GRIZZLY BEAR AND HUMAN INTERACTION IN YELLOWSTONE NATIONAL

PARK, BEAR MANAGEMENT AREAS

by

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APPROVAL

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This dissertation has been read by each member of the dissertation committee and has been found to be satisfactory regarding content, English usage, format, citation, bibliographic style, and consistency and is ready for submission to The Graduate School.

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ABSTRACT

In 1982 Yellowstone National Park, WY, USA created a Bear Management Area (BMA) program. The objective of the BMA program was to minimize human-bear conflict by separating bears from people in areas of the Park where overlap may occur. This was accomplished primarily through area closures, trail closures, and backcountry campsite closures. Our objective was to evaluate the interaction between grizzly bears and people and use the results to test the effectiveness of the BMA program. From 2007 to 2009, we obtained fine scale human and grizzly bear GPS data in 6 of 16 BMAs. To determine how grizzly bears responded to close interactions with people, we evaluated the GPS locations of bears and people in close proximity. We found that bears consistently avoided human interaction and often showed an avoidance response to people at close distances. We also evaluated spatiotemporal patterns of bear and human movements during times when BMAs were restricted (closed to human use) and unrestricted (open to human use). Through the comparison of the two time periods we found that bears continued to avoid people on a large scale. Furthermore, a significant amount of overlap between people and bears would occur if BMA restrictions were not in place. We also evaluated the effectiveness of backcountry campsite closures by testing if grizzly bears were attracted to, or avoiding occupied backcountry camps. We found that grizzly bears were attracted to the location of backcountry campsites, however there was a strong avoidance when these sites were occupied by people. Finally, we evaluated the behavioral and activity adaptations of bears occupying areas frequently used by people. We found that bears were primarily more night active and less day active when near areas that humans use. In addition, we found that if BMA restrictions did not exist, we could expect overlap between bears and people when both were highly active. Overall, our results suggest that grizzly bears consistently avoid contact with humans and that the BMA program in Yellowstone National Park is effective at reducing human-bear overlap, potential conflict, and reducing displacement of bears by humans.

CHAPTER ONE

INTRODUCTION TO DISSERTATION

Overview of Dissertation

Yellowstone National Park (YNP) has a long history with human-bear conflict

and interaction (Schullery 1992, Gunther 1994, Wondrack-Biel 2006). Starting in the

early 1900s black bears (Ursus americanus) and grizzly bears (Ursus acros) in YNP had

unrestricted access to human foods and garbage. Black bears often received handouts on

roadsides and other developed areas, while grizzly bears frequented open pit dumps

where people discarded garbage and foods scraps. In 1960, YNP implemented a bear

management program to help reduce the risk of human injuries caused by food-

conditioned bears (*sensu* Hopkins et al. 2010). The program helped reduce the exposure

of bears to human foods. Nevertheless, a number of open pit garbage dumps were still

located within park boundaries and surrounding areas. Therefore, a substantial number of

grizzly bears within YNP remained food-conditioned throughout the 1960s. In 1970,

YNP closed all open pit garbage dumps within park boundaries, via executive order

(Gunther 1994). This action essentially cut off all bears from human foods.

Subsequently a large number of food-conditioned grizzly bears were removed from the

population because of nuisance behavior and the potential threat to human safety

(Gunther 1994). Consequently, the grizzly bear population in YNP declined throughout

the 1970s and into the early 1980s. By the early 1980s it was suspected that most of the

grizzly bears that were conditioned to eating at garbage dumps had been removed from

the population (Meagher and Phillips 1983). At that time, YNP began to place more emphasis on proactive management, in part, by protecting grizzly bear habitat and natural food sources (Gunther 1994). Many of these proactive management plans were outlined in the 1982 Grizzly Bear Management, Environmental Impact Statement (EIS) (National Park Service 1982). One of the key provisions of the 1982 EIS was the creation of Bear Management Areas (BMAs). The BMA program restricted human access to portions of YNP with high seasonal concentrations of bears or bear foods. Sixteen different areas were delineated and included area closures, backcountry campsites closures and other restrictions designed to reduce human-bear overlap. Since 1982 little research has been done to study the effectiveness of the program. Our objective was to research human and bear interaction in 6 of the 16 BMAs to determine of the rules and regulations implemented in the 1982 EIS were still effective at reducing human-bear conflict and overlap.

Between 2007 and 2009 we collected fine scale spatiotemporal data of grizzly bears and humans to address our research questions. We utilized the GPS radio collar data of a sample of grizzly bears utilizing the 6 study area BMAs. In addition, we tracked human use and movement by randomly sampling human users and providing hand-held GPS units to people. We instructed all human users to track their movements throughout the BMAs and record times when they arrived and departed designated backcountry campsites. Our study area consisted of BMAs with distinct management restrictions, however we determined that people were generally absent or present in two time periods. People were primarily absent prior to July 1, and present on the landscape

after July 1, each year. These two time periods allowed us to compare and contrast bear behavior when people were absent or present, in the same areas. This comparison allowed us to evaluate what may occur if BMA rules did not exist and helped determine if BMAs were effectively separating people and bears in space and time.

