased mortality or indirectly by changing habitat use patterns. I examined how human use on low, medium, and high use trails impacted grizzly bear trail and habitat use in Banff, Yoho, and Kootenay National Parks. I deployed remote cameras on 423 trails over 8,278 camera trap days from fall 2013 to summer 2015; I also used GPS collar data from 2012 to 2015 from 27 different grizzly bears. Using the remote camera data, I created a model to estimate human use on all trails throughout my study area. The human use model was incorporated in to a step selection function (SSF) to predict grizzly bear habitat use in relation to low and high human use trails. Grizzly bears were significantly more likely to be detected on trail cameras during the spring and summer than the fall; grizzly bear camera detections were most likely to occur at night or dawn before 8 human events on the trail. Grizzly bears consistently selected for higher quality habitats. The SSF showed a high degree of individual variation in grizzly bear step selection in relation to trails and roads; most bears selected steps closer to low human use trails but only some also selected steps farther from high use trails. Most bears crossed roads less often than random, but crossed trails more often than expected during the day. Grizzly bear step lengths were longer, indicating increased movement, during the day. Grizzly bears in the study area were willing to access high quality habitat near human use features and during times when people were active, showing a degree of tolerance for human use. Grizzly bears selecting habitat near human use areas are, however, at risk of increased mortality from habituation or when they disperse outside of the National Parks.

3.1 Introduction

Most National Parks in the world were largely created to protect ecological attributes, but are also important tourist attractions worldwide. All forms of recreation have the potential to alter an animal's habitat, behaviour, survival and/or reproductive success (Cole & Landres, 1995). Managing for sustainable recreation in protected areas requires understanding how human use effects ecological integrity on various temporal and spatial scales, while providing for an authentic experience that will satisfy visitors (Petersen, 2000). Park managers are, therefore, required to plan for positive recreational experiences that have minimal impacts on the ecological attributes people come to enjoy (Juutinen et al., 2011). Each year, over 3 million people visit Banff, Kootenay, and Yoho National Parks (Parks Canada, 2010a,c,d), many of whom recreate on a diverse and extensive network of hiking, biking, and equestrian trails (Garshelis et al., 2005). This is one of the most intensively developed series of protected areas where a grizzly bear population still survives (Gibeau, 1998). These high levels of visitor use can impact grizzly bear habitat use spatially and temporally (Gibeau et al., 2001). Minimizing these impacts requires an understanding of how bears navigate their home ranges in the presence and absence of trail users.

Habitat quality, in terms of forage richness and landscape attributes, has been directly linked to grizzly bear presence and abundance (Ciarniello et al., 2007a; Mertzanis et al., 2008; Stewart et al., 2012). Incorporating the influence of other habitat dimensions like spatial and temporal human use is also important, however, to avoid potentially erroneously assuming habitat quality is the only or main predictor variable (Nielsen et al., 2006). For this reason, most models defining grizzly bear habitat quality have incorporated some measure of human use, whether in the form of human use numbers (Gibeau et al., 2001; Hood & Parker, 2001), roads (Braid & Nielsen, 2015), or other human-use features (Elfström et al., 2013).

Non-consumptive recreation, defined as recreation that does not involve hunting or other forms of removing the animal from the area (Reynolds & Braithwaite, 2001), can affect animals in several ways. Direct impacts include changes in animal behaviour, physiological state, survival rates (Green & Giese, 2004), and habitat displacement events resulting from harassment of animals by recreationists (Gauthier, 1993). These are typically observed over short time frames through observation of an animal's fleeing response or decreased foraging due to disturbance. Some of these impacts may appear inconsequential, however, continued exposure to the disturbance may result in long-term impacts to the population's reproductive success, or even overall ecosystem health (Duffus & Dearden, 1993; Green & Giese, 2004).

Direct impacts to grizzly bears, including increased mortality, can stem from the construction and existence of infrastructure (e.g., roads, towns, trails; Benn & Herrero, 2002; Boulanger & Stenhouse, 2014). Increasing road densities, in particular, can increase mortality rates through vehicle collisions, habitat loss, degradation, or fragmentation (Ament, Clevenger, Yu, & Hardy, 2008; Boulanger & Stenhouse, 2014). Grizzly bears may alter habitat use to avoid high road densities and areas with abundant human use (Coleman, Schwartz, Gunther, & Creel, 2013; Martin et al., 2010; Schwartz, Gude, Landenburger, Haroldson, & Podrzny, 2012). Changes in behaviour and habitat use can lead to alterations in activity budgets, which in turn can affect foraging efficiency (Rode, Farley,

& Robbins, 2006; Smith & Johnson, 2004). In Banff and Yoho National Parks, Benn and Herrero (2002) found that 90% of known grizzly bear mortalities were human-caused, and all of those with a known location occurred within 500m of a road or 200m of a trail. While grizzly bears have shown a lack of resilience behaviourally and demographically to anthropogenic disturbance (Weaver, Paquet & Ruggiero, 1996), recent research suggests that bears are capable of adjusting habitat use patterns temporally (Fortin et al., 2013; Gibeau et al., 2001; Rode et al., 2006) or spatially (Chi & Gilbert, 1999; Nevin & Gilbert, 2005a; Stewart et al., 2012) in response to human use or development, thus retaining access to important food resources and displaying a level of resiliency at the individual level. Understanding how grizzly bears in Banff, Kootenay, and Yoho adjust their habitat use patterns when in proximity to roads and trails will contribute to understanding their level of resiliency to human disturbance and help inform management recommendations.

3.1.1 Influence of Human Activity on Grizzly Bears in Mountainous Areas

In mountain landscapes, anthropogenic infrastructure and human use tend to focus in valley bottoms, which also contain some of the most productive grizzly bear habitats (Benn & Herrero, 2002; Garshelis et al., 2005; Rogala et al., 2011). With bears and people occupying the same areas, the potential for interactions increases (Gibeau et al., 2002). In response, grizzly bears may display increased avoidance of habitat near high traffic areas (Gibeau et al., 2001), and be displaced to less productive habitats (Hood & Parker, 2001) or display overt stress responses (e.g., fleeing or increased vigilance) that are energetically costly and disruptive (McLellan & Shackleton, 1989). Grizzly bears in Montana foraging on cutworm moths discontinued foraging or were displaced from high alpine foraging locations by climbers, resulting in reduced food intake (White, Kendall & Picton, 1999). In Alaska, grizzly bears spent 7% less time in or immediately adjacent to salmon streams when people were present (Rode, Darley, Fortin, & Robbins, 2007). Because alternative foraging locations were not available, an avoidance of people resulted in a decline of crude protein and biomass consumption. This displacement extended several days, even once humans were absent, demonstrating that bears did not respond quickly to irregular human absences. Therefore, grizzly bears displaced spatially from habitat may be negatively impacted unless alternate forage locations are available (Rode et al., 2007).

Grizzly bears may also be temporally displaced by human use, becoming more nocturnally or crepuscularly active (Klimka & Reimchen 2002; Reimchen, 1998). In these cases, bears do not necessarily incur the same decreases in foraging efficiency as they alter their daily habitat use patterns to avoid people (Rode et al., 2007; Smith, 2002). In some cases, this avoidance of people can be a stronger factor for habitat selection than food availability (Olson & Gilbert, 1994). How strongly a bear reacts to anthropogenic impacts varies by individual, age/sex class, season, and location (Elmeligi & Shultis, 2015; Graham et al., 2010; MacHutchon, 2001).

In the Canadian Rocky Mountains, grizzly bear home range selection research has incorporated these impacts of human use in “habitat security” analyses, which define the extent of habitat patches where human use is <100 people/month (Gibeau et al., 2001; Hood & Parker, 2001). Grizzly bears select for secure areas within their home ranges. In the late 1990s, 69% of the land within the average grizzly bear home range in BNP and YNP was secure but potentially declining with increasing human use (Gibeau et al., 2001). The reduction in secure habitat due to increased human use levels on trails and roads is further compounded by the fact that more than half of BNP does not represent productive grizzly bear habitat due to high elevations with little to no vegetation (Gibeau, 1998); of the productive habitat, 75% was considered secure in the late 1990's (Gibeau et al., 2001). Habitat security analyses applied in JNP similarly found that human use of recreational trails led to decreases in grizzly bear habitat use near trails (Hood & Parker, 2001). Both studies found it was not the presence of the hiking trail, but the volume of people using it, that reduced grizzly bear habitat use (Gibeau, 1998; Hood & Parker, 2001). While grizzly bears can survive in home ranges that have a large amount of non-secure habitat, those that do will likely run a higher risk of human-caused mortality (Gibeau et al., 2001). It is therefore important to understand the amount of secure habitat at the individual grizzly bear home range scale, which in a non-uniform landscape like my study area is not equally distributed amongst bears.

The amount of secure habitat is not consistent between grizzly bear home ranges, but may be partially influenced by a bear's level of tolerance towards people in its home range. The degree of tolerance a bear exhibits towards people is related to the degree of tolerance that bear exhibits towards other bears, which is affected by food availability, population density, and age/sex class (Herrero, Smith, DeBruyn, Gunther, & Matt, 2005). In Alaska, the highest quality habitats were typically inhabited by male grizzly bears higher in the population's social hierarchy, and females with cubs were sometimes displaced to suboptimal habitats to avoid infanticidal males (Ben-David, Titus, & Beier 2004). Females with cubs may perceive humans as lower risk when compared to the threat associated with these large males, which has been exhibited by an increase in habitat use in the presence of people (Nevin & Gilbert, 2005b; Rode et al., 2006) and females using habitat closer to human use features than males (Gibeau et al., 2002). Females with cubs decreased energy intake by 37% when people were not present compared to when people were on site, thereby decreasing foraging effectiveness; these same females displayed no change in foraging behaviour when humans were the only 'threat' present (Nevin & Gilbert, 2005a). In these cases, habituated females are able to increase their foraging success by taking refuge from large males in areas of human use (Nevin & Gilbert, 2005a; Rode et al., 2006).

In the cases described above, females with cubs have a higher level of habituation to people partially defined by their low tolerance for large males. While similar terms, tolerance and habituation are not synonymous. Tolerance is defined as the intensity of disturbance that an individual endures without responding in a defined way (Smith, Herrero, & Debruyn, 2005). Habituation has been defined as a form of learning where individuals stop responding to stimuli that carry no consequences for the individuals that are exposed to them (Alcock, 1993). Both tolerance and habituation are adaptive behaviours as they reduce time and energy costs by eliminating or reducing irrelevant behaviours (Alcock, 1993; Smith et al., 2005). Often non-habituated individuals display a greater behavioural response to people than habituated ones; for example, non-habituated bears delayed their use of a salmon-spawning river in the presence of people (Olson et al., 1997).

Three forms of bear specific habituation have been defined: bear to bear, bear to human, and human to bear (Smith et al., 2005). All of these impact the dynamic and complex relationship among bears and people who share the same space; as bear density increases, so too do the first two forms of habituation. The third form of habituation occurs when people spend more time with bears exhibiting a high tolerance for humans and the people lose their wariness of bears possibly becoming careless and casual (Smith et al., 2005). Habituation occurs most frequently when human activity is spatially and temporally predictable (e.g., people are limited to viewing platforms during certain hours of the day; Matt & Aumiller, 2002; Nevin & Gilbert, 2005a and 2005b); bears also appear to be more tolerant of people and their activities where interactions are innocuous (Chi & Gilbert, 1999). In these scenarios, bears can modify their behaviour based on information they gather from understanding spatial and temporal human use patterns (Fagen & Fagen, 1994); this allows habituated bears to access habitat in proximity to people without negative incidents, and non-habituated bears to avoid areas of high human use. The predictability of human use in these situations is key, but some recreational activities like hiking are more unpredictable temporally and spatially than other human activities (Naves et al., 2001). According to Herrero et al. (2005), habituation may lead to increased fitness by allowing bears access to habitat in the presence of people but it is only positive in populations where habituation is not related to increased mortality. In threatened and endangered populations, where habituation can increase mortality risk due to increasing conflict with people, habituation should be discouraged unless the mortality risk can be managed (Herrero et al., 2005).

In the Canadian Rocky Mountain National Parks visitor use can be less intense than on surrounding public lands (i.e., bears are not being hunted and human trail use is non-motorized), but people are not always temporally or spatially predictable and human-caused mortality is still a risk to overall population viability (Nielsen et al., 2009). In BNP and the surrounding landscape, the survivability of radio-marked bears ranged from 69-73% for subadult males to 96% of adult females, male mortality rate was 3 times higher than that of females, and overall bear mortality due to purposeful killing by humans was equal to natural and accidental causes of mortality combined (Garshelis et al., 2005). As the majority of mortalities occur within human use areas, there is the need to manage human use levels on roads and trails to reduce human use and development in grizzly bear habitat, which will decrease bear mortality risk (Benn & Herrero, 2002; Graham et al., 2010; Stewart et al., 2012).

3.1.2 Measuring and Defining Potential Impacts

Previous research efforts measuring the impacts of human behaviour and presence on grizzly bear habitat use have used several approaches, including observation of vigilance or foraging behaviours, GPS or radio collars, and remote cameras. My research used the data from GPS collared grizzly bears, supplemented with stationary data generated by remote cameras to quantify grizzly bear habitat use in proximity to human use trails in the study area. In addition to understanding habitat selection, there is often a desire to quantify thresholds of levels of anthropogenic use and disturbance that potentially cause negative trends on individual habitat use and population size (Boulanger & Stenhouse, 2014), although due to confounding variables this cannot always be done. A threshold occurs where the system being studied responds rapidly to a relatively small change in a driver (Dodds, Clements, Gido, Hildergrand, & King, 2010); ecological thresholds can offer critical insights into ecosystem functioning or species-specific requirements (Toms & Villard, 2015). Due to individual variation between grizzly bears and their level of habituation, it is important for managers to have a basis of predicting impact thresholds for both habituated and non-habituated bears (Chi & Gilbert, 1999), which can change with availability of food resources, grizzly bear population density (Herrero et al., 2005), and the behaviour of people (Chi & Gilbert, 1999). Another challenge of quantifying thresholds is defining exactly when a bear is impacted. Internal reactions, such as increased heart rate, may be a stress response to stimuli that is not visible to the researcher (Herrero et al., 2005). Thus, how displacement or disturbance is defined is critical in the definition of thresholds.

Statistical approaches to examine habitat selection use data from remote cameras or GPS collars in: 1) use-availability comparing GPS location data to habitat available (random locations) but not used in the home range; and 2) presence-absence comparing when animals are in an area to when they are not and is done with remote camera data (e.g., Chapter 2). Use-availability can be done in simple models comparing used points to randomly generated points on the landscape, or it can be assessed using more robust, complex models through Step Selection Functions (SSFs) that incorporate an animal's movement in addition to its used locations.

3.1.2.1 Step selection functions (SSFs). Step Selection Functions are complex habitat-use models that use an animal's "steps", the straight-line segments between successive GPS locations (Turchin, 2015), to investigate the effects of environmental features on animal movement and habitat use patterns (Fortin et al., 2005). A SSF is a special case of use-availability design that compares environmental attributes of observed steps relative to alternative random steps that could have been taken from the same starting points (Fortin et al., 2005; Thurfjell et al., 2014). SSFs are an extension of a Resource Selection Function (RSF) model as they use a similar approach but incorporate the animal's movement (speed and direction) in the model (Roever, Boyce & Stenhouse, 2010; Thurfjell et al., 2014), as such SSF address some of the issues associated with autocorrelation between GPS locations (Fortin et al., 2005; Boyce et al., 2010). Plotting autocorrelation is done by taking into account that one step's length is likely to be similar to the length of the preceding step (i.e., an animal moving is likely to keep moving; Boyce et al., 2010). Autocorrelation among successive steps can have an important impact on the standard error estimates of landscape variables (Fortin et al., 2005), thus accounting for this autocorrelation can reduce standard error of the estimates. The autocorrelation between sequential step lengths can be paired with models of habitat use, movement over time, and knowledge of species to provide a more holistic view of animal behavioural patterns (Boyce et al., 2010). Including movement in selection models incorporates spatial and temporal realities to a series of locations, which allows the data to define the availability sample that randomly generated steps will be based on (Johnson et al., 2008). Reducing the impacts of autocorrelation creates a better, more robust model of animal habitat selection and movement by incorporating variables such as animal speed, timing of increased movement, and distances travelled.

By incorporating movement between used GPS locations combined with human use features on the landscape, SSFs are particularly useful for investigating the potential effects of human-related features or wildlife use of man-made linear features (e.g., roads and trails; Fortin et al., 2005) or temporal patterns in human activity on movement behaviour of animals (Thurfjell et al., 2014). In grizzly bear research, SSF analyses have shown that although grizzly bears are more likely to select steps closer to roads irrespective of traffic volume, their step lengths were longest near roads with high traffic volume indicating faster movement (Roever et al., 2010). While the selection for habitat close to roads could be found with more traditional use-availability analyses, the information regarding movement rates is apparent using an SSF. Other research used SSF to model grizzly bear habitat selection and movement as a function of broad landscape characteristics and road traffic volume to determine the influence of traffic on grizzly bear habitat selection relative to other landscape characteristics (Northrup et al., 2012b). Again grizzly bears selected habitat closer to roads, but the SSF analysis also showed increased movement across roads during the night when traffic volume was its lowest (Northrup et al., 2012b). This behaviour was related to the time of day; during the day, bears selected areas further from high and medium traffic volume roads and avoided crossing roads of all traffic volume levels (Northrup et al., 2012b).

Challenges with SSFs are largely associated with the decisions made as the model is being constructed. The fix rate of GPS location (how often a location is obtained) directly pertains to the scale of possible analysis and should be considered prior to commencing research (Thurfjell et al., 2014). For example, a fix rate of 15 minutes will likely generate steps over a smaller spatial and temporal scale than a fix rate of 60 minutes, depending on the subject species and their inherent movement patterns; the scale of analysis is limited by the fix rate as inevitably the researcher will make assumptions about behaviours the animal engages in between fix rates. Finer scale questions require more frequent fix rates. The scale needs to be fine enough to capture the behaviour of interest and have sufficient extent to observe the entire process not just part of it; temporal scale in habitat use patterns that can change daily, seasonally, or annually should also be considered (Thurfjell, et al. 2014).

Defining random steps (step length, step angle, and number of random steps per used step) is likely the most critical aspect of SSFs (Thurfjell et al., 2014). Drawing random steps from empirical distributions using the same method as Fortin et al. (2005) is a common approach; random step lengths and angles are drawn for each individual based on two empirical distributions built with the data collected from other individuals in the same population. Directional persistence should also be considered when drawing random steps as an animal is less likely to go backwards than it is to go forwards. Two distributions of data from the population are involved for creating random steps: one associated with step length and another associated with step angle. This creates a data set that can be analysed at the individual level and based on the movement of several individuals, which can have important implications for further analyses aiming to understand habitat selection at the population scale (Thurjell et al., 2014).

The last factor that can influence the model and results are the predictor covariates recorded for both used and random steps; these will vary depending on the research question and the behaviour of the species (Thurfjell et al., 2014). Steps can be characterised by the lines between locations, the average or extreme values of continuous variables along the step, the proportion of habitat along the step (Fortin et al., 2005), or environmental features at the end point of the step (Bjørneraas et al., 2011; Fortin et al., 2005). SSFs that consider the path of the animal may further improve understanding of the animal's habitat use and implications of the model (Webb & Merrill, 2012). SSF uses habitat characteristics along the movement path to statistically characterize the factors that affect step selection (Roever et al., 2010). The variables selected should therefore match the research question and ecological attributes of the species or landscape being studied. SSF models should incorporate a variety of predictor variables, including habitat variables (e.g., distance to nearest road/linear feature, proportion of step within particular habitat types; Fortin et al., 2005), other environmental variables (e.g., snow depth, slope, elevation), or human use levels (e.g., traffic volumes; Roever et al., 2010; Northrup et al., 2012b). Previous research aiming to understand grizzly bear habitat use adjacent to roads used minimum distance to road, a count of the number of roads crossed, and traffic volume of roads in each step as part of the SSF model (Roever et al., 2010; Northrup et al., 2012b). Thurfjell et al. (2014) suggest a thorough understanding of the ecology of the species and extensive data exploration are necessary to evaluate how best to make the above decisions and create a reliable SSF model.

In SSF analysis, observed and random steps are compared using conditional logistic regression (Fortin et al., 2005; Northrup et al. 2012b). Studies wishing to analyse data at the individual scale can use a two stage modeling approach by first fitting models of individual animals and then averaging regression coefficients across individuals to estimate population-level selection (Thurfjell et al., 2014).

3.1.3 Chapter Objectives and Hypotheses

The main objective of this chapter was to examine grizzly bear habitat use around trails of varying human use levels in Banff (BNP), Yoho (YNP), and Kootenay National Parks (KNP). I first wanted to increase understanding of grizzly bear habitat preference at the home range scale. I also aimed to define a threshold level of human use on trails, after which grizzly bears would be less likely to be detected by cameras. To quantify these details of grizzly bear habitat and trail use, I used remote cameras on hiking trails from fall 2013 to summer 2015 and grizzly bear GPS collar data from 2012 to 2015. I aimed to quantify the spatial and temporal patterns of human recreational use, by creating a human use model of trails. This model was then used to quantify impacts of human use levels on grizzly bear habitat use through a SSF, which supported a habitat use-availability analysis. The larger goal is to interpret these results and assemble management recommendations to help ensure visitors have opportunities for quality recreational experiences while conserving habitat security for grizzly bears. Specific hypotheses examined were:

H_1: Grizzly bear use of trails will be highest in the spring.

H_2: Grizzly bear use of high human use trails will be lower than low human use trails.

H_3: Grizzly bears will respond to a threshold level of human use, after which bear use of trails will be less likely. Thresholds will be associated with the number of human events and the amount of time since the last human event.

H_4: Grizzly bears will continually select for high quality habitat, regardless of human use levels on trails.

H_5: Grizzly bears will select for habitat farther from high human use trails and closer to low human use trails.

H_6: Grizzly bear movement rates will increase when in proximity to high human use trails.

3.2 Methods

This chapter included all GPS data from 2012 to 2015 and all remote camera data from fall 2013 to summer 2015. Where Chapter 2 focused on comparing GPS and remote camera generated data, this chapter focuses on grizzly bear habitat use in the presence or absence of people on trails.

I conducted camera sampling twice per season: fall 2013, spring to fall 2014, and spring to summer 2015; I had 55 cameras in rotation and deployed them at selected sites for 21 days at a time. In all, 426 camera sites were sampled over 8,611 camera trap days during the 3 years of data collection (Table 3.1; Figure 3.1). Of those, five cameras containing data from a total of 25 camera trap nights were not used in data analysis due to technical issues. Each of these cameras observed human use level was classified as low (<100 human events/month), medium (101-1439 human events/month), or high (<1440 human events/month). Grizzly bear GPS collar data from 6 adult females, 9 adult males, 4 females with cubs (included all dependent offspring), and 9 subadults from spring to fall of 2012 to 2015 were also used in analysis (Table 3.2). Subadult grizzly bears were defined as bears less than six years old; age was determined through knowledge of the bear's birth year by monitoring reproducing females or through inspection of teeth during capture.

Table 3.1: Number of trail networks sampled from fall 2013 to summer 2015. Camera capture days refer to the number of 24-hour days that cameras were deployed on trails.

Season and Year	Trail Networks Sampled	Camera sites	Camera capture days	Total number of images
Fall 2013	12	79	1,055	93,307
Spring 2014	9	49	1,012	50,318
Summer 2014	14	63	1,262	28,126
Fall 2014	17	91	2,342	114,724
Spring 2015	14	65	1,278	116,342
Summer 2015	15	79	1,662	102,306
Total	81	426	8,611	505,123

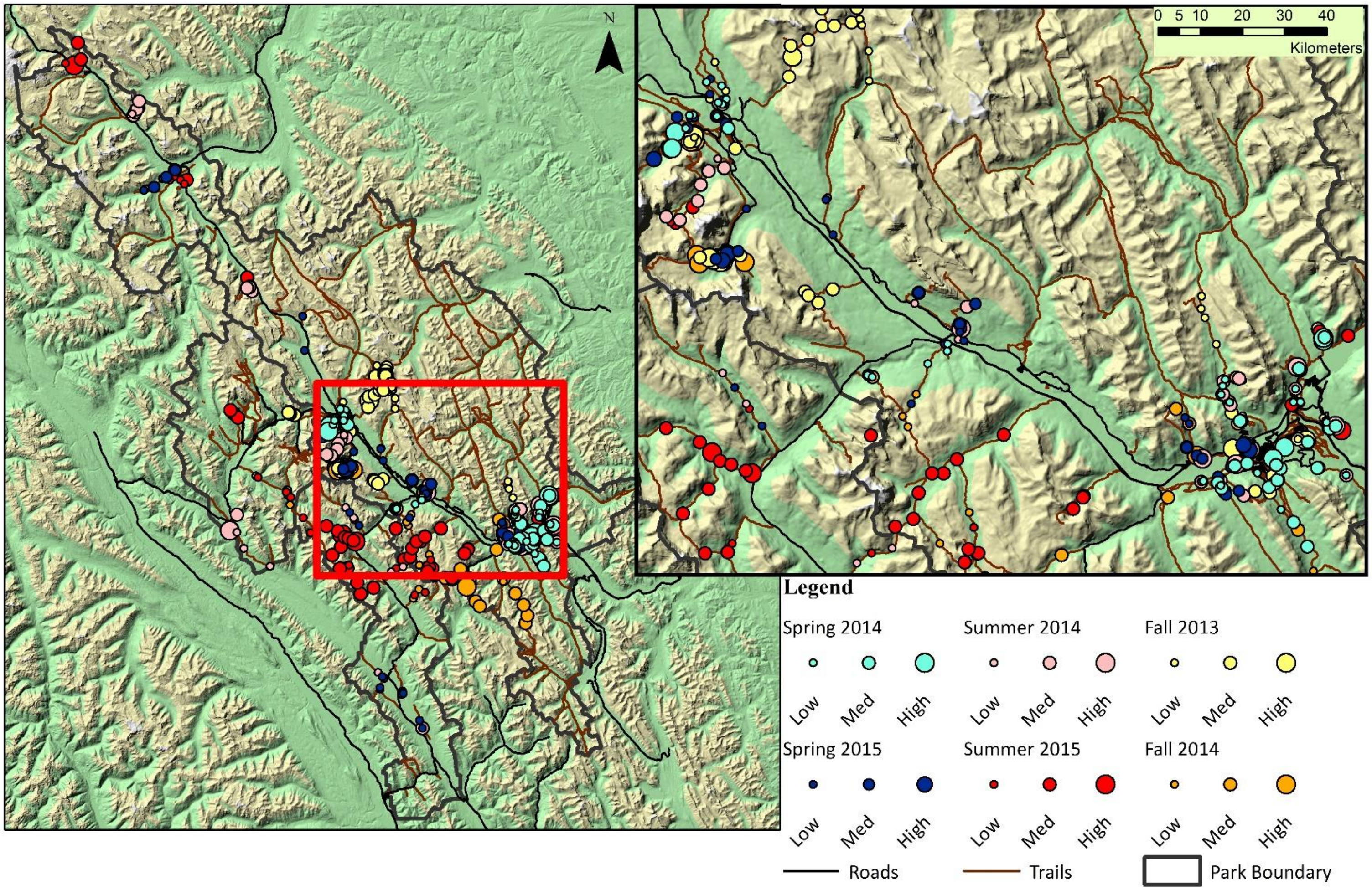


Figure 3.1: Camera locations from fall 2013 to summer 2015. In all 426 sites were sampled. Inset map shows the area around Banff and Lake Louise town sites that contained a higher density of camera sites because of a higher density of trails nearer to towns. Different size dots represent the levels of human use level (low, medium, high) of each camera based on the number of human events detected.

Table 3.2: Age/sex class of all bears fitted with GPS collars and whose data was used in analysis. Age sex classes were split into adult females (AdF), adult males (AdM), females with cubs (FwC), and subadult females and males (SadF and SadM respectively).

Bear ID	Age/Sex Class	Year	Seasons of Data
72	AdF	2013	Summer
			Fall
		2014	All
130	AdF	2012	Summer
		2013	Summer
		2014	All
		2015	Spring
135	AdF	2015	Summer
138	AdF	2013	Summer
			Fall
		2014	All
		2015	Spring
161	AdF	2015	All
122	AdM	2012	All
125	AdM	2012	All
126	AdM	2012	All
		2013	All
		2014	All
132	AdM	2014	Summer Fall
		2015	All
134	AdM	2012	Summer Fall
		2015	Summer
136	AdM	2012	Summer Fall
		2013	Spring
		2015	Summer
			Fall
140	AdM	2014	Spring
141	AdM	2014	All
158	AdM	2015	All

Table 3.3 continued

Bear ID	Age/Sex Class	Year	Seasons of Data
64	FwC	2012	All
		2013	Spring
72	FwC	2012	All
		2013	Spring
131	FwC	2012	Summer
			Fall
		2013	All
135	FwC	2012	All
		2013	All
142	SadF	2014	Spring
			Summer
		2015	Fall
143	SadF	2014	All
148	SadF	2014	Summer
			Fall
155	SadF	2015	All
156	SadF	2015	All
160	SadF	2015	Summer Fall
128	SadM	2013	All
144	SadM	2014	Spring Fall
149	SadM	2014	Summer

3.2.1 Data Analysis

I wanted to examine grizzly bear habitat use around and on human use trails from multiple perspectives, which lead to the application of several analytical approaches. The data from the remote cameras and GPS collars were analysed independently to investigate the chapter hypotheses. A summary of the analytical tools I selected is contained in Table 3.3 and detailed below.

3.2.1.1 Remote camera data analysis. Remote camera data were used in a presence/absence analysis to identify any factors that contributed to the probability of detecting a grizzly bear on camera. For these binary logistic regression analyses, I set the dependent variable as the presence/absence of grizzly bears; presence was defined as all events where a grizzly bear was detected on camera (GB event = 1). Absences were all those camera trap-days where a bear was not detected on camera. Each date for each remote camera also contained the following covariates: sum of human events, trail type (1= hiking, 2= hiking, biking, equestrian, 3= hiking, biking, equestrian, vehicles), habitat quality (as defined by the seasonal RSF), season, and the camera's straight line distance to the nearest road. Dates that did not record any people or bears were marked as 0's for grizzly bears and human events. This created a dataset with 114 grizzly bear events, 217,642 human events, and 8,500 camera days where no people or bears were captured.

I used a breakpoint regression analysis to examine if bear trail use was more likely to occur before a certain number of human events. A breakpoint is similar to a threshold except it refers to a place or time at which a sharp jump occurs from one function to

Table 3.3: Data analysis approaches used to investigate grizzly bear habitat use adjacent to and on human use trails, as per the hypotheses pertaining to this Chapter.

Research Objective	Hypothesis	Data Source	Analysis
To describe grizzly bear home range characteristics		GPS collars	Descriptive General Linear Mixed Model
To describe grizzly bear use of human use trails	H_1 and H_2	Remote cameras	Presence-absence – binary logistic regression.
The define thresholds of human use after which bear use of trails is less likely	H_3	Remote cameras	Breakpoint regression
To create a human use model	Needed to address H_4, H_5, and H_6	Remote cameras	Presence-absence – backwards stepwise regression
To refine understanding of grizzly bear habitat use at the seasonal home range scale	H_1	GPS collars	Use-availability – binary logistic regression
To determine variables leading to grizzly bear habitat selection	H_4 and H_5	GPS collars	Step Selection Function – conditional logistic regression
To measure grizzly bear movement rates in response to human use of trails	H_6	GPS collars	Step Lengths – general linear mixed model

another (Dodds et al., 2010). Breakpoint threshold analyses are used to examine non-linear relationships represented by a change in slope between the response and explanatory variables of concern (Sankaran et al., 2005; Toms & Villard, 2015). Also known as a piecewise regression, this analysis statistically determines if 2 linear relationships fit the data better than one (Dodds et al., 2010). This approach has been applied to freshwater systems (Dodds et al., 2010), crop production in relation to salinity (Oosterbann, Sharma, Singh, & Rao, 1990), and determinants of habitat types in Africa (Sankaran et al., 2005). One of the strengths of this approach is that piecewise regression model estimates will not converge if a threshold does not exist (Toms & Villard, 2015). The simplest method to prepare for this analysis is to visually examine the data in a scatterplot and estimate a potential breakpoint (Toms & Villard, 2015). Once I identified these potential break points, I used linear regression lines to find the best fit for the break points (Toms & Villard, 2015). I used two separate breakpoint analyses – one for the number of human events in 24 hours and another for the number of human events since dawn. Only data pertaining to all grizzly bear camera detections were included in this analysis; these analyses did not include any representation of when grizzly bears were not detected on camera.

I used a similar approach to identify an amount of time after human events where grizzly bears were more likely to use trails. In this analysis, I compared the time since the last human event and the time to the next human event for all grizzly bear camera detections. This was defined as the "human free window". If grizzly bear trail use was related to the time since last human event, then I expected there to be a significant difference between "time since human event" and "time to next human event". If bear trail use was not influenced by the last human event, then I would expect that bear use would randomly occur in the “human free window”. I created a scatterplot comparing the cumulative frequency of grizzly bear events over time and the amount of time since human events (Dodds et al., 2010). I identified 5 breaks in the exponential line – at 5 minutes, 18 minutes, 57 minutes, 292 minutes, 533 minutes, and 1032 minutes. Time since the last human event was not normally distributed, so I ran a series of Kruskall-Wallis tests. This analysis helped define at which point in time bear use of trails was potentially influenced by the last human event.

3.2.1.2 Creating the Human Use Model. Similar to Northrup et al. (2012b), I compared grizzly bear habitat use to a GIS layer of linear features (trails) within the study area with varying levels of human use. Since it was not the presence of the trail, but rather how many people use it that may influence grizzly bear habitat use (Gibeau, 1998), I needed to incorporate an estimate of human use on trails.

To create the model of human use, I defined values for each of the following covariates for each of the remote cameras:

- Sum of human events. I created three measures of human events for each camera - night (Ni), weekday daytime (WD), weekend daytime (WE). Total (T) human use in a month was generated by dividing the number of human events on each camera by the number of camera trap nights and multiplying by 30. Daytime was defined as dawn/dusk and day together from the previous time categories associated with the remote camera data (see Chapter 2); this did not consider changes in day length with the progressing seasons but used the earliest dawn (4:30am) and latest dusk (9:59pm) typical of June throughout the field season. The remote cameras showed human activity starting on trails as early as 4:30am and going as late as 10:00pm from June into October.

- Terrain ruggedness based on the VRM toolbox in ArcGIS. This is an index of ruggedness estimated as a variation in 3-D orientation of grid cells within a neighbourhood (proximity to original location). It combines variability in the slope and aspect ratio into a single measure and used the study area's digital elevation model (ArcGIS, 2016).
- Driving distance. I used the network analyst program in ArcGIS to calculate the road distance from the nearest town (either Banff or Lake Louise) to the trailhead.
- Hiking distance. I calculated the distance from the nearest trailhead to the camera via the hiking trail network using the same road and trail network I created in ArcGIS to calculate driving distance.
- Mean daily precipitation for each camera was derived from the Environment Canada records for the town of Banff, the weather recording site closest to most camera locations in the study area (Government of Canada, 2016).
- Mean temperature for each camera was derived using the same Environment Canada database for the town of Banff.

In creating the human use model, there were several cameras that had malfunctioned while recording the date and time. Therefore, no reliable estimates for mean precipitation or temperature could be generated and data from these cameras were eliminated from the human use model. In all data from 392 camera sites were used to create the human use model.

I first wanted to quantify any predictors of human use on trails in the study area; I did this with a backwards stepwise regression. This regression used a similar approach as the one examining predictors of grizzly bear presence-absence in that the dependent variable was the total number of human events each day and the 0's in the regression were defined by days when no people were detected on camera. The daily sum of human events was not normally distributed so I used a Log10 transformation to create the dependent variable.