In Chapter Two, I evaluated the landscape level patterns of use by people and bears to determine how the two interact, and what may occur if people were allowed access during times currently restricted to human use. I established an area of human use by utilizing the human GPS sample and creating a Human Recreation Area. I evaluated how bears behave around the Human Recreation Area when people are absent and present on the landscape. This analysis provided insight into what type of overlap may occur if BMA rules were lifted.

In Chapter Three, I evaluated the effect of overnight backcountry camping on bear movement and behavior. This analysis was done to determine if backcountry campsite closures prevented displacement of bears from foraging opportunities and other behaviors. I investigated if bears were primarily attracted to, or deterred by, backcountry campsites when occupied by people.

In Chapter Four, I evaluated the direct responses of bears to the presence of people. I isolated circumstances where bears and people were in very close proximity at the same place and time. We determined that bears showed a strong avoidance response to the presence of people in close proximity. This response occurred regardless of any additional environmental covariates.

In Chapter Five, I investigated what occurs when bears do not respond to the presence of people and choose to occupy areas near consistent human use. We did this to determine what type of behavioral adaptions bears use to adjust to the presence of people and determine how bear behavior may change if BMAs did not exist.

In Chapter Six, I provide general conclusions and discuss how the research results relate to Yellowstone National Park, Bear Management Area program.

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CHAPTER TWO

GRIZZLY BEAR AND HUMAN INTERACTION IN YELLOWSTONE NATIONAL
PARK; AN EVALUATION OF BEAR MANAGEMENT AREAS

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4, and 5

Author: Tyler H. Coleman

Contributions: Conceived and implemented the study design. Collected and analyzed
data. Wrote first draft of the manuscript.

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Contributions: Helped conceive the study design. Provided feedback on statistical
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Contributions: Provided feedback on the study design. Provided statistical advice and
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Manuscript Information Page

Abstract

In 1982 Yellowstone National Park officials created a program to protect Threatened grizzly bears (*Ursus arctos*) from human disturbance. The program delineated areas of the park where human recreation was closed or restricted. These places were referred to as Bear Management Areas, and they currently cover 21% of Yellowstone National Park. The program goal was to allow bears unhindered foraging opportunities, decrease the risk of habituation, and provide safety for backcountry users. The objective of this study was to evaluate these closures and determine if they were effective at limiting human-bear interaction. We evaluated 6 of 16 Bear Management Areas and compared human and bear interaction during dates when they were restricted to dates when they were unrestricted. We used Global Positioning System data for humans and bears to determine if human presence influenced bear activity and what might occur if Bear Management Areas did not restrict human access. We used data collected during dates when people were allowed access to the Bear Management Areas and created a Human Recreation Area layer. We also established times when people were likely to be active and inactive. We applied this spatiotemporal layer to bear location data and evaluated bear behavior when people were present and absent. We found that grizzly bears were twice as likely to be within the Human Recreation Area when Bear Management Areas were restricted and people were mostly off the landscape. We also found that grizzly bears were more than twice as likely to be within the Human Recreation Area when Bear Management Areas were unrestricted but people were inactive. Our results suggest that human presence can displace grizzly bears. We also

found that grizzly bears and humans will have an increase in overlap if people are allowed unrestricted access to the 6 Bear Management Areas in our study. Our study provides evidence for Yellowstone National Park managers that the current Bear Management Area program is adequate at providing space for grizzly bears while allowing people adequate recreational opportunities.

Keywords: Bear management, human-bear interaction, displacement, Global Positioning System (GPS), grizzly bear, recreation, *Ursus arctos*, Yellowstone National Park.

Introduction

Interaction between grizzly bears (*Ursus arctos*) and people have been an issue of great importance since the creation of Yellowstone National Park in 1872. For much of the early park history, bears were allowed access to human foods either through direct handouts, public feedings, or unrestricted access to garbage dumps (Schullery 1992, Wondrack-Biel 2006). This misguided philosophy led to numerous bear-caused human injuries (Gunther 1994). In the 1960s and early 1970s the National Park Service and collaborating wildlife researchers began a more active role in bear management. This marked the transition of bears from a diet consisting of human foods to a diet based on natural foods (Meager and Phillips 1983, Gunther 1994, Haroldson et al. 2008). By 1970 all open pit garbage dumps on federal lands were ordered to be closed, via executive order. In the following years (1970-1979) many food conditioned bears were removed from Yellowstone Park and surrounding areas by state and federal agencies (Gunther 1994, Haroldson et al. 2008). This difficult transition led to critically low grizzly bear

numbers and in 1975 prompted the U.S. Fish and Wildlife Service to list grizzly bears in

the lower 48 states as "threatened" under the Endangered Species Act (USFWS 1993). In

the subsequent years Yellowstone National Park (hereafter, Yellowstone Park) began to

implement policies to provide additional protection for bears that reside within park

boundaries. A synthesis of these management actions was compiled in the 1982 U. S.

National Park Service-Grizzly Bear Management, Environmental Impact Statement (EIS)

(National Park Service 1982).

The objective of the Grizzly Bear Management EIS was to establish rules and

guidelines for managing threatened grizzly bears within Yellowstone Park.

Consequently, the EIS outlined a plan for preserving critical grizzly bear habitat and

proactively preventing human-bear conflict. The plan followed guidelines established by

Craighead (1980) and involved setting aside special areas of the park that were thought to

be critical for grizzly bear recovery. These areas were referred to as Bear Management

Areas (BMAs). Sixteen individual BMAs were identified and are still in place today.

Bear Management Areas comprise 188,032 hectares (21%) of Yellowstone Park and have

unique management guidelines (Gunther 2003). Mostly designed for the backcountry,

BMAs seasonally restrict recreation in pre-determined areas of Yellowstone Park with

high seasonal concentrations of grizzly bears and bear foods. As outlined in the EIS, the

goals behind the BMA restrictions were to: 1) minimize bear-human interactions that

may lead to habituation of bears to people, 2) prevent human-caused displacement of

bears from prime food sources, and 3) decrease the risk of bear-caused human injury in

areas with high levels of bear activity (National Park Service 1982).

Several BMAs were designed to allow bears specific foraging opportunities on seasonally available food items such as spawning Yellowstone cutthroat trout (*Oncorhynchus clarki*), whitebark pine nuts (*Pinus albicaulis*) and winter-killed elk (*Cervus elaphus*) and bison (*Bison bison*) (Kendall 1983, Mattson et al. 1991, Mattson 1997, Felicetti et al. 2003). These protein-rich foods have changed in abundance and distribution since BMA boundaries and restrictions were implemented in 1982 (Koel et al. 2005, Haroldson et al. 2005, Gibson 2007, Creel 2010, Haroldson and Podruzny 2010). Changes to key bear foods and bear habitat have been the result of extensive wild fires in 1988, the reintroduction of gray wolves (*Canis lupus*) influencing ungulate numbers and distribution, the introduction of non-native lake trout (*Salvelinus namaychush*) decimating spawning cutthroat (*Oncorhynchus clarki*) trout in Yellowstone Lake and extensive whitebark pine (*Pinus albicaulis*) mortality from mountain pine beetles (*Dendroctonus ponderosae*) (Haroldson et al. 2005, Koel et al. 2005, Gibson 2007, Creel 2010, Romme et al. 2011). Furthermore, park visitation has increased in the last 30 years and consequently recreational use has increased in BMAs (National Park Service 2012). Overnight backcountry use has increased slightly from an average of 39,380 people user nights (PUN) during the 1980s, to 40,362 PUNs during the first decade of the 2000s. Overall park visitation was 2.3 million visitors per year during the 1980s, and has since increased to over 3 million visitors per year during the first decade of the 2000s (National Park Service 2012). Changes to bear foods and bear habitat in combination with increasing visitation has created different conditions for the 30 year old BMA program. Therefore, it is undetermined if the current BMA restrictions are still

adequate at providing seasonal foraging opportunities for bears while allowing reasonable access for an increasing number of recreational users, or if the new conditions have created the need for different regulations.

Since their creation few attempts have been made to research BMAs or provide quantitative information about their effectiveness. One research project in the mid 1980s (Gunther 1990) offered empirical evidence for the importance and effectiveness of the BMA program.   The results suggested that area closures and time of day restrictions were effective at limiting human-bear conflict and were essential for maintaining the three primary goals of BMAs. The study consisted of a lone observer evaluating human-bear interaction in an open valley from a central lookout. It was hampered by the inability to observe during times of poor visibility, during low light conditions and in areas that were impossible to view. Further research has evaluated bear habitat within Yellowstone Park and considered the potential impact of human developments and roads (Mattson et al. 1987). However, few projects have focused on the impact of backcountry recreation, particularly non-consumptive or non-motorized recreation in areas with only occasional human use. When human recreation is considered, researchers often fail to adequately measure and understand fine scale human recreational patterns in prime bear habitat. Outside of Yellowstone Park, studies of the recreational impact on bear populations often focus on one particular resource or one commonly used area, such as a coastal spawning stream (Jope 1985, Gunther 1990, Tollefson et al. 2005, Rode et al. 2006, Rode et al. 2007). Other studies have focused solely on the impact of consumptive or motorized recreation, such as off-road vehicles, hunting and snowmobiles (Mace et al. 1996, Graves

2002, Mclellean and Shakleton 1989, Podruzny et al. 2002, Johnson et al. 2005). Furthermore, many wildlife research projects have been limited by the use of very high frequency radio collars which provide a crude location and often restrict data collection to daylight hours and only a few days per month (Hebblewhite et al. 2010, Urbano et al. 2010). There has been a lack of studies which utilize Global Positioning System (GPS) technology to research the influence of non-consumptive recreation on a threatened bear population in a wilderness setting.