I then prepared the model for the SSF by executing a linear regression analysis with each camera's monthly human use as the dependent variable and the above variables as covariates. I validated the model by withholding 20% of the used camera points and creating a new linear regression equation with the remaining 80% and using this equation to estimate the human use level for the withheld cameras (similar to Graham et al., 2010). The model underestimated the level of human use on most trails, particularly those with very high human use levels (>1440 human events/month) and slightly over estimated human use on the low use trails. Given the poor model performance, I simplified the model to improve reliability for inclusion in the SSF. I first removed temperature and precipitation from the model to only include spatial variables, this reduced uncertainty associated with temporal variables which were already averaged across a period of time and were based on attributes for the town of Banff that was potentially hundreds of km from an actual camera location. Again, I ran a linear regression on 80% of the camera and tested it on a withheld 20%. Still the model underestimated human use when more than 1000 human events were recorded, thus the model was not accurate in defining the difference between medium and high human use levels. I eliminated the “medium” human use category and split human use in to low (<100 people/month) and high (>100 people/month; as in Gibeau et al., 2001). Through this validation process, I suspected that other confounding variables were influencing the model’s ability to predict human use at very high levels. These variables may include trail popularity, marketing, or recommendations (from guide books, visitor centres etc.), which could not be included in this spatial model. I used a Chi-Square test to compare the number of observed and expected human use levels (low or high) for the withheld 20% of the cameras; observed values were those measured by the camera and expected were those predicted by the model. This test showed no significant difference in the actual and estimated low and high human use levels (X^2= 0.581, df= 1, p= 0.446).

To extrapolate this model to all trails in the study area, I created a series of random points in each season on trails available for human use. To best replicate my remote camera sampling design, I created one random point for each trail segment between junctions. In the spring, I only included trails in the valley bottoms since the higher elevations are still snow covered and not likely to see trail users. In the summer and fall, all trails were considered available. I assumed that human use at randomly generated points would be reflective of human use on that particular trail segment. I measured the same covariates as above for each of the random camera points. Using the final human use model linear regression equation from the validation process, I created an inverse log estimated measure of monthly human events for each random camera. These numbers were used to determine the human use category (low or high) for each random camera point, which was used as an approximate measure of human use in each season and on each trail in the study area for the SSF.

There were assumptions and limitations associated with this human use model. The model assumed that only trails in the valley bottoms would see human use during the spring, and that the probability of people using a particular accessible trail would be equal between seasons. Even though human use may vary slightly between seasons, these differences are more likely due to other factors than season. Another assumption made with the model was that estimated human use was reflective of human use along the entire trail segment (i.e., assuming once people started a trail, they would finish it and human use would not significantly change along the length of the trail).

3.2.1.3 GPS Analysis - Use-availability analyses at the home range scale. I analysed grizzly bear GPS locations to investigate resource selection within their seasonal home ranges using a use-availability design. Random points representing available habitat were generated within home ranges at a 1:1 used:available ratio. I only included bears that had a minimum of 100 locations within their seasonal 95% Kernel Density Estimate (KDE) home range, which allowed for more robust analyses between used and random locations. For home range descriptions, I also only included bears that had locations within 10 days of both the season start and end dates. I used a general linear mixed model to test for differences in seasonal home range trail and road density between age/sex classes. For the use-availability analyses, I ran a series of binary logistic regression analyses using Bear ID as a random factor to account for the individual variation exhibited in the dataset (Gillies et al., 2006). I ran one regression comparing habitat use in each season separately – predictor variables distance to road, distance to trail, and habitat quality for each location. In a second pair of regression models, I compared habitat selection in terms of proximity to roads and trails between seasons; only bears with more than 100 locations/season in one year were included in this analysis.

3.2.1.4. GPS Analysis - Step selection function. GPS locations were recorded from collared bears at a variety of time intervals ranging from 20 minutes to 4 hours depending on the location and behaviour of the bear, collar battery strength, collar performance, manufacturer, programming issues, and hardware malfunctions (Garrow et al., 2015). I rarified the data into two sets for the SSF, one based on 2 hour-steps and another based on 4 hour-steps. For each of these steps, I estimated habitat quality for the start point (based on the RSF), straight distance to the nearest road, and straight distance to the nearest trail. I also identified whether the step took place during the WD, WE, or Ni time categories used for the human use model. As the RSF (Nielsen, 2005) was only available for the BNP portion of the study area, I ran two SSFs for each location fix rate: one using habitat quality as a covariate (limited to the BNP extent of the RSF map) and one without habitat quality as a covariate (encompassing the entire study area). Using a model that encompassed the entire study area allowed an increased sample size of locations/bear and the number of individuals included in the model as several bears had locations largely outside of BNP. I used a separate SSF to compare bear activity at night to activity during the day. Therefore, in all eight SSFs were run (four on the 2-hour steps, and four on the 4-hour steps): one pair compared step selection to the various covariates, including habitat quality during the day; one pair compared step selection to the various covariates without habitat quality during the day; and two pairs compared step selection to the various covariates at night for the 2-hour and 4-hour steps. I used 20 random steps generated based on empirical step length and angle distributions; I used conditional logistical regression to compare used to random steps (Northrup et al., 2012b). As in Northrup et al. (2012b), I created individual models based on Bear ID. Correlations between some variables were recorded for some bears, so I deleted one of these variables from that bear's SSF model. In most cases "distance to high use trail" correlated with "distance to road", as I was most interested in habitat use in proximity to trails I deleted "distance to road". For several bears, the model could not calculate a coefficient for crossings of high use trails because it was non-convergent; this is because all of the available steps were greater or less than all of the used steps and the coefficient became infinite. In these cases, I ran a reduced model without crossings of high use trails. This combined with the inherent individual variation in the models made averaging regression coefficients across individuals inappropriate. Using a general linear mixed model, I compared 2-hour and 4-hour step lengths based on proximity to roads and trails of varying human use levels to test for differences in movement rates as bears moved closer to roads and trails.

3.3 Results

3.3.1 Presence-Absence and Remote Camera Analyses

I used the number of human events captured by each camera to determine the level of human use for each trail segment sampled; in total 159 camera sites were on low use trails, 207 were on medium use trails, and 58 were on high human use trails. The mean camera trap days, defined as a 24-hour period from camera set-up to take-down, were 19.5

(standard deviation = 3.85) per camera for a total of 8,278 camera trap nights. The bulk of events recorded were of people, regardless of a trail's human use level: I recorded 217,135 human events and 132 grizzly bear events (Table 3.4). The majority of grizzly bear events were recorded in the spring and summer on trails of low and medium human use in low value or secondary habitat. The mean number of grizzly bear detections was 1.38 bear events/100 camera trap days. I used the seasonal RSF score for a particular camera's location as a surrogate for habitat quality in the $90m^2$ area immediately surrounding the camera.

The first binary logistic regression used habitat quality as a predictor variable and found season positively related to the likelihood of detecting a bear on camera, supporting H_1 (spring: $\beta = 0.77$, $p=0.004$; summer: $\beta = 0.725$, $p = 0.009$); trail type was negatively correlated (hike: $\beta = -0.832$, $p = 0.019$; Table 3.5a). I had expected that trail type would be positively correlated, as human activity went from hiking to biking to vehicles there would be fewer grizzly bear events. After examination of the data, I found that this trend was influenced by a series of cameras in an area near the Banff town site called Vermilion Lakes. This area is highly popular with people and all trails in the area are very high use, one trail coincides with a road open to vehicles. The Vermilion Lakes area is also managed differently as it connects directly to major landscape scale wildlife corridors and managers frequently guide bears, using mild hazing or aversive conditioning techniques, through the Vermilion Lakes area to see them safely through the town site without incident. In the second regression, I eliminated all of the Vermilion Lake cameras. The results of this second regression showed that only season was a significant predictor of grizzly bear presence

Table 3.4: Distribution of human and grizzly bear events from remote cameras from fall 2013 to summer 2015. Capture per unit effort (CPUE= number of camera detections/ 100 camera trap days).

	Sum of Human Events n	Human Events CPUE	Sum of Grizzly Bear Events n	Grizzly Bear CPUE
Season				
Spring	55,650	672.26	52	0.63
Summer	63,875	771.62	47	0.57
Fall	97,610	1179.15	33	0.40
Human Use Level				
Low	3,775	45.60	56	0.68
Medium	71,411	862.66	47	0.57
High	141,949	1714.77	29	0.35
Trail Type				
Hiking only	130,414	1575.43	64	0.77
Hiking, biking, equestrian	68,931	832.70	58	0.70
Vehicles	17,790	214.91	10	0.12
Grizzly bear habitat quality				
Low Value	79,409	959.28	41	0.50
Secondary	78,011	942.39	48	0.58
Primary	39,261	474.28	20	0.24
Outside BNP	20,454	247.09	23	0.28
Total	**217,135**		**132**	

Table 3.5: Binary logistic regression results examining grizzly bear presence/absence on cameras. The camera's distance to road (continuous variable), habitat quality, sum of human events (per day/camera), season, and the trail type were the covariates tested. Because road density is part of the RSF model, two regressions were run with these predictor variables separately. In the model using all the data and distance to road as a predictor variable, distance to road, sum of human events and trail type were eliminated in the final model. In the model using habitat quality, habitat quality and sum of human events were eliminated from the final model. In the models eliminating the Vermilion Lake cameras, these same variables were eliminated in addition to trail type in the model using habitat quality as a predictor. This left season as the only significant predictor of grizzly bear presence on cameras. * denotes significance at p<0.05.

a. Regression results using all cameras in the data set

	Input		**Coefficients**	
Model	**Dependent Variable**	**Independent Variables**	**Standardized *β***	**p-value**
Distance to road as a predictor	Grizzly Bear (presence/absence)	Season	Spring = 0.778 Summer = 0.519	0.002* 0.035*
Habitat quality as a predictor	Grizzly Bear (presence/absence)	Season	Spring = 0.770 Summer = 0.725	0.004* 0.009*
		Trail Type	Hike = -0.832 Bike/Horse = -0.648	0.019* 0.073

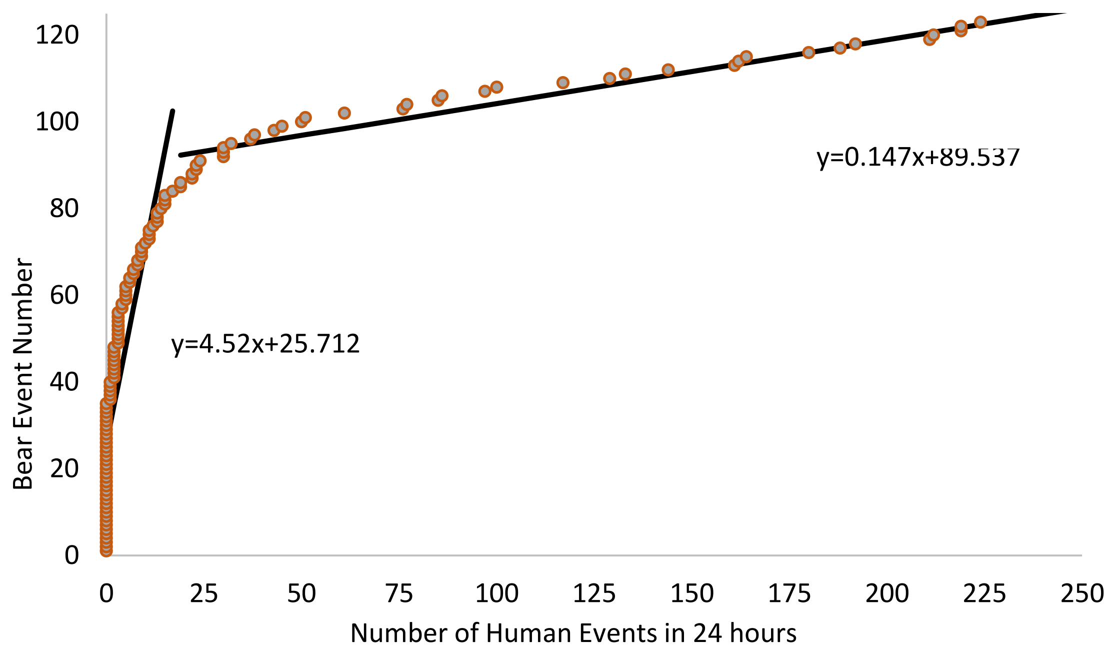
b. Binary regression results eliminating Vermilion Lake cameras from the data set

	Input		**Coefficients**	
Model	**Dependent Variable**	**Independent Variables**	**Standardized *β***	**p-value**
Distance to road as a predictor	Grizzly Bear (presence/absence)	Season	Spring = 0.710 Summer = 0.386	0.006* 0.140
Habitat quality as a predictor	Grizzly Bear (presence/absence)	Season	Spring = 0.683 Summer = 0.507	0.016* 0.089

(spring: β= 0.683, p= 0.016), thus the relationship with trail type was being driven by the Vermilion Lake cameras.

The binary logistic regressions that used distance to road as one of the predictor variables only found season to be a significant predictor of grizzly bear presence on trails (spring: β= 0.778, p= 0.002; summer: β= 0.519, p= 0.035; Table 3.5b). Therefore, both analyses showed that there were significantly more detections of grizzly bears in the spring and summer than in the fall and that other trail attributes were not significant predictors of grizzly bear detection on camera. This supported H_1 and rejected H_2.

The breakpoint regression analyses attempting to identify a number of human events in the last 24 hours and since dawn after which bears were less likely to be detected on camera found that many grizzly bear events occurred before any people used the trail (n= 35/124 for 24 hours, and n= 58/120 for human events since dawn). As a result, I began the breakpoint analysis at the last 0 to better capture the regression line once people were using the trail. The breakpoint identified in the analysis examining the number of people in 24 hours was found at 17 people (regression equation: y= 4.52(x)+25.712; Figure 3.2a). The breakpoint analysis examining the number of people since dawn found a break at 8 human events (regression equation: y= 11.736(x)+33.361; Figure 3.2b). Thus, most grizzly bear events on camera occurred before 8 people since dawn had used the trail, which supported H_3 as it pertained to the number of human events. This analysis shows a correlation, but it does not necessarily represent a cause and effect relationship of human use on grizzly bear trail use.



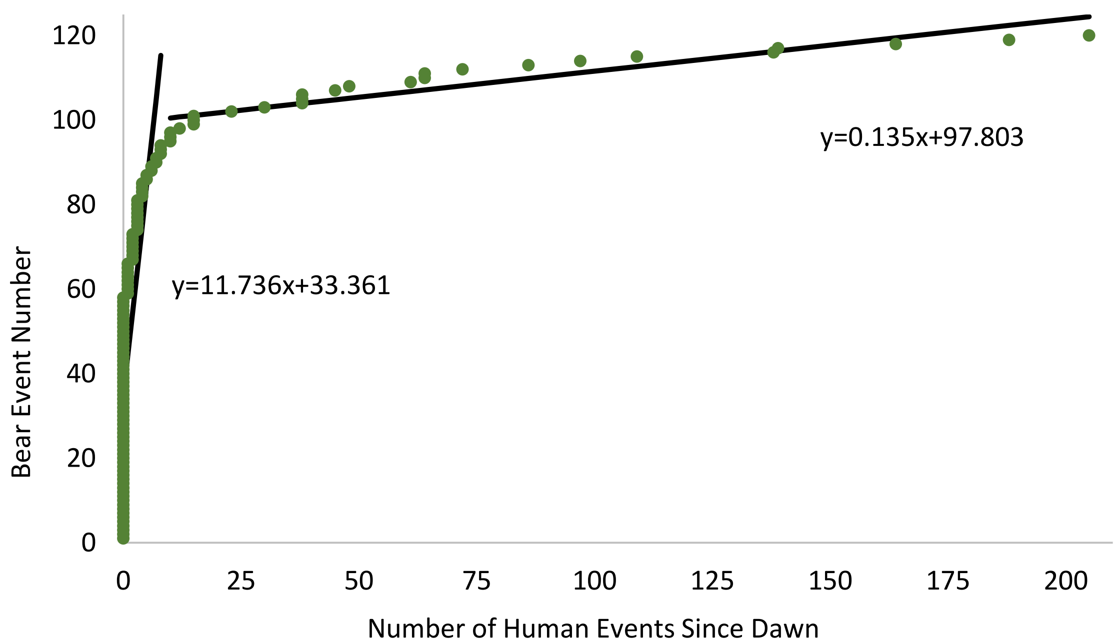


Figure 3.2: Regression breakpoint analysis identifying threshold numbers of people before grizzly bear trail use changed. Bear Event Number (on the y-axis) represents a count of bear camera detections used in these analysis; all bear events were considered independently but were ordered by the number of preceding human events. A. Analysis examining the number of human events in 24 hours found breaks at 17 people (n= 128). B. Analysis examining the number of people since dawn found one major break at 8 people (n= 124).

I found significant differences in the time since last human event and time to next human event at 18 ($p= 0.04$), 57 ($p= 0.03$), 292 minutes ($p= 0.003$), and 533 minutes ($p=0.001$; Figure 3.3). On very busy human use trails where the timing between human events was less than 5 minutes, however, grizzly bear use did not appear to be related to the timing between people. Beyond 533 minutes (over 8 hours), no significant differences since last human event and time to next human event were observed. Rather than define a specific threshold of time, this analysis essentially separated out regularly used and unused trails as there are very few trails where human groups are actually more than 8 hours apart. On regularly used trails, grizzly bears tended to be closer in time to the most recent person to use the trail (the last human event). Beyond 533 minutes there was no evidence for correlation between grizzly bear use and time since last human event. H_3 as it pertained to the time since the last human event was rejected as the relationship could not be clearly defined.

3.3.2 Human Use in the Study Area

The first backwards stepwise regression was not used for the SSF, but did show significant predictors of human use. This model did not exclude any covariates in predicting daily human use levels of cameras. Mean temperature and terrain ruggedness were positively correlated with the number of human events, and precipitation was negatively correlated with the number of the human events (Table 3.6). Hiking distance and driving distance were both negatively correlated with the number of human events suggesting that most trail use occurs closer to either Banff or Lake Louise and on shorter hikes. Weekday

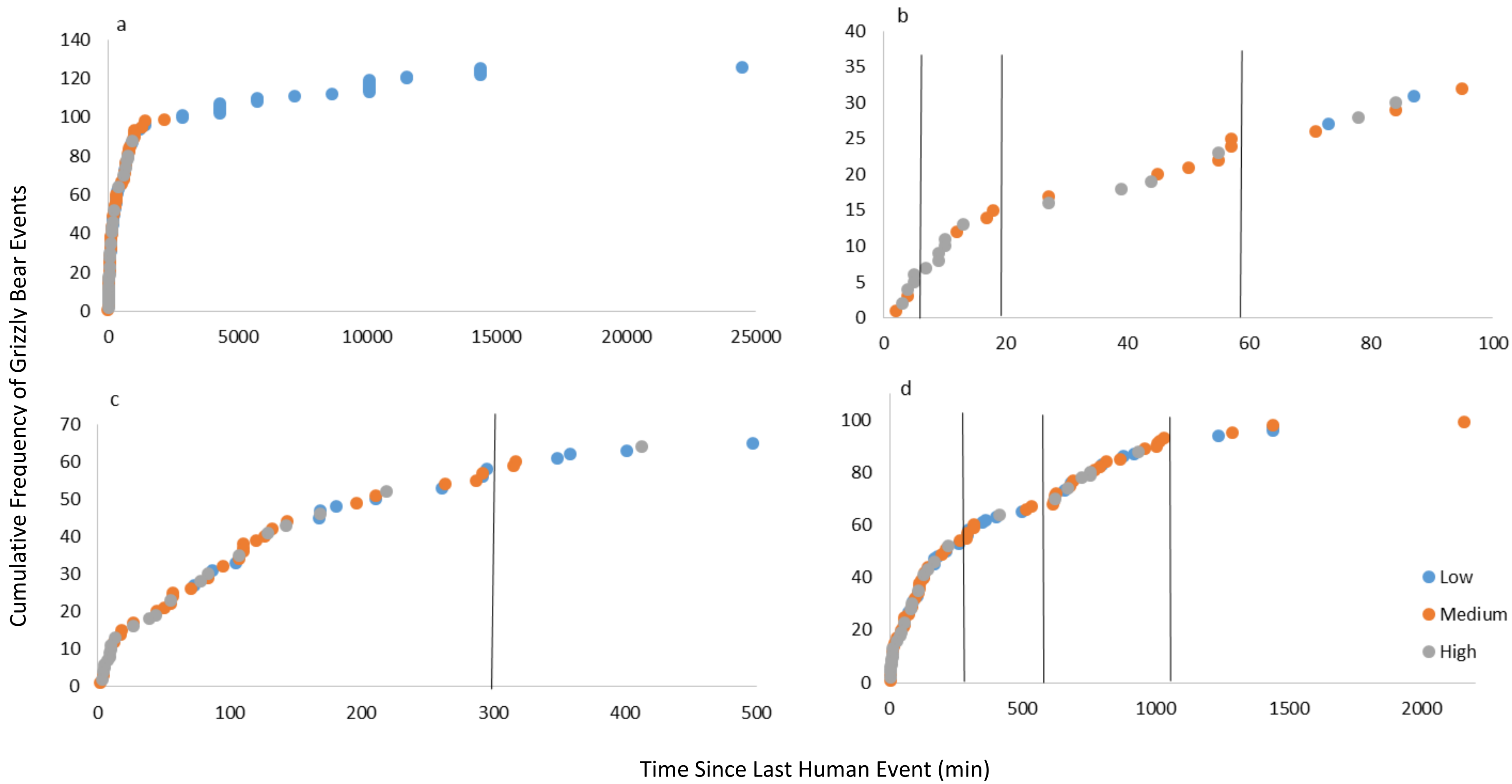


Figure 3.3a-d: Scatterplots of time since last human event and cumulative frequency of grizzly bear events. 1a) scatter of all events; 1b) scatter of events up to 100 min since last human event; 1c) scatter of events up to 500 min since last human event; 1d) scatter of events up to 2000 min since last human event. Vertical lines denote areas where a break in the line was found and the curve began to alter its slope. Breaks were found at 5 min (n= 6 events), 18 min (n= 15 events), 57 min (n= 25), 292 min (n= 57 events), 533 min (n= 67 events), and 1032 min (n= 93 events). Figure legend refer to low, medium, and high human use trails.

Table 3.6: Backwards stepwise regression results of human use on sampled trails in the study area. Model $R^2 = 0.120$. Dependent variable was the Log10 transformation of daily human use on each camera. Covariates were hiking distance as calculated from the trailhead, driving distance as calculated from the nearest town (Banff or Lake Louise), terrain ruggedness, weekday vs weekend, mean daily temperature, and total daily precipitation. All days where no human events were recorded were included as 0's. Weekdays (Monday through Friday) were compared to weekends (Saturday and Sunday). A total of 393 cameras were included in the regression with a total of 8,094 camera trap days. All covariates were significant predictors of human use levels, no covariates were excluded from the model.

Predictor Variable	Standardized β Coefficients	p-value
Hiking distance	-0.268	<0.001
Driving distance	-0.140	<0.001
Terrain Ruggedness	0.125	<0.001
Weekday	-0.064	<0.001
Mean temperature	0.134	<0.001
Total precipitation	-0.032	0.003

was also negatively correlated with the number of human events demonstrating an increase in human use of trails on the weekends.

3.3.3 Use-Availability Analyses from GPS Data

All GPS data for bears were separated into seasons and years. Analysis included GPS locations from 27 individual grizzly bears; 6 adult females, 9 adult males, 4 females with cubs, and 9 subadults (1 female with cubs weaned her cubs in 2013 and from then on was considered a single adult). Use-availability analyses used a total of 33,183 locations, which were paired with an equal number of random locations.

There was a large amount of variation evident in the size of bear seasonal home ranges by age-sex class (Figure 3.4). Adult male bears had the largest home ranges across seasons, especially in the spring. In the spring and summer adult females also had large home ranges; subadult bears had the smallest home ranges in the fall. Overall, there was less variation between bears in home range size in the spring and the greatest variation between bears in the fall. Bear 130, an adult female had the smallest seasonal home range (95%KDE = 3.37km^2) and had no trails within her home range. Eleven bears had no roads in their fall home ranges (3 adult females, 4 adult males, 2 females with cubs, and 2 subadults). There was little difference in seasonal home range trail and road density between age/sex classes; the only significant differences were adult males had a lower trail density that subadults in the summer, and females with cubs had higher trail densities than subadults in the fall (Table 3.7a-b).

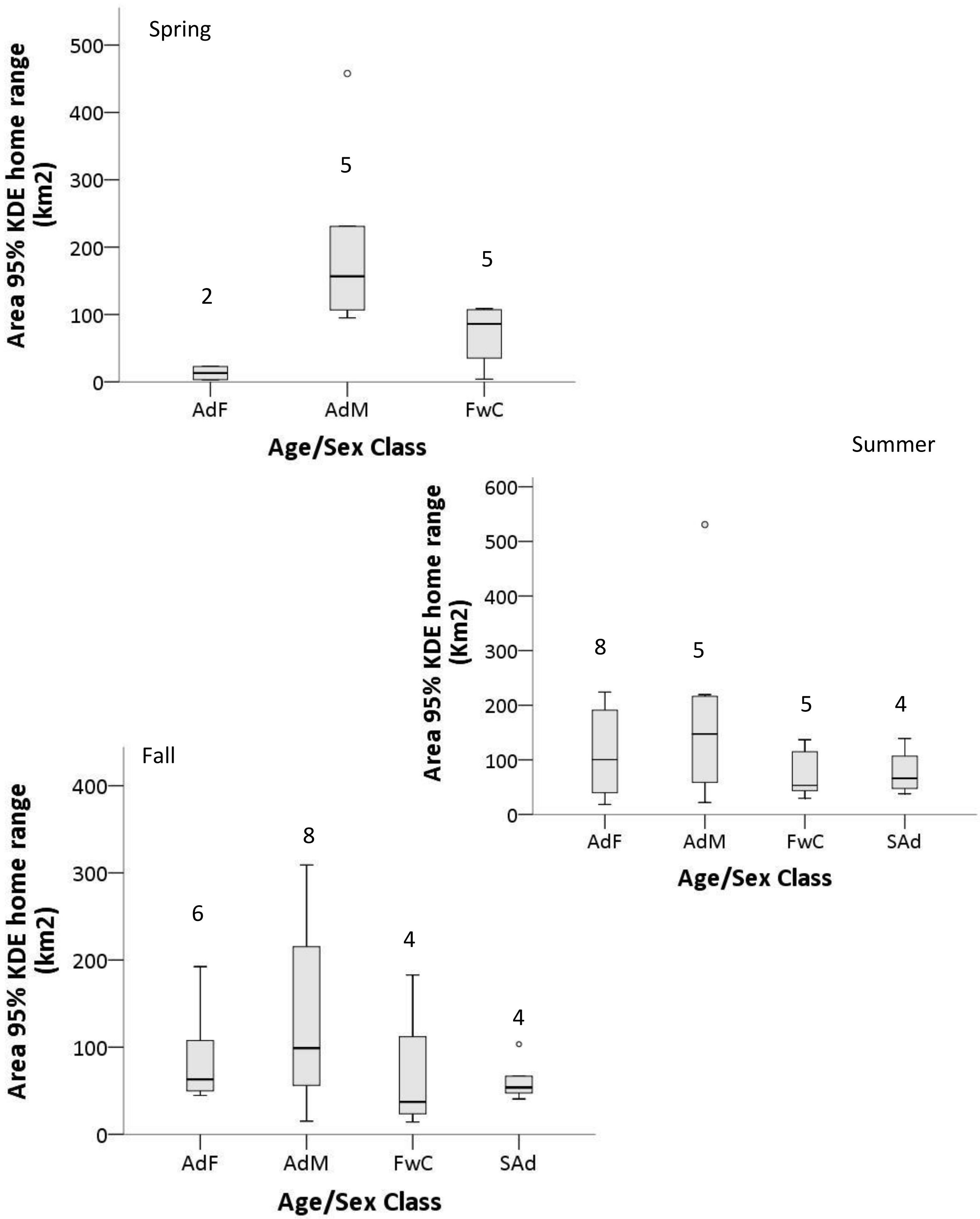


Figure 3.4: Whisker box-plot showing seasonal home range size (95% KDE km2) for age sex classes. Home ranges were based on variable GPS fix rates, all contained locations within 10 days of season start and end dates. AdM: adult male, AdF: adult female, FwC: female with cubs, SubAd: subadult. Sample sizes indicated above bar on graph. Small dots represent outliers defined as 1.5*interquartile range.

Table 3.7a-b. General linear mixed model showing differences in trail and road density between age/sex classes. Each season was run separately with trail density or road density as the dependent variable. Bear ID was set as a random factor, and age/sex class was the dependent variable. AdM= adult male, AdF- adult female, FwC= female with cubs, SAd= subadult. In the spring, the age/sex class FwC was set as the constant, in all other seasons SAd was set as the constant. * denotes statistical significance at p<0.05.

a) Trail density

		Coefficients		
	Age/Sex class	**β**	**Standard Error**	**p-value**
Spring				
	AdF	-0.255	0.225	0.257
	AdM	0.041	0.174	0.814
Summer				
	AdF	-0.252	0.134	0.059
	AdM	-0.281	0.134	0.036*
	FwC	-0.083	0.147	0.570
Fall				
	AdF	0.116	0.138	0.402
	AdM	-0.036	0.130	0.784
	FwC	0.330	0.153	0.031*

b) Road density

		Coefficients		
	Age/Sex class	**β**	**Standard Error**	**p-value**
Spring				
	AdF	0.124	0.101	0.219
	AdM	0.140	0.078	0.071
Summer				
	AdF	-0.156	0.220	0.478
	AdM	-0.289	0.220	0.488
	FwC	-0.188	0.241	0.0434
Fall				
	AdF	-0.134	0.081	0.095
	AdM	-0.068	0.076	0.370
	FwC	-0.068	0.090	0.447

Grizzly bears selected for primary habitat quality in every season (Table 3.8a-c), supporting H_4. In the spring, grizzly bears selected habitats farther from roads than random and closer to trails that were close to roads. As discussed in chapter 2, spring home ranges inherently had higher road densities as they were centered in lower elevations where more forage was available. In the fall, grizzly bears selected habitats closer to trails and roads than random. Fall home ranges were located in higher elevations further away from the transportation corridor and high human use areas of the study area. The coefficients for habitat quality did not change from summer to fall showing consistent preference for habitat quality. Other than selecting for higher quality habitat, no significant relationships were found for habitat selection within home ranges for the summer.

The binary logistic regression examining differences in bear seasonal habitat selection in terms of proximity to roads and trails shed further details on these relationships (Table 3.9). Significant differences were found in habitat selection between seasons. Bears selected habitat closer to roads in the summer than in the fall; bears selected habitat closer to trails in the spring and summer than in the fall. While H_4 was supported by these results, showing bears continually selected for high quality habitat, the seasonal differences in selection begin to showcase the complexity of this selection.

3.3.4 Step Selection Functions (SSFs)

All SSFs found proximity to high quality habitat positively correlated with used steps, this was significant for most bears regardless of step length (Figure 3.5a-d), further supporting H_4. Selecting for higher habitat quality was not significant for one bear during

Table 3.8. Binary logistic results detailing bear habitat use in each season. Analysis completed at the bear home range scale based on 95% seasonal KDE. Bear ID was set as a random factor in analysis. For habitat quality, I set the lowest value as the reference category. This analysis was only run on locations within Banff National Park as the RSF habitat quality layer did not extend beyond BNP boundaries. *denotes statistically significant at p<0.05.

a. Spring

Parameter	B Estimate	Standard Error	P-value
Habitat Quality – secondary	0.036	0.019	0.055
Habitat Quality – primary	0.184	0.019	<0.001*
Distance to trail (km)	0.018	0.013	0.139
Distance to Road (km)	0.031	0.005	<0.001*
Distance to Trail * Distance to Road	-0.043	0.006	<0.001*

b. Summer

Parameter	B Estimate	Standard Error	P-value
Habitat Quality – secondary	0.093	0.014	<0.001*
Habitat Quality – primary	0.244	0.013	<0.001*
Distance to trail (km)	-0.012	0.009	0.185
Distance to Road (km)	-0.004	0.002	0.061
Distance to Trail * Distance to Road	0.0003	0.002	0.842

c. Fall

Parameter	B Estimate	Standard Error	P-value
Habitat Quality – secondary	0.216	0.007	<0.001*
Habitat Quality – primary	0.259	0.007	<0.001*
Distance to trail (km)	-0.011	0.005	0.019*
Distance to Road (km)	-0.002	0.0007	0.041*
Distance to Trail * Distance to Road	0.0007	0.0004	0.110

Table 3.9. Binary regression results detailing habitat use across seasons in terms of proximity to roads and trails. Analysis completed on bears with >100 locations in each seasonal 95% KDE per year. I set fall as the reference category for seasonal comparisons. For habitat quality, the lowest value was set as the reference category. *denotes statistically significant at p<0.05.

Parameter	B Estimate	Standard Error	P-value
Spring	0.017	0.009	0.049*
Summer	0.038	0.008	<0.001*
Distance to Road	0.001	0.001	0.316
Distance to Trail	-0.009	0.003	0.002*
Spring * distance to road	-0.001	0.001	0.338
Spring * distance to trail	-0.021	0.006	<0.001*
Summer * distance to road	-0.005	0.001	<0.001*
Summer * distance to trail	-0.020	0.004	<0.001*

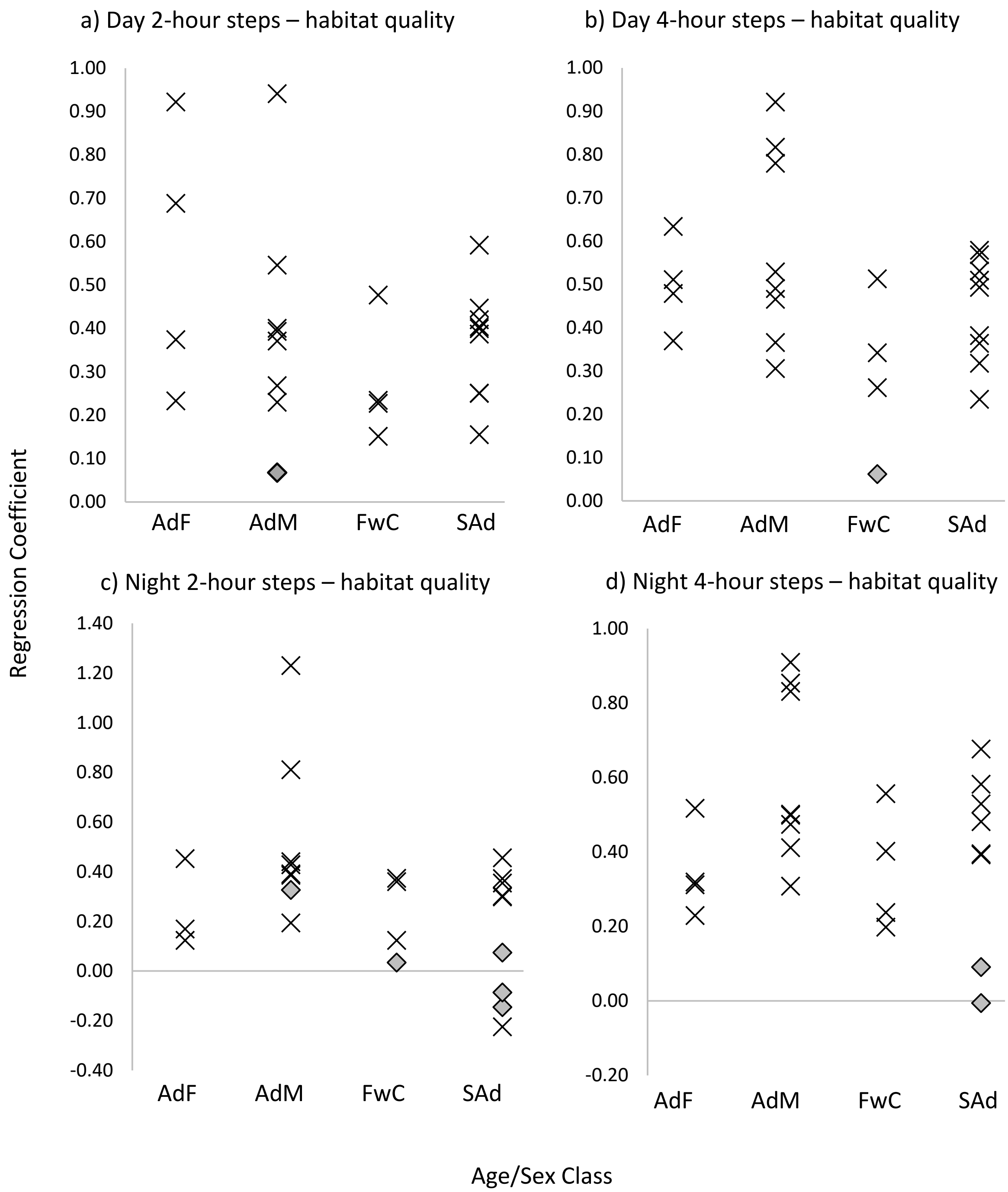


Figure 3.5. Step Selection Function results from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class) and habitat quality. Sample sizes varied between analyses; figures include 25 bears from 2-hour and 4-hour day step data, 24 from 2-hour night step data, and 25 from 4-hour night step data. Significant relationships are indicated by "X" (p<0.05); non-significant relationships are indicated by grey diamonds.

the day 2-hr steps (bear 125, an adult male), and one bear during the day 4-hr steps (bear 131, a female with cubs). At night, this relationship became less consistent and several bears did not select for higher quality habitats significantly during the 2-hour steps. During the 4-hour steps, however, the relationship to higher quality habitat was significant for most bears (except for three subadults bear 144, 148, and 149).