As part of a comprehensive study to research the behavior and diet of grizzly bears in the Yellowstone Lake area of Yellowstone Park, we had the opportunity to evaluate human-bear interaction in 6 of 16 BMAs and also evaluate the potential effects of non-consumptive human recreation on a grizzly bear population. The collection of GPS data of bears and people allowed us to assess the potential influence of wilderness recreation on bear behavior. It also allowed us to determine if the recreational restrictions of 6 selected BMAs were effective at separating grizzly bears and people in space and time. Ultimately these data helped provide information to determine if the current BMA rules meet the 3 criteria set out in the 1982 NPS Grizzly Bear Environmental Impact Statement.

One important factor of this study is that we wanted to determine the location and frequency of potential human-grizzly bear interactions in BMAs if regulations were not in place and people were allowed to recreate freely. Due to safety concerns we were unable to provide access to recreational users in the study area BMAs during dates when they were normally restricted. Therefore, we collected data on human recreation patterns

while BMAs were unrestricted and applied what we learned to the same BMAs during the restricted time periods. A comparison of bear movement patterns to projected recreation patterns allowed us to examine what type of human-bear interaction may occur if BMA restrictions were not in place and people were allowed unrestricted access.

Annual park visitation, recreational trends, weather conditions, food availability and daily bear activity may play a role in the seasonal distribution of grizzly bears in Yellowstone Park. Park visitation and trail use is low in the spring and early summer, high in mid-summer and low again in the autumn (National Park Service 2012). This may influence bear distribution because grizzly bears have been shown to avoid recreational areas that are popular for motorized and non-motorized recreational users (Gunther 1990, Kasworm and Manley 1990, Graves 2002). Furthermore, grizzly bears often avoid areas of human developments, such as neighborhoods, roads, and hotels (Mattson et al. 1987, Mace et al. 1996, Apps et al. 2006). Yellowstone Park snowpack may also influence bear distribution and behavior because it peaks in April, melts by mid-summer and resumes accumulation in mid-October (Despain 1990). High elevation sites may not provide access to bear foods before the annual snowmelt. Seasonal foods also play a role in behavior because in the spring and early summer, grizzly bears may utilize lower elevation foods such as succulent vegetation, elk calves and winter killed ungulate carrion that become associated with snow free areas. During the mid-summer grizzly bears may move to higher elevations to access seasonal foods such as green grasses and forbs, whitebark pine, and army cutworm moths (*Euxoa auxiliaris*) (Mealey 1980, Gunther and Renkin 1990, Mattson et al. 1991, Mattson 1997, Bjornlie and Haroldson

2002). Finally, grizzly bear activity patterns change throughout the year as they are often more day active during the spring and autumn and have a more crepuscular pattern during the summer months (Schwartz et al. 2010). In the 6 study area BMAs we examined 1) GPS locations and temporal data on backcountry recreational users, 2) the GPS spatial and temporal movement of grizzly bears, 3) the distance of grizzly bears from areas of consistent human recreational use, 4) the odds of grizzly bear occupancy near areas of human use while BMAs were restricted and unrestricted, 5) the odds of grizzly bear occupancy in areas of human use during periods when people were active compared to when people were inactive. Based on the seasonal availability of bear foods, snow pack, bear activity trends, and human presence we hypothesized that grizzly bears would be near areas of human use during the spring and early summer, further away during the mid summer and close during the late summer and fall. We hypothesized that grizzly bear locations would be found in areas of consistent human use more often when BMAs were restricted, compared to random chance. We also hypothesized that grizzly bear locations would be found in areas of consistent human use less often when BMAs were unrestricted, compared to random chance. Finally, we hypothesized that grizzly bear locations would be found in areas of human use during times of the day when people we less active compared to when they were more active.

Study Area

Geography, Vegetation, and Climate

We conducted our study from April 2007 to October 2009 in an area of Yellowstone Park that contained 6 Bear Management Areas. The study area encompassed the southeast portion of Yellowstone Park, which is within in the core of the Greater Yellowstone Ecosystem (GYE). The GYE is geographically defined as the Yellowstone Plateau and the surrounding mountain ranges above 1,500 m to 3,600 m (Fig. 2.1). Grizzly bears used habitats within this range throughout the GYE (Schwartz et al. 2002). The main geographic and recreational characteristic of the study area was Yellowstone Lake. Yellowstone Lake was a high elevation (2,359 m) oligotrophic lake that covered 35,391 ha, and had a mean depth of 42 m. The east and southeast drainage of Yellowstone Lake was dominated by larger stream tributaries draining from high mountain topography, closed canopy mixed forest, and subalpine meadows. The west and north drainages were characterized by smaller streams draining from low relief plateau topography, lodgepole pine (*Pinus contorta*) forest, and alluvial meadows. The 10-year (1998-2008) mean high and low temperatures were -5.4º C and -17.0º C, respectively, in January and 23.3º C and 4.6º C, respectively, in July at Yellowstone Lake (Western Regional Climate Center 2010). Approximately 80% of precipitation typically fell as snow (Reinhart and Mattson 1990, Fortin 2011).