Since all bears selected for higher quality habitat, I chose to present the results pertaining to the SSF without habitat quality for all other covariates. In addition to isolating the effects of trails and roads, this approach ensured a higher sample size of steps per bears and included all data from all bears with GPS collars. Grizzly bear habitat use in relation to human use variables showed a greater degree of individual variation. Grizzly bears used habitat at varying distances to road and no trends between age/sex classes were apparent. During the day, half of the bears sampled significantly selected for steps farther from roads than random in their 2-hour steps, and half of the bears selected steps closer to roads than random; in the 4-hour steps most of the significant relationships were negative meaning steps were closer to roads than random (Figure 3.6a-d). In the 2-hour steps at night, more bears selected steps closer to roads than random, but this trend did not continue for all bear in the 4 hour steps. These general patterns were observed for at least one individual in each age/sex class. At night, fewer significant relationships between individual bears and distance to road were recorded for the 4 hours steps.

Several bears crossed roads less often than random; this relationship was mostly apparent with the 4-hour steps during the day (Figure 3.7a-b). Bear 132, an adult male crossed roads more frequently than random at night; Bear 122, another adult male, and

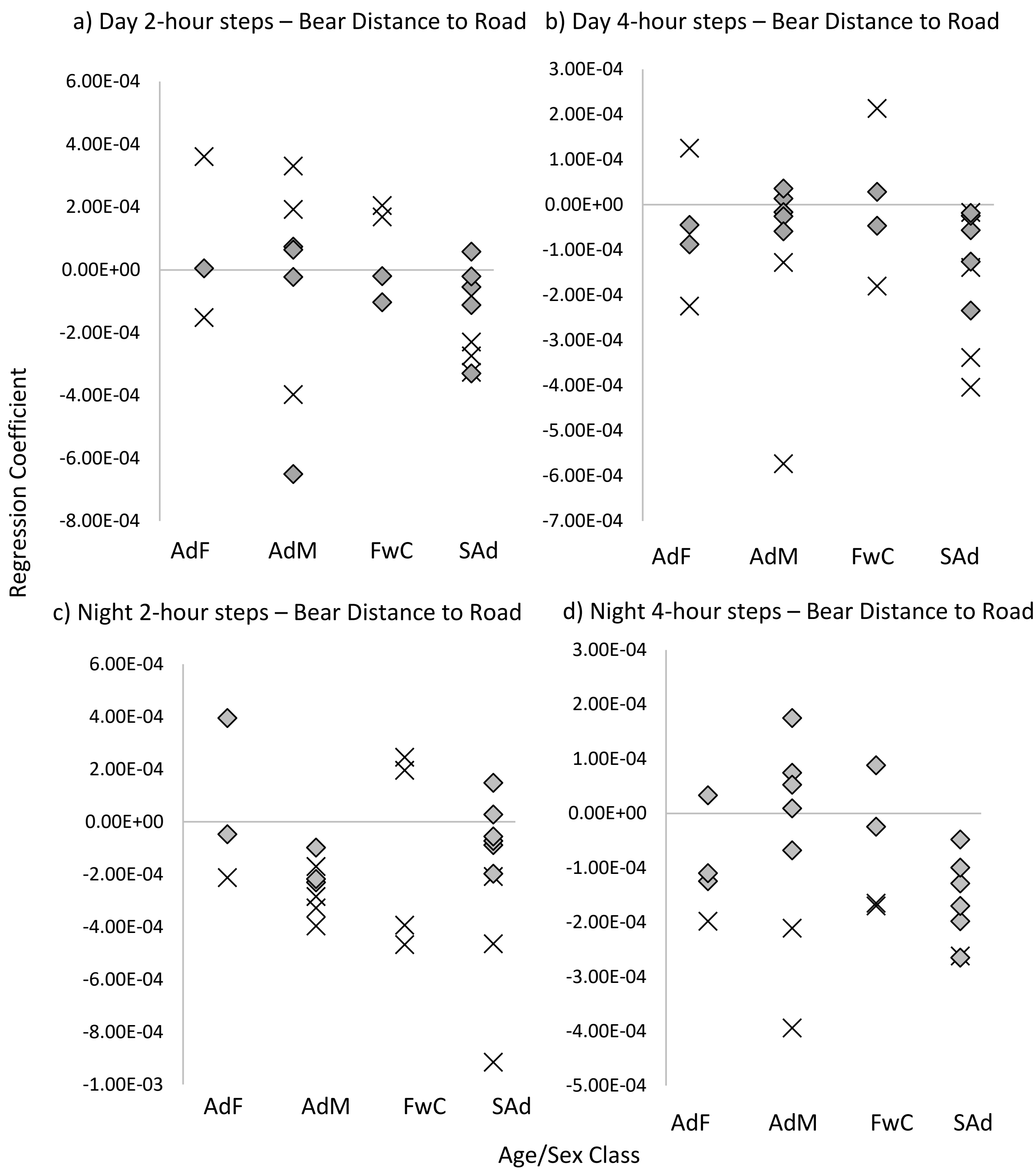


Figure 3.6. Step Selection Function coefficients for the effect of distance to road on grizzly bear movement behaviour from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class) and distance to road. Sample sizes varied between analyses; figures includes 21 bears from 2-hour, 24 from 4-hour day step data, 23 from 2-hour night step data, and 21 from 4-hour night step data. Significant relationships are indicated by "X" (P<0.05); non-significant relationships are indicated by grey diamonds.

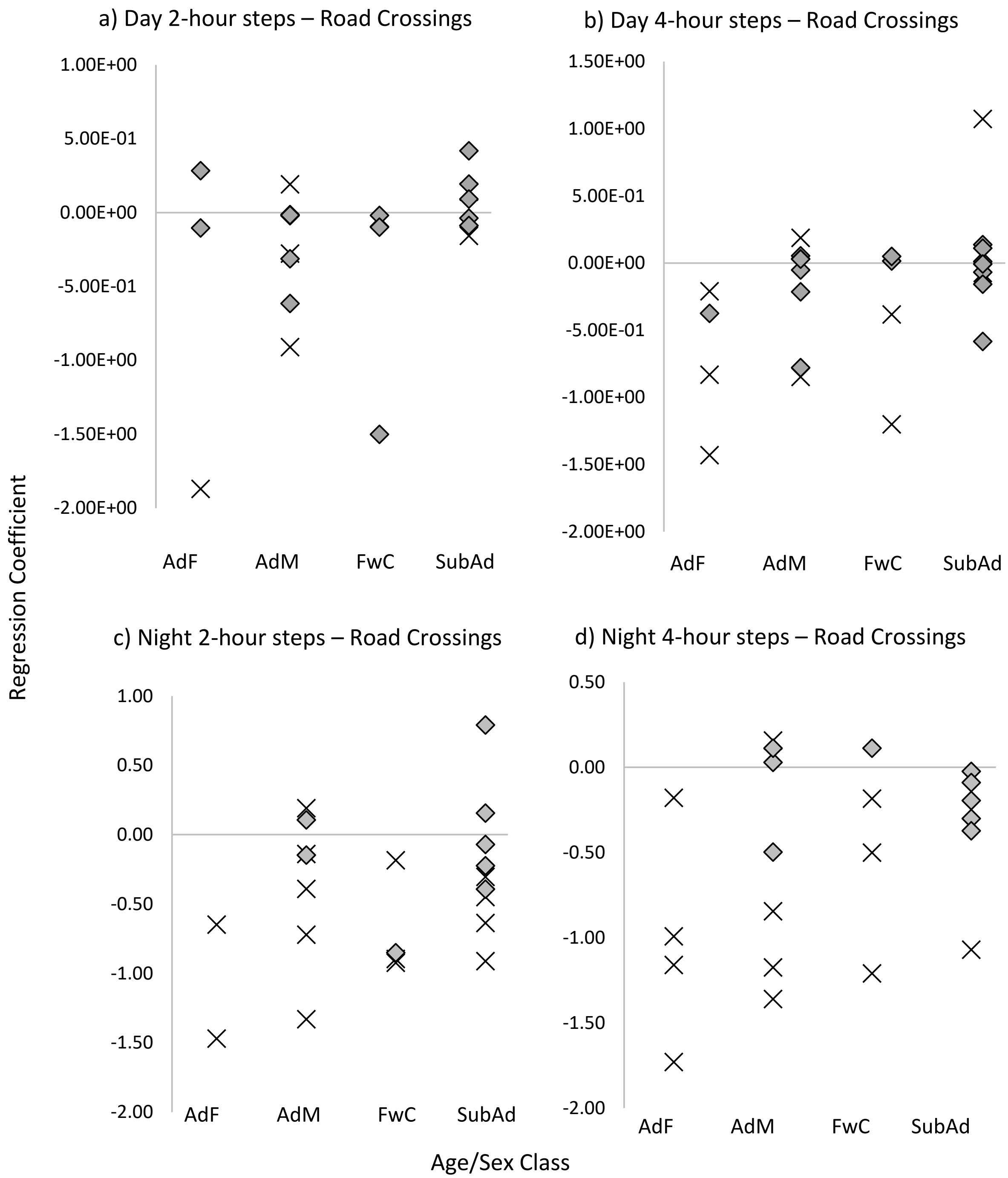


Figure 3.7. Step Selection Function coefficients for the number of road crossings related to grizzly bear movement behaviour from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class). Sample sizes varied between analyses; figures includes 19 bears from 2-hour and 23 bears from 4-hour day step data, 19 from 2-hour night step data, and 19 from 4-hour night step data. Significant relationships are indicated by “X” (P<0.05); non-significant relationships are indicated by grey diamonds.

Bear 142, a subadult, crossed roads more frequently than random on their 2 hour steps during the day. With the exception of these individuals, all bears displaying a significant relationship with this variable crossed roads less often than random. The majority of significant relationships with this variable were seen on 2-hour steps at night (Figure 3.7c-d). Two bears that selected steps close to roads also crossed roads more often (Bear 122, an adult male; and Bear 142 a subadult). Conversely, Bear 161, an adult female, selected steps close to roads and crossed roads less often than random.

A higher degree of variability was recorded for bear habitat use in proximity to human use trails, although there was less variability in proximity to low use trails (Figure 3.8a-d). Most bears in both the 4-hour and 2-hour step data selected steps closer to low use trails during the day and night. Half of the females with cubs selected for habitat away from low use trails. Conversely, most subadult bears used habitat nearer low use trails than random. At night, more bears selected steps away from low use trails than during the day, particularly in the 2-hour steps, this difference was most common for subadult bears.

While most bears displayed a significant relationship to habitat use and distance to high use trails, the nature of those relationships varied. Half of the grizzly bears selected steps closer to high use trails and half farther from high use trails (Figure 3.9a-d). In the 4-hour step time interval, most subadults selected steps closer to high use trails. Two females with cubs selected habitat close to high use trails and two selected habitat away from high use trails. These relationships changed very little at night. At night, two adult females selected 2-hour steps away from high use trails, but closer to high use trails in their 4-hour steps. The relationship bears displayed with their distance to high or low use trails was not

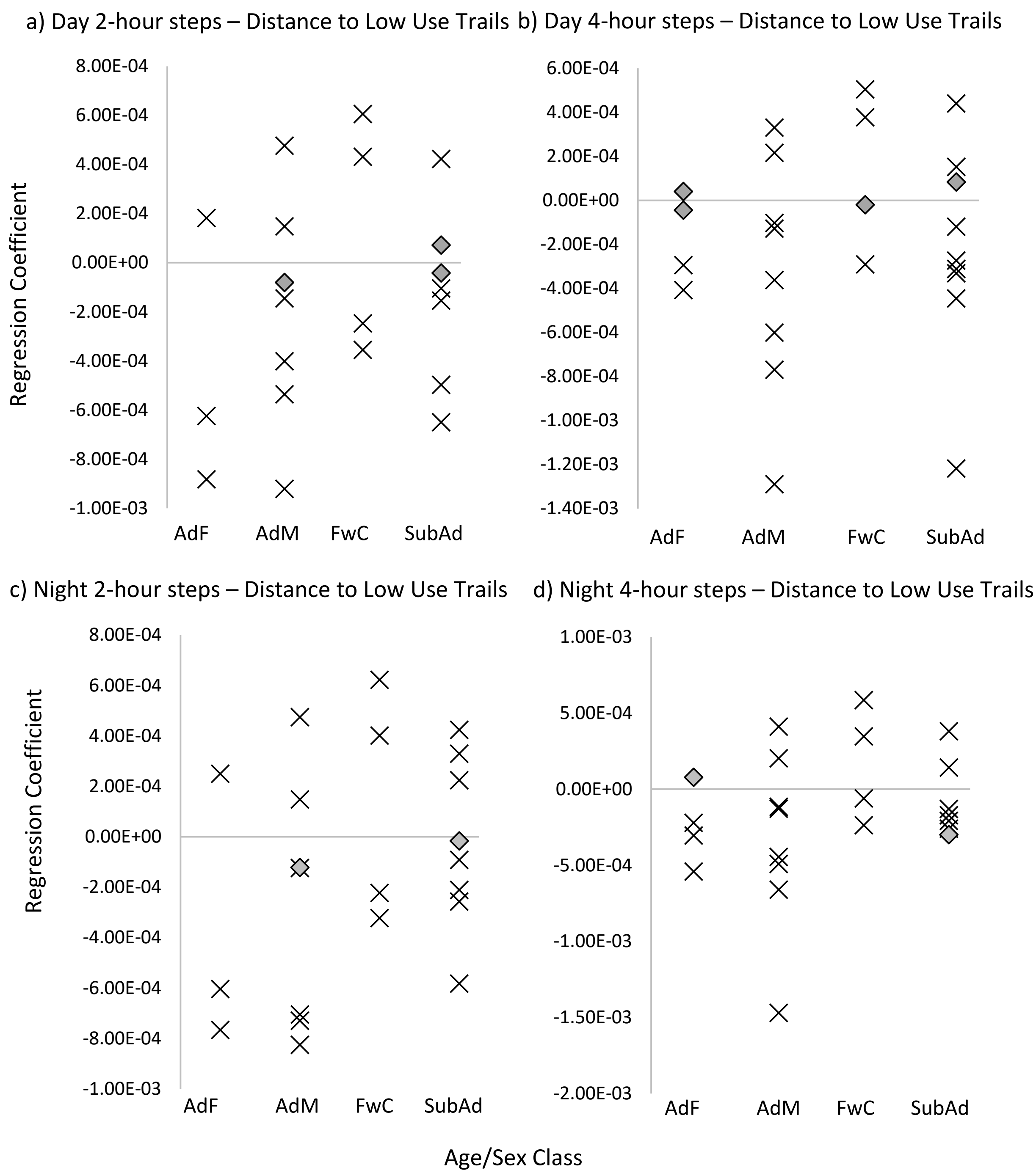


Figure 3.8. Step Selection Function coefficients for the effect of distance to low human use trails on grizzly bear movement behaviour from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class). Sample sizes varied between analyses; figures includes 22 bears from 2-hour day steps, 25 from 4-hour day step data, 25 from 2-hour night step data, and 22 from 4-hour night step data. Significant relationships are indicated by “X”; non-significant relationships are indicated by grey diamonds (P<0.05).

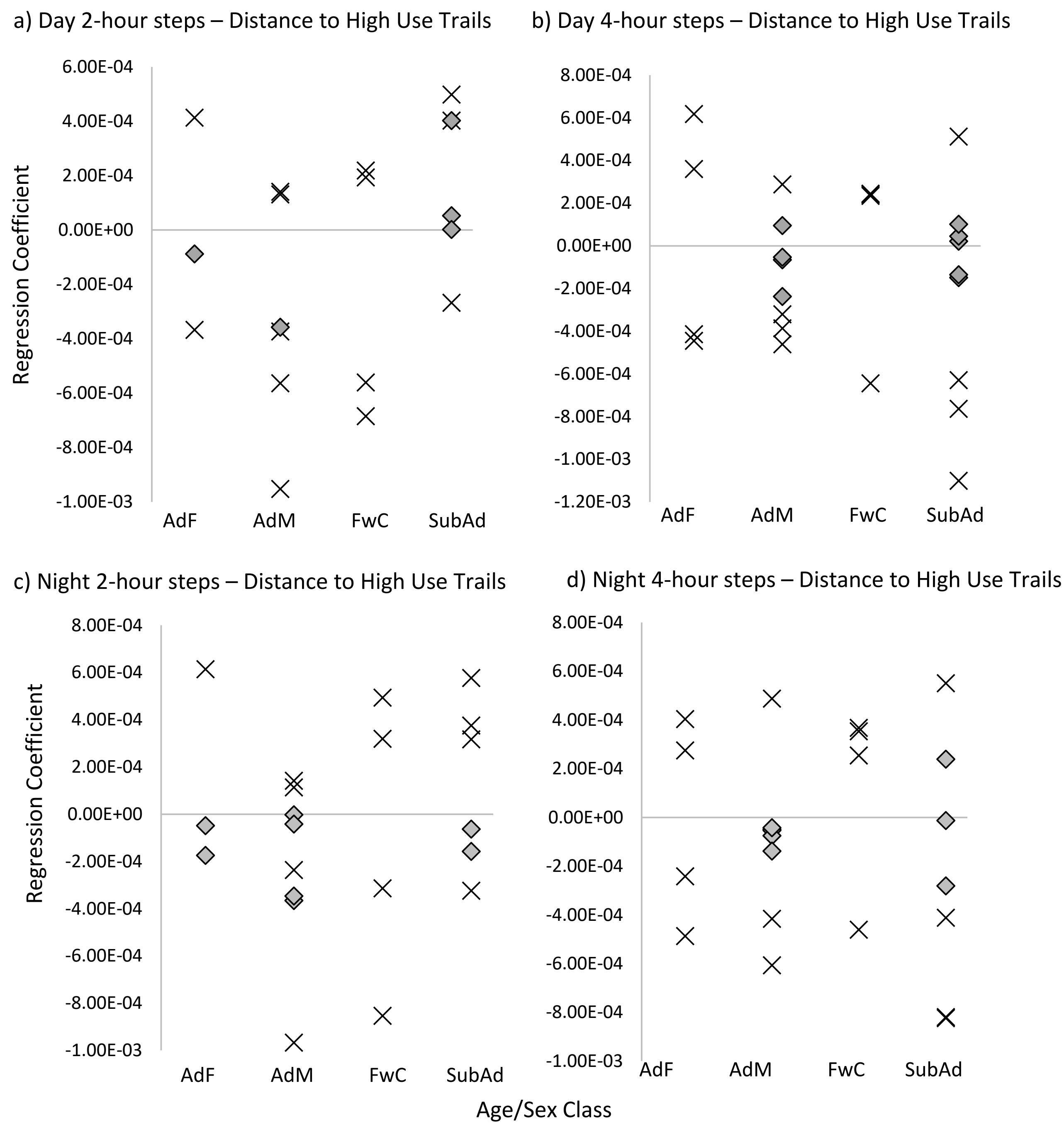


Figure 3.9. Step Selection Function coefficients for the effect of distance to high human use trails on grizzly bear movement from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class). Sample sizes varied between analyses; figures includes 22 bears from 2-hour day steps, 25 from 4-hour day step data, 24 from 2-hour night step data, and 22 from 4-hour night step data. Significant relationships are indicated by "X"; non-significant relationships are indicated by grey diamonds (P<0.05).

consistent between individuals. Bear 134 (adult male) and Bear 135 (female with cubs) consistently selected steps close to low and high use trails in the day or night, whereas Bear 130 (female with cubs) consistently selected steps far from low and high use trails. Some bears (AdF 161, FwC 131, and SAd 155) selected steps close to low use trails and far from high use trails, whereas Bear 64 (FwC) and Bear 148 (SAd) did the reverse.

The complex relationship bears have with hiking trails becomes more evident when examining their likelihood of crossing trails of low and high human use during the day or night. Whether with the 2-hour or 4-hour steps, most bears from all age/sex classes were more likely to cross trails of low and high use during the day than random (Figure 3.10 a-d). Bears do, however, cross high use trails less frequently as demonstrated by the lack of significance from low to high use trails in both the 2-hour and 4-hour steps during the day. This was the case across all age/sex classes. At night, there were more individual bears that crossed low and high use trails less often in their 4-hour steps than their 2-hour steps. This difference demonstrates how fix rate can impact results when examining movement patterns rather than habitat selection patterns.

Whether or not a bear selected steps close to or far from a trail did not always directly relate to frequency of trail crossing. For example, Bears 72 (AdF), 122 (AdM), 64 (FwC), and 130 (FwC) crossed low use trails more often even though they selected steps farther from low use trails. Bear 144 (SAd) and 148 (SAd) selected steps closer to high use trails, but Bear 144 crossed them more often and Bear 148 crossed them less often. The conflict in these patterns suggest that some bears are using trails as movement corridors purposefully and not crossing them at random simply because they are in the area. At night, all females with

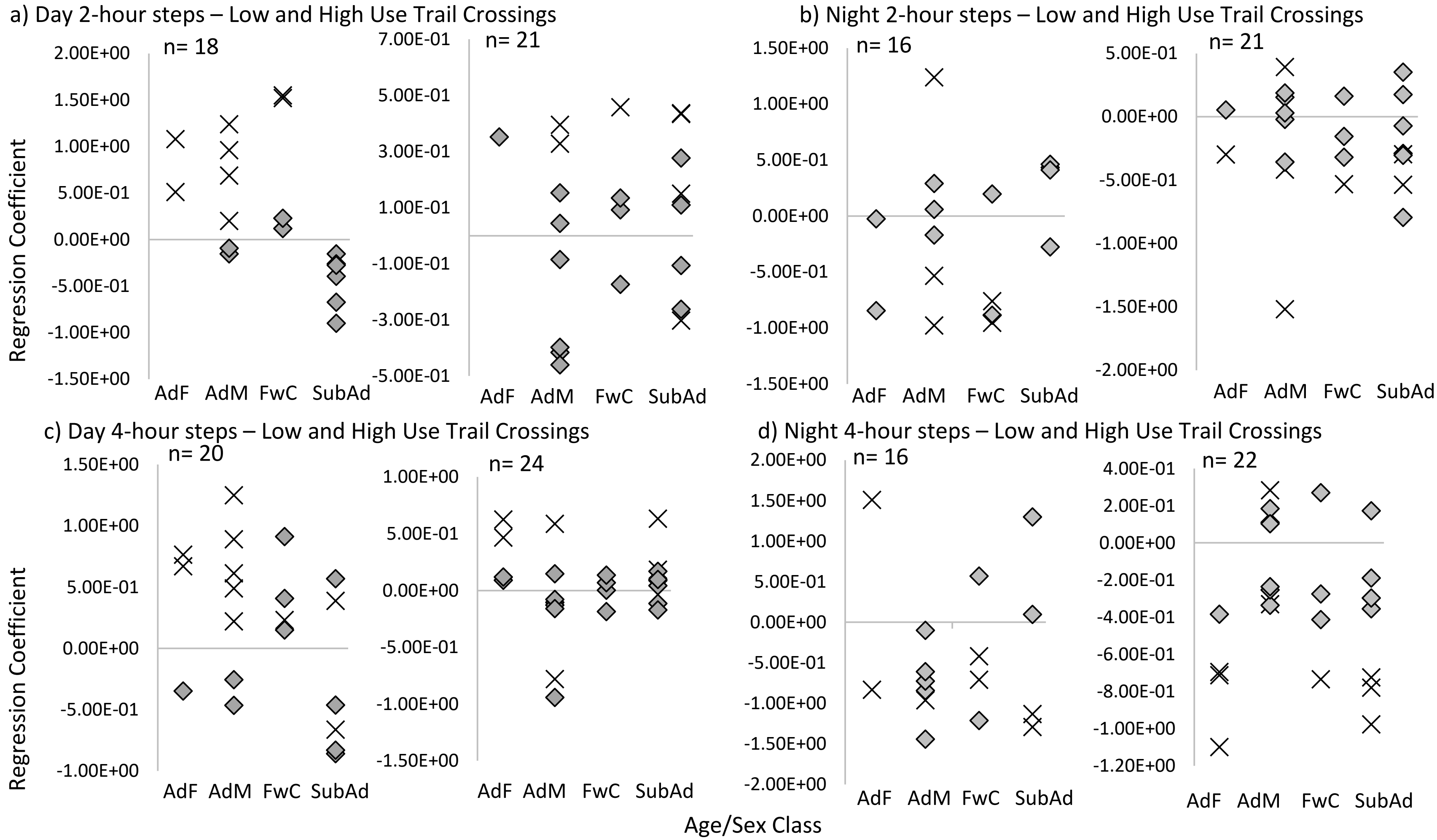


Figure 3.10. Step Selection Function coefficients for number of trail crossings for low and high human use trails on grizzly bear movement from 2-hour and 4-hour steps during the day and night for individual bears (by age/sex class). Points represent coefficients for individual bears; sample sizes indicated in upper left hand corner of each graph. Significant relationships are indicated by “X”; non-significant relationships are indicated by grey diamonds (P<0.05).

cubs crossed trails less frequently than random, but only Bear 130 also selected steps far from high and low use trails at night. Bears 126 (AdM), 134 (AdM), 144 (SAd), and 148 (SAd) selected steps close to high use trails at night but crossed them less frequently than random.

Grizzly bear step lengths did change in relation to human use covariates in the linear mixed model. In the 4-hour step data, grizzly bear step length was negatively correlated with spring, meaning that grizzly bear movement was lower in this season than in the fall (Table 3.10). Bear step length were also longer when bears were closer to roads. During the day, bear steps were shorter with increasing distance from low human use trails. Thus, grizzly bears' rate of movement increased as they were closer to low use trails and roads. The 2-hour step lengths were longer during the spring with increasing distance from high use trails (Table 3.11). Grizzly bear 2-hour and 4-hour step lengths were shorter during the summer when bears were closer to high use trails, suggesting decreased movement in proximity to high use trails and rejecting H_6. Grizzly bears also displayed higher rates of movement in lower quality habitats, as exhibited by long step lengths, in both the 2-hour and 4-hour steps.

In both the 2-hour and 4-hour step length analysis, step length increased during the day suggesting that bears were diurnally active. Graham and Stenhouse (2014) found bears were most active during the morning and evening, which may have been the case in my study area but I did not separate our crepuscular time periods in this analysis.

Table 3.10: Linear mixed model regression results examining impacts of covariates on 4-hour step length. Individual grizzly bear ID was set as subjects to account for individual variation. Step length was the dependent variable. Covariates tested were distances to low and high use trails, season (fall set as reference category), time of day (night set as reference category), interactions between, roads, and habitat quality. Significant relationships designated with *, p<0.05.

Covariate	β	Standard Error	p-value
Spring	-324.15	110.68	0.003*
Summer	-49.26	83.01	0.553
Habitat quality – non-critical	-96.97	42.42	0.022*
Habitat quality – secondary	-70.23	41.19	0.088
Day	822.90	72.57	<0.001*
Distance low use trail	0.011	0.01	0.317
Distance high use trail	-0.027	0.02	0.066
Distance road	-0.009	0.004	0.024*
Spring*Distance low use trail	0.019	0.012	0.128
Summer*Distance low use trail	0.002	0.012	0.841
Spring*Distance high use trail	0.031	0.020	0.129
Summer*Distance high use trail	0.947	0.018	<0.001*
Day*Distance low use trail	-0.037	0.001	<0.001*
Day*Distance high use trail	-0.014	0.016	0.366

Table 3.11. Linear mixed model regression results examining impacts of covariates on 2-hour step length. Individual grizzly bear ID was set as subjects to account for individual variation. Step length was the dependent variable. Covariates tested were distances to low and high use trails, season (fall set as reference category), time of day (night set as reference category), interactions between, roads, and habitat quality. Significant relationships designated with *, p<0.05.

Covariate	β	Standard Error	p-value
Spring	-125.65	67.07	0.061
Summer	-8.26	50.43	0.870
Habitat quality – non-critical	-68.97	25.54	0.007*
Habitat quality – secondary	-90.16	24.85	<0.001*
Day	347.12	43.36	<0.001*
Distance low use trail	0.003	0.007	0.672
Distance high use trail	-0.015	0.009	0.103
Distance road	-0.003	0.003	0.348
Spring*Distance low use trail	0.002	0.007	0.816
Summer*Distance low use trail	0.003	0.007	0.714
Spring*Distance high use trail	0.048	0.014	0.001*
Summer*Distance high use trail	0.054	0.011	<0.001*
Day*Distance low use trail	-0.011	0.004	0.018*
Day*Distance high use trail	-0.016	0.010	0.093

3.4 Discussion

3.4.1 Grizzly Bear Seasonal Habitat Use and Selection

In my study, grizzly bears displayed variation in seasonal home range size that appeared to be related in part to their age/sex class. I observed similar patterns of mean 95% KDE home range size as in previous research with adult males occupying the largest home ranges and females with cubs the smallest (Ciarnello et al., 2007a; Dahle & Swenson, 2003; Smulders et al., 2012). Home ranges can change shape and size across years as well as seasons depending on resource availability. For example, female bears with cubs of the year have smaller home ranges than females with older cubs (annual home range shift) and solitary bears increase their home range size in the fall (seasonal home range shift; Smulders et al., 2012). The descriptive analyses showed some of the smallest home ranges in the spring, which may possibly be explained by late snow melt restricting available habitat in the spring and the mating season, running from early June through to mid-July (Smulders et al., 2012). During mating season, largely summer, males occupy a much larger home range than any other age/sex class and more spatial overlap between grizzly bear home ranges occurs as adult males roam farther in search of multiple females (Stenhouse et al., 2005). Thus a larger home range during mating season increases adult male fitness (Dahle & Swenson, 2003).

I found grizzly bears continually selected for higher quality habitats compared to random locations within their home ranges in all seasons, supporting H_4 and concurring with other research (Mueller, Herrero, & Gibeau, 2004; Northrup et al. 2012b, Nielsen et al., 2006). Interpreting use-availability analyses is also dependent on understanding the availability of resources. As much of my study area is comprised of very high elevations, only 52% of YNP and BNP are considered suitable grizzly bear foraging habitat (Gibeau et al., 2001); the RSF model validation in Chapter 2 concurred with this assessment showing that the majority of area within BNP fell within habitat quality categories lower than 4. With limited high quality habitat available across the landscape, bears must make increased efforts to select that habitat. In addition, bears living in the mountains in Alberta do not consume ungulates to the same degree as bears living in the foothills (Munro, Nielsen, Price, Stenhouse, & Boyce, 2006). This reduced availability of high quality forage may contribute to poorer body condition of bears living in Alberta's mountainous protected areas compared to bears inhabiting public lands (Cattet, Caulkett, Obbard, & Stenhouse, 2002) and may be a factor contributing to increased long-term stress levels experienced by female bears (Bourbonnais et al., 2013). My remote camera data showed medium to high levels of human activity in most of the study area, throughout all seasons and hours of the day. For bears that avoided habitat close to high use trails (as reflected by the SSF), human activity may further impact access to high quality and abundant forage and potentially compound stress levels. Gibeau et al. (2001) estimated the average size of a secure habitat patch for grizzly bears in Banff National park was 56 km^2. Female grizzly bears averaged 60% of their home range in secure areas and only 12 out of 27 bear management units within the Park exceed habitat security target levels. Through the SSF, a wider variation in response to high human use trails was recorded, whereas most bears selected habitat close to low human use trails. This suggests the volume of people on trails directly affected how some individual bears use and move through habitat, thus impacting habitat security of individual home ranges. Since 2000-2001, visitor use to BNP has continued to increase steadily from just over 3 million annually in 2008 (Parks Canada, 2008) to 3.3 million in 2013-2014 (Calgary Herald newspaper, published June 8, 2015). As a result, the habitat security for grizzly bears has presumably decreased. Thus, it may be more challenging for some bears to find high quality habitat in areas with a low probability of encountering people. This is particularly important for the bears with lower levels of habituation and that avoided trails of high use.

As discussed in Chapter 2, grizzly bear spring home ranges were located largely in the valley bottom, and were thus inherently closer to roads than in other seasons. As demonstrated with the use-availability analysis, grizzly bears preferred habitat farther from roads, but closer to trails that were also close to roads within their spring home ranges. This suggests that bears prefer habitat close to trails and are using trails as movement corridors in the spring, regardless of these trails proximity to roads. Bears may exhibit a forced tolerance of roads during the spring in order to access high quality habitat in their proximity. During the spring, bears occupied smaller home ranges with higher road densities and still selected for high quality habitat as far from roads as possible. In JNP, June was the month with the least amount of suitable habitat for grizzly bears and April and May were the months with the least amount of human disturbance (Hood & Parker, 2001). With the remote cameras, I detected the lowest levels of human trail use and the highest levels of grizzly bear trail use in the spring. Although habitat effectiveness may be higher during the spring due to reduced human use, there is less high quality habitat available due to snow in higher elevations of the study area. Much of the habitat that is not snow-bound in early spring is near linear features (roads and trails) as these are the first areas to green-up with the changing seasons. Use of roadside vegetation compounds a bear's mortality risk (Benn & Herrero, 2002). Any positive impacts of lower human use during these months may be negated by bears needing to use habitat nearer to roads or in areas of human use. Although I did not assess some mechanisms of this pattern directly, it may be age/sex class dependent as other research found subadult females use habitat closer to roads in the spring and first part of summer than adult females and adult males (Mueller et al., 2004). This defines a complicated balance for bears between accessing available high quality forage near trails that are also near to roads while simultaneously avoiding the roads themselves.

Research has shown that bears accessing habitats near human activity are at significantly greater risk of mortality both from habituation problems leading to management removals and from direct collision mortality (Benn & Herrero, 2002; Mueller et al., 2004). Predicting bear-human conflict potential spatially and temporally can be a strong management tool when prioritizing grizzly bear habitat security and human safety (Hood & Parker, 2001). Other research has shown subadults to be more vulnerable to mortality when accessing habitats near human activity (Mueller et al., 2004). The results of the SSF showed that some individuals from all age-sex classes selected steps closer to trails and roads; combined with the results from the use-availability analyses showing habitat use nearer to roads and trails in the spring suggests that this potential increased mortality risk may also be related to season in my study area.

During the spring people and bears occupy the same areas in valley bottoms and there is little high quality bear habitat available away from people, which has implications for an increasing rate of human-bear encounters and meeting habitat security objectives. Habitat quality is a strong attractant and some bears will still select for high quality habitat even if human use nearby is moderate, which can put them at increased risk (Berland, Nelson, Stenhouse, Graham, & Cranston, 2008; Gibeau et al., 2002). I found increased likelihood of detecting bears on remote cameras during the spring; since cameras were placed on human use trails, this increased detection can be equated to an increased potential for trail users to encounter a bear. Grizzly bear 4-hour step lengths were also shorter in the spring overall, but particularly when in proximity to high use trails, suggesting lower rates of movement. Given their decreased movement rates, grizzly bears may be less likely to be displaced by people during this season, but this could contribute to higher chances of an encounter. Seasonally restricting human use in areas of known high quality habitat may be more important in the spring as grizzly bears are not likely to have alternative foraging locations.