Patterns of precipitation and temperature produced predictable vegetation patterns (Marston and Anderson 1991). Low elevations (<1,900 m) supported foothill grasslands or shrub-steppe communities. With increasing moisture, open stands of Rocky Mountain

juniper (*Juniperus scopulorum*), limber pine (*Pinus flexilis*), and Douglas-fir

(*Pseudotsuga menziesii*) occurred. Lodgepole pine dominated mid-elevations where poor

soils formed from rhyolite predominated. With increasing elevation, spruce-fir or

subalpine forests dominated. Engelmann spruce (*Picea engelmannii*) and whitebark pine

(*Pinus albicaulis*) formed the upper tree line. Alpine tundra occurred at the highest

reaches of all major mountain ranges (Patten 1963, Waddington and Wright 1974,

Despain 1990, Schwartz et al. 2002).

Bear Management Areas and Human Recreation

        Our study area consisted of 6 of the 16 Bear Management Areas. All 6 of these

BMAs were near or adjacent to Yellowstone Lake: Clear Creek #1 (J1), Clear Creek #2

(J2), Lake Spawn (K), Riddle Lake (M), Two Ocean Plateau (L) and Heart Lake (O).

Collectively the 6 BMAs were 81,175.91 ha or 9.0% of Yellowstone Park (Fig. 2.1). The

6 study area BMAs ranged in elevation from the shoreline of Yellowstone Lake at 2,380

m to the top of Two Ocean Plateau at 3,062 m. The 6 BMAs were 97.3% "recommended

wilderness", which prohibited or restricted motorized equipment from being used and any

type of road from being built (The 1964 U.S. Wilderness Act). Therefore, the study area

was only accessible by man-powered watercraft, foot, stock and motorboats in limited

circumstances. No other forms of transportation or recreation were allowed.

        Access for recreational users was via foot and stock trailheads or from the

Yellowstone Lake shoreline. Yellowstone Lake had 177 km of shoreline, which provided

near continuous entry into the 6 study area BMAs. Yellowstone Lake provided access for

backcountry trips via commercial boat drops, personal watercraft, or hiking from a

designated backcountry camp on the shoreline. The 6 BMAs had 4 major trailheads which lead into and through the study area (Riddle Lake (day-use only), Nine-mile, Heart Lake and South Boundary trailheads). These trailheads provided access for foot and stock travel, including day and overnight users. All day users could access study area BMAs without informing Yellowstone Park. However, all overnight users were required to fill out a trip plan in advance and use a designated backcountry camp. The designated backcountry camp system allowed use of pre-determined camp locations by backcountry parties. The system was in place since the 1973 and has had minimal changes to camp locations since. The study area BMAs contained 54 designated backcountry camps (14 accessible by boat only, 12 accessible by boat, foot or stock and 28 accessible by foot or stock only). The 6 BMAs contained 160 km of maintained trail for foot or stock users.

The 6 study area BMA's were created by Yellowstone Park because prior to 1982 there was a disproportionate density of grizzly bears that occurred in the area (National Park Service 1982, Gunther 2003). Grizzly bear densities were thought to be high because of protein-rich seasonal foods, in particular spawning Yellowstone cutthroat trout, winter-killed ungulate carcasses, elk calves, whitebark pine nuts, and lush vegetation associated with Yellowstone Lake tributaries, the shoreline, and thermal areas (National Park Service 1982). To protect foraging bears the 6 BMA restrictions differed slightly, but in general human use in the area was mostly restricted before July 1 and mostly unrestricted after July 1. From early spring to July 1 human recreation was limited to a subset of backcountry camps, off-trail travel was restricted and several trail segments were closed. The result was a mean of 4.5 recreational users per day in the

study area during this time period (2007-2009). Following July 1, the study area showed

a sharp increase in human use. July, August and September reflected the peak of

seasonal recreation. The increase was the result of improved weather, open Lake fishing

starting June 15th, permitted stock use starting July 1, and employee entrance for trail and

backcountry patrol cabin maintenance. By July 15th all 6 BMAs were completely open

and unrestricted. From July 1 to September 30 the study area had a mean of 146.7

recreational users per day (2007-2009). By October 1, human use dropped off

substantially due to inclement weather and the closing of park facilities. During October

there was a mean of 10.9 recreational users per day in the study area (2007-2009)

(Fig.2.2).

Methods

Human Recreation Sample

We sampled overnight backcountry users and day users during July, August, and

September starting from July 1, 2007 to September 30, 2009. We met sampled parties at

trailheads and boat access points. One member of each sampled party was asked to carry

a hand-held Garmin 12 XL or Gamin e-Trex GPS unit on their trip (Montana State

University Institutional Review Board-Human Subjects Committee, protocol approval

number = TC042606-EX). We asked individuals to leave the GPS unit on all day and

record all movements while on or off backcountry trails, except when boating and in their

designated backcountry camp. We programmed units to record a location every 1 or 2

minutes depending on the duration of the trip. We sampled overnight users from the

Yellowstone backcountry permit system database by using a stratified random sample

design with proportional allocation. The four strata were: private users, outfitters,