Limiting human access and/or modifying habitat quality to create areas where bears are less likely to encounter people should be considered, especially in areas that occur near contiguous areas of relative habitat security (Nielsen et al., 2006). For example, Parks Canada instituted a nighttime closure of a popular roadway (the Bow Valley Parkway) during the spring to increase habitat security for grizzly bear and other wildlife. I could not find any trends in grizzly bear step selection between day and night; several bears selected steps close to roads and trails during the day and night. The SSF did clearly show, however, that grizzly bear activity was highest during the day. The current temporal seasonal closure of the Bow Valley Parkway likely increases habitat security at night and may reduce the risk of grizzly bear mortality or habituation by decreasing the likelihood of grizzly bears encountering people (Benn & Herrero, 2002). This directly benefited at least 2 females with cubs and 4 subadult bears with home ranging overlapping this area. This management action, however, does not address habitat security during the day or affect habitat adjacent to human use trails. While human use levels were not found to be a significant predictor in whether or not grizzly bears used a hiking trail, the SSF did show that some bears were less likely to use habitat close to high use trails. Therefore, potentially restricting human access on trails through high quality habitat during the day in the spring could further increase seasonal habitat security for these bears.

The use-availability analysis showed that grizzly bears selected habitat closer to trails and roads in the summer than in the fall. My remote camera data shows bears are still more likely to be detected on trails in the summer than fall, but the SSF showed this response is individually variable. This contradicts work from Montana that showed grizzly bears selected for habitat away from trails during the summer and consistently away from campgrounds regardless of seasons (Mace & Waller, 1996). In other studies, grizzly bears avoided human presence but used habitat close to human settlement in areas where important seasonal food resources were available (Mertzanis et al., 2008). Habitat selection is scale dependent, and managers should understand the pattern and consequences across different spatial and temporal scales (Ciarnello et al., 2007a). Effectively considering grizzly bear habitat security should be done at the seasonal rather than annual scale.

Other research has shown adult grizzly bears in BNP and YNP avoided areas close to people. Adult females in particular selected habitat farther from the TransCanada highway than males (Gibeau, 2002). Subadult grizzly bears have been found to use habitat closer to roads than adult bears (Mueller et al., 2004), and male grizzly bears spent less time than females in more human-dominated areas of BNP (Sawaya et al., 2012). I found no differences in home range road density between age/sex classes, but adult male grizzly bears had lower trail densities in their summer home ranges than subadults. Therefore, this avoidance of roads or trails is not necessarily related to lower road and trail densities in their home ranges, but more a reflection of habitat selection within home ranges. Grizzly bear home range selection (2nd order of selection) may be based on age/sex class with adult males occupying larger home ranges with overall greater habitat quality (Bourbonnais et al., 2013), but my results show that habitat selection within the home range (3rd order of selection) is based on the individual bear's preferences.

3.4.2 Impacts of Human Use on Grizzly Bears

Individual variation amongst grizzly bears in response to stimuli has been well documented (Elmeligi & Shultis, 2015; Herrero et al., 2005; MacHutchon, 2001; White et al., 1999). With the SSF, I was able to demonstrate that grizzly bear consistently selected for high quality habitat. This allowed me to remove habitat quality from the model and isolate the impacts of human use features (i.e., roads and trails) on grizzly bear habitat selection and movement. The one consistent result from the SSFs was the level of individual variation between bears and within bears in response to human use variables; some bears selected steps close to trails while others selected steps away from high use trails. Some bears selected steps close to roads during the day while others selected steps close to roads at night. This precluded me from making any conclusions or conducting any analyses on bears based on age/sex class; Ordiz et al. (2013) also showed that the effects of both age and sex on grizzly bear response to human use were non-significant.

For bears that do select habitat close to high human use trails or roads, one of two scenarios can result – bears can use habitat around people and not be seen, or bears can use habitat around human use areas and encounter people. The implications of these two scenarios can differ based on whether or not people are aware of the encounter. In the following section of this chapter, I will first discuss the implications of bears using habitat in areas of human use, then I will discuss the implications of what happens when this increased habitat use also results in increased human-bear encounters.

3.4.2.1 Grizzly bear habitat use in areas of human use. Previous research examining grizzly bear habitat use near roads has typically been conducted in landscapes with much higher road densities than my study area. These studies found grizzly bear survival is related to road density and access (Boulanger et al., 2013; Mace, Waller, Manley, Lyon & Zuuring, 1996; Nielsen et al., 2006), with subadult bears being the most vulnerable to road-based mortality (Boulager & Stenhouse, 2014). Females with cubs have also been found to select habitat closer to roads than expected (Graham et al., 2010). Increasing road density compromises grizzly bear habitat security and can create population sinks (Nielsen et al., 2006). This may be particularly relevant with the increased potential for high quality forage near road-sides (Braid & Nielsen, 2015). Due to the large home ranges bears occupy and long dispersal distances, a single highway can affect bear populations across a much larger landscape (Kaczensky et al., 2003). Although protected areas contain a much lower road density than adjacent public lands, roads are still a concern for human-caused mortality in these areas (Ament et al., 2008).

Within BNP, YNP, and KNP roads affect grizzly bear behaviour, survival, and population health. Gibeau et al. (2002) found bears within BNP adjusted their behaviour spatially and temporally in response to the TransCanada highway, with subadults and adult males selecting for habitat closer to the highway. Other research also found bears selected habitat closer to roads than random, especially low volume roads (Chruszcz, Clevenger, Gunson, & Gibeau, 2003). I found a high degree of individual variation in habitat use and distance to road, although many bears selected steps closer to roads than random. This was especially apparent in the 2-hour steps at night, during human inactive times. This may be related to traffic volume or type of road. The TransCanada highway, while containing the highest volume of traffic, is also the only highway in the study area that is fenced for the majority of its length and has many wildlife crossing structures facilitating animal movement. Wildlife crossing structures, particularly overpasses, are used by both male and female grizzly bears to cross the TransCanada Highway especially in the summer when forage in the valley bottoms is at its height (Sawaya, Clevenger & Kalinowski, 2013). Additionally, grizzly bears have increased use of these crossing structures over time displaying a learning response to overpass use and the fact that habitat adjacent to this highway can be accessed safely (Chruszcz et al., 2003).

Grizzly bears are more likely to cross narrow roads than wide roads (Graham et al., 2010), but other secondary highways in my study area are not currently fenced to the same degree if at all. Gibeau et al. (2002) found that females avoided these other roads whereas males did not, particularly if there was high quality habitat adjacent to the roads. On Alberta public lands, females with cubs occurred closer to roads compared with other age/sex classes (Boulanger & Stenhouse, 2014); females with cubs and adult females also crossed roads more often than males during the summer (Graham et al., 2010). I found most bears selected steps near roads; proximity to roads also resulted in longer step lengths indicating increased movement. Distance to road was also not a significant predictor of whether or not a bear would be detected by remote camera. I did find, however, that bears in all age-sex classes crossed roads less frequently than random; this applied to all age-sex classes at night and most adult males, adult females during the day. Therefore, my SSF results showed that even though some bears may select steps closer to roads, they cross roads less often than random and this habitat selection results in increased movement. This is slightly different from Northrup et al. (2012b) who found grizzly bears were more likely to cross roads at night. In other research, female grizzly bears that spent more time moving around roads at night than during the day had higher chances of surviving, showing a significant advantage to changing behaviour patterns in response to human traffic (Kite et al., 2016).

Roads in my study area do have an influence on grizzly bear habitat use and movement, but I did not separate roads based on traffic volume or size and all roads (from residential roads towns to highways) were treated equally in analysis. Grizzly bears have selected for habitats closer to roads with <10 vehicles per day and avoided roads with >10 vehicles per day (Mace et al., 1996); in BNP bears were more likely to cross low-volume roads than high-volume roads, particularly at points with higher habitat quality rankings (Chruszcz et al., 2003). In Southern Alberta, grizzly bears selected areas near roads with <20 vehicles per day and were also more likely to cross these roads; bears avoided roads with >20 vehicles per day at all times (Northrup et al., 2012b). Significant levels and variation in traffic volume on roads may obscure the effect of roads on bear habitat selection in my study area. Concurring with my results, other research found grizzly bears of all age and sex classes more likely to select steps closer to roads irrespective of traffic volumes (Roever et al., 2010).

Selecting habitat nearer to roads comes with increased mortality risk; other research has found elevated mortality rates near roads (Braid & Nielsen, 2015), trails and other human settlement features (Benn & Herrero, 2002). Grizzly bears that spend more time moving around roads, particularly during the day, had a higher chance of mortality in other parts of Alberta (Kite et al., 2016). Highways in the study area are still a source of mortality for grizzly bears (Parks Canada, 2010a; Whittington and Sawaya, 2014). Incorporating traffic volume into my analyses would improve understanding of grizzly bear habitat use adjacent to roads, but my main research objective was to examine bear habitat use near trails of varying levels of human use.

Wolves in BNP clearly select for areas more than 400m from trails with increasing human activity levels (Rogala et al., 2011), which mirrored the grizzly bear “zone of influence” analysis results from (Gibeau, 2002). I had hypothesized bears would show similar consistency in avoidance of high use trails, but that relationship was not as simple as I expected. I found two bears to consistently avoid trails, and three to select steps close to low use trails and away from high use trails; four bears consistently selected steps close to trails regardless of human use levels. Two females with cubs, two subadults, and one adult male consistently selected habitat close to high use trails during the day and night. Mueller et al. (2004) found that neither distance to roads or trails were consistent significant predictors in models comparing subadult to adult males. My results concur in that no patterns of avoidance or selection of habitat near high use trails between age/sex classes was evident. Gibeau et al. (2002) found bears closer to high use trails than random and that this proximity related to habitat quality. I found that when bears did select steps closer to high use trails, their step lengths were shorter, particularly in the summer. If Gibeau et al. (2002) is correct about bears using habitat near high use trails to access higher quality habitat, then these shorter step lengths could reflect foraging behaviour patterns. My analysis also showed, however, that step length was longer in high quality habitats, thus complicating this premise. While the shorter step lengths in proximity to high use trails could reflect foraging behaviour, they may also reflect a bear moving slightly away from a trail and potentially seeking cover when people approach. Moen, Støen, Sahlen, and Swenson (2012) experimentally approached brown bears on foot and found great variation in the bear's reaction towards human disturbance, but that most bears left the area before the observers passed the bear's location. Bears have also been recorded increasing their distance traveled immediately after a disturbance by people, then decreased their movement shortly after (Ordiz et al., 2013). While it is possible that bears in my research were displaced by people on high use trails, if they decreased movement shortly thereafter or sought cover that could lead to decreased step lengths when in proximity to high use trails.

Grizzly bears in Spain exhibited increased movement on holidays and weekends when human trail use also increased (Naves, Fernandez-Gil & Delibes, 2001). Changes in movement patterns in proximity to roads can vary seasonally and by age/sex class; females have been found closer to roads during the non-breeding season than breeding season whereas males had a more consistent response to roads across seasons (Kite et al., 2016). Grizzly bears in northern Alberta were also more likely to increase step lengths when nearer to roads indicating more rapid movement, potentially a reflection of bears selecting roads or adjacent habitats for travel (Roever et al., 2010). While I observed increased movement associated with roads, this pattern was not extended to habitat use near high use trails; rather, bears increased movement away from high use trails in the spring and summer. This concurs with my use-availability analysis that showed bears selected for habitat closer to trails in the spring and summer than the fall. Therefore, in the fall, bears were not detected on cameras and their step length was less likely to be impacted by trail proximity.

Unlike Gibeau et al. (2002), I did not see marked differences in bear habitat use near trails between the day and night. Most bears selected for high quality habitat at night in their 4-hour steps and their 2-hour steps. While there were some bears who did not have a significant selection for higher quality habitat at night, this could be related to bear selection of bedding sites for short periods at night (Munro et al., 2006; Roever et al., 2010). Alternatively, bears may be altering activity levels not in response to the amount of daylight or human use patterns but in response to the types of seasonal forage available (McLellan &

McLellan, 2015). My results showed that it is a combination of all of these factors. Step lengths changed seasonally with smaller step lengths in the spring. Step lengths were related to an interaction between season and distance to high use trails with increasing step lengths away from high use trails in the spring and summer. Step lengths were also shorter with increasing distance from low use trails during the day. Thus, grizzly bears display increased rates of movement when farther from high use trails, potentially seek cover when close to high use trails, and have lower rates of movement when farther from low use trails. This change in movement may suggest that there is a Zone of Influence surrounding trails and the size of that ZOI varies with human use level on trails. Their smaller step lengths when close to high human use trails suggests, however, that grizzly bears are not necessarily displaced from habitat as human use on trails increases.

Predictability in human use does allow bears with lower tolerance of people to access habitat in the absence of people (Chi & Gilbert, 1999; Matt & Aumiller, 2002). Human use in my study area is not predictable, except during the middle of night when it is at its lowest, which was consistently reflected in the remote camera data. Still, bears in my research did not alter their habitat use and become more active during these times of human inactivity (similar to findings of Munro et al., 2006). This implies that the level of human impact on grizzly bear habitat use is still low enough that bears are not required to adopt nocturnal foraging patterns to obtain sufficient caloric intake while avoiding people, as is seen in some coastal grizzly bear populations in areas with high human use (Gende et al., 2001; Olson et al., 1997; Rode et al. 2006). Therefore, bears that select habitat near to trails are not changing their patterns of habitat use in response to human use levels and may be continually subject to the costs associated with that selection, including stress and potentially heightened mortality risk. While human use does not preclude grizzly bears from using habitat near or adjacent to trails, it does have an impact on how and sometimes when they use that habitat.

3.4.2.2 Results from increasing human-bear encounters. Habitat quality does not appear to affect how bears use trails, based on my results from the remote camera data. Trails are movement corridors and bears may use them whether or not they are in areas of high habitat quality. When grizzly bears use trails to manoeuver the landscape, they run the risk of encountering people who are using those same trails. A trail's human use level did not predict whether or not a bear would be captured by remote cameras, but the SSF showed that many grizzly bears were more likely to cross low use trails than high use trails during the day. The threshold analyses did suggest that the time of day influenced when bears would use trails; bears were most likely to be detected on camera before humans used the trail, either at night or in the early morning hours. Grizzly bears have been found to exhibit increased activity levels during dawn (Graham & Stenhouse, 2010; McLellan and McLellan, 2015). I found the majority of grizzly bear trail events were more likely to occur before 8 human events since dawn, and before 17 human events in the last 24 hours. Therefore, trail use appears to be dependent on individual bear and time of day. These threshold analyses show that bears may use trails at times that reduce their chances of an encounter with people. Mace and Waller (1996) suggested that since trails in their study were not through optimum grizzly bear habitat, the chances of an encounter were reduced. Bears have also been known to spend time in more dense cover and denser habitats during the day and when closer to human settlements (Ordiz, Stoen, Delibes, & Swenson, 2011), suggesting that even though bears are using habitats nearer people they seek cover to minimize detection. Grizzly bears are capable of learning and adapting their behaviour when human use is predictable to avoid encounters with people, which has been documented with shifts to nocturnal behaviour (Reimchen, 1998; Klinka & Reimchen, 2002) and shifting habitat use patterns (Olson et al., 1997; Nevin & Gilbert, 2005b). My results also suggest that grizzly bears are capable of learning and adapting when human use is less predictable spatially.

Long term, human-caused selection has been posited to explain reduction in aggression of bears towards people (Swenson, 1999). In the late 1990's several key management shifts occurred in my study area that led to reduced negative human-bear encounters (Benn & Herrero, 2002). Bourbonnais et al. (2013) suggested grizzly bears in west-central Alberta displayed a willingness to risk human contact to optimize foraging opportunities. Some bears also displayed lower stress levels that may have been related to their level of habituation around human developments. While the risks for negative encounters is still possible, I suggest grizzly bears in my study area have learned how to change their behaviour and habitat use patterns to minimize encounters with people by accessing habitat near human use during the day and crossing trails before dawn. The high levels of human use in my study area throughout the day and seasons combined with the fact that some bears select steps close to trails suggests that these bears may be avoiding encounters with people.

In addition to the concerns above regarding direct mortality and habitat security, roads in protected areas may also provide opportunities for people to illegally feed wildlife, which can lead to increased risk of mortality (Ament et al,. 2008). If bears are conditioned to associate food with people, then they are put at risk for future conflict and potential management destructions (Can, D'Cruze, Garshelis, Beecham, & MacDonald, 2014). Several anecdotal stories of tourists feeding bears from a vehicle occurred during my study. While these events are becoming more rare, they demonstrate the need to continue public education efforts aimed at illegal feeding and preventing bears from becoming food conditioned. Establishing a solid public understanding before discussing solutions is a recommended strategy (Herrero, Roulet, & Gibeau, 2001). This presents a challenging balance – while habituated bears may exploit habitats in areas of higher human use, bears that become habituated run a higher risk of mortality. The high level of individual variation observed in my research suggests that this level of habituation is also individual and should be managed as such. This is already part of Parks Canada's management strategy, for those bears that occupy home ranges near towns and other areas of high human use.

The other side of a human-bear encounter is the human, and the behaviour the person engages in during the encounter can also influence the outcome. Around 50% of human-bear encounters resulted in negative outcomes because of human behaviour, not bear behaviour (Penteriani et al., 2016). Therefore, it is not only how people are managed in bear habitat through access and activity restrictions, but also how they are educated to behave in bear habitat that is important. How people perceive the encounter and the management actions they expect to be taken are explored in Chapter 4.

3.5 Management Implications and Conclusions

The grizzly bear population in the central Bow Valley portion of my study area is one of the slowest reproducing ones in North America (Sawaya et al., 2012). Given the importance of reproductive females to overall population persistence within and outside of these protected areas, it would be worthwhile to promote high quality habitat near low human use trails. This is supported by the patterns I found in response to low use trails with the SSF. The remote cameras clearly demonstrated that human use is abundant throughout these National Parks, even in areas considered to be the back country and away from larger human development centres (i.e., towns, and large parking lots and staging areas for popular day use). As was the case with Gibeau et al. (2002), delineating important sites for bears and protecting them from disturbance in the form of abundant human use is still important. Some bears will continually select habitat in proximity to trails and roads, however, so it is just as important to ensure that when bears do access these habitats their likelihood of mortality does not increase nor does the chance of a negative encounter with people. While efforts to reduce grizzly bear mortality have been successful through appropriate garbage management and fencing the TransCanada highway (Benn & Herrero, 2002), these actions do nothing to manage human use on trails which can have an impact for some bears. To mitigate risks associated with trails, Parks Canada currently implements seasonal closures in areas with high quality grizzly bear habitat, and trail restrictions at time when bears are active in certain areas. These efforts could be expanded and my research suggests they would be most effective in the spring.

While grizzly bear habitat selection varies based on the extent of available habitat, some variables are consistently selected for, such as greenness, or avoided, such as roads (Ciarniello et al., 2007b). The only thing I found grizzly bears to consistently select for was habitat quality. Habitat quality contributes directly to nutritional condition of bears and may be linked to reproductive success (McLellan & Hovey, 1995; Boulanger et al., 2013). In BNP, YNP, and KNP selection for habitat away from human use is most influenced by the bear's individual identification. Habitat effectiveness or accessibility can decrease with human use even with an increase in habitat quality (Hood & Parker, 2001). There is a trade-off between body condition and survival for bears that live in landscapes with a high degree of human activity (Boulanger et al., 2012). Habitat in parts of JNP have been found to qualify as safe harbours or refuges for grizzly bears where habitat productivity is high and mortality risk is low (Braid & Nielsen, 2015), as opposed to adjacent public lands that have lower safe harbour values (Nielsen et al., 2006). Grizzly bears have also been found more abundant nearer to these mountain protected areas and in other high-elevation, less disturbed areas on adjacent public lands; this may be related to the increased risks of human-caused mortality outside of protected areas (Apps, McLellan, Woods, & Proctor, 2004; Linke, McDermid, Fortin, & Stenhouse, 2013). Bears living in these areas have higher survival rates than those living outside of protected areas, but also had less probability of increasing their body condition (Boulanger et al., 2013). Parts of BNP, YNP, and KNP far from heavily used roads and trails may have similar safe harbour characteristics. These kinds of areas are in need of continual protection as they are assumed to correlate with survival and reproductive success associated with population growth (Nielsen et al., 2006). The index of safe harbour habitat increases where there is high quality forage available away from roads (Braid et al., 2015). With a low road density, there is higher potential within the parks to meet grizzly bear habitat security needs than outside of these protected areas. This potential can further increase if habitat is managed in ways that increases forage across the landscape, such as by creating regeneration habitats (Boulanger et al., 2013) through prescribed burns. The abundance of a high-energy food source growing in undisturbed portions of the Flathead Valley enabled that grizzly bear population to increase in spite of intense industrial development and being subject to legal hunting (McLellan, 2015).

Habitat security should not only be thought of spatially, but temporally. Increasing habitat security will help reduce the number of habituated bears and related mortalities inside and outside of protected areas (Gibeau et al., 2001). The spring appears to be a particularly crucial time for grizzly bears in my study area. With home ranges restricted to valley bottoms and increasing bear-human encounter chances, applying seasonal restrictions to human use on some trails can ensure bears access to high quality habitat at this time (also recommended by Gibeau et al., 2002). Ensuring alternative foraging locations away from high levels of human use are available will ensure bears can alter their resource use patterns to avoid humans while simultaneously acquiring adequate forage (Rode et al., 2007).These actions could also help reduce habituation in bears accessing these habitats and increase seasonal habitat security at a time when available habitat is already low.

The protected areas in this study could serve as source habitats for provincial grizzly bear populations in Alberta and British Columbia (Benn & Herrero, 2002). This is especially important as human-caused grizzly bear mortality outside of these protected areas is much higher due to hunting (in British Columbia only), conflict with other land uses, and a much higher road density (Benn & Herrero, 2002; Graham et al., 2010). As bears, particularly subadults, may disperse outside of these protected areas on to surrounding public lands, keeping the level of habituation in bears low will help prevent these bears from human-caused mortality on public lands. This may be especially important for subadult bears that occupy habitat nearer to trails or other areas of high human use. Male subadult bears are likely to disperse farther than females subadults, but females can still disperse up to 20km (McLellan & Hovey, 2001). For grizzly bears reared near the Town of Banff, a 20km dispersal may take them outside the boundaries of the protected area. Private lands have been classified as ecological traps in southern Alberta, particularly since private land contains some very high quality habitats (Northrup, Stenhouse, Boyce, Gompper & Vanak, 2012a). The future of any grizzly bear population lies in the health of the subadult age/sex class and their likelihood of future reproduction (Mueller et al., 2004). Dispersal is a gradual process regardless of age/sex class taking up to 4 years for some female grizzly bears in the Flathead Valley of British Columbia, but successful dispersal from a source population is necessary for natural augmentation of suitable habitat (McLellan & Hoveym 2001). This is required if the Alberta grizzly bear population is to recover. My work suggests that some subadult bears are accessing habitat nearer to people and therefore I predict there is more risk of habituation and future conflict with people. Habituated bears in protected areas may have a higher risk of mortality, particularly if they subsequently disperse to areas with different land uses or tolerance by people (Herrero et al., 2001). Habituated bears who disperse on to private lands can be the subject of increasing human-bear conflict (Northrup et al., 2012a), ultimately resulting in the destruction or relocation of the bear. Grizzly bears have low resiliency at the population level to cope with high human-caused mortality levels (Weaver et al., 1996), thus a conservative style of management that prioritizes grizzly bear habitat security and reduces risk of negative encounters with people will be most successful.

CHAPTER 4 – TRAIL USER EXPECTATIONS OF GRIZZLY BEAR MANAGEMENT

Abstract

Protected areas are frequently challenged to balance ecological integrity and human recreational use. In western North America, Parks are challenged to manage for grizzly bear habitat security while also providing for quality human recreational experiences. Visitors and residents have varying perspectives regarding how grizzly bears should be managed to ensure human safety and visitor satisfaction. From August to September 2013, and June to September 2014, I disseminated surveys at trailheads to assess trail users' normative beliefs associated with bear management options. This approach helped define evaluative standards for specific management actions and identify situations where people felt most strongly. I assessed support for 13 different management options based on two scenarios: 1) a lone grizzly bear in the area and 2) a female with cubs in the area. In all, 696 trail users completed surveys in Banff, Yoho, Kootenay, and Jasper National Parks. Trail users were supportive of restrictive management options, such as closing the trail or implementing trail opening times, particularly if a female grizzly bear with cubs was in the vicinity of the trail. The least supported management options in both scenarios was to apply aversive conditioning or to relocate the bear(s). Overall, trail users were supportive of prioritizing grizzly bear habitat use over their own recreational needs. My results may help to alleviate some of the controversy in grizzly bear management by quantifying support among trail users for various bear management strategies. These results will assist in addressing grizzly bear conservation and visitor experience objectives of current park management plans across grizzly bear habitat in North America.

4.1 Introduction

National Parks are usually established to conserve biological and cultural values, but they are also important tourist attractions worldwide (Juutinen et al., 2011). For several decades now, the purposes of national parks have been diversified to forward ecological science, create sustainable recreational interests and address the needs of visitors, sustain the livelihood of local communities, and serve as places for environmental education (Papageorgiou, 2001). Designing management plans that balance these multiple complex objectives is inherently challenging and a long standing dilemma (Skibins et al., 2012), potentially leading to tensions between and amongst managers and stakeholders (Richie, Oppenheimer, & Clark, 2009).

Visitors to protected areas are also interested in ensuring such areas remain ecologically intact and healthy (Brisette, Haas, Wells, & Benson, 2001; Juutinen et al., 2011), but conflict can arise when visitors' sense of freedom is reduced through regulations that limit human access in an effort to either reduce a visitor's sense of crowding or to protect ecological systems (Papageorgiou, 2001). Such regulations can be viewed as punitive by visitors and may not be supported (Hall, Seekamp, & Cole, 2010). To increase park management effectiveness, decision makers and managers need to understand the impacts of recreational activities on ecological integrity and the trade-off between visitors' preferences for the protection of biodiversity and their own recreational needs (Juutinen et al., 2011).

Grizzly bear habitat security, defined as access to high quality habitat with little human presence, declines with increases in the amount and intensity of human use (Gibeau et al., 2001; Hood & Parker, 2001). High quality grizzly bear habitat is not distributed evenly throughout the Rocky Mountain National Parks; valleys contain a disproportionate amount of high quality habitat and become increasingly important to grizzly bears. Much of the commercial and residential development as well as recreational activity is also focused in these low-elevation valleys (Rutherford et al., 2009). As a result, most management aimed at increasing grizzly bear habitat security has often restricted human access. This can keep people safe and allow bears access to needed habitats, but is frequently opposed by park residents and other stakeholders (Richie et al., 2012). This opposition can influence management direction when efforts are also being made to ensure visitor satisfaction. Many visitors want to see a bear, however. Research from Yellowstone National Park showed that 81% of visitors listed grizzly bears as one of the top 5 animals they wanted to see on their trip (Richardson, Rosen, Gunther, & Schwartz, 2014). While providing adequate access to positive recreation experiences and protecting grizzly bear habitat, managers also put strategies in place to reduce the potential for negative bear-human encounters (Campbell, 2012; Coleman et al., 2013). Incorporating visitor perspectives into National Park management is important as it directly relates to visitor experience. Determining the extent to which trail users will prioritize grizzly bear needs over their own, and their threshold of tolerance for various use restrictions, is an important social component of grizzly bear management in Alberta's protected areas.

Long standing challenges surround grizzly bear related management policies in BNP (Chamberlain, Rutherford, & Gibeau, 2012; Richie et al., 2012). The central challenge is whether restricting human use is required to improve grizzly bear habitat security, and if this can be done without negatively impacting the visitor's park experience (Chamberlain et al., 2012). Both biological and human dimensions research can play an important role in guiding discussion around these controversies, and the trade-offs that lead to viable solutions (Fix, Teel, Manfredo, & Boston, 2010). Attempts to address this complexity in Banff National Park (BNP) began in the early 2000's through collaborative, interjurisdictional management based on biological research at the ecosystem scale. These efforts involved various stakeholders representing a cross-section of attitudes and perspectives with the goal of ensuring grizzly bears persist in the park as a key component of the ecosystem and symbol of wilderness for all Canadians to appreciate (see Richie et al., 2012 for a detailed review of these processes). These stakeholder workshops gathered scientists, managers, local businesses, environmental organizations, and other participants to define problems, assess available and required knowledge, integrate knowledge from a variety of sources to develop a reliable understanding of the causal factors underlying problems, and generate effective solutions that were in the common interest (Rutherford et al., 2009). Involving local stakeholder groups in the discussion helped shape current management actions in the study area (Parks Canada, 2010a-b), but the perspectives of trail users themselves has not been explicitly incorporated. While assumptions have been made regarding how management action would impact trail users' park experience in previous stakeholder workshops, no research has been conducted directly surveying trail users. Understanding the perspective of park visitors is an essential component to this discussion (Gul, Orucu, & Karaca, 2006). Effective grizzly bear management in North American protected areas requires an understanding of trail user perspectives to help ensure a more inclusive and comprehensive approach to management.

Several factors feed in to how people feel about the possibility of a bear encounter or observation, what steps they take to reduce the chance of a negative encounter, and what expectations they have regarding their safety. These factors include how familiar they are with bears (based on knowledge and previous encounters), whether they live in an area inhabited by bears, and how prepared they are for a potential encounter. Cognitions people hold to be true are essentially defined by these factors, which result in their beliefs regarding the outcome of an encounter with a bear (Campbell, 2012). Beliefs translate to attitudes, which are evaluative judgements that define feelings of favourableness or unfavourableness for a given object (Manfredo, Teel, & Henry, 2009). Personal attitudes and the influence of peers are two principal components affecting human behaviour (McCool & Braithwaite, 1989). An individual person's attitudes can define what kinds of management options they are most or least supportive of (Dandy et al., 2012). Support for management options has been correlated with a person's basic beliefs and values about wildlife (Fix et al., 2010). The belief that a management approach, or specific management method, is 'effective' and 'natural' is a strong influence for support, as well as the perception that management action is required in the first place (Dandy et al., 2012). A person's perception of what is 'natural' and how or whether the environment has been 'impacted' shapes what kinds of attitudes they will have towards management actions attempting to return the environment towards some kind of 'natural' state.

The Theory of Planned Behavior (Azjen, 1991) is one of the fundamental behavioral models used in research investigating visitor support for protected areas management (Campbell, 2012; Daigle, Hrubes, & Ajzen, 2002; McFarlane, Stumpf-Allen, & Watsone, 2007). It postulates that human behaviour results from three belief constructs: beliefs about likely consequences (behavioural beliefs), beliefs about the normative expectations of importance to others (e.g., parents, friends) and motivation to comply with these expectations (normative beliefs), and beliefs about the presence of factors that may support or prevent performance of the behaviour (control beliefs; Daigle et al., 2002; Lee, 2011; Sahin, 2013). There are some differences in the literature regarding the use and definition of 'normative (or subjective) beliefs' depending on the context they are being applied. I used the definition from the Consumer Health Informatics Research resource (CHIRr), which states a broad definition of perceived or subjective norm as 'the perceived social pressure to perform or not to perform a given behaviour' (after Azjen, 1991; CHIRr, 2015). Normative beliefs are tied to social pressure or subjective norms, the individual's perceived appropriateness of the action with regard to his/her social referents (Rossi & Armstrong, 1999), and can be considered as that individual's support for performing the behavior (Fielding, Terry, Masser, & Hogg, 2005). I used a definition from Zinn, Manfredo, Vaske, & Whittman (1998) and Kneeshaw, Vaske, Bright, & Absher (2004), which expanded on the definition of normative beliefs to include the evaluation of the acceptability of wildlife management actions towards animals involved in human-wildlife interactions, to evaluate trail users support for management options pertaining to grizzly bears. Normative beliefs about bears are dependent on a person's attitude towards the species, and can be related to larger issues such as support for a policy to expand grizzly bears beyond their current range (McFarlane et al., 2007), or relate to what a person thinks a referent thinks they should do, such as removing bear attractants from their property (Campbell, 2012).

Studies of attitudes and values can make important contributions to interdisciplinary approaches to environmental problems (Manfredo et al., 2009). The study of values has defined two basic systems in the context of environmental management; one value is essentially a 'domination' over nature perspective and the other more of a 'mutualistic' or 'harmony with nature' perspective (Dandy et al., 2012; Manfredo et al., 2009). The stronger the domination orientation, the more likely a person's cognitions and actions will prioritize human well-being over wildlife; indeed, this person is more likely to support management actions that result in death or other intrusive control of wildlife (Manfredo et al., 2009, Teel et al., 2010). Those with a mutualism orientation are more likely to engage in welfare-enhancing behaviours for individual wildlife and less likely to support actions resulting in death or harm to wildlife (Manfredo et al., 2009; Teel et al., 2010).

In the case of large carnivore management, fear can shape attitudes to support or oppose government policies directed towards these species (Johansson, Sjöström, Karlsson, & Brännlund, 2012). The concept of fear refers to a complex emotional and somatic reaction to the experience of danger and is primarily linked to the perceived harm that the animal represents (Johansson & Karlssonm 2011). A person's beliefs regarding the outcome of an encounter and their perceptions of the likelihood of a negative encounter also influence fear; if the risk of attack is overestimated, human fear of carnivores can intensify and negatively impact support for species conservation (Penteriani et al., 2016). For example, even though most people felt coyotes should be protected and preserved, they also felt the population should be controlled; the more people feared coyotes, the less likely they were to support their presence in the area (Draheim, Patterson, Rockwood, Guagnano, & Parsons, 2013). The intensity of this kind of fear is greater as animal size increases. In Norway, people were most fearful of the two largest carnivores (wolves and brown bears) than they were of smaller carnivores (lynx and wolverine; Røskaft, Bjerke, Kaltenborn, Linnell, & Andersen et al., 2003). People fear bears, especially when they are approaching settlements or in areas of human use (Elfström et al., 2013). The level of fear experienced by different user groups adds an additional dimension to management as it can vary among species and situations and influence the level of support for various management options.

Attitudes towards bears typically result from 4 inter-related factors: basic wildlife values (mutualistic or dominating), perceptions of particular species, knowledge and understanding of wildlife, and people-animal interactions (Kellert, 1994). People with a mutualistic belief system and a strong positive attitude towards bears will most likely support actions favorable to bears, tolerate bear damage, and maintain this position in case of conflict (Kaczensky, Blazic, & Gossow, 2004); they are also likely to be less supportive of lethal control (killing the bear) in cases of conflict (Teel et al., 2010). Non-consumptive recreationists, those who participate in forms of recreation that does not include hunting or fishing, have been in support of restricted access and limitations on backcountry use if these actions result in enhanced bear protection and reduced human-bear conflict (Kellert, 1994). Regardless of their value set, visitors have a “threshold of tolerability” to change that allows for some degree of tolerance to management restrictions before their preferences for travel destinations are affected (Northcote & Macbeth, 2008). Defining how flexible people are in changing their plans to allow grizzly bears adequate access to high quality habitats over human use is one of the challenges facing protected area managers.

Past bear-related management plans in Yellowstone National Park and other protected areas in western North America were put in place largely to reduce bear-human conflict by separating people and bears spatially and/or temporally (Braithwaite & McCool, 1989). This type of management is effective when there remains “untouched” forested environments where bears can live without being impacted by people or human development, which is not always the case (Knight, 2008). With an increasing body of knowledge on bear behaviour, management approaches have started to incorporate possible ways for bears and people to peacefully coexist in the same landscape (Wondrak-Biel, 2006). Within this new context, the possibility of negative human-carnivore encounters is best managed based on an improved understanding of carnivore behavioural ecology and public attitudes, drawing on empirical knowledge and local experiences (Treves & Karanth, 2003). Involving a broad base of stakeholders in management discussions as this paradigm shifts can inflate controversy and potentially lead to an inertia amongst land managers needing to make decisions (Dandy et al., 2012). In essence, grizzly bear management in protected areas is undergoing two paradigm shifts, moving towards coexistence and from top-down management to a more open and inclusive approach actively seeking stakeholder feedback regarding management actions. These shifts in management approach require new information on how recreationists view their relationship with grizzly bears and how their expectations of management have progressed.