Yellowstone Park employees or research groups staying in a designated backcountry

camp, and Yellowstone Park employees or research groups staying in a backcountry

cabin. The sampling frame for overnight users was a list of any recreational party that

had reserved at least one designated backcountry site which required travel through one

of the 6 study area BMAs, including any park employee or researcher with overnight

business which required travel through the same BMAs. We attempted to sample

approximately 20% of the users from each strata per week. Day users were not required

to obtain a backcountry permit therefore; we measured day use by randomly selecting

hiking parties at two commonly used day-use trailheads. We sampled day users by

randomly selecting one of the two study area trailheads frequently used by day users

(Nine mile trailhead and Riddle Lake trailhead). We sampled day users 1 day/week

during July, August, and September from July 1, 2007 to September 30, 2009. We

stationed a crew member at the selected trailhead from 0700-1800 hours on sample days

and randomly selected every other hiking group. Upon completion of their trip, we asked

recreational parties to return their GPS units to Yellowstone park staff via inter-park mail.

All units were successfully received in good condition. We used Garmin Map Source 4.0

(Garmin Inc., Olathe, KS) to download all GPS units to a laptop computer. The GPS

units provided a UTM location, a date, and time for each fix. If a GPS unit failed to

obtain a satellite connection or did not receive data at the 1-2 minute rate, we removed

those days from analysis. For each party we recorded the number of individuals and

recreation type (stock or foot). We considered any party that accessed the BMAs by boat would be travelling on offshore on foot and any party that started a trip with stock would always travel on horseback.

Bear Trapping and Collaring

We trapped and radio collared grizzly bears from autumn, 2006 to mid-summer, 2009. Trapping was performed by the Interagency Grizzly Bear Study Team under the procedures approved by the Animal Care and use Committee of the United States Geological Survey, Biological Resources Division and conformed to the Animal Welfare Act and United States Government principles for the use and care of vertebrate animals used in testing, research and training. We used culvert traps placed within approximately 1km from the shoreline of Yellowstone Lake to capture grizzly bears that utilized the BMAs. We fitted all captured bears with Telonics Spread Spectrum (SS) Global Positioning System (GPS) collars (Telonics, Inc., Mesa, AZ) with a biodegradable canvas spacer and a CR2-A programmable remote drop-off device set a specific release date. Collars were set to obtain a position fix every 30 or 60 minutes. We programmed collars to shut off during the expected denning season (Nov 15 to Apr 14) and programmed a release date of October 1 of the 1st or 2nd year. We flew telemetry flights weekly from late April through mid-October to retrieve collar data. We calculated fix success and excluded collars that malfunctioned due to antenna fatigue. Bears that immediately dispersed after capture and did not frequent the BMAs were not included in the sample and were not considered for analysis.

Human Use Analysis

To evaluate how people used the landscape, we created a Human Recreation Area (HRA) layer by adding a buffer to GPS locations from individual recreational parties. Each GPS location received a buffer equal to the mean distance a backcountry user traveled per minute, plus one standard deviation, plus 10 meters to incorporate typical GPS error (Wing et al. 2005). We used this formula because it provided enough space to incorporate any aberrant movement for a hiking or horse party between subsequent GPS locations. We separated all GPS locations into two distinct groups; on trail users and off trail users. Off trail use was defined as any hike that occurred >100m beyond a maintained backcountry trail for >15 minutes. All other GPS locations were considered on trail. A "hike" was defined as a continuous walking or horse riding path with no intentional break in GPS locations. Some recreational parties recorded more than 1 hike/day, most being those who traveled by boat and repeatedly going to shore to recreate. We used two methods to select GPS locations that were associated with areas of primary human use and remove locations that were associated with atypical human travel. To do this, we first categorized all on trail and off trail hikes into 1 km sections. We calculated the total number of hikers in each 1 km segment for on trail users only. A distribution of all 1 km on trail sections was created and the 1 km trail buffers with the fewest overall number of hikers were removed (the lowest 10 percentile). Second, we analyzed all 1 km sections of off trail hikes and categorized them by the maximum distance from a designated trail or backcountry camp. Approximately 90% of all off-trail hikers occurred within 3 km of the nearest maintained trail or camp. Therefore, any off

trail buffer that occurred beyond 3 km was truncated beyond that distance and eliminated from analysis. All designated backcountry camps received the same buffer size as 1 GPS location. All on trail, off trail, and camp buffers were merged together to create the single HRA layer. To assess available cover for grizzly bears within the HRA we used the forest cover type classification system used by Despain (1990). We determined the percentage forested, non-forested and mixed cover types within the HRA using the 2006 cover type layer developed by the spatial analysis center in Yellowstone Park (Spatial Analysis Center, 2010). The human GPS data and HRA layer was analyzed using the mapping software ArcGIS 9.3 (Environmental System Research Institute, Inc., Redlands, CA).

To evaluate times of the day when people were actively recreating in the BMAs we used the time associated with each location recorded by the GPS units. We created two distinct time periods based upon these data: a period when humans were active, and period when they were inactive. We applied these two time periods to the HRA to create a dichotomous map layer with a spatial and temporal component. We determined these human active and inactive periods by pooling all GPS location times from all years. We calculated the percentage of hikers that were actively moving (away from a camp or trailhead) at sequential 15 minute categories for a 24 hour period. We created a distribution of these percentages by each 15 minute category and evaluated how patterns of human activity changed throughout the day. This helped determine when people were most likely to be actively hiking or moving. We determined a time cutoff for the human active period between the time when at least 10% of all sampled parties were actively

moving in the morning and at least 90% of parties were no longer moving in the evening (e.g. they were done hiking or at camp).

Bear and Human Interaction Analysis

To evaluate bear behavior in relation to human presence or absence, we considered two distinct time periods for the BMAs. We defined the BMA restricted period as between April 15 (den emergence) and June 30. The BMA unrestricted period was defined as between July 1 and September 30. We excluded October and November because inclement weather inhibited human recreation and radio collars were designed to drop off by October 1st (Fig 2.2).

A key assumption for our analysis was the expectation that human recreational users would travel to similar places at similar times if unrestricted during April, May, and June. We felt this was a reasonable assumption because many of the areas that people frequented in July, August and September were accessible and snow free in May and June. Also, with few exceptions, there was nothing to prohibit recreational users from traveling to similar places during similar times of the day (I. Kowski, Yellowstone Park Central Backcountry Office, personal communication). Furthermore, designated backcountry camps and maintained backcountry trails have been in near exact locations for many decades. The same trails and camps would still be available as centers of activity and would still serve as launching points for off trail travel. Finally, use was restricted, but not totally closed, in certain areas of the 6 study area BMAs during April, May, and June. As a result, we were able to sample 4 recreational parties during the restricted period. The parties recorded 8 hikes during 8 days in May and June. An

overlay of their locations on the Human Recreation Area layer established that they were all within the boundaries of the HRA. Furthermore, all 4 of the recreational parties were active within the time we considered the human active period. Therefore, we used the Human Recreational Area layer with the same temporal patterns during the restricted period despite the fact that people were mostly absent. As a result, we were able to apply bear movement data to the HRAs during the restricted and unrestricted periods. This method allowed us to evaluate human-bear interaction directly during the unrestricted period and it allowed us to examine what may occur if BMAs were completely open to human access in the restricted period.

We used the distance of each grizzly bear from the Human Recreation Area to evaluate the seasonal movement of bears in relation to annual trends in recreation. We measured the distance from each bear to the HRA at bi-monthly periods from April 15 to October 31. We used the regression approach of Murtaugh (2007) and fit no-intercept models to distance from the HRA. Resulting coefficient estimates were sample mean distances and standard errors for each bear. We summarized the results for all bears in each two week period using the weighted average of the bear specific regression coefficients, with weights proportional to reciprocals of the squared standard errors for individual fits (Murtaugh 2007, Schwartz et al. 2010).

We also used the Human Recreation Area layer to determine if bears were within areas of human use more or less than random and if a change in preference occurred when BMAs were restricted or unrestricted. We tested this by comparing individual bear locations to randomly generated locations within each animal's home range. We created

individual home ranges using the *k* nearest neighbor convex hull method (*k*-LoCoh) with

$k = \sqrt{\frac{n}{2}}$ (Getz and Wilmers 2004). The *k*-LoCoh method was used because it adequately

delineated the shoreline of Lake Yellowstone, where a good deal of recreation occurred

(Fig. 2.1). We created the home range shapefiles using the LoCoh home range generator

for ArcGIS 9.x (University of California, LoCoh home range generator for ArcGIS 9,

http://nature.berkeley.edu/~alvons/locoh, Accessed 21 April 2011).   We chose 100%

isopleths as a boundary to generate random locations. We generated the same number of

random locations as were available per bear. All random locations were created using the

Alaska Pak Toolkit in ArcGIS 9.3. We compared the random locations to bear locations

within the HRAs during the BMA restricted period and the BMA unrestricted period.

We analyzed random locations and bear locations to determine if bears had a preference

to the HRA or if human presence/absence altered bear behavior. We considered 4

different scenarios in 2 time periods: 1) bear locations and random locations within the

HRA and outside of the HRA during the BMA restricted period, 2) bear locations and

random locations within the HRA and outside of the HRA during the BMA unrestricted

period. We created 2X2XK contingency tables with K= individual bear, to control for

individual bear effects. For the BMA restricted period and the BMA unrestricted period

the cell values in the contingency tables were: bear locations within HRA, bears locations

outside of HRA, random locations within HRA, random locations outside of HRA. A

comparison of the bear locations and random locations during the restricted period

allowed us to determine if bears use areas that may be commonly used by people if

BMAs were open in April, May, and June.