Successful grizzly bear management in North American protected areas should aim to ensure grizzly bear access to high quality habitat, minimal human-caused grizzly bear mortality, visitor satisfaction, and to minimize negative human-bear encounters. From a human perspective, this largely involves managing people through recreational access and restrictions. This requires an understanding of normative beliefs, the variation in the attitudes and acceptance of management policy among rural communities, visitors, and park residents (McFarlane et al., 2007). While all groups of park users can have positive attitudes towards grizzly bears, support for various management options that are restrictive (e.g., trail closures) can vary (McFarlane et al., 2007).

4.1.1 Chapter Objectives and Hypotheses

The objective of the research contained in this chapter was to examine trail user support for various management options pertaining to grizzly bears. This was done through a trail user survey assessing support for 13 different management options if a lone bear or a female grizzly with cubs was in the vicinity of the trail. I wanted to define what kinds of management actions would be most and least supported, and by which demographic groups of people using trails in my study area. I examined several demographic variables based on:

- Trail users previous experience with bears;
- Trail users' reason for visiting the Study Area, the activity they engaged in, and their intended length of stay on the trail;
- The trail's level of human use;

- When trail users had started planning their trip and how often they visited the Study Area;
- General demographics – trail users' accommodation, country of residence, age, and sex.

Specific hypotheses examined were:

H_1: Trail users who are more familiar with bears, as evidenced through previous encounters or residing in areas with bears, will be less supportive of management options that directly management the bear's habitat use or behaviour (i.e., more supportive of management options that tend towards coexistence.

H_2: Trail users that reside locally or recreating in the Study Area daily will be less supportive of management options that restrict human access or recreational activities.

H_3: Trail users who had started planning their trip farther in advance or who were planning to be on the trail for more than one day will be more supportive of restrictive management actions.

H_4: Trail users visiting the Study Area to experience nature or wildlife and staying in campgrounds (as opposed to hotels) will be more supportive of restrictive management options than prioritize grizzly bear habitat use over human recreational needs.

H_5: Trail users will be more supportive of restrictive management options if a female grizzly with cubs is in the area, as opposed to a lone grizzly bear.

4.2 Methods

4.2.1 Sampling Design

I conducted trail user surveys from August 16 to September 30, 2013 and from June 1 to September 30, 2014 with a user intercept survey at trailheads in Banff, Jasper, Yoho, and Kootenay National Parks (BNP, JNP, YNP, KNP respectively; Figure 4.1) with the assistance of 24 volunteers. The survey (Appendix C) was reviewed, approved, and conducted according to Central Queensland University Australia Human Ethics permit number H13/04-045 (Appendix D) and Parks Canada Research Permit BAN-2013-14576. I was delayed in the first field season due to a large flooding event in June 2013 that closed several trails slated for sampling and delayed the research permitting processes until late July.

I separated the field season into two seasons (shoulder: June 1 to 30 and September 1 to 30; and peak: July 1 to August 30). Using stratified random sampling, I attempted to select an equal number of low (< 100 people/month), medium (101-1449 people/month), and high (>1450 people/month) human use trails in each season. I used the Parks Canada Master Trails Database (Parks Canada Agency, unpublished data, 2013) to assign human use levels to trail networks, as I had done with the remote camera sampling (Chapter 2 and 3). I conducted surveys at the main trail in a trail network, which meant there were not very many low use trails to sample. In the shoulder season, three low, three medium, and five high use trails were sampled respectively. In the peak hiking season, one low, three medium, and seven high use trails were sampled respectively. I did attempt to sample at least two other low use trails during peak season but did not encounter any trail users during the sampling week, thus there was no data to include in analysis. Each trailhead was

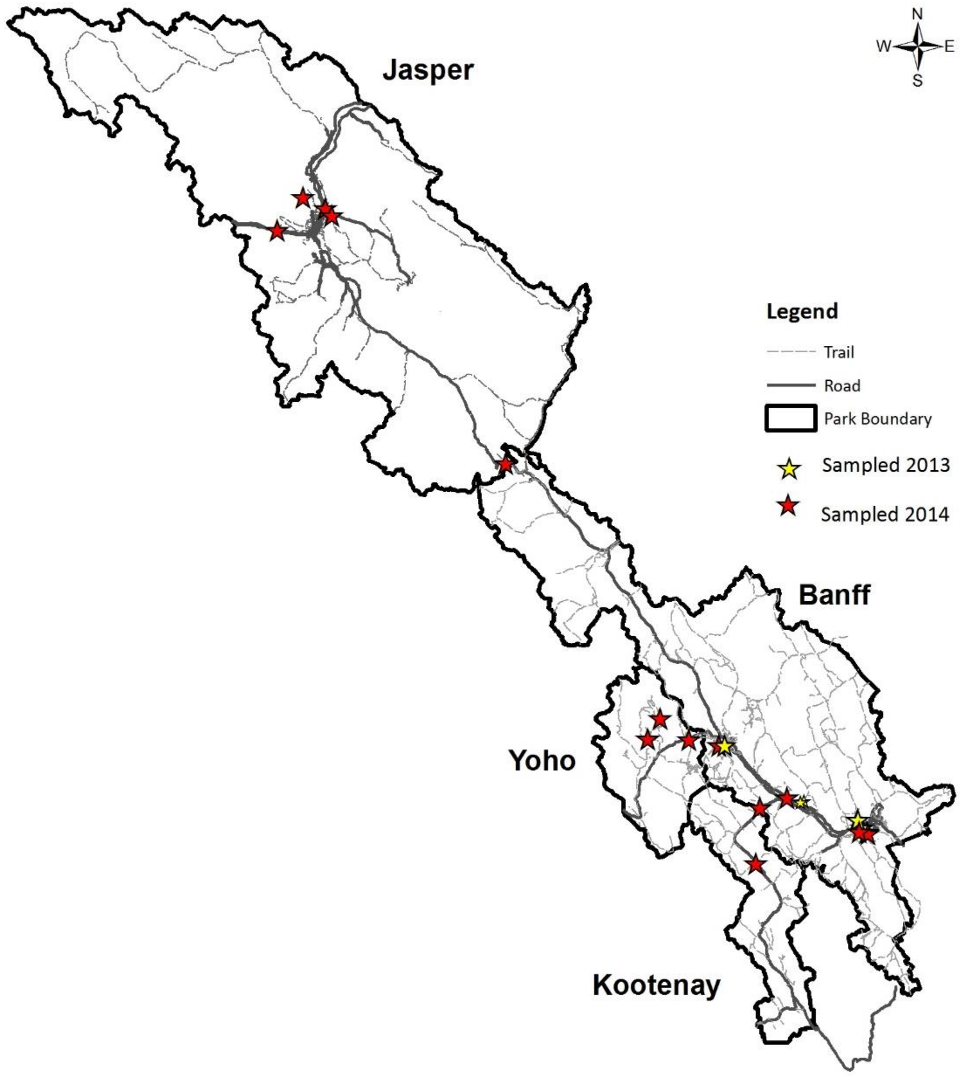


Figure 4.1: The survey study area: Banff, Jasper, Kootenay, and Yoho National. Trailheads sampled are represented by stars. In 2013, only trails in Banff were sampled (yellow stars); in 2014, the research permit was extended to include the other 3 Parks (red stars). Stratified random sampling was used to select low, medium, and high human use trails across the survey study area.

sampled for five randomly selected days in a week including at least one weekend day since visitor use increases dramatically in the National Parks on Saturdays and Sundays (from 2008-2014 annual counts from all trails in Banff National Park averaged over 44,000/day on weekend days and over 28,000/day on weekdays; Parks Canada Agency, unpublished data, 2013).

Trails were sampled from approximately 9:00am – 1:00pm as most people start recreating within those hours (K. Rogala, Parks Canada, personal communication, March 2013). An introductory script (Appendix E) was provided for all volunteer surveyors to ensure consistency in approaching and inviting trail users to participate in the survey (Hughes, Ham, & Brown, 2009). All parties who approached the trailhead were asked to select one group representative to complete the survey, which was anonymous and took 10-15 minutes to complete. All trail users, whether they agreed to participate or not, were given a card with the contact information of the CQU human ethics board for any concerns or complaints and a link to an online research blog where they could learn more about this research project. No party registered complaints about this research with the human ethics board. Surveys were only delivered in English. The population of interest was all trail users in the survey study area from June 1 to September 30. Surveyors also registered the group size, activity type, and the number of dogs in the group.

I conducted a pilot season from July 30 to August 15, 2013, during which time 9 surveyors completed 67 surveys. I used the pilot season to test survey question clarity and the length of time required for completion; subsequently I made minor modifications to increase question clarity. The only significant change was with one of the management options. Originally, respondents were asked to rank their support for the management option: “Park Management should destroy the bear (euthanasia)”. This question elicited such extreme opposition from respondents that they became distracted while answering further questions as reflected in observations recorded by the surveyors. In addition, current practice of park managers is not to euthanize bears except as a last resort in rare and exceptional circumstances. Therefore, this management option was removed and replaced with “actively chase the bear from the area (aversive conditioning or hazing)”, which is a management option currently implemented when bears enter town sites or campgrounds and pose a high risk of conflict with people. Survey responses were recorded by interviewers on android tablets using Quick Tap survey software (QuickTapSurvey, 2010); data were then analysed using SPSS (version 21, IBM, 2011).

4.2.2 Survey Design

The survey had three sections: 1) bear awareness and recreational preparedness detailing what steps hikers took to prepare for their recreational experience in the study area, 2) trail user support for various management options, and 3) demographics and trip details. Bear awareness was assessed by determining if the respondent had previous experience with bears through direct encounters or if the respondent had checked recent bear sightings/activity in the area. One of the preparatory steps was directly related to bear safety (e.g., carrying bear spray); other preparedness options included general wilderness recreation preparation steps (carrying a first aid kit, arranging for a check-in person at the end of their hike).

The second section of the survey was the largest and focused on management option support. In natural resource management, examining normative beliefs with a bipolar scale has helped define specific management options that were supported/opposed and clarified the intensity of this support/opposition (Kneeshaw et al., 2004; Zinn et al.,1998). According to Ajzen (1991), bipolar scaling is appropriate for belief strengths and evaluation of those beliefs. Management options intensely supported or opposed by the majority of respondents display highly skewed distributions towards one end of the scale. Management options that do not elicit strong public opinion in either direction create more equally distributed results and more neutral means (Kneeshaw et al., 2004). Using a series of open and closed-ended questions, I assessed trail user support and opposition for 13 different management options relating to grizzly bears around hiking trails in two distinct scenarios 1) a lone grizzly bear being in the area, or 2) a female grizzly bear with cubs being in the area (similar to Zinn et al., 1998). Management options were rated on a seven-point bipolar scale ranging from -3 (extremely unsupportive), through 0 (no opinion), to 3 (extremely supportive; Kneeshaw et al., 2004; Zinn et al., 1998).

Several factors enter into managing grizzly bears in the vicinity of trails in the National Park, including the bear's behaviour, if attractants (e.g., anthropogenic food sources) are in the area, or if the bear has a previous history with park managers. The average trail user is not likely to be aware of the complexity of factors entering in to these decisions; for simplicity, trail users were asked their support for management options if a bear was in the area they were intending to use that day. Management options tested ranged from "no management action required" (do nothing) to "actively remove the bear from the area (relocation)". All options were based on recommendations resulting from grizzly bear ecology research, existing management tactics in the Canadian Mountain Parks, existing management tactics elsewhere, and other management tactics that have not been attempted for grizzly bear management but have been put in place elsewhere for other ecological or social reasons (Table 4.1). Basing the list of potential management options on recommendations from both social (e.g., visitor perspectives on use restrictions) and biological (e.g., bear habitat requirements) literature ensured an interdisciplinary perspective was integrated into survey design and data collection.

The third section of the survey asked a series of demographic and trip-specific questions. The type of accommodation people stay in (Brisette et al., 2001), whether people are local residents or visitors (Spencer, 2013), how much previous experience they have recreating in the Park (Hughes et al., 2009; Popovicova & Gregg, 2010), the intention of their visit and the amount of previous planning (Hughes et al., 2009) may all affect visitors' support for management options. Each of these factors was addressed in a question; additional demographics such as age category, sex, and country of residents were also collected. As I hypothesized that people from communities in and adjacent to bear habitat may respond to management options differently, so Canadian and American residents were asked to define their city/state of residence, which was later categorized in to areas with or without bears.

4.2.3 Focus Group

A focus group was used to gather qualitative data to further explore survey results and respondents' motivations for management option support. Focus groups are a method of group interview that explicitly includes and uses the group interaction to generate data

Table 4.1: Testing trail user support for 13 different grizzly bear related management options. Most options were based on existing bear habitat or social science research, or are currently employed in the survey study area. The "group numbers limited to less than 8" was designed to also be a counterpart to limiting group sizes to 4 or more. "Encourage human use on this trail" is a potential way to more equally distribute human use on trails throughout the week and season to increase predictability of human use.

Management Option	Based on	Reference(s) or Example
Trail closed until further notice	Current management action	
Implementing trail opening times from 9am-6pm	Implementing predictability of human use to increase habitat effectiveness for bears; selecting times/dates to reduce bear-human interaction.	Coleman et al. 2013 Elfström et al. 2013 Gibeau et al. 2001 Matt & Aumiller 2002
Group numbers limited to less than 8	Social science literature around crowding and seeking solitude; bear literature around controlling human group size.	Chi & Gilbert 1999 Herrick & McDonald 1992 Dawson and Watson 2000
Number of hikers per day limited to 50	Social science literature around human crowding and seeking solitude.	Chi & Gilbert 1999 Manning 1999 Herrick & McDonald 1992
No dogs being permitted on this trail	Current management action in JNP for sensitive caribou habitat.	Parks Canada 2010a Parks Canada 2010b
Placing a warning sign of bear in area at trailhead	Current management action.	
Re-route this hiking trail to avoid areas with high quality bear habitat	Past management action in areas of highly sensitive and critical bear habitat.	Done in Paradise Valley in BNP and Lake O'Hara in YNP
Group numbers needing to be more than 4	Current management action.	Parks Canada 2010a
No management action required	Providing a baseline from where management involvement could only increase.	
Actively remove the bear from the area (relocation)	Current management action on Alberta public lands and protected areas.	Alberta Government grizzly bear response plan (2012)
Actively chase the bear from the area (aversive conditioning or hazing)	Current management action in town sites and campgrounds.	Parks Canada 2010a
Encourage human use on this trail	To increase predictability of human use and to facilitate females seeking refuge in areas of human use from dominant males.	Nevin & Gilbert 2005a,b Rode et al. 2006 Olson et al. 1997

(Pope & Mays, 1995). Focus groups can be useful in identifying and exploring in detail the foundational attitudes towards wildlife management methods (Dandy et al., 2012). The purposes of the focus group were to: 1) seek public reaction to preliminary survey results, 2) seek public input regarding potential explanations of survey results, and 3) increase understanding of public support/opposition to management options. One focus group was held in Calgary, Alberta with 12 participants who were recruited through local hiking clubs and environmental organizations; all participants were required to have hiked in Banff National Park some time during the summer of 2013 as this most closely resembled the sampled respondents.

Focus group participants were presented with some preliminary survey results and trends with a short presentation. Specific trends presented were 1) an overall support for closing the trail in the presence of bears, 2) the difference in support for management options between the lone bear and female with cubs scenarios, 3) the most and least supported management options overall, 4) the difference in levels of support between relocation and aversive conditioning, and 5) the difference in support for management options between local residents and visitors. With each theme, preliminary results were presented and then a series of questions were posed to the group for discussion. Participants were asked why they thought these trends were apparent and what motivations trail users may have had for supporting certain management actions more than or less than others. Group discussion was allowed to flow freely so that participants' responses could feed into one another, thus allowing overarching themes to emerge (Pope & Mays, 1995). Comprehensive notes were taken and the discussion recorded.

4.2.4 Data Analysis

Survey data were not normally distributed; therefore non-parametric techniques were used for analysis. I used a Chi-Square test, with expected values calculated based on an overall management score for a particular management option, to test for differences in support for that management option under each scenario (lone bear vs. female with cubs) similar to Kneeshaw et al. (2004). A Principal Component Analysis with direct obleman rotation was used to group management options into categories for functional, interdisciplinary management approaches. The boundary value for the factor score in the PCA was set at 0.30 for inclusion of that item in the factor (Sahin, 2013). A Mann-Whitney U Test was then used to rank management options in order of support. A series of Kruskall-Wallis tests were used to test any differences in support between demographic characteristics. The K-W tests did not allow me to control for the effects of other factors or gauge the relative contribution of a demographic category on management support level. Therefore, I presented the demographic group that showed the most and the group that showed the least support for the management options. Even though management approaches are sometimes similar between the National Parks in my study area, the parks do attract different visitors. Another series of Kruskall-Wallis tests were used to test differences between the individual National Parks.

Open-ended question responses regarding visitor expectations for management and requested justification for various management actions were analysed descriptively and qualitatively by identifying the major categories and themes emerging from participants' responses (Ballantyne, Packer, & Hughes, 2009). Data from the focus group was categorized based on common emerging themes and example quotes were transcribed; due to small sample size, however, these data was not subject to statistical analysis. These data were used to supplement the quantitative survey results and as part of a multi-method approach to examine trail user motivations at a deeper level (Pope & Mays, 1995).

Survey error can occur in several areas throughout the methodological approach. While there are estimates for the number of people visiting the National Parks, there is no estimate for the total number of people using trails. I reduced potential sampling error by using a stratified random sample to target trails of varying levels of human use. Grizzly bears have been known to inhabit all areas of the park, so I assumed that any trail where surveys were being disemminated could also have a grizzly bear in the area at any given time. While I could have quantified how much GPS collared bear activity was in the vicinity of sampled trails, I chose not to because there could be an uncollared bear in the area and I did not want to bias a trail users' responses by indicating there was (or was not) a bear currently in the area. As all surveys were anonymous and I did not collect contact information of respondents and non-respondents, I had no way of further contact with trail users. Therefore, people who refused to participate in the survey, non-responders, were not accounted for in analysis except for calculating the overall survey response rate.

4.3 Results

4.3.1 Sample Characteristics

In 2013, I sampled a total of 7 different trailheads over 26 days producing a total of 265 completed surveys; 53 parties declined to participate leading to a response rate of 83.2%. The response rate was calculated by dividing the number of parties who participated by the number of parties who were approached. Parties who were not asked or who were missed because surveyors were already engaged are were not included in the calculation of the response rate. In 2014, I sampled a total of 17 trailheads, 432 surveys were completed, and 362 parties declined to participate providing a response rate of 57.7%. In total 696 surveys were completed and included in analysis and the response rate was 62.7%. In 2013 and 2014 I missed approximately 143 and 461 groups respectively.

The majority of people (93.4%) were hikers, and the remainder were engaged in another form of activity such as biking, rock climbing, running, or other (Table 4.2). Most people were recreating in a group of two (48.8%). The vast majority of people were on the trail for either a half day or full day (93.69%), and were largely from Canada (44.5%). I categorized country of residence based on common themes in responses, similar to the method for identifying categories in other open ended questions in the survey. This resulted in separating Canadians from residents of the United States, and residents of the United Kingdom from the rest of Mainland Europe. Only 24.3% of people lived in communities with bears. The sample contained 52.0% females; the modal age category was 26-35 years old but all age categories were strongly represented. The majority of people had not seen a bear on this visit to BNP, JNP, YNP, or KNP (66.8%), but more had encountered a bear while hiking at some point in the past (46.2%) either inside or outside of a protected area. A large portion of people sampled were visiting the study area for the first time (43.0%) and were staying in a hotel or hostel (45.2%). Most people were primarily in the park for recreation (41.9%); 22.7% of people stated seeing wildlife or nature was their primary reason for visiting the park.

Table 4.2: Summary of respondents' trip-specific details and demographics. All categories for each trip detail and associated sample size (n) are presented.

Trip Details and Categories with Sample Size (n)					
Where Staying		**Often Visit**		**Group Size**	
RV	77	<1/10yrs	43	1	65
Tent	125	<1/5yrs	48	2	339
Hotel	309	<1/yr	21	3	70
Home	118	Annually	94	4	75
Other	42	Monthly	82	5+	38
		Weekly	50		
Age		Daily	51	**Country of Residence**	
18-25	73	First Time	299	Canada	304
26-35	174			Mainland Europe	140
36-45	99	**Reason for Visit**		United Kingdom	52
46-55	122	Wildlife/Nature	157	United States	142
56-65	129	Recreation	289	Other	38
66+	60	Vacation	169		
		Other	35	**Sex**	
Days on Trail				Male	294
Half	527			Female	318
One	108				
2+	42				

4.3.2 Preparedness to Recreate in Bear Country

Many people took at least two steps to prepare for their recreation experience in the survey study area (35%), 17% of people took none of the preparatory steps listed as options. Of those steps taken, carrying a first aid kit was the most common (Figure 4.2). Although 47% of respondents said they knew how to use bear spray, only 37% of respondents were carrying it when interviewed. The percentage of people carrying bear spray increased with more days on the trail – 35% of half day hikers, 46% of day hikers, and 81% of back country hikers carried bear spray. The most common way for people to inquire about either trail conditions or bear activity in the area was to talk with Parks Canada staff; very few people consulted friends or other non-Parks contacts (e.g., hotel concierge). People were more prepared to take steps to reduce the chance of an encounter by making noise on the trail (90%) and hiking in a group (67%).

4.3.3 Visitor Support for Management Options

Visitors were asked two open ended questions pertaining to what they thought wildlife managers should do if there was a) a lone grizzly bear or b) a female grizzly bear with cubs in the immediate vicinity of the hiking trail they were on; these were analysed descriptively. The most popular response in the lone bear scenario was to put a sign at the trailhead (48.6%), the second most stated response was to close the trail (17.7%; Figure 4.3). The situation was reversed if it was a female with cubs in the area – closing the trail was the most common first response (43.6%) and putting a sign at the trailhead was the second most common (31.4%). Another commonly stated expectation was for information

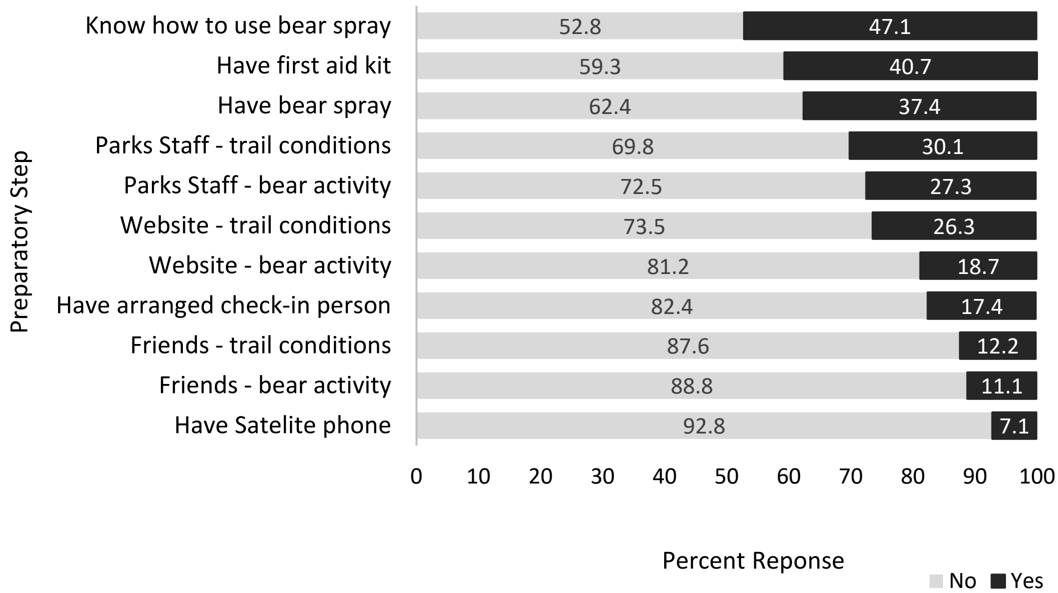


Figure 4.2: Preparatory steps taken by hikers in the survey study area. Visitors were asked to say whether they had or had not taken the step in question.

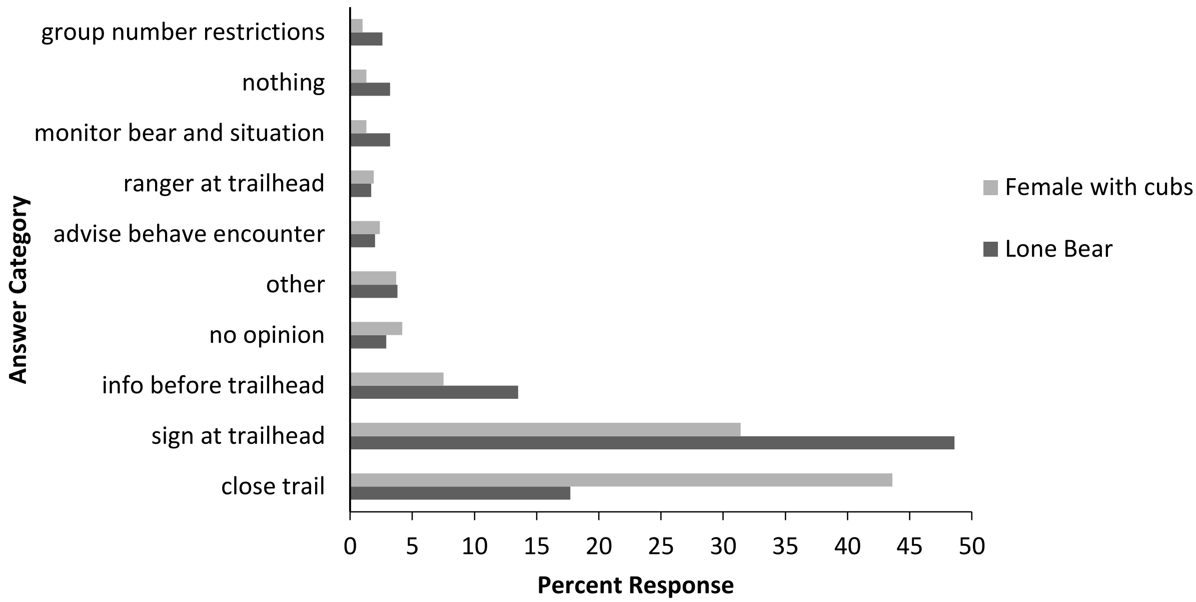


Figure 4.3: Trail user first response to what management action should be taken with a bear in the area. Answers to this open ended question were compiled and condensed in to 10 different categories. “Advise behave encounter” refers to people wanting advice on how to behave in the event of an encounter. Some people simply wanted wildlife managers to be monitoring the bear and the situation. The most supported management actions were to close the trail or install signage at the trailhead. Closing the trail was much more commonly stated if it was a female with cubs in the area.

about bears in the area to be provided before arriving at the trailhead, for example through the park visitor centre or park website.

Similar patterns were reflected in the trail user support for various specific management options. The Chi-Square test revealed significant differences in the support for several management options between the two scenarios (Figure 4.4). The only management options that did not show a significant difference between scenarios were: group sizes less than 8 people, warning sign at trailhead, reroute the trail to avoid bear habitat, and relocate the bear(s). Encouraging people to hike the trail, implementing no management action and applying aversive conditioning were considerably more supported if it was a lone bear in the area. Closing the trail, not permitting dogs, and group sizes of 4 or more were considerably more supported if it was a female with cubs in the area, thus supporting H_5 that predicted trail users would be more supportive of restrictive management options in the female with cubs scenario.

The PCA results corroborated these relationships. In the lone bear scenario, two components resulted in the analysis that explained 34.9% of the variance. The first component contained management options that were largely supported and dealt with the management of the trail and people (Table 4.3a). The second component was made of management options that were not supported and mostly dealt with management of the bear directly (aversive conditioning, relocation). In the female with cubs scenario, three components were identified that explained 47.7% of the variance (Table 4.3b). The first component contained a series of management options that were most highly supported, and the second component contained many of the same people-related management

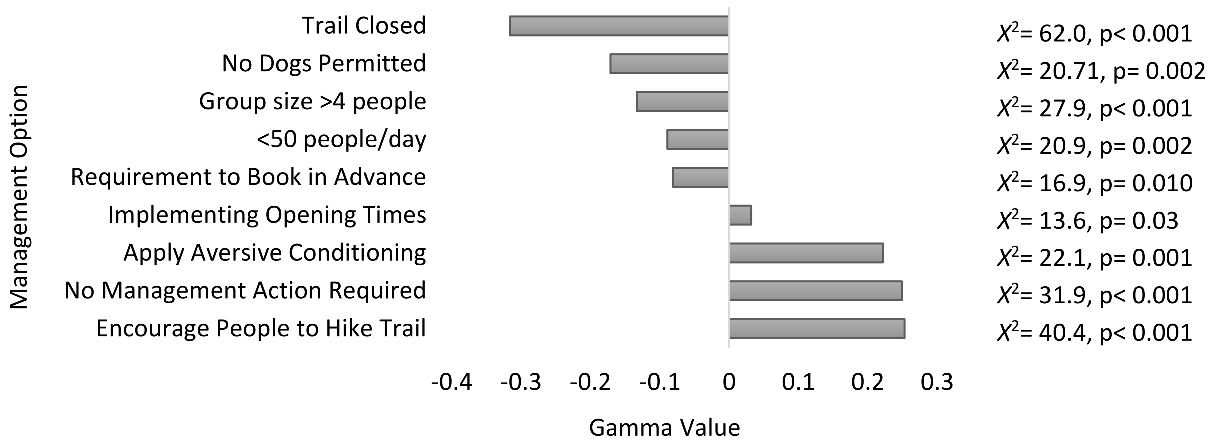


Figure 4.4: Significant differences in support for management options when a lone grizzly bear is in the area. The gamma value associated with the Chi-Square test showed which options were more supported in the case of a lone bear in the area (positive values). Expected values for the Chi-Square test were calculated based on the distribution of support for the particular management option; a significant value reflects a different distribution in support from the lone bear to the female with cubs scenario. Negative gamma values reflect management options that were less supported if it was a lone bear, therefore more supported if it was a female with cubs in the area. Chi-Square values and significant levels for each management option are listed to the right, degrees of freedom = 6 for all tests.

Table 4.3: Principal Component Analysis (PCA) and Ranking of management options results based on Mann Whitney U-test. Results are displayed for the lone bear (table a) and female with cubs (table b) scenarios. Two PCA components were identified in the lone bear scenario and three were identified in the female with cubs scenario. In the lone bear scenario, putting a warning sign at the trailhead was the most supported management option and did not fit within a component. The ranking of management options based on Mann-Whitney U test with Kendall's Coefficient matched the PCA results; the mean rank listed was assigned by the Mann Whitney U-test. Results were significant $p<0.001$ for both scenarios. The last column shows the mean score for each management option and the standard deviation (SD) from the raw data. Colours in the graph correspond to options that were either intensely supported (dark green), supported (green), opposed (red), or intensely opposed (dark red); this same colour scheme is used in Figure 5a and 5c showing differences in support for management options across demographic groups.

a) Lone Bear Scenario

PCA Component	Management Option	PCA Component Score	Mean Rank	Mean (SD) score
No component	Warning Sign		11.25	2.88 (0.603)
Component 1 – supported management options	Reroute Trail	0.435	9.58	1.85 (1.740)
	No Dogs	0.479	9.14	1.55 (2.025)
	Trail Closed	0.568	9.07	1.56 (1.952)
	Open Times	0.622	8.83	1.43 (1.910)
	Group size >4ppl	0.495	8.33	1.09 (2.079)
	Group size <8ppl	0.579	7.41	0.50 (2.102)
	Max 50ppl/day	0.730	6.33	-0.22 (2.145)
	Book in Advance	0.657	5.51	-0.74 (2.222)
Component 2 – opposed management options	More People	0.418	4.99	-1.29 (1.860)
	Aversive Conditioning	0.816	3.70	-2.11 (1.609)
	No Management	0.322	3.46	-2.34 (1.343)
	Relocate	0.827	3.41	-2.28 (1.479)

b) Female with Cubs Scenario

PCA Component	Management Option	PCA Component Score	Mean Rank	Mean (SD) score
Component 1 – Most supported management options	Warning Sign	0.591	10.88	2.85 (0.698)
	Trail Closed	0.662	9.75	2.19 (1.605)
	Reroute Trail	0.384	9.31	1.83 (1.865)
	Group size > 4ppl	0.374	8.60	1.36 (2.133)
Component 2 – Supported management options	No Dogs	0.423	9.35	1.85 (1.938)
	Open Times	0.595	8.40	1.24 (2.132)
	Group < 8ppl	0.802	7.33	0.52 (2.195)
	Max 50ppl/day	0.820	6.67	0.11 (2.289)
	Book in Advance	0.716	5.96	-0.42 (2.404)
Component 3 – Opposed management options	More People	0.341	4.37	-1.81 (1.756)
	Aversive Conditioning	0.889	3.50	-2.37 (1.423)
	Relocate	0.893	3.49	-2.40 (1.418)
No Component	No Management		3.39	-2.53 (1.218)

options that were found in the first component of the lone bear scenario. The last component contained the same management options that were opposed in the lone bear scenario.

The results from the ranking of management options with the Mann-Whitney U test matched the results from the PCA. Significant differences were found in the ranking of support for management options between the two scenarios ($p< 0.01$; Kendall's Coefficient lone bear = 0.516, Kendall's Coefficient female with cubs = 0.554). Putting up a warning sign was the most supported management option for both the lone bear and female with cubs scenario (Table 3a and 3b). Encouraging people to hike the trail and aversive conditioning were the third and fourth most opposed management options in both scenarios respectively. In the lone bear scenario, taking no management action was the second most opposed and relocating the bear was the most opposed management option; in the female with cubs scenario this was reversed with taking no management option being the most opposed. These results provided further support for H_5.

In the Kruskall-Wallis tests comparing support for management options between the different National Parks, I combined YNP and KNP as there were only 13 surveys completed in KNP and these are the two smallest parks. There were more significant differences in the female with cubs scenario suggesting more disagreement between trail users as to what management options should be applied in the specific parks (Table 4.4). In the female with cubs scenario, trail users in BNP were less opposed to relocation and aversive conditioning than trail users in JNP or KNP or YNP. Trail users in JNP were more supportive of limiting the number of people per day on the trail and not allowing dogs on the trail. Implementing trail

Table 4.4: Management option support between National Parks as per Kruskall-Wallis tests. Median management support on the bipolar scale and (variance) are presented in each cell; *denotes a significant difference between parks for that management option, p<0.01.

	National Park					
Management Option	**Banff**		**Yoho/Kootenay**		**Jasper**	
	Female W Cubs	Lone Bear	Female W Cubs	Lone Bear	Female W Cubs	Lone Bear
Trail Closed	3 (2.51)	3 (3.61)*	3 (2.52)	2 (3.86)*	3 (2.92)	2 (4.44)*
Opening Times	2 (4.23)*	2 (3.36)*	2 (5.07)*	2 (3.59)*	2 (5.07)*	1.5 (4.52)*
Groups < 8ppl	0 (4.95)	0 (4.57)	0 (4.41)	1 (4.03)	1 (4.77)	0 (4.21)
Max 50ppl/day	0 (5.27)*	0 (4.58)*	1 (2.16)*	0 (4.51)*	1 (5.37)*	0 (4.48)*
Book in Advance	-1 (5.71)	-1 (4.86)	-1 (5.68)	-1 (4.97)	-0.5 (6.30)	-1 (5.30)
No Dogs	3 (4.08)*	3 (4.36)*	3 (3.17)*	3 (3.47)*	3 (2.81)*	3 (3.39)*
Warning Sign	3 (0.68)*	3 (0.47)	3 (0.17)*	3 (0.13)	3 (0.02)*	3 (0.16)
Reroute Trail	3 (3.31)	3 (3.27)	3 (2.38)	3 (2.02)	3 (3.31)	2 (3.02)
Groups > 4ppl	2 (4.32)	2 (4.33)	3 (5.23)	2 (4.65)	2 (4.85)	1 (4.00)
No Management	-3 (1.63)*	-3 (1.90)	-3 (1.92)*	-3 (2.42)	-3 (0.43)*	-3 (0.73)
Relocate	-3 (2.45)*	-3 (2.38)*	-3 (1.12)*	-3 (1.72)*	-3 (1.03)*	-3 (1.81)*
Aversive Conditioning	-3 (2.39)*	-3 (2.86)	-3 (1.40)*	-3 (1.75)	-3 (1.11)*	-3 (2.28)
Encourage People to Hike	-3 (3.44)*	-2 (3.79)	-3 (2.69)*	-2 (2.94)	-3 (1.90)*	-1 (2.59)

opening times was more supported by trail users in BNP and least supported by visitors in JNP.

The series of Kruskall-Wallis tests revealed significant differences for the support of management options between demographic groups. Figures 4.5a and 4.5c use icons to display these differences, a legend of icons is provided in Figure 4.5b. Tables 4.5a to 4.5d display the medians, variances, and p-values for demographic groups that showed significant differences in their support for management options. Some management options showed less variation in response than others as shown by the number of demographic groups with significant differences in levels of support; differences between many groups may represents options with a higher level of disagreement or controversy.

All trail-based management options are supported in both scenarios, although there were significant differences between demographic groups. In the lone bear scenario, closing the trail was more supported by trail users staying at home (local residents and people visiting the park on day trips) and out for a half day hike, and less supported by trail users who were camping or out for a full day hike. This result rejects H_2 and H_3 since closing the trail can be considered a restrictive management option and it was more supported by local residents and people hiking for a half day.

In the female with cubs scenario, implementing trail opening times was more supported by residents of the United States (US) living in communities with bears, trail users who had never seen a bear hiking, women, people staying in a hotel, and those who visited the study area less than once a year. Implementing trail opening times from 9am-6pm was more controversial as demonstrated by the number of demographic groups showing significant

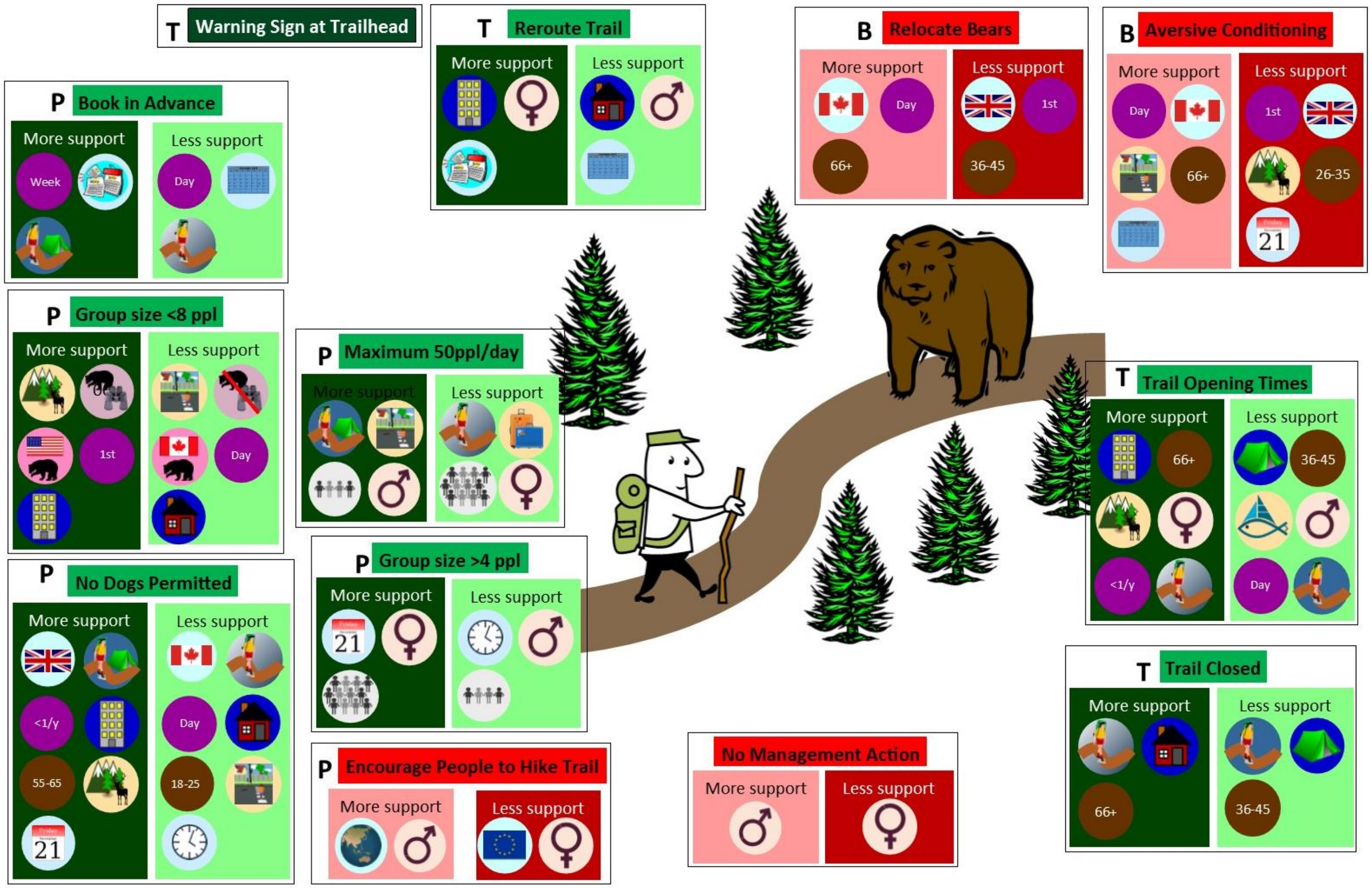


Figure 4.5a: Significant differences for support of management options between demographic groups in the lone bear scenario. Management options in green are supported overall and part of Component 1 from the PCA, except warning at the trailhead which was not part of any component and is highly supported. Options in red are opposed by respondents and were part of Component 2 from the PCA. All icons beneath management actions represent the group most supportive or least supportive. Icons are based on the icon legend in Figure 5b. All management options were labelled as people management (P), trail management (T), or bear management (B) in the upper left corner of the box. Significant differences determined with Kruskall-Wallis tests, p<0.05 (medians, variances and p-values are in Tables 5a-d).

Demographic group	Category	Icon
Seen Bear Hiking	Yes	
	No	
Sex	Male	
	Female	
Level of Human Use	High	
	Low/Medium	
Where Staying	Campground—RV	
	Campground—tent	
	Hotel	
	Home	
	Other	
Seen Bear This Visit	Yes	
	No	
Start Planning	Hours	
	Days	
	Weeks	
	Months	
Often Visit	<1/10yrs	<1/10
	<1/5yrs	<1/5
	<1/yr	<1/y
	Annually	Anl
	Monthly	Mos
	Weekly	Week
	Daily	Day
	First Time	1st

Demographic group	Category	Icon
Bear Community Type	Canada No Bears	
	Canada Bears	
	US Bears	
	US No Bears	
Reason For Visit	Wildlife/Nature	
	Recreation	
	Vacation	
	Other	
Activity Type	Hiking	
	Other	
Days on Trail	Half	
	One	
	Two or more	
Country	Canada	
	Mainland Europe	
	United Kingdom	
	Other	
	USA	
Age	18-25	18-25
	26-35	26-35
	36-45	36-45
	46-55	46-55
	56-65	55-65
	66+	66+

Figure 4.5b: Icon legend for all demographic categories subjected to analysis.

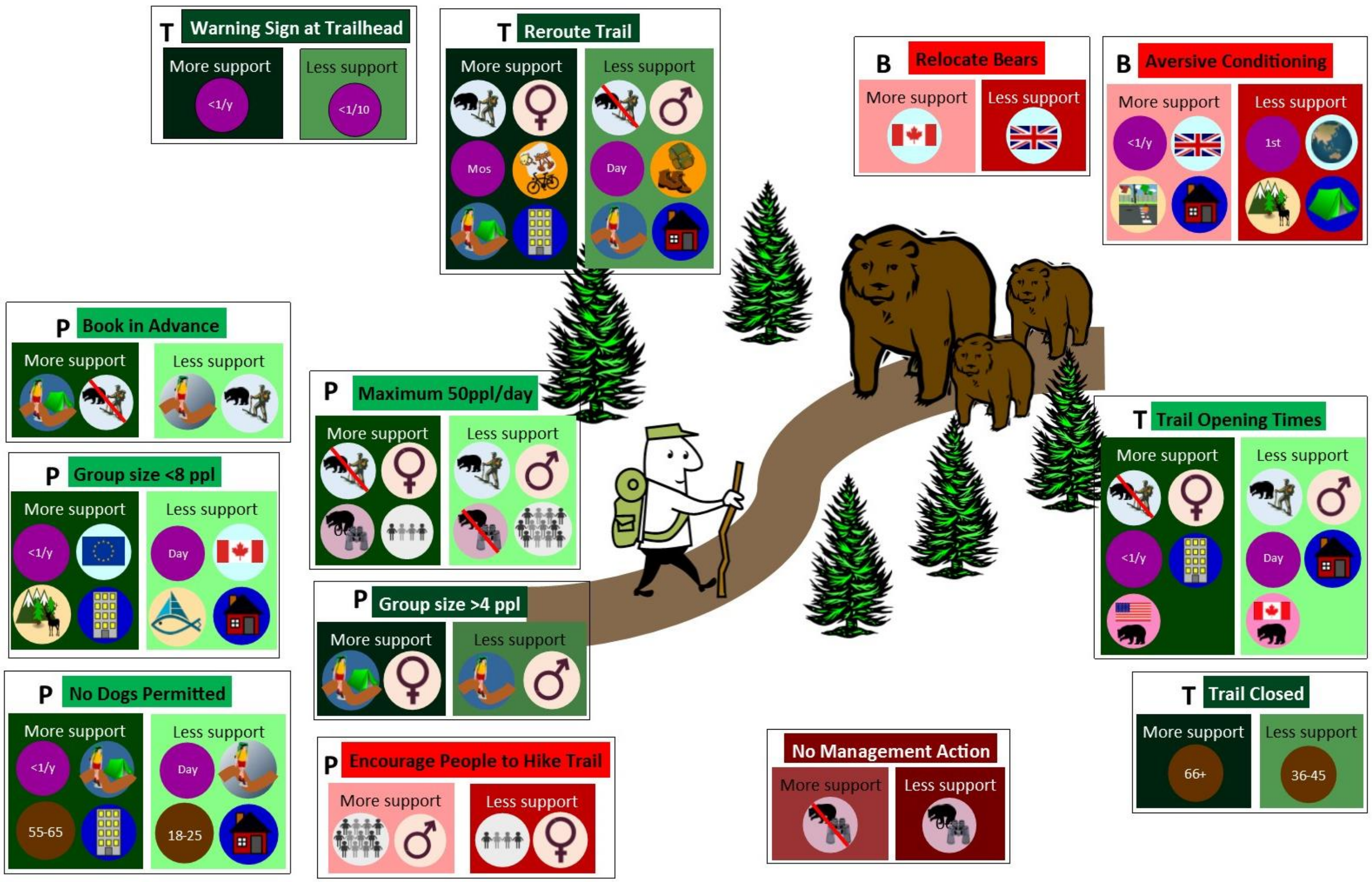


Figure 4.5c: Significant differences for support of management options between demographic groups in the female with cubs scenario. Management options in dark green were the most supported and made up the first component of the PCA. Lighter green management options were also supported and made the second PCA component; options in red were opposed and made the third PCA component. Taking no management action was intensely opposed and was not part of a component. All icons beneath management actions represent the group most supportive or least supportive. Icons are based on the icon legend in Figure 5b (above). All management options were labelled as people management (P), trail management (T), or bear management (B) in the upper left corner of the box. Significant differences determined with Kruskall-Wallis tests, p<0.05 (medians, variances and p-values are in Tables 5a-d).

Table 4.5a: Significant differences in support for management options amongst demographic groups for trail-based management options in the female with cubs (FwC) and lone bear (LB) scenarios. Each demographic group with the highest and lowest support for the particular management option, its median (and variance) are represented. P-Values are those generated with the Kruskall-Wallis tests. Demographics with no significant difference in support are represented with blank cells.

Demographic Group	Management Option							
	Trail Closed		Open Times		Warning Sign		Reroute Trail	
	FwC	LB	FwC	LB	FwC	LB	FwC	LB
Activity Type	--	--	--	--	--	--	Hike: 3 (3.34); Other: 2 (5.67); p= 0.04	--
Age	66+: 3 (0.84); 36-45: 3 (3.22); p< 0.01	66+: 3 (2.20); 36-45: 2 (4.20); p< 0.01	--	66+: 3 (3.24); 36-45: 2 (3.31); p= 0.05	--	--	--	--
Community w or w/o bears	--	--	US bears: 2 (3.66); Canada bears: 1 (5.48); p= 0.04	--	--	--	--	--
Country	--	--	--	--	--	--	--	--
Days on Trail	--	½: 3 (3.74); 1: 2 (4.02); p= 0.01	--	½: 2 (3.63); 1: 2 (3.77); p= 0.02	--	--	2+: 3 (1.25); 1: 2 (3.97); p= 0.03	--
Level of Human Use	--	--	--	--	--	--	--	--
Often visit	--	--	<1/yr: 3 (1.39); daily: 1 (5.68); p< 0.01	<1/yr: 3 (1.05); daily: 1 (4.87); p= 0.02	<1/yr: 3 (0.00); <1/10yrs: 3 (0.85); p= 0.04	--	Month: 3 (30.5); daily: 2 (4.17); p= 0.03	--
Reason for visit	--	--	--	Nature: 3 (3.17); Rec: 2 (3.90); p= 0.05	--	--	--	--
Seen bear hiking	--	--	No: 1 (4.05); Yes: 2 (5.08); p= 0.05	--	--	--	No: 3 (2.69); Yes: 3 (4.34); p< 0.01	--
Seen bear this visit	--	--	--	--	--	--	--	--
Sex	--	--	F: 2 (4.19); M: 2 (4.76); p< 0.01	F: 2 (3.13); M: 2 (3.93); p< 0.01	--	--	F: 3 (4.43); M:3 (3.73); p< 0.01	F: 3 (2.50); M: 2 (3.37); p< 0.01
Start Planning	--	--	--	--	--	--	--	Months: 3 (2.09); Weeks: 2 (4.14); p= 0.04
Where staying	--	Home: 3 (3.49); Camp-tent: 2 (3.64); p= 0.05	Hotel: 3 (4.15); home: 1 (5.40); p< 0.01	Hotel: 2 (3.25); Camp-tent: 2 (3.37); p< 0.01	--	--	Hotel: 3 (2.46); home: 2 (5.13); p< 0.01	Hotel: 3 (2.43); Home: 2 (4.05); p< 0.01

Table 4.5b: Significant differences in support for management options amongst demographic groups for people-based management options that were supported overall in the female with cubs (FwC) and lone bear (LB) scenarios. Each demographic group with the highest and lowest support for the particular management option, its median (and variance) are represented. P-Values are those generated with the Kruskall-Wallis tests. Demographics with no significant difference in support are represented with blank cells.

Demographic Group	Management Option			
	No Dogs		Group size >4ppl	
	FwC	LB	FwC	LB
Activity Type	--	--	--	--
Age	56-65: 3 (3.00); 18-25: 2 (3.36); p= 0.01	56-65: 3 (3.35); 2 (3.86); p< 0.01	--	--
Community w or w/o bears	--	--	--	--
Country	--	UK: 3 (4.44); Canada: 2.5 (4.95); p< 0.01	--	--
Days on Trail	2+: 3 (1.13); ½: 3 (3.95); p= 0.03	2+: 3 (1.28); ½: 3 (4.13); p= 0.01	2+: 3 (3.06); 1: 2 (4.79); p= 0.04	--
Level of Human Use	--	--	--	High: 2 (4.28); Med: 1 (4.50); p= 0.01
Often visit	<1/yr: 3 (1.46); daily: 3 (7.02); p= 0.03	<1/yr: 3 (1.26); daily: 1 (6.44); p< 0.01	--	--
Reason for visit	--	Nature: 3 (3.53); Other/ living: 1 (6.49); p< 0.01	--	--
Seen bear hiking	--	--	--	--
Seen bear this visit	--	--	--	--
Sex	--	--	F: 3 (2.79); M: 2 (4.69); p= 0.01	F: 2 (4.21); M: 1 (4.22); p< 0.01
Start Planning	--	Months: 3 (2.66); Hours: 3 (4.96); p= 0.03	--	Day: 2 (3.63); Hours: 1 (4.91); p= 0.02
Where staying	Hotel: 3 (2.98); home: 3 (5.59); p= 0.01	Hotel: 3 (3.54); Home: 2 (5.30); p= 0.01	--	--

Table 4.5c: Significant differences in support for management options amongst demographic groups for people-based management options in the female with cubs (FwC) and lone bear (LB) scenarios from Kruskall-Wallis tests. Each demographic group with the highest and lowest support for the particular management option, its median (and variance) are represented.

Demographic Group	Management Option							
	Group Size < 8ppl		Max 50 ppl/day		Book in Advance		More People	
	FwC	LB	FwC	LB	FwC	LB	FwC	LB
Activity Type	--	--	--	--	--	--	--	--
Age	--	--	--	--	--	--	--	--
Community w or w/o bears	--	US bears: 1 (4.22); Canada bears: 0 (4.53); p = 0.04	--	--	--	--	--	--
Country	Europe: 1.5 (4.72); Canada: 0 (4.97); p= 0.03	--	--	--	--	--	--	Other: 0 (3.77); Europe: -3 (3.29); p= 0.02
Days on Trail	--	--	--	2+: 1 (3.81); ½: 0 (4.59); p= 0.01	2+: 1 (5.23); ½: -1 (5.71); p< 0.01	2+: 0.5 (4.69); ½: -1 (4.79); p< 0.01	--	--
Level of Human Use	--	--	Med: 0 (4.47); High: 0 (5.35); p< 0.01	Med: 0 (3.99); High: 0 (4.69); p= 0.01	--	--	High: -3 (3.33); Med: -3 (1.62); p= 0.02	--
Often visit	<1/yr: 0 (2.85); daily: -1 (4.90);p= 0.02	1st time: 1 (4.02); daily: 0 (4.89); p< 0.01	--	--	--	Week: 0 (5.87); daily: -3 (3.97); p< 0.01	--	--
Reason for visit	Nature: 1 (4.60); Rec: 0 (4.66); p= 0.04	Nature: 2 (4.35); Other/ living: 0 (5.38); p< 0.01	--	Other/ living: 0 (5.91); Vac'n: -1 (4.70); p= 0.03	--	--	--	--
Seen bear hiking	--	--	No: 0 (5.04); Yes: 0 (5.39); p= 0.02	--	No: 0 (5.78); Yes: -1 (5.67); p= 0.03	--	--	--
Seen bear this visit	--	Yes: 1 (4.30); No: 0 (4.43); p= 0.03	No: 0 (5.15); Yes: 0 (5.34); p= 0.05	--	--	--	--	--
Sex	--	--	F: 0 (5.16); M: 0 (5.043); p= 0.02	F: 0 (4.75); M: 0 (4.40); p= 0.03	--	--	M: -3 (3.15); F: -3 (2.75); p= 0.04	M: -2 (3.34); F: -2 (3.31); p= 0.05
Start Planning	--	--	--	--	--	Months: 0 (4.97); Week: -2 (5.37); p< 0.01	--	--
Where staying	Hotel: 1 (4.94); home: 0 (4.71); p= 0.02	Hotel: 1 (4.31); Home: 0 (5.02); p= 0.05	--	--	--	--	--	--

Table 4.5d: Significant differences in support for management options amongst demographic groups for bear-based management options and no management required in the female with cubs (FwC) and lone bear (LB) scenarios from Kruskall-Wallis tests. The median and variance for each demographic group with the highest and lowest support for the particular management is represented. Demographics with no significant difference in support are represented with blank cells.

Demographic Group	Management Options					
	No Management		Relocate		Aversive Condition	
	FwC	LB	FwC	LB	FwC	LB
Activity Type	--	--	--	--	--	--
Age	--	--	--	66+: -3 (3.56); 36-45: -3 (1.78); p< 0.01	--	66+: -2 (4.63); 26-35: -3 (1.95); p< 0.01
Community w or w/o bears	--	--	--	--	--	--
Country	--	--	Canada: -3 (2.70); UK: -3 (0.27); p< 0.01	Canada: -3 (2.78); UK: -3 (0.23); p< 0.01	Other: -3 (2.41); UK: -3 (0.41; p< 0.01	Canada: -3 (2.97); UK: -3 (0.80); p<0.01
Days on Trail	--	--	--	--	--	--
Level of Human Use	--	--	--	--	--	--
Often visit	--	--	--	Daily: -3 (3.60); 1st time: -3 (1.33); p= 0.02	<1/yr: -3 (2.79); 1st time: -3 (0.99); p< 0.01	Daily: -3 (3.88); 1st time: -3 (1.77); p< 0.01
Reason for visit	--	--	--	--	Other/ living: -3 (5.50); nature: -3 (1.61); p< 0.01	Other/ living: -3 (5.48); nature: -3 (2.23); p= 0.01
Seen bear hiking	--	--	--	--	--	--
Seen bear this visit	No: -3 (1.71); Yes: -3 (1.04); p= 0.05	--	--	--	--	--
Sex	--	M: -3 (2.16); F: -3 (1.31); p< 0.01	--	--	--	--
Start Planning	--	--	--	--	--	Weeks: -3 (2.48); days: -3 (2.25); p= 0.03
Where staying	--	--	--	--	Home: -3 (3.40); Camp-tent: -3 (2.06); p= 0.01	--

differences in levels of support. In the lone bear scenario, implementing restricted trail opening times was more supported by trail users visiting the park to experience nature/wildlife and less supported by trail users visiting the park for recreation, thus supporting H_4. In the female with cubs scenario, implementing trail opening times was more supported by residents from the US living in communities with bears than by Canadians living in communities with bears. It was also more supported by trail users who had never seen a bear hiking, females, people staying in a hotel, and those who visit the Parks less than once a year. Conversely, it was less supported by trail users who visited the park daily and were staying at home (residents), which supports H_2. In the lone bear scenario, opening times was more supported by trail users visiting the park to experience nature/wildlife and less supported by trail users visiting the park for recreation. Trail users displayed a diversity of opinion relating to rerouting the trail. In the lone bear scenario, respondents who had been planning their trip for months, staying in hotels, or female were more supportive than respondents who had been planning their trip for weeks, staying at home, or male. In the female with cubs scenario, trail users who had seen a bear hiking and were back country users were also more supportive of rerouting the trail.

Management options around limiting the number of people in groups or on the trail were more controversial as reflected by a greater number of demographic groups showing significant differences in level of support. Booking in advance was more supported by backcountry hikers, trail users who visited the park weekly, or users who had planned their trip months in advance than by half day hikers and local residents. Implementing a maximum of 50 people/day on the trail was more supported on trails with low and medium human use levels. In the female with cubs scenario, this action was also more supported by women and trail users who had seen a bear on this visit to the study area. Limiting group sizes to four or more was supported overall, but was more supported on trails of high human use, by women, and by trail users who had planned their hike days in advance.

Not permitting dogs on a trail because of a bear in the area was least supported in both scenarios by daily trail users, people staying at home, 18-25 years old, and out for a half day hike. Additionally, in the lone bear scenario, Canadians were less supportive of this management option than people from the UK. Encouraging people to hike on the trail when a bear is in the area was more opposed by females than males in both scenarios. In the female with cubs scenario, it was more opposed by users of low use trails than high use ones.

Management actions dealing directly with the bear (aversive conditioning and relocation) were opposed overall in both scenarios (Table 4.3 above). The survey questions did not provide the respondent with any detail regarding the types, purposes, or methods of aversive conditioning or relocation but were designed to obtain trail users' opinion on these concepts as they pertain to managing bears near hiking trails. Aversive conditioning, which was defined as hazing or chasing the bear from the area, was slightly more controversial, as demonstrated by the number of demographic groups with significant differences. Aversive conditioning was less opposed in the lone bear scenario by people who were daily park users, aged 66+, Canadian, visiting the park for "other" reasons (largely living and working), and who had planned their trip weeks ago. In the female with cubs scenario, it was less opposed by trail users who visited the park less than once a year, were from the UK, or were staying at home. Relocation was consistently less supported by trail users from the UK; in the lone bear scenario it was also less supported by trail users who were visiting the park for the first time and who were 36-45 years of age. My results showing that people staying at home or who used the park daily were less opposed to aversive conditioning, thus rejecting H_1.

Trail users were asked how much they agreed with this statement “Grizzly bear habitat use and recovery should take priority over human use in mountain parks”. Overall, trail users were in support of this statement (median = 3.0; variance = 1.43). Trail users who had seen a bear on this visit to the park (median = 3, variance = 1.08) were more supportive than people who had not ($p<0.01$; median = 3, variance = 1.59). Trail users from the UK were also more supportive (median = 3, variance= 0.67) than users from the USA ($p<0.01$; median= 3, variance= 1.80).

In an open-ended question, trail users were asked what explanations or justifications they would require from wildlife managers to increase their support of management actions (Figure 4.6). The two most commonly cited justification required were awareness/education (29.2%), which included responses requesting advice on what to do in an encounter with the bear in the area, general details of where the bear was and when, and reasons/outcomes (27.7%), which included why a management action had been taken and what the outcomes would be. Several respondents wanted management action to be based on scientific data. Several respondents wanted to know that the management action was a step towards coexisting successfully with grizzly bears, that it was for the bear’s safety, or that it was designed to reduce the chance of bear-human conflict (coexistence, 8.8%).

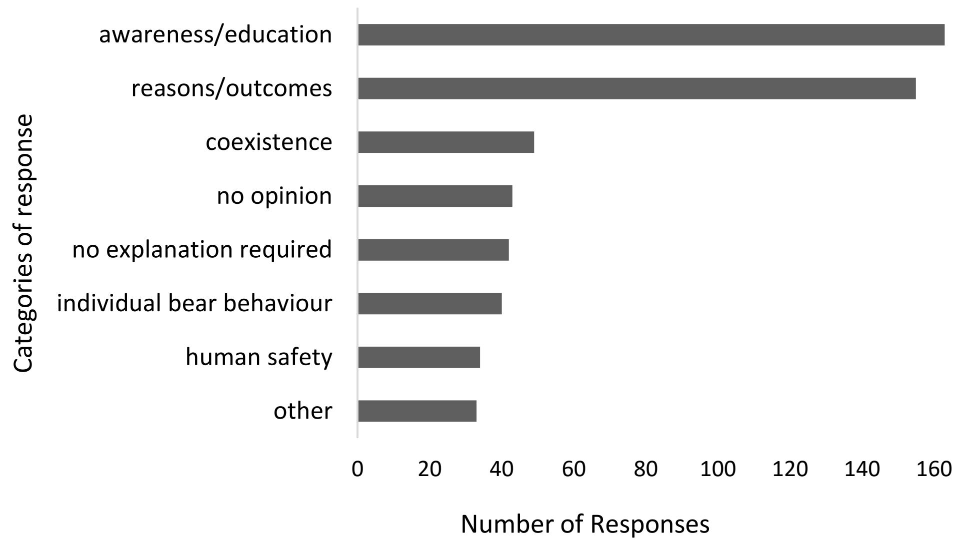


Figure 4.6: Hiker required explanations for management action taken. Categories for this open-ended question were defined based on the hikers' first response to what kinds of explanations or justification they would need from wildlife managers to increase their support for management options that they were not currently supportive of. Some respondents misunderstood the question and answered by stating one of the management options they had been asked to rank (n= 109), all other responses were included (n= 559).

Others wanted to know it was an individual bear's aggression or sensitivity towards people that prompted the management action (individual bear behaviour 7.2%). Others wanted the management action to keep people safe (6.1%); and some trail users did not require an explanation or justification (7.5%).

I found four central themes that resulted from the focus group discussions. The first was regarding signage at trailheads, which participants commented should raise awareness of bears in the immediate areas. Second, participants stated that management options should be for the safety of or in the best interests of the bear. This related to comments that "this is the bear's habitat" and that all management options should consider the safety and well-being of the bear before visitor experience. The third theme that emerged was the idea that female grizzly bears with cubs are more dangerous, which is why trails should be closed if this bear age/sex class is in the area. The last theme that was discussed at length was a general opposition to relocation and aversive conditioning. Participants felt that relocation had negative impacts on the health of bears and that it was not guaranteed to be successful since bears can return. Although aversive conditioning was opposed, participants felt it was a better option than relocation. Participants felt that aversive conditioning might not be effective if it did not address the root cause of the human-bear conflict, particularly if the bear was in an area accessing food. Another participant thought that aversive conditioning might make a bear angry and more likely to display aggressive behaviours towards people.

4.4 Discussion

4.4.1 Overall Support for Grizzly Bear Management

While growing visitation to protected areas can increase negative impacts to species (Cole & Landres, 1995), overly restricting tourists can be met with public resistance because some believe that these efforts unfairly constrain an individual's right to use publicly owned resources (Brisette et al., 2001). This can diminish the recreation experience and lead to decreased public support for conservation (Skibins et al., 2012) and protected areas. My survey results identify options where a large base of trail user support exists. This can help inform management as well as multi-stakeholder discussions, particularly when disagreements arise pertaining to potential impacts to trail users. Overall, trail users to BNP, YNP, KNP, and JNP are supportive of management actions that partially restrict their activity (e.g., closing the trail and group size restrictions) and prioritize grizzly bear habitat use and recovery. This supports previous research from Oregon and Washington where people were supportive of human use limits (Hall et al., 2010), and from public lands in Alberta where people were willing to restrict some uses and access to recreational activities to enhance grizzly bear conservation (McFarlane et al., 2007).

In Yellowstone National Park, seeing a bear was a priority for visitors and the Park incurred an economic benefit from the opportunity of tourists to view grizzly bears (Richardson et al., 2014). In other research outside of protected areas, however, attitudes towards bears in an urban-wilderness interface became more negative after increased sightings and higher problem-bear activity (Dubois & Fraser, 2013). These encounters can even lead to psychological trauma stemming from the bear's size, strength, its potential for aggressive behaviour, and the consequent danger (both real and perceived) that it poses to people (Knight, 2008). The nature of bear encounters can influence attitude and people who perceived their experience with black bears as negative or neutral were significantly more likely to disagree with wildlife protection (Kretser et al., 2009). Therein lies one of the greatest challenges of management – to maintain and enhance public support for bear habitat use, while ensuring risks to human safety do not contribute to a decline in the public's willingness to protect habitat. I found increased support for prioritizing grizzly bear habitat use over recreational use if people saw a bear during their visit to the park. This suggests that people recreating inside protected areas that have a positive (or neutral) encounter with a bear may be more likely to support management actions that are aimed at conserving bears. Enabling safe encounters (for the bear and people), combined with improving the public's knowledge of grizzly bears, could reduce fear, foster positive attitudes, and garner support for restricting human use of grizzly bear habitat (McFarlane et al., 2007; Røskaft et al. 2003). Safe encounters between bears and people can involve ensuring visitors have a safe viewing experience to appreciate bears in their natural habitat. This can be accomplished through the implementation of minimum viewing distances in coastal bear-viewing sites (Elmeligi & Shultis, 2015) or through programs like the bear-guardian program in BNP and JNP where a park ranger supervises tourists viewing bears adjacent to roadsides or other human use areas (Parks Canada, 2015).

4.4.2 Support for particular management options

Similar to Draheim et al. (2013), I found management options aiming to protect grizzly bears and decrease human-bear conflict could essentially be split into two groups: 1) actions that modify human behaviour or trail characteristics, which were largely supported, and 2) actions targeted directly at modifying bear behaviour, which were largely opposed. This concurs with the general result that people are willing to prioritize grizzly bear habitat use over their own recreational needs. Although several trail-based management options do not directly affect human or bear behaviour, they influence where and when people may use bear habitat. These actions were the most supported, particularly in the female with cubs scenario, and should be considered as a priority to reduce the potential for human-bear conflict without overly impacting visitor experience. The level of public acceptance for these management actions varied between scenarios, supporting H_5. Therefore, the age/sex class of the bear needs to be taken into account for managers to understand when their decisions will be judged more or less favourably (Kneeshaw et al., 2004).

Previous research has shown that people expect restrictions to be placed on their activities in order to protect wildlife, and they can become distressed if they perceive animals are suffering as a result of their presence (Ballantyne et al., 2009). These restrictions do not always have negative impacts on visitor experience. Despite feeling affected by changes to human use zoning in Australia, park users still rated their stay as either good or excellent; widespread curtailing of activities did not lead to a decline in park use or enjoyment (Northcote & Macbeth, 2008). In another example from Australia, the aspect of turtle management that tourists considered the most important was ensuring human use had minimal impact on turtle behaviour and habitat use (Ballantyne et al., 2009). I found similar sentiments among trail users in Rocky Mountain National Parks; the majority of trail users in my research were supportive of closing the hiking trail if a grizzly bear was in the area, especially if that grizzly bear was a female with cubs. Focus group participants articulated their perceived differences between a female with cubs and a lone bear commenting that females with cubs are “more dangerous”, and as such should be “left alone”. My research demonstrated trail users in my study area are open to management actions that limit their recreational access; the literature suggests they may even expect to be limited if it is to protect grizzly bears and the National Park ecosystem. The focus group participants commented that “this is the bear’s habitat” and that management options should consider the “safety and well-being” of the bear before visitor experience. This contradicts assumptions from previous grizzly bear multi-stakeholder workshops where concerns have been raised that restricting visitors will negatively impact their park experience (Chamberlain et al., 2012). Current management practices in my study area use the bear’s habitat use and human safety parameters in decision making. The aspect that takes priority is often dependent on the bear’s proximity to towns or other high human use features – as bears are closer to high human use areas, human safety becomes increasingly important.

The more controversial people-based management options (e.g., limiting group size to less than 8, maximum 50 people/day, and booking in advance), were less supported overall. This may be because these management options have not been previously attempted in these National Parks. Focus group participants stated their uncertainty regarding the outcome of these management options and their effectiveness to meet grizzly bear habitat or human safety objectives. For these more controversial and less understood management actions, it is important to understand trail users’ minimal satisfaction and ideal expectation levels (Northcote & Macbeth, 2008). In this case, user satisfaction is not likely to be affected, as evidenced by high support rates for closing the trail. Trail user expectation is that management will benefit the bear or people, but if the effectiveness of the management option is unclear trail user expectations cannot be met. Trail user support for these newer and potentially more controversial management options may increase if such management tactics are applied slowly, explained clearly, or piloted and closely monitored for effectiveness to reduce human-bear conflict or increase grizzly bear habitat security.

Relocation of bears and aversive conditioning were intensely opposed by trail users in the study area as demonstrated by median scores of -3 with low variance. People are not supportive of management actions that may cause harm or suffering to an animal (Dandy et al., 2012). Similarly, Dubois and Fraser (2013) found most people took a "live and let live" attitude towards bears and said it was normal to encounter bears when living near natural bear habitat. People in Colorado, US consistently supported management options that actively restored wildlife habitat and consistently evaluated hazing techniques as unacceptable (Fix et al., 2010). Relocating grizzly bears has longer lasting negative impacts to bear behaviour, energetic requirements, and habitat use than aversive conditioning (Blanchard & Knight, 1995) and, although this practice is used in many other jurisdictions, it is no longer conducted in the Rocky Mountain National Parks.

Hazing and aversive conditioning are applied in the Rocky Mountain National Park to discourage bears from frequenting town sites or other areas of high human use (D. Gummer, Parks Canada, personal communication, January 2016). Ideally, aversive conditioning is conducted in such a way that bears make a strong connection between humans and aversive stimuli (Mazur, 2010). Focus group participants thought it might make the bear more “angry” and be ineffective over the long term if the bear was foraging (on anthropogenic or natural food sources) in a particular area. In Colorado, monitoring mountain lions that had been sighted in residential areas was the most supported management approach, whereas frightening a mountain lion away with rubber bullets was unacceptable to Denver and Colorado Springs residents in all situations (Zinn et al., 1998). A bear using habitat in the vicinity of a hiking trail might be perceived differently than a bear entering a human community, especially if it is engaged in natural non-threatening behaviours away from human settlements. Future research could examine the difference in support for aversive conditioning when a bear is within towns or campgrounds compared to when a bear is in less developed areas foraging on natural sources (e.g., hiking trails). When aversive conditioning or relocation is deemed necessary, it should be accompanied by public education programs explaining the reasons for the management action, potential harms and benefits to the bears (at the individual and population scale) and human safety. Educational programs and materials explaining aversive conditioning should target local trail users, as well as domestic and international park visitors. Individual bears subject to aversive conditioning and relocation programs should also be monitored to ensure the program’s effectiveness in reducing the bear’s habitat use near human settlements and risk of human-bear conflict.