We also investigated the spatial and temporal patterns of human recreation to assess how they might influence bear behavior. We used the designated human active period and inactive period, combined with the HRA layer to assess bear locations as they related to human spatiotemporal movement. To evaluate the effect of human presence on bear activity we again considered 4 different scenarios in 2 time periods: 1) bear locations within and outside the HRA during the human active period and bear locations within and outside the HRA during the human inactive period, when BMAs were restricted 2) bear locations within and outside the HRA during the human active period and bear locations within and outside the HRA during the human inactive period, when BMAs were unrestricted. We created 2X2XK contingency tables with K= individual bear, to control for individual bear effects. For the BMA restricted period and the BMA unrestricted period the cell values in the contingency table were: bear locations within the HRA during the human active period, bear locations outside of the HRA during the human active period, bear locations within the HRA during the human inactive period and bear locations outside of the HRA during the inactive period. Finally, we performed the same contingency table analysis at sequential distance intervals from the HRA. We categorized distances into 6 ordinal bins (within the HRA, 0 to 100 m from the HRA boundary, >100-200 m, >200-300 m, >300-400 m and >400-500 m). A comparison of bear locations within the HRA during the human active and inactive period allowed us to determine what type of overlap may occur if humans had open access to the BMAs during April, May, and June. A comparison of bear locations within the HRA when the BMAs were unrestricted allowed us to investigate human-bear interaction more directly.

Both analyses used exact inference procedures to estimate odds ratios in the 3-way contingency tables (BMA status, location, individual bear) or (time of day, location, individual bear). The test was conditioned on fixed-strata marginal totals and was an exact small-sample alternative to the Cochran-Mantel-Haenzel test (Agresti 2007:114). Our null hypothesis was that the odds ratios were = 1 (equal odds). We accepted the alternative hypothesis for any odds ratio where the 95% CI did not overlap 1. We assumed that individual bears share a common odds ratio. We evaluated this by fitting log-linear models corresponding to this assumption and plotting fitted values with observed values. The plots allowed for a visual assessment of the reasonability of the common odds ratio assumption (Haroldson et al. 2004). We conducted our analysis using the statistical program R (R version 2.12.2, www.r-project.org, accessed 2 September 2011).

Results

Human Sample and Human Recreation Area Results

We sampled 385 recreational parties. This included 286 overnight users from the 4 sample strata, and 99 day users from selected trailheads. In our sample 345 parties traveled by foot (via trailhead or boat access) and 40 traveled on horseback. Party size had a range from 1 person to 15 people with a mean of 3.48 ± 2.87 ($\bar{x} \pm SD$). Within the study area BMAs, the sampled parties recorded a total of 827 usable individual foot hikes and 140 individual horse rides. On trail use was common with foot hikers including 554 (67.0%) staying on trail the entire time, 220 (26.6%) going off and on trail during the

same hike and 53 (6.4%) going completely off trail for an entire hike. No horseback

riders traveled off trial. Recreational parties collected 205,004 GPS locations which were

used in the analysis. The number of GPS locations that were not considered for the

analysis because of inadequate GPS collection was 3,604, including 17 hikes from 15

different recreational parties.

The buffer size used to create the Human Recreation Area was 102 m

(66+26.3+10), ($\bar{x}$ +SD+10 m GPS error) around each GPS location and backcountry

camp. The HRA was 6,251.4 hectares or 7.7% of the 6 study area BMAs. Our HRA was

a near continuous polygon because many GPS locations were stacked upon one another

(Fig 2.3). The HRA polygon was 74.7% forested cover type, 18.1 % non-forested cover

type, and 7.2% was a mix of non-forested and forested cover. Within the HRA we

determined that fewer than 10% of people were actively recreating before 0800 hours.

Furthermore, we found that 90% of people were no longer recreating at 1900 hours.

Therefore, determined that the human active period was from 0800-1859 hours, and the

inactive period was from 1900-0759 hours (Fig 2.4).

Bear Sample

We deployed 18 radio collars on 14 bears including 10 male and 4 female bears.

Our GPS collars successfully obtained 84.3% percent of 72,443 fix attempts.

Bear Distance Results

The weighted mean distance of bears from the HRA was close during the BMA

restricted period, further away during the BMA unrestricted period, and close again

during October (Fig 2.5).   When the BMAs were restricted, the weighted mean distances

of bears from the HRA at 2 weeks intervals were: April 15-30 (3,875 m $\pm$ 2,357) ($\bar{x}$ $\pm$

SE), May 1-14 (1,874 m $\pm$ 757) ($\bar{x}$ $\pm$ SE), May 15-31 (1,498 m $\pm$ 404) ($\bar{x}$ $\pm$ SE), June 1-

14 (2,233 m $\pm$ 404) ($\bar{x}$ $\pm$ SE) and June 15-30 (2,651 $\pm$ 901) ($\bar{x}$ $\pm$ SE). When the BMAs

were unrestricted, the weighted mean distances of bears from the HRA at 2 week

intervals were: July 1-14 (6,364 m $\pm$ 3,050) ($\bar{x}$ $\pm$ SE), July 15-31 (5,498 m $\pm$ 2,190) ($\bar{x}$ $\pm$

SE), August 1-14 (4,174 m $\pm$ 1,704) ($\bar{x}$ $\pm$ SE), August 15-31 (4,174 $\pm$ 1,704) ($\bar{x}$ $\pm$ SE),

September 1-14 (4,229 $\pm$ 1,443) ($\bar{x}$ $\pm$ SE) and September 15-30 (4,519 $\pm$ 1,302) ($\bar{x}$ $\pm$

SE). During October, the weighted mean distances