4.4.2.1 Differences between the Rocky Mountain National Parks. I found evidence of different levels of support for management options between the national parks, especially in the female with cubs scenario. Trail users in JNP appeared more supportive of restrictive type management actions, such as limiting the number of people and no dogs, whereas trail users in Banff appeared more supportive of group sizes more than four. Acceptability of actions should be framed in reference to a particular place and purpose (Kneeshaw et al., 2004). There are more trails in JNP that are already closed to dogs for caribou habitat protection (Parks Canada, 2010b), whereas there are more trails in BNP that are only open to group sizes of four or more (Parks Canada, 2010a). Perhaps the existing management options are more supported because users have already experienced and accepted their application. As normative agreement increases, managers can have more confidence in the tactic applied (Kneeshaw et al., 2004). In other research, management actions that resulted in the greatest change from current conditions received the lowest levels of support and compliance (Ishizaki, Teel, & Yamaguchi, 2011). Thus, rapid changes from current conditions decrease a user's threshold of tolerance for management change. This may also demonstrate that trail user support for management options are based on a current reality, but they may have the capacity to change over time as perceived norms change. This implies that similar trail restriction in BNP could be accepted once social norms change over time. A park user's threshold of tolerability for management is dependent on the attractiveness of other destinations that could serve as alternatives (Northcote & Macbeth. 2008). In the context of the four parks in my study area, there is an opportunity to market and communicate park use in a way that trail users understand the difference in management between the parks and how these impact the variety of recreational experiences permitted.

4.4.2.2 Differences between demographic groups. Recreationists need to be served in different ways to optimize the types, quantity, and likelihood of realizing specific benefits (Daigle et al., 2002). Many factors influence a visitor's satisfaction levels including the number and type of other visitors, the activities of managing agencies, and the visitors' expectations (Brisette et al., 2001). I found support for H_3 in that back country users, people on the trail for 2 or more days, were significantly more supportive of rerouting a trail, requirements for booking in advance, not allowing dogs on the trail, limiting group size to a maximum of 50 people per day (lone bear scenario), and group sizes of 4 or more (female with cubs scenario) than all other trail users. Similarly, previous research has shown that specialized wilderness hikers were less tolerant of trail encounters with other people and were more accepting of restrictive trail use limits, although these relationships were not statistically strong (Hall et al., 2010). These users may have different expectations partially tied to their need to invest more in trip planning, such as purchasing a wilderness permit in advance and ensuring they have appropriate gear and skills to be in the wilderness for several days. This difference in preparation may impact their support of management actions. Back country users represent a minority of park users, and if managers focus on protecting experiences that satisfy this group, they risk being challenged by the majority who may feel differently about restrictions (Hall et al., 2010).

Considering the back country differently in terms of trail management may benefit a range of trail users over the medium to long term. Some of the more controversial management options may be more acceptable in a back country setting where fewer users will be impacted and management actions can be tested for effectiveness before being applied to front country trails. Once management options become accepted in the back country, they could become incorporated into trail users' normative beliefs or expectations of what is appropriate, thus increasing trail user support over a broader area. Therefore, should some human use restrictions (e.g., implementing trail opening times or making a requirement to book in advance) be deemed useful to achieve grizzly bear related management objectives, they could be first applied in the back country. Through subsequent trail user surveys and grizzly bear habitat monitoring research, their application can be tested for effectiveness in meeting human and bear management objectives. After which point, they could be phased in slowly on front country trails that go through high quality grizzly bear habitat.

For local people in Slovenia, the most important parameters affecting their support for bear conservation were whether they regarded the bear as dangerous or if they had a previous negative encounter (Kaczensky et al., 2004). Other research, however, has shown that how people feel about bears, the affective component of attitude, has more influence on normative behaviours than perceived impact beliefs (Glikman, Vaske, Bath, Ciussi, & Boitani, 2011). My research showed that people who had previous direct experience with bears, either having seen one while hiking or on this visit to the national park, were more supportive of rerouting the trail, and less supportive of implementing trail opening times, booking in advance, and taking no management action in the female with cubs scenario. Perhaps trail users with previous experience with bears may be more supportive of recreating elsewhere (rerouting the trail) than taking other measures that simply adjust human use temporally or in intensity, thus giving the bear "the space it needs" as suggested by focus group participants. These trail users, however, were also less opposed to aversive conditioning than other respondents. This suggests that they may be seeking consistency in which trails are available and are more accepting of management approaches that satisfy this predictability in trail availability and access.

I found several differences between local trail users, defined as people staying at home, visiting the park for “other” reasons, and using the park daily and those visiting from elsewhere. Residents of the study area were less supportive of restrictive management, particularly not allowing dogs on trails, limiting group sizes, or implementing trail opening times, potentially reflecting their protectiveness over recreational access or their lack of flexibility to changing plans. Local users ascribe greater importance than tourists to visiting recreation areas to maintain and enhance their personal health and fitness (Spencer, 2013); trail users living locally in the survey study area thus may have different goals and expectations of their trail use than visitors. Residents of a protected area are also inherently subject to numerous regulations in their daily lives, thus further restrictions could result in further inconvenience (Ishizaki et al., 2011). Local trail users may also have been displaced from a recreational opportunity in the past because of a bear, potentially making them less flexible in altering their plans and thus less supportive of restrictive style management options. The context and setting of these activities and how they help a person reach their personal goals are important in the context of management support (Daigle et al., 2002).

Not allowing dogs on the trail was least supported by trail users who live locally, were out for a half day hike, and were 18-25 years of age. Outdoor recreationists’ subjective norms and weaker intentions are associated with the outcome they expect from their experience (Daigle et al., 2002), as is likely the case here. Behavioural intention refers to the strength of a visitor's prior intention to perform or not perform a specific behaviour (Hughes et al., 2009). A local resident out for an hour walking their dog is likely seeking exercise for themselves and their dog. If dogs are not permitted on the trail, this interferes directly with their objective, thus decreasing their support. Recent research, however, found that dogs off leash were the second most common way human behaviours contributed to carnivore attacks (Penteriani et al., 2016). This management option was less controversial, and thus more acceptable, in the female with cubs scenario. Spencer (2013) recommended that park managers provide areas tailored specifically to meet the needs of local park users that are not advertised in any tourist-oriented information. Creating off-leash dog-parks for local dog owners that are closed to bears through electric fencing or other means may be beneficial. While these areas are different from a trail open to dogs, they may address the needs of local residents out for a short dog walk.

Local hikers are more likely to have a range of previous bear experiences; as people have increased exposure to large carnivores, their levels of fear decrease (Røskaft et al., 2003). Previous research found people living in rural areas with at least one carnivore species or in close proximity to a protected area were less fearful of large carnivores than people who lived farther away in areas without large carnivores (Kaltenborn, Bjerke, & Nyahongo, 2006; Røskaft et al., 2003;). Increases in the amount of direct experience can also lower the acceptance of the existence of carnivores and lower the support for policy goals aimed at conservation (Eriksson, Sandström, & Ericsson, 2015), which implies that residents in my study area may have less tolerance for living with bears that visitors.

Understanding whether human-bear encounters have been positive or neutral (Kaltenborn et al., 2006), or even if people feel they have been displaced before by bears can inform management. In other research, the more respondents recreated in a protected area, the more protective they were of it (Popovicova & Gregg, 2010). Local respondents in this study may want wildlife managers to strike a balance between the needs of people and bears, but they may also be less flexible in changing their plans, particularly if they do not fear bears because of repeated neutral encounters. They may not view management as necessary. Local trail users may still be conservation minded, but their experience and perspectives brings a complexity to grizzly bear management in my study area.

4.4.3 Justification for management and public communication

Differing levels of support for conservation and wildlife management strategies are rooted in fundamental differences in how people relate to wildlife; understanding these differences can help anticipate where social conflicts may occur and what kinds of communication will be critical to achieve success (Teel et al., 2010). My results may help guide education efforts by highlighting the kinds of management approaches that require more detailed explanation or justification. The public can recognize and support many different reasons for implementing management actions, including those associated with human-use restrictions (Brisette et al., 2001). Where impacts are clear, widespread support for management intervention is likely to exist (Dandy et al., 2012). This is challenging when sometimes the mere presence of people may displace a bear from habitat without people ever seeing the bear, so trail users may not clearly witness their impacts. As human use increases in areas inhabited by large carnivores, the risk of human-carnivore encounters increases, which requires an improvement in management action as well as available information, education, and prevention guidelines to reduce the risk of conflict between people and carnivores who may be removed or aversively conditioned in response (Penteriani et al., 2016). It becomes the responsibility of the management agency or other educational organizations to communicate the potential impacts, whether they be negative or positive, and their implications at the individual and population scales. Communicating the reasons why certain management actions have been taken can increase support and be used as an opportunity to teach visitors about grizzly bears and their habitat requirements.

Changing attitudes towards bears and support for management actions can be difficult, but information that improves visitor awareness of bears and their role as an important component of the ecosystem can help increase support of restrictive management options (McCool & Braithwaite, 1989). With their support for prioritizing bear habitat use, trail users in the survey study area appear open to coexisting with bears, but they may not understand what that truly means. The definition of coexistence is “to exist together in peace” (Collins, 1989); this means grizzly bears and people living together at the landscape level peacefully and does not imply bears and people should be in exactly the same place at the same time. In an area such as the Rocky Mountain National Parks where grizzly bear habitat is suboptimal, coexistence requires giving bears space to forage or access other resources without human disturbance. There is an opportunity to convey conservation related messages describing potential and known impacts of recreation on bear habitat use, and incorporating those within the context of coexistence. This could be particularly meaningful for those management decisions pertaining to safety for the bear.

For example, communicating that a trail is closed because a bear is in the area and this particular bear is frequently displaced from high quality habitat due to people, so closing the trail will allow this bear access to important forage. Several trail users in my study also recognized that grizzly bears can behave individually, which provides an opportunity for specific messaging such as this. Ensuring people adapt their own behaviours is the essence of coexistence and can reduce the number of attacks from large carnivores by nearly half (Penteriani et al., 2016).

Ballantyne et al. (2009) suggest that tourists may be receptive to these kinds of messages and the opportunity to learn about conservation is likely to enhance rather than detract from their experience. While park managers in my study consistently take management action with sound reasoning and scientific support, this justification is not always consistently communicated to trail users through various forms of media. Placing management actions into the context of larger National Park Management is a good way for people to understand why management actions vary across trails and between parks. Increasing understanding that high-quality grizzly bear habitat is not dispersed homogeneously across the landscape and that some valleys have disproportionately higher levels of importance for their size and location, could further increase support for some controversial management options. Creating effective messages that convey the reason why a management action was taken, how it will directly benefit recreationists, and how it is unique to a particular area's attributes should be a part of public communication (Brisette et al., 2001).

Trail users surveyed in my research sometimes requested information on how to behave in an encounter. How harmful the bear is, or perceived to be, is a key factor in predicting attitudes towards bear management (Kaczensky et al., 2004). Johansson and Karlsson (2011) recommended that education programs help to reduce the fear people associate with a possible encounter by educating them on the biology of the animal while also enabling them to learn more about their own reactions and how that might impact the outcome of an encounter. Penteriani et al. (2016) suggested an important strategy to reduce attacks of carnivores on people is to inform people not only how to avoid an attack, but how to manage aggressive encounters.

Education should be a dynamic and interactive process and new tools need to be continually developed to adapt to changing community demographics and needs (Can et al., 2014); it should be vibrant, engaging, and hands-on and using real-life examples (Visser, 2007). Educational messaging should also be kept fresh and its look updated so as to avoid people assuming they have read the message before. In Yosemite, visitors barely glanced at signage stating that the information was already familiar (Matthews et al., 2003). Placing a warning sign at the trailhead was consistently supported and expected in the survey results. Sign messages should be brief and vivid and signs should be placed in strategic locations such as natural resting spots on a trail, or an area of high traffic (Matthews et al., 2003). Focus group participants also recommended that trail signage be kept current and use improved graphics to increase awareness amongst non-english speaking visitors. Given the high numbers of foreigners recreating in the National Parks, this option may serve to reach a broader audience. Trail signage should also give more information than simply indicating the presence of a bear. Trail users expressed interest in learning about how to reduce the risk of a negative encounter or about how a particular management approach was related to an individual's bear behaviour; this kind of information should be incorporated into public communication materials, particularly when implementing a more controversial management option.

Other educational tools, particularly social media marketing (e.g., facebook, twitter, and Instagram), should also be applied to communicate up-to-date bear sightings and recreation restrictions. These forms of communication are becoming more prevalent (Bayne & Cianfrone, 2013); among young adults they have become the primary source of information (Men & Tsai, 2015). One of the best advantages of social media marketing is its reduced cost in comparison to other educational tools and that it can be used as an experimental forum to test messages and brand awareness (Dehghani & Tumer, 2015). The main distinction between social media and other forms of advertising is that it is interactive, personal, and allows organizations to engage the public in conversations, supportive behaviours, and meaningful relationships (Men & Tsai, 2015). All educational materials are most effective if used consistently by local managers, communities, funding agencies, practitioners, and facilitators to ensure best practices are being understood and adopted broadly (Madden, 2004).

Repeat visitors with strong intentions or habitual behaviour, i.e., local residents, require an alternative approach involving different messages and different delivery systems (Hughes et al., 2009). In addition, entrenched behaviours and use patterns may not be amenable to persuasive influence, particularly if they have not resulted in any negative experience (Hughes et al., 2009). For example, a local resident who always walks his or her dog on a specific trail and has not had any negative encounters with bears on that trail may be less supportive of management actions that close that trail to dogs. In these cases, Hughes et al. (2009) recommended using a campaign style of communication using different messages and different delivery systems. These messages are best based on understanding the beliefs of users that actually underlie the behaviour, which was not part of the scope of this study but should be examined in the future. A diversity of reasons may exist for why individuals find a particular action acceptable or unacceptable, making it difficult to develop a single approach to outreach that can effectively reach all audiences (Fix et al., 2010). Therefore tailoring messages, messengers, and delivery mechanisms to particular audiences is important to ensure overall public support.

The key to balancing the needs of tourists with the needs of wildlife is to clearly communicate the reasons behind particular management practices in terms that relate directly to protecting animals from human impact (Ballantyne et al., 2009). When it came to the more controversial management options around trail opening times, several people in the focus group commented that they did not understand how that would benefit the bear or increase human safety. Trail opening times, however, could ensure predictability of human use spatially and temporally thus allowing less tolerant bears to avoid human use (Nevin & Gilbert 2005a, 2005b; Olson et al., 1997; Swenson, 1999). This predictability of human use is a central tenet to managing bear-viewing in coastal areas and could have success in the interior as well (Chi & Gilbert, 1999; Matt & Aumiller, 2002). In coastal areas this approach is being used to purposefully habituate bears to human use, but habituation in my study area could increase grizzly bear mortality. I am proposing predictability in human use to allow non-habituated bears access to important habitats in the absence of people. Accomplishing this without further habituating other bears is one of the central dilemmas to grizzly bear management in these National Parks. The public in my survey study area has not, however, been exposed to this concept and the implementation of this management action would require clearly communicated reasons and outcomes to have public support.

Understanding visitors' motivations can be helpful for planning and management (Farias, 2011). Local hikers and nearby residents are likely to have the strongest opinions about the future management of the park and are more likely to participate in public meetings because of their attachment to place (Popovicova & Gregg, 2010). In many of the previous workshops involving multiple stakeholders to address grizzly bear management, this has been the case. Residents, however, were not the largest portion of trail users. Parks Canada's mandate is to:

> "*protect and present nationally significant examples of Canada's natural and cultural heritage, and foster public understanding, appreciation and enjoyment in ways that ensure the ecological and commemorative integrity of these places for present and future generations on behalf of all Canadians" (Parks Canada Charter, 2002).*

While Parks Canada does this for the enjoyment of Canadians, it also aims to share these places with the world. It would be beneficial for the Protected Area agencies to actively seek out the opinions of other users who live both inside and outside of the Park or the Country during times of public consultation around management options. Strategically planning for this increased visitor engagement could provide a wealth of additional perspective in planning. Managing agencies could obtain email addresses of international visitors at various public events during the summer months, or create a standing panel of international users for consultations. Protected area agencies should also plan and budget for implementing trail surveys such as mine at predetermined time intervals to assess how thresholds of tolerability and social norms change over time. As wildlife value orientations shift between locals and visitors, so do attitudes and behaviours towards wildlife (Manfredo et al., 2009); these behaviours can be extended towards support for management actions. Where attitudes and behaviours are context specific, value orientations transcend context and are more predictable (Manfredo et al., 2009). By continually taking efforts to better understand visitors and their motivations and expectations, protected area agencies can ensure positive visitor recreation experiences. This information should then be incorporated into biological data to define the local, park specific balance between conservation and visitor satisfaction.

4.5 Conclusion and Management Implications

Given the diversity of people visiting, living in, and using the National Parks, grizzly bear management can sometimes be a source of conflict and controversy (Campbell, 2012); incorporating the views of trail users themselves can help alleviate some of the conflict that centers around assumptions of how the visitor will react to management tactics. An interdisciplinary approach that combines biological and social data can increase the success of grizzly bear management and support for grizzly bear conservation with greater attention to the “human side” of potential conflict, including its social, cultural, political, and historical roots (Teel et al., 2010). As North American society becomes increasingly urbanized, there is a corresponding shift in the way people perceive and value wildlife. This has significant implications for the public’s response to wildlife issues; there is a gradual movement away from a domination orientation and a corresponding increase in mutualism perspectives (Teel et al., 2010). Decision makers can be better informed about the range of potential support for decisions that protect grizzly bear habitat use and human safety, and when necessary restrict human access to certain areas when there is particular risk of conflict with people.

Encountering a bear can be a unique part of a hiker’s experience in the Rocky Mountain National Parks, yet at the same time, increased human use can negatively impact biophysical, cultural, and historical resources, thus changing the character of an area (Brisette et al., 2001). In my study area, trail users were more supportive of management actions to protect grizzly bear habitat use if they saw a bear. Maintaining the possibility of a safe human-bear encounter in areas where additional impacts to habitat will be minimal (e.g., road-side or at long distances) may be important to maintain and increase public support of management options, particularly those that restrict human use in more environmentally sensitive areas. My research findings may have implications for multi-stakeholder management-related discussions where views on grizzly bear management are assessed against the impact of various restrictive management actions on the visitor experience. When multiple stakeholders are engaged in management problem solving, there is a need for compromise for the common interest (Rutherford et al., 2009); my research provides a unique representation of the perspectives of trail users, that can be used to inform these trade-offs among potential management actions for bears and people.

Multiple stakeholders with varied, sometimes conflicting attitudes, objectives, and ethical positions frequently become engaged in wildlife management (Dandy et al., 2012). This is frequently the case in my study area. The Parks Canada mandate (Parks Canada Charter, 2002) states clearly that park management will be designed to meet ecological and visitor experience objectives, therefore, park managers should prioritize these broad objectives over other, potentially competing interests. Local residents are affected by recreation areas in their vicinity, whether they use them regularly or not, and have views that should be considered in management planning (Spencer, 2013). The findings of this research can help guide multi-stakeholder discussions that attempt to incorporate multiple views in defining commonly desired tactics and outcomes of management.

CHAPTER 5: CONCLUSION

Large carnivores like grizzly bears are especially sensitive to human activity because their habitat requirements often conflict with those of people (Woodroffe, 2000b). The Canadian Rocky Mountain National Parks of Banff (BNP), Jasper (JNP), Kootenay (KNP), and Yoho (YNP) represent a complex landscape where grizzly bears and people are continually sharing space. This reality is further complicated by the fact that both bears and people have experiences outside of these protected areas, which may shape their perceptions of experiences within the Parks. While grizzly bears represent an iconic element of North American wilderness (Nevin, Convery, & Swain, 2014; Sandy, 2012), they are also sources of fear for recreationists (Johansson & Karlsson, 2011). Grizzly bears have also decreased dramatically throughout their range in North America (McLellan et al., 1999; Nielsen et al., 2006); in 2010 grizzly bears were listed as *threatened* in Alberta (Alberta Queen's Printer, 2012). Although grizzly bears have been considered to display low resilience to human development and use (Weaver et al., 1996), more recent research suggests their responses to human development is much more complex and bears are capable of exhibiting a level of resiliency to industrial landscape uses and other human development impacts (Elfström et al., 2013; Kite et al., 2016; Martin et al., 2010).

People recreating in bear habitat have various levels of previous experience with bears and can bring different emotional reactions, ranging from fear (Røskaft et al., 2003) to acceptance (Dubois & Fraser, 2013) when considering the possibility of an encounter. These factors create complex management problems that involve people, bears, and the myriad kinds of interactions that occur between them. I researched this challenge from an interdisciplinary perspective, integrating biological and social information to provide management recommendations that maximize grizzly bear habitat security and meet trail user expectations.

5.1 Interdisciplinary Synthesis

Interdisciplinary approaches to protected area management and research are relatively new and methods chosen for integrating data and results are often dependent on the type of data collected and the research question being posed (Claeys et al., 2011). As a result, there are multiple ways to synthesize data from multiple sources to create recommendations that are founded in robust science and applicable to on-the-ground management. For interdisciplinary science to succeed, it needs to clearly demonstrate how science can address protected area management questions by providing answers to complex natural and social problems simultaneously (van Riper III et al., 2012). I used an interdisciplinary approach throughout my research because grizzly bear management is inextricably intertwined with people management. Researching grizzly bear habitat use associated with human use features (i.e., trails) in my study area without incorporating human dimensions is an incomplete approach, particularly since the perspectives of the park users and stakeholders have the potential to influence management decisions (Chamberlain et al. 2012).

5.1.1 Ways to Improve Interdisciplinary Approaches

One of the biggest challenges with interdisciplinary approaches is the diversity of skills and knowledge required. An interdisciplinary researcher should be skilled as a biologist and a social scientist, and knowledgeable of the methodological and analytical tools available in both fields (St. John et al. 2014). It is for this reason that most large scale, long-term interdisciplinary projects involve a team of experts representing each field of research interest. Interdisciplinary collaborations typically involve a unified approach to problem definition, sharing of methods and data, and even the development of new questions (Allen et al. 2014). Success of interdisciplinary projects in protected areas are dependent on how the outcomes inform and educate decision-makers, policy makers, and managers (van Riper III et al. 2012). This requires ongoing communication about projects as well as the utility of interdisciplinary approaches for future research projects. PhD research does not occur over the same temporal scale as other long-term research efforts, but I did take care to strategically create a graduate committee comprised of biologists, a social scientist, and a park manager. Each committee member provided assistance and advice in all stages of my research and reviewed all chapters including those outside of their area of expertise. My diverse committee helped me address complex priorities and provided assistance from the definition of research or management objectives through to data collection/analysis and the formulation of conclusions (van Riper III et al., 2012). This same approach can be applied in parks and protected areas research and management by involving representative from all relevant departments (e.g., ecology, planning, visitor experience management, enforcement) in the development and execution of research projects. The end result can be management recommendations with applicability across disciplines, thus increasing park management effectiveness overall.

A challenge of interdisciplinary research is the many differing perspectives about the roles and drivers of humans in ecosystems encountered in the literature, deciding at what spatial or temporal scale to collect the biological and social data, and the lack of a clear framework for integrating natural and social sciences (Allen et al., 2014). Two of the most common ways to integrate data are dialogue methods and model-based methods (Pooley et al., 2013). A dialogue method is the most straightforward and involves considering the results from different sources simultaneously to create a series of management recommendations that combine both approaches. This has been done to create “voluntary code of conduct” recommendations in the wildlife-viewing industry pertaining to grizzly bears (Elmeligi, 2008) and with harbour seals in Iceland (Granquist & Nilsson, 2016). An example of a model-based method is to combine biological and social data through a geo-spatial planning framework using GIS-based data; this was conducted in Alaska to map critical moose habitat with subsistence hunting access (Shanley, Kofinas, & Pyare, 2013). Using GIS technology for evaluating social and biological data can significantly contribute to land use planning and management (Shanley et al., 2013). I used both approaches to identify potential areas of focus for trail management in the spring and to create a series of management recommendations. By focusing on grizzly bears and trail users BNP, JNP, KNP, and YNP, I have garnered a comprehensive understanding of how grizzly bears select habitat around human use features and trail user expectations of grizzly bear management.

5.1.2 Interdisciplinary management recommendations

By combining information from biological and social data sources, I identified six specific management objectives (Figure 5.1). As management in BNP may set precedents for other parks, many of the lessons learned in my research can be applied across a much broader spectrum of protected areas in western Canada where large carnivore conservation

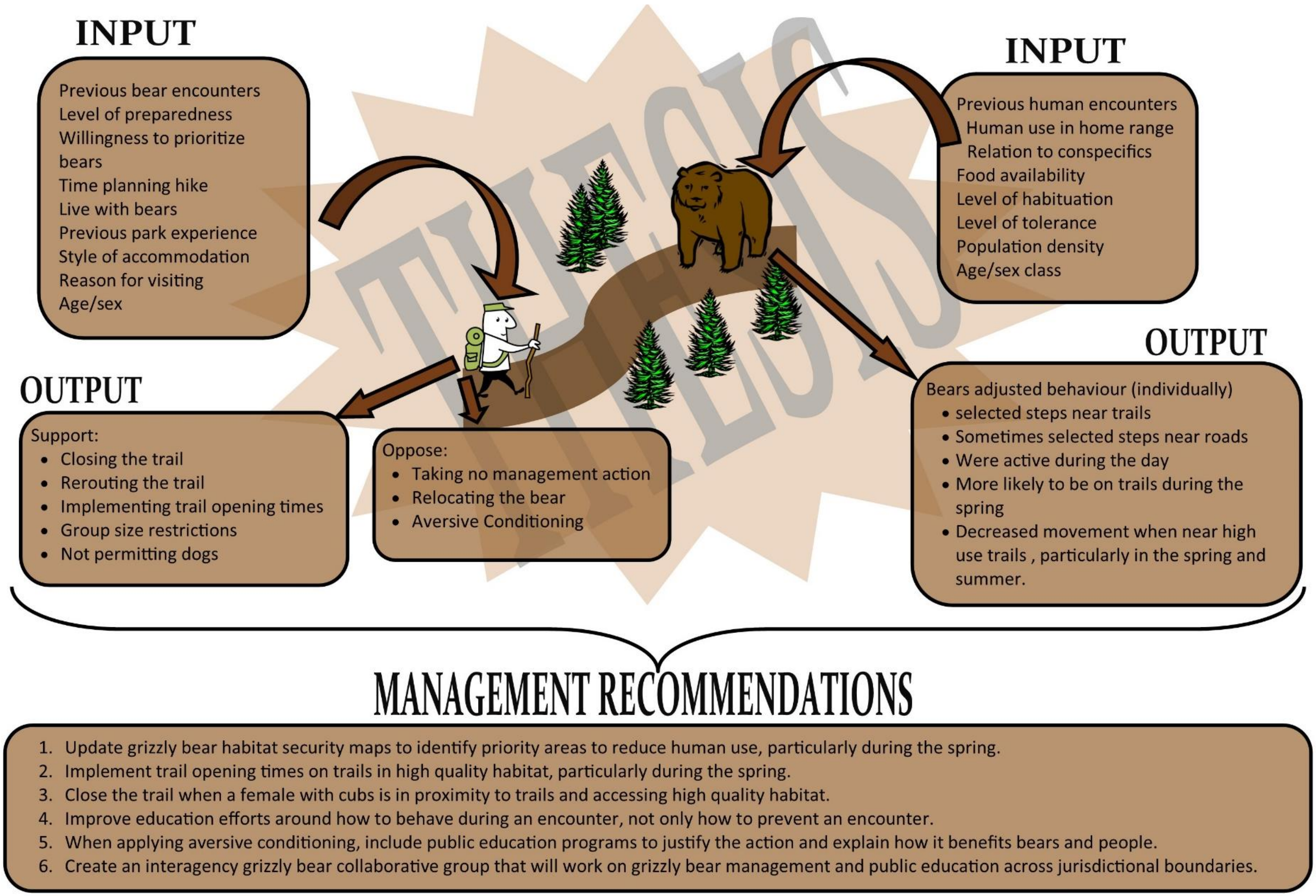


Figure 5.1: Final thesis management recommendations based on biological and social data results described throughout this thesis.

and human recreation are competing objectives. The use-availability analyses showed that grizzly bear habitat preference is related to proximity to human use trails, particularly in the spring. Through the SSF, I demonstrated that grizzly bears habitat selection and movement is also related to the level of human use on trails, but the intensity of impact and how it affected grizzly bear step selection in relation to proximity to trails varied between individuals. My research did clearly show, however, that when bears selected habitat close to roads their movement rates increased; this concurs with other research in Alberta (Kite et al., 2016; Northrup et al., 2012b; Roever et al., 2010). This increased movement may relate to ease of travel along open road corridors (Roever et al., 2010), but can increase a bear's mortality risk (Kite et al., 2016). A grizzly bear's longer step lengths near roads therefore reduce the amount of time the animal is at risk (Roever et al., 2010). The results from my SSF showed that when bears selected habitat close to high use trails, however, their movement rates decreased. This could be related to bears selecting habitats with dense cover when in proximity to human use areas, which suggests bears are taking efforts to avoid confrontations with people (Moen et al., 2012; Ordiz et al. 2011). Increasing or decreasing movement rates in response to roads and trails can alter optimal foraging and resting patterns thus affecting energy gain (Ordiz et al., 2013). All of these factors can impact individual grizzly bear fitness, and since this population has potential to act as a source for the surrounding provincial population (Sawaya et al., 2012) these changes can have implications at the provincial population level.

With the descriptive analysis of seasonal home ranges and the presence-absences remote camera analysis, I showed that bears had the smallest home ranges and were more likely to use human use trails as movement pathways in the spring. With the delayed green-up in the spring due to the higher elevations of the Rocky Mountains (Munro et al., 2006), grizzly bears in my study area may not have access to alternative forage during the spring; this can increase the likelihood of encounters with people who are also largely limited to the valley bottoms for recreation during the spring and early summer. The more people that recreate in bear habitat, the higher the chances of a human-bear encounter (Penteriani et al., 2016), and annual visitation to the Canadian Rocky Mountain National Parks continues to rise in line with management objectives (Parks Canada, 2010a-d).

To implement successful conservation strategies requires collaboration among stakeholders (Rutherford et al., 2009), and an understanding of trail user expectations of management. Trail users in my study area were supportive of prioritizing grizzly bear habitat use and recovery over their own recreational needs, and expected management action to be taken if a bear was in the vicinity of a hiking trail. Trail users mainly supported management actions that were focused on trail management, some of which were restrictive such as closing the trail and implementing trail opening times. This concurs with previous research by McFarlane et al. (2007) who found recreationists were supportive of closing recreational areas for the purpose of grizzly bear conservation. However, such findings contradict a number of assumptions by stakeholders in BNP that the visitor experience will be diminished by restrictive management options (Rutherford et al., 2009). When it comes to environmentally related norm-beliefs, actions stem from acceptance of particular personal values, beliefs that things important to those values are under threat, and beliefs that actions initiated by the individual can help alleviate the threat and restore the values (Stern, 1999). Through the focus group, I observed that trail user support for management action stemmed from concern for grizzly bears and for human safety. Trail users did possess conservation-related values and believed that action on the part of wildlife managers would protect those values. Support for these management options were impacted by the inherent differences between local residents and visitors using the trail network in the study area. I found local people less supportive of management options that regulated their use of trails, even though they were still supportive overall. In addition, the majority of trail users are not local residents and this should be considered in management planning. Personal norms create a general predisposition to support overall environmental movement goals (Stern, 1999), but the factors affecting these personal norms happen far before trail users arrive in the park.

Conservation efforts depend in part on understanding the interactions between predators and people (Woodroffe, 2000). Managing people recreating in grizzly bear habitat is done through access management or other ways to restrict the number of people in grizzly bear habitat. Using a geo-spatial analysis, I have identified areas of focus for management action in the spring (Figure 5.2). To create this map, I used the RSF habitat quality layer, combined with a buffer of 400m around trails (based on the zone of influence from Gibeau et al., 2001), and the measures of human use generated from the remote cameras. I chose to apply the 400m buffer because it is a more conservative measure that was created based on bear habitat use within my study area. Within the 400m buffer, grizzly bears may be seeking cover to avoid encounters with people or altering habitat use while also attempting to access high quality habitat. I generated the map for the spring only as the remote cameras and GPS use-availability analyses suggested this was the season when bears would be more likely to use habitat near trails and human-bear encounter probability was highest. I identified areas of focus for management as

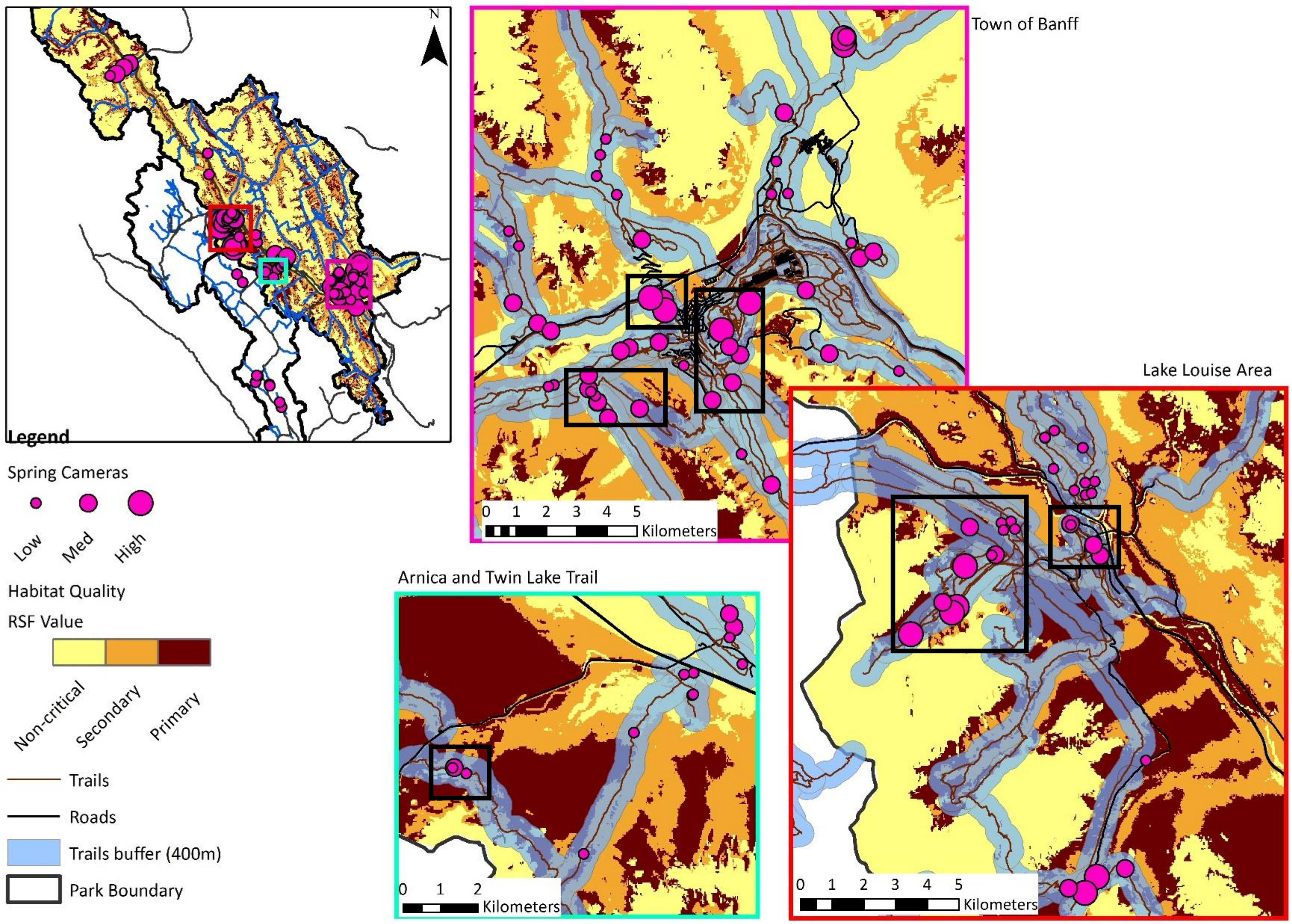


Figure 5.2. Interdisciplinary map identifying areas of focus for grizzly bear management actions during the spring. Human use level was defined by remote camera generated data (low, medium, high); trails were surrounded by a 400m zone of influence buffer. Areas of focus were defined as containing high quality habitat and a high level of human use; designated by black squares.

ones that were in high quality habitat and experienced medium or high levels of human use. Most high levels of human use in the spring occur near the towns of Banff and Lake Louise. Suggested areas for management focus are: the Pipestone and Tramline to Lake Louise trail networks near the village of Lake Louise; Arnica Lake trail; and the Bow River Hoodoos, Fenland/Vermilion Lakes and Cave and Basin trail networks near the town of Banff. All of these areas, with the exception of Arnica Lake, are already a focus of management action in the spring; the map produced from my thesis research lends quantitative, interdisciplinary support to these management efforts. This approach could be applied to other protected areas where carnivores and recreationists frequent the same areas; the most important components requires for this type of spatial analysis are a measure of human use and a measure of carnivore habitat quality.

From the perspective of a grizzly bear, management in my study area should focus on two prongs: 1) ensuring bears that avoid human use areas have adequate access to alternative high quality forage locations, which is essentially habitat security, and 2) ensuring that bears who do select habitat close to human use areas do not have negative encounters with people, which can lead to increased likelihood of mortality. All of the management actions described below can be applied in the focus areas identified in Figure 5.2 during the spring, but are also relevant to other areas throughout the year.

5.1.2.1 Increasing grizzly bear habitat security. As human densities continue to rise across the globe, carnivore populations can be expected to decline; for grizzly bears as little as 4.2 resident people/km^2 may lead to local population declines inside and outside of protected areas (Woodroffe, 2000). While this figure places the urgency of grizzly bear conservation into an international context, human density alone is a poor predictor of carnivore extinction (Woodroffe, 2000) and other factors are at play. My research clearly showed one of these factors is the level of individual variation among bears; not all bears use high quality habitat near human use areas but some do. All individual bears are an important part of the population, however, and have potential to contribute to overall provincial population growth. Previous research has used the concept of habitat security to define parts of my study area where high quality habitat exists in the relative absence of people (Gibeau et al., 2000). These areas are still critical for the success of this grizzly bear population, but my data from remote cameras show there are few areas of the park that do not experience medium or high levels of human use. I suggest that my human use model be used to examine how the percentage of secure areas in bear home ranges has changed with increasing numbers of visitors to BNP in the last 15 years. This map should also be extended to include JNP, YNP, and KNP. Given the significant seasonal differences in grizzly bear habitat use that I found, habitat security maps may be most applicable if they are developed for spring, summer, and fall separately. In west-central Alberta grizzly bear females with offspring were found closer to roads in the spring, which was attributed to early herbaceous vegetation and could lead to increased mortality (Graham & Stenhouse, 2010; Roever et al., 2006). The areas of focus identified in Figure 5.2 should be closed or subject to human use restrictions (e.g., trail opening times) in the spring to ensure grizzly bears have continued access to high quality habitat at a time of year when alternative forage may not be available and the chances of human encounter is higher than in other seasons.

Due to the high level of individual variation demonstrated in my research results, it would be ideal to develop habitat security models for individual bear home ranges. This would not, however, be feasible from either a cost or human capacity perspective. The grizzly bears that have been equipped with GPS collars inhabit areas with the highest human use levels in these National Parks. The GPS data and my results from the SSF can be used to identify individuals that avoid human use features. I recommend focusing efforts to ensure these individual bears have access to high security habitat within their home ranges.

Managers may also benefit from considering habitat security temporally as well as spatially. I found little difference in grizzly bear steps between day and night, but the threshold analysis did find bears were more likely to use trails before eight human events occurred that day. Despite higher levels of human activity during the day, bears in my study did not become nocturnal in an effort to avoid people. This may suggest that human activity levels in the National Parks is not high enough to disrupt typical diurnal activity (Munro et al., 2006). Therefore extending the period of human inactivity in areas of high habitat quality, particularly in the spring in the focus areas identified, may be beneficial to some bears with lower tolerance of human use levels. This could be done by implementing trail opening times on certain trails seasonally. Support for this management approach was lower than for other options, likely in part because trail users did not understand why it would be effective and what it would accomplish. Implementing this management action should be accompanied by educational materials explaining the scientific data and rationale behind the decision. Grizzly bears are capable of learning human use patterns and adjusting their behaviour accordingly, but this may not happen immediately. Therefore, actions such as implementing trail opening times should be monitored over several years before their effectiveness is determined.

5.1.2.2 Preventing negative encounters. How a person and how a bear reacts during an encounter will determine whether the outcome is negative or neutral. A negative encounter can be where a person feels threatened or is attacked by a bear, both of which could result in management action to aversively condition, relocate, or destroy the bear to protect people. People can also, however, have a positive encounter with a bear if they gain an increased appreciation for this threatened species or even feel fortunate to have seen a bear in its natural habitat (Dubois & Fraser, 2013; Eriksson et al., 2015). Grizzly bear management typically aims to reduce the potential for a negative encounter.

As in many North American protected areas, grizzly bears in BNP, JNP, KNP, and YNP inhabit an area with abundant human use. The type of human use and intensity are frequently much lower than the surrounding landscape, however, and grizzly bears have potentially learned that they can access habitat close to human developments with little risk to their immediate survival. Any bear that becomes habituated or tolerant of human activity can eventually become a management problem or risk to human safety (Weaver et al., 1996), but only females with cubs risk passing these behaviours on to their offspring. Females teach cubs various behaviours and home range attributes necessary to survival, such as the location of foraging locations and mechanisms to access forage (Gilbert, 1999; Noyce & Garshelis, 2014). Closing the trail when a female and cubs are in the area is advised to avoid cubs from becoming habituated, which can be important to reducing mortality if those cubs disperse outside of the National Park boundaries as subadults. This management action was also highly supported by trail users from all demographic groups and is applicable to other protected areas in North America where grizzly bears and people share space.

Bears are capable of learning, and this impacts how they relate to people and how they use habitat within their home ranges. Black bears have been found to take social cues from conspecifics to learn where seasonal forage is located (Noyce & Garshelis, 2014), and also have capacity for spatial memory when in competition with conspecifics (Zamisch & Vonk, 2012). Grizzly bears have been shown to change their habitat use based on human use patterns, potentially becoming more nocturnal to avoid people (Klinka & Reimchen 2002; Northrup et al., 2012b; Smith 2002), or exploiting habitats based on the predictability of human use (Chi & Gilbert, 1999; Nevin & Gilbert, 2005a,b). This plasticity in behavioural response to people may extend back to the early 1900s when early explorers recorded grizzly bears attacks declining and bears acting with “more discretion and less valor toward man” (Warren 1910 as cited in Sandy, 2012). It is therefore possible that bears residing in some protected areas have learned that their immediate mortality risk by accessing habitat near trails is low. I am suggesting that bears in my study area have learned to select and use habitats in ways that reduce the chances of a negative encounter with people. This is slightly different from habituation as I am not suggesting the bear does not have a response to human presence, but that it does not view people as a threat; in other areas this has been referred to as tolerance (Herrero et al., 2005). This allows the bear to access habitat in areas of high human use, trading off the higher physiological costs for access to high quality habitat. This learning is difficult to measure or prove in a wild setting but warrants further investigation, particularly since this population has been studied over several decades and data exists for multiple generations of bears.

Managing people and measuring that success is much more possible. In an encounter with a bear, how a person reacts and what behaviours they are engaged in can directly impact the outcome of that encounter (Penteriani et al., 2015). It is the responsibility of trail users to take precautions to prevent negative encounters, such as keeping their dog on a leash, recreating in groups, making noise on the trail, and carrying bear spray. It is also the responsibility of the trail user to understand how their behaviour during an encounter could impact the outcome; trail users should know to walk away slowly and leave the area when they see a grizzly bear. Not all trail users recreating in my study were aware of these things, however, particularly since the majority of them did not live in areas with bears and potentially had little experience with these large carnivores. Direct experience is one way for people to learn more about bears and how to stay safe during an encounter, but this could negatively impact their attitude towards bears if they are not equipped (Eriksson et al., 2015). Signage informing trail users that there is a bear in the area should share information on how to prevent encounters and how to behave during an encounter. Reducing human-wildlife conflict requires changes in the behaviour of people (Treves & Karanth, 2003), as much as managing the behaviour or habitat use of wildlife. Currently, all visitors to the park who pass through the park gates receive a brochure on recreating in bear country that contains some of this information. The majority of information available to visitors, however, focuses on how to prevent an encounter. In addition, a brochure handed to a visitor along with maps and other information may not necessarily be read. While delivering surveys at trailheads, many trail users asked myself or other members of the research team for advice on how to behave during an encounter. This information should be available at all trail heads. By educating people how to behave in grizzly bear habitat and ensuring management action allows non-tolerant bears access to adequate forage, we can be managing for true coexistence between people and bears.

5.2 The Risks of Coexistence

Some grizzly bears in the Rocky Mountain National Parks occupy home ranges that extend beyond the boundaries of these protected areas. Likely one of the biggest challenge facing Alberta grizzly bears is the diversity of jurisdictions that manage their habitat: Parks Canada is responsible for managing federal lands, Alberta Environment and Parks manages provincial parks and other public lands, and private lands are managed by the land owner. How a grizzly bear is managed in these different jurisdictions can vary. For example, Alberta Environment and Parks captures grizzly bears that have been involved in conflict situations on public lands, such as causing property damage or killing livestock, and relocates them to other Bear Management Areas in the province (Alberta Environment and Parks, 2016). Conversely, Parks Canada, does not relocate grizzly bears at all and uses aversive conditioning to prevent grizzly bears from accessing resources near people. Natural grizzly bear dispersal, which is required for provincial population recovery, can lead to human-bear conflict in areas where management approaches may not be tolerant of human-bear coexistence. In these areas, biological sciences alone cannot provide a complete understanding of or solutions to conflict; half of the challenge in addressing human-wildlife conflict is in understanding and working with the human dimension (Madden, 2004). It is too simplistic to utilize linear relationships to score habitat quality and trail user expectations of where and what kinds of management should occur. The reality is that there is no clear "winner" in these situations (Shanley et al., 2013). Recreationists will need to make some sacrifices, just as bears will need to adjust their habitat use.

Subadult grizzly bears are most likely to disperse across the National Park boundary. This age/sex class has the highest levels of human-caused mortality in British Columbia (McLellan, 2015) and Alberta; but McLellan and Hovey (2001) found no clear relationship between the survival of young bears and their tendency to disperse. This may be more directly related to where they disperse from and to. In the case of my study area, grizzly bears are dispersing from a highly protected landscape without motorized recreation or industrial activity to an unprotected landscape with a higher road density and higher intensity of human activity (e.g., motorized recreation and industrial activity). Bears dispersing into areas with human settlement have higher rates of mortality (McLellan & Hovey, 2001). If a subadult has been raised by a female who selected habitat nearer to roads and trails, it follows this bear may seek similar habitats when it disperses. Subadults that spend more time moving around roads had a higher chance of being killed (Kite et al., 2016). This issue is compounded if a subadult bear has learned that people do not represent a large threat from years of living in the national parks. The mortality risk to these individuals increases when they leave the boundaries of the protected areas, but their survival has implications for the provincial recovery of the species.

This dynamic highlights the need for interagency, multi-stakeholder cooperation in grizzly bear management. The interagency grizzly bear committee (IGBC) in the United States is a multi-stakeholder group coordinating grizzly bear population recovery policy, planning, management and research that formed in 1983 to recover grizzly bears in the lower 48 States. The IGBC consists of representatives from the US Forest Service, the National Park Service, the

US Fish and Wildlife Service, the Bureau of Land Management, the US Geologic Survey, state wildlife agencies, and some Native American Tribes with grizzly bear habitat (IGBC, 2016). By working collaboratively between agencies and, in many cases, with landowners, the Yellowstone grizzly bear population exceeded recovery goals and has been recommended for delisting from the Federal Endangered Species Act (IGBC, 2016). No such formal collaborative exists in Canada.

Within Alberta, interagency cooperation should include Parks Canada and Alberta Environment and Parks, as well as private land owners, industrial stakeholders, and First Nations Governments. Only by working and planning together can mortality across jurisdictional boundaries be reduced for those bears living at the interface between federal and provincial land. The interdisciplinary problem solving workshops described in Rutherford et al. (2009) instigated this type of collaboration in my study area and were successful in improving communication within the local community; these efforts should be expanded to include multiple locations inside and outside of the national parks (Rutherford, et al. 2009). Having local people involved in defining their values associated with management dilemmas is important as they are the ones most heavily affected by policy development (Plummer & Fennell, 2009). Workshops should aim to find common ground in grizzly bear management between jurisdictions while involving all relevant stakeholders. Based on my research findings, I also recommend that visiting or foreign trail users be represented in these processes. These processes should embrace adaptive management, monitoring the effectiveness of applications, recognizing that sometimes mistakes will be made and actions will require improvement. Adaptive management is the answer to the inherent uncertainty of managing complex systems as it focuses on experimentation and learning from feedback (Plummer & Fennell, 2009); it is also more proactive in using research, best practices and other resources, and can be more assertive in learning about, developing, and implementing solutions (Madden, 2004).

Management agencies are influenced by people living and using the landscape they manage, and local attitudes towards carnivores strongly influence policies put in place that prioritize coexistence (Woodroffe, 2000). Education can be used to increase tolerance of grizzly bears on public and private lands outside of the national parks. Interagency management is not only about managing bears and human activity, but also managing educational messaging and awareness. It is important that human behaviour in this complex landscape is similar across jurisdictional boundaries. Joint education between Parks Canada and Alberta Environment and Parks can work collaboratively to target recreationists and people using bear habitat. People who engage in forms of recreation supported in the National Parks (e.g., hiking, mountain biking, climbing) should have the same kind of information at their disposal when recreating in bear habitat outside of these protected areas. Tourists commonly want to behave in ways that ensure the least damage possible; informing them of the biologically-related appropriate behaviours and the reasoning behind them can reduce negative impacts of recreationists on wildlife (Granquist et al., 2016). This can be accomplished through joint educational programs and materials created and distributed by Parks Canada and Alberta Environment and Parks.Emphasis should be placed on how to prevent a negative encounter, such as portable electric fencing around clean camps, how to behave during an encounter, how to use bear spray (McLellan, 2015), and having dogs on leash or leaving the area (Penteriani et al. 2016). Part of the objective of this recommendation is to communicate to Alberta trail users that bears are crossing interjurisdictional boundaries and potentially being treated differently on either side of a human-created line on a map. This increased public awareness may lead to an increased understanding of the complexities associated with grizzly bear management inside and outside of protected areas, which may in turn lead to increased public support for various difficult management decisions.

Grizzly bear habitat use in response to people is complex as is the human response to grizzly bears, which creates management challenges beyond the scope of this thesis and all of the literature reviewed in it. Taking a conservative and adaptive management approach is one way to cope with this high level of complexity and uncertainty. This may involve diversifying policies and practices, especially when uncertainty is high (Bormann & Kiester, 2004). Including social studies that define human motivation and responses as integral parts of the management or ecosystem being studied is another way to reduce uncertainty (Ludwig et al., 1993). Grizzly bears in Alberta are threatened and recovery is a provincial goal, but both male and female grizzly bears disperse gradually (McLellan &Hovey, 2001) and population recovery will be slow. Aldo Leopold, a forefather of conservation in North America, emphasized minimizing the effect of our interference with nature, believed that grizzly bears belonged on this landscape, and displayed an ecological conviction that humans ought to be humble in their relationship with the natural world (Davradou & Namkoong, 2001). I have combined biological and social aspects to contribute to this growing body of knowledge and influence grizzly bear management in the Rocky Mountain National Parks. Grizzly bears are individual, people are individual, and human use can take infinite forms and levels of intensity. It is this diversity that makes coexistence possible, but it is a provincially threatened grizzly bear population that makes it necessary.

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APPENDIX A: VOLUNTEER WORKSHOP AGENDA

Volunteer Training Day – Agenda

Date: July 14, 2013
Time: 10:00am – 3:00pm
Location: Theater, Cave and Basin, 311 Cave Ave., Banff

10:00 – Arrival and introductions

10:15 – Introduction to research project objectives and goals (Sarah Elmeligi)

10:45 – Bear Safety (Tina Barzo) and project safety measures (Sarah Elmeligi)

11:30 – Leave no Trace camping and hiking

12:00 – Q & A/ discussion

12:30 – Potluck Lunch (please bring a yummy dish to share with the team)

1:30 – Remote camera training

2:30 – Visitor survey training

3:30 – Wrap up and schedule sign up

We thought it might be fun to have a potluck for lunch, but participation is completely voluntary. Sarah is going to bring a large spinach salad. Please bring whatever you would like to contribute or bring your own lunch if you prefer.

Participation in this training in its entirety is mandatory, regardless of which volunteer team you are on. It's always good to know what the other team is doing and how their work fits into yours. We all need to be on the same page to ensure data collection consistency and our own safety.

If you cannot attend this training, please contact Sarah Elmeligi ([redacted]) and I will try to arrange an alternative.

APPENDIX B: PARKS CANADA RESEARCH PERMIT

PARKS CANADA AGENCY
RESEARCH AND COLLECTION PERMIT
(NOT TRANSFERABLE)

PERMIT No.: BAN-2013-14576

START DATE: 2013-06-25 **EXPIRY DATE** 2015-10-12

Project Title: Grizzly Bear and Human trail use in Banff, Yoho, Kootenay National Parks: Balancing Visitor Experience with Bear Habitat Requirements

Principal Investigator Name: Elmeligi, Sarah, Miss.

Address: [redacted]

Telephone: [redacted]

Email: sarah.elmeligi@cqumail.com

Affiliation: Central Queensland University, School of Graduate Research. Rockhampton, Australia

Is hereby authorized to conduct the research project entitled "Grizzly Bear and Human trail use in Banff, Yoho, Kootenay National Parks: Balancing Visitor Experience with Bear Habitat Requirements " , Research and Collection Permit Application Number 17630, In Banff National Park of Canada, subject to the terms and conditions set out below and/or attached to and forming part of this Research and Collection Permit.

Members of Research Team:

Associate Professor Owen T Nevin Dean, School of Graduate Research CQUniversity Bryan Jordan Drive Gladstone, 4680 AUSTRALIA TEL: +61 (0)7 4970 7324 FAX: +61 (0)7 4970 7345 MOB: +61 [redacted] Email: o.nevin@cqu.edu.au www.cqu.edu.au David Gummer Ph.D. Wildlife Biologist | Biologiste de la faune Banff National Park of Canada | Parc national du Canada Banff Parks Canada | Parcs Canada P.O. Box 900, Banff AB T1L 1K2 | C.P. 900, Banff AB T1L 1K2 david.gummer@pc.gc.ca Telephone | Téléphone 403-762-1402 Facsimile | Télécopieur 403-762-3240 Government of Canada | Gouvernement du Canada Gordon B. Stenhouse Research Scientist and Program Leader Foothills Research Institute Grizzly Bear Program Box 6330 Hinton Alberta T7V 1X7 (780) 865-8388 FAX (780) 865-8331 gstenhouse@foothillsri.ca Dr Ian Convery Reader

in Conservation & Forestry Chair of the University Ethics Panel National School of Forestry University of Cumbria CA11 0AH Tel:01768 893570 Dave Swain Senior Research Fellow Centre for Environmental Management (CEM) CQIRP Building 361/G.44 CQUniversity Australia Ibis Avenue North Rockhampton QLD 4702 E-mail: d.swain@cqu.edu.au Tel: +61(0)7 4923 2564 Mobile: [redacted] Web Page: http://fseh.cqu.edu.au/FCWViewer/staff.do?site=100&sid=SWAIND

Additional PHA's involved

Issuing Authorities and Terms and Conditions:

Permit issued pursuant to:

National Parks General Regulations: Section(s) __7(5),__11(1); __14(2)

National Historic Parks General Regulations: Section(s) __3(2); __4(2); __12(3)

National Parks Wildlife Regulations: Section __15(1)(a)

National Historic Parks Wildlife and Domestic Animals Regulations: Section __5(1)

(Other applicable Act(s) or Regulations)

National General Conditions:

Failure to comply with applicable Heritage Area regulations or the conditions of the permit may constitute grounds to cancel or suspend the permit, refuse to issue future permits, and may be considered as grounds for prosecution under the applicable Act(s) or Regulation(s).

All permit holders must be in possession of a valid permit before the fieldwork commences and at other periods as stated on the permit.

Permits are not transferable and each member of the field work team must have a copy of the valid permit in their possession.

The permit is valid only for the geographic location, the time period, the activities, and under the terms and conditions described on the permit, unless amended and revalidated by the Superintendent.

Restrictions:

The Superintendent may suspend, cancel, or restrict the scope of the permit.

The permit shall cease to be valid if the fieldwork is not started within six months of the date of issue.

Other Acts and Regulations:

The Principal Investigator must abide by applicable regulations and all other federal, provincial, territorial or municipal regulations applying to the Heritage Area.

If requested by the Superintendent, an authorized Heritage Area staff member, or police constable, the Principal Investigator or any team member will identify themselves and show the permit.

Principal Investigator Responsibilities :

A site, or site component(s) that has been excavated or disturbed shall be restored or conserved by the Principal Investigator to the satisfaction of the Superintendent.

The Principal Investigator must advise the Research Coordinator of any adjustments in work location, research plan and methodology, implementation schedule, or main personnel, etc., during the course of the research.

Unless otherwise negotiated, Researchers working in a Heritage Area are required, as a condition of their permit, to submit:

a) A report of progress sixty (60) days following the completion of the field season, unless otherwise agreed with the Research Coordinator;

b) A final report, one (1) electronic copy and three (3) hard copies, no later than eight (8) months following the completion of the field season, unless otherwise agreed with the Research Coordinator;

c) Submission of an online Investigator's Annual Report (IAR) within one year of signing the permit. In the case of a multi-year permits, the principal investigator will submit an IAR for each year of the research.

The reporting requirements above do not replace any reporting requirements set out in any contract between Parks Canada and the Principal Investigator.

The Principal Investigator will be responsible for all members of their party. All field assistants must observe any general or specific conditions of the permit.

The Principal Investigator shall at all times indemnify and save harmless the Crown from and against all claims, demands, loss, costs, damages, actions, suits, or other proceedings, by whosoever made, sustained, brought or prosecuted, in any manner based upon, occasioned by, or attributable to, anything done or omitted by the Principal Investigator or the project personnel in the fulfillment or purported fulfillment of any of the conditions of the Permit.

General Conditions Governing Natural Science Research:

Any natural objects collected under authority of this permit remain the property of the Crown (Canada) and are considered on loan to the permit holder. Final disposition of natural objects must be as shown in the project proposal unless amended by the Superintendent. Export of objects or specimens require approval by the Superintendent and is subject to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Cultural Property Export and Import Act and the Export and Import Permits Act. Intention to export specimens must be indicated in the project proposal.

Only the natural objects or categories of natural objects indicated on the permit may be collected.

A detailed inventory of material collected will be provided to the Heritage Area prior to its removal by the researcher.

When fossils or evidence of previous human occupation are found, they should be reported to the Superintendent and must be left undisturbed until inspected by a Parks Canada palaeontologist or archaeologist.

Special Conditions:

General Conditions Governing Social Science Research

Special Conditions:

Use of Parks Canada data is subject to a no fee end-use restricted data licence agreement.
- Researchers are expected to follow Parks Canada protocols for image analysis and management.
- All researchers, volunteers and paper materials are to be prominently marked as Central Queensland University.
- Any complaints regarding conduct of this research be communicated by the researchers not only to Central Queensland University ethics committee but also Parks Canada contact David Gummer.
- Specific sampling schedule and locations (trails and GPS coordinates of cameras) be provided to Parks Canada contact David Gummer in advance of surveys, or in the case of final camera locations as soon as available (within 1 week, throughout the field season)
- Installation of up to 60 covert (infrared) remote cameras clearly labelled "Property of Central Queensland University for research under Parks Canada permit #"

Principal Investigator Signature

I, Elmeligi, Sarah, Miss. , the Project Principal Investigator, accept all the stated Research and Collection Permit terms and conditions.

[redacted]

16/05/14
Date (yyyy/mm/dd)

Approval:

Permit issued/approved by:

W. Hunt
~~Superintendent Name~~ (Please Print) Resource Conservation Manager

[redacted]
Superintendent Signature

16 May 2014
Date (yyyy/mm/dd)

Parks Canada Parcs Canada

Canadä

Parks Canada Contact

Susan Hairsine
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Parks Canada Parcs Canada

Canada

APPENDIX C: TRAIL USER SURVEY

Pre-Hike Survey –Grizzly Bear Habitat Use Research 2013

Section A: Bear-Awareness
This section is designed to determine how prepared hikers are in bear-country. Please answer the following questions honestly. You are not being judged for your answers and there are no wrong answers.

1. Have you ever seen a bear while hiking? Yes No

2. Have you seen a bear on this visit to the National Park? Yes No

3. Please say what steps you have taken to prepare for your hike today (check all that apply):
   - ☐ Consulted a website for current trail conditions
   - ☐ Consulted a website for current bear activity in the area
   - ☐ Spoke with a Parks Canada information officer about trail conditions
   - ☐ Spoke with a Parks Canada information officer about bear activity in the area
   - ☐ Spoke with friends about current trail conditions
   - ☐ Spoke with friends about current bear activity in the area
   - ☐ Am carrying bear spray that is not expired
   - ☐ Know how to use bear spray
   - ☐ Am carrying a first aid kit
   - ☐ Am carrying a satellite phone or other remote communication device (cell phone doesn't count)
   - ☐ Have arranged for a check-in person at the end of the hike
   - ☐ Other: ____

4. Please say what steps you intend to take to reduce your chance of an encounter with a bear (check all that apply):
   - ☐ Will keep my dog on leash
   - ☐ Will make noise on the trail
   - ☐ Will hike in a group
   - ☐ Other: ____

Section B: Visitor Support for Management Options
This National Park is managed for visitor experience and ecosystem protection. Finding this balance is sometimes challenging.

1. Imagine recent research data has provided information that there is a grizzly bear in the immediate vicinity of this trail you are planning to hike today. What, if anything, would you expect Parks Canada to do about it?
____
____.

2. Imagine it was known that a female grizzly bear with cubs was in the immediate vicinity of this trail you are planning to hike today. What, if anything would you expect Parks Canada to do about it?
____
____.

3. Imagine you arrived at this trail head and one of the following management actions had been taken because of a grizzly bear in the immediate vicinity of this hiking trail. Please say how supportive you would be of the following possible management options on a scale from -3 to +3 where -3 to -1 are not supportive, 0 is no opinion, and 1 to 3 represent support.

Bear in Area Management Action	NOT Supportive ←			No Opinion	Supportive →		
	-3	-2	-1	0	1	2	3
Trail closed until further notice							
Implementing trail opening times (e.g., trail only open from 9am-6pm)							
Group numbers limited to less than 8							
Number of hikers per day limited to 50							
A requirement for booking in advance to hike this trail							
No dogs being permitted on this trail							
Placing a warning sign of bear in area at the trailhead							
Re-route this hiking trail to avoid bear habitat							
Group numbers needing to be more than 4							
No management action required							
Actively remove the bear from the area (relocation)							
Park management should destroy the bear (euthanasia)							
Encourage human use on this trail							

4. How supportive of these same management options would you be if it was known that the bear in the area was a female grizzly with cubs? Use the same scale for your answers.

Bear in Area Management Action	NOT Supportive ←			No Opinion	Supportive →		
	-3	-2	-1	0	1	2	3
Trail closed until further notice							
Implementing trail opening times (e.g., trail only open from 9am-6pm)							
Group numbers limited to less than 8							
Number of hikers per day limited to 50							
A requirement for booking in advance to hike this trail							
No dogs being permitted on this trail							
Placing a warning sign of bear in area at the trailhead							
Re-route this hiking trail to avoid bear habitat							
Group numbers needing to be more than 4							
No management action required							
Actively remove the bear from the area (relocation)							
Park management should destroy the bear (euthanasia)							
Encourage human use on this trail							

5. Thinking about the options you were least supportive of, what justifications or explanations would you require from Parks Canada to increase your support?

____

____

____

6. Grizzly bears are a threatened species in Alberta. Using the same scale as above from -3 to +3, how much do you agree with this statement:

> *"Grizzly bear habitat use and recovery should take priority over human use in mountain parks."*

-3	-2	-1	0	1	2	3
Strongly Disagree	Disagree	Somewhat Disagree	No Opinion	Somewhat Agree	Agree	Strongly Agree

Section C: Demographic information:
This last section is going to ask you a few questions about you and your trip. None of these questions will be able to be used to identify you.

1. How long do you intend to stay on this trail?
   - ☐ One day
   - ☐ Three days
   - ☐ More than four days
   - ☐ Two days
   - ☐ Four days
2. If more than 1 day, what day of your trip is this? (1, 2, 3, 4, or 4+) _______
3. How long ago did you start planning to do this hike?
   - ☐ Hours ago
   - ☐ Days ago
   - ☐ Weeks ago
   - ☐ Months ago
4. What country do you reside in?
   - ☐ Canada
   - ☐ Other: _______________
   - ☐ United States
5. If Canadian, what city or town do you live in: ___________________________
6. How often do you visit the Rocky Mountain National Parks (Banff, Jasper, Kootenay, and Yoho)?
   - ☐ This is my first time
   - ☐ Weekly
   - ☐ Daily
   - ☐ Monthly
   - ☐ Annually
   - ☐ Less than once every 5 years
   - ☐ Less than once a year
   - ☐ Less than once every 10 years
7. Where are you staying while here?
   - ☐ Campground – tent
   - ☐ Friends' house
   - ☐ Campground – RV
   - ☐ Home
   - ☐ Hotel/Motel
   - ☐ Other: ____________________
   - ☐ Vacation condo rental
8. What is the primary reason for your visit to the Park today?

   ____
9. Sex:
   - ☐ Male
   - ☐ Female
10. Age category (circle one):

    18-25 26-35 36-45 46-55 56-65+

APPENDIX D: HUMAN ETHICS APPROVAL

Office of Research

CQUniversity AUSTRALIA

Secretary, Human Research Ethics Committee
Ph: 07 4923 2603
Fax: 07 4923 2600
Email: ethics@cqu.edu.au

A/Prof Owen Nevin
Ms Sarah Elmeligi
School of Graduate Research

11 April 2014

Dear A/Prof Nevin and Ms Elmeligi

HUMAN RESEARCH ETHICS COMMITTEE ETHICAL APPROVAL MODIFICATION TO PROJECT: H13/04-045
GRIZZLY BEAR HABITAT MANAGEMENT IN CANADA'S ROCKY MOUNTAIN PARKS: BALANCING VISITOR EXPERIENCE WITH BEAR HABITAT REQUIREMENTS

The Human Research Ethics Committee is an approved institutional ethics committee constituted in accord with guidelines formulated by the National Health and Medical Research Council (NHMRC) and governed by policies and procedures consistent with principles as contained in publications such as the joint Universities Australia and NHMRC *Australian Code for the Responsible Conduct of Research.* This is available at http://www.nhmrc.gov.au/publications/synopses/_files/r39.pdf.

On 20 May 2013, the Chair of the Human Research Ethics Committee considered your application under the Low Risk Review Process. This letter confirms that your project has been granted approval under this process, pending ratification by the full committee at its June 2013 meeting. On 10 April 2014, the Chair approved your request to modify this project by the inclusion of focus groups.

The period of ethics approval will be from 20 May 2013 to 12 October 2015. The approval number is H13/04-045; please quote this number in all dealings with the Committee. HREC wishes you well with the undertaking of the project and looks forward to receiving the final report.

The standard conditions of approval for this research project are that:

(a) you conduct the research project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments required to be made to the proposal by the Human Research Ethics Committee;

(b) you advise the Human Research Ethics Committee (email ethics@cqu.edu.au) immediately if any complaints are made, or expressions of concern are raised, or any other issue in relation to the project which may warrant review of ethics approval of the project. *(A written report detailing the adverse occurrence or unforeseen event must be submitted to the Committee Chair within one working day after the event.)*

(c) you make submission to the Human Research Ethics Committee for approval of any proposed variations or modifications to the approved project before making any such changes;

(d) you provide the Human Research Ethics Committee with a written "Annual Report" on each anniversary date of approval (for projects of greater than 12 months) and "Final Report" by no later than one (1) month after the approval expiry date; *(A copy of the reporting pro formas may be obtained from the Human Research Ethics Committee Secretary, Sue Evans please contact at the telephone or email given on the first page.)*

(e) you accept that the Human Research Ethics Committee reserves the right to conduct scheduled or random inspections to confirm that the project is being conducted in accordance to its approval. Inspections may include asking questions of the research team, inspecting all consent documents and records and being guided through any physical experiments associated with the project

(f) if the research project is discontinued, you advise the Committee in writing within five (5) working days of the discontinuation;

(g) A copy of the Statement of Findings is provided to the Human Research Ethics Committee when it is forwarded to participants.

Please note that failure to comply with the conditions of approval and the *National Statement on Ethical Conduct in Human Research* may result in withdrawal of approval for the project.

You are required to advise the Secretary in writing within five (5) working days if this project does not proceed for any reason. In the event that you require an extension of ethics approval for this project, please make written application in advance of the end-date of this approval. The research cannot continue beyond the end date of approval unless the Committee has granted an extension of ethics approval. Extensions of approval cannot be granted retrospectively. Should you need an extension but not apply for this before the end-date of the approval then a full new application for approval must be submitted to the Secretary for the Committee to consider.

The Human Research Ethics Committee wishes to support researchers in achieving positive research outcomes. If you have issues where the Human Research Ethics Committee may be of assistance or have any queries in relation to this approval please do not hesitate to contact the Secretary, Sue Evans or myself.

Yours sincerely,

[redacted]

Professor Phillip Ebrall
Chair, Human Research Ethics Committee

Cc: *Project file*

Approved

APPENDIX E: SURVEY PREAMBLE INVITING PARTICIPATION

Good morning,

I am representative of a research team from Central Queensland University studying grizzly bear habitat use in Banff National Park. This interdisciplinary research represents a partnership between CQU in Australia and a new non-profit organization called Grizzly Research in the Rockies (GRR) based out of Canmore. **The overall objective of this study is to increase understanding of grizzly bear habitat use adjacent to hiking trails while simultaneously improving understanding about hikers' expectations.** This research is NOT being conducted by Parks Canada, but we do have a research permit to be here.

This trail has been randomly selected for data collection today. **We are asking hikers to participate in this research study by completing a short survey** focusing on management options for grizzly bears in this part of the park.

This research is being undertaken by a graduate student at Central Queensland University, who is also the lead researcher of Research in the Rockies.

The survey should take approximately 15 minutes to complete and **is entirely voluntary. If you would like to withdraw, you may absolutely do so at any time**. Other than a slight loss of your time, we do not anticipate any risk associated with this research, but do believe that there will be notable benefits. The information you provide in this survey will be used to create management recommendations to help conserve grizzly bears while ensuring a positive visitor experience in the mountain parks.

Your responses are completely confidential, will be kept anonymous, and we will not be recording your identity. Completed surveys will be stored in a locked storage cabinet for five years, after which they will be shredded. Only the principal investigator (Sarah Elmeligi) will have access to this raw data.

A summary of the research results will be posted on the GRR blog at the end of the research period. Should you want more information or a summary of the survey results sent to you, **you can contact Grizzly Research in the Rockies or Sarah Elmeligi** with the information on this card. **If you have any concerns, the contact information for CQUniversity's Office of Research is on the other side of the card.**

Do you consent to participating in this survey today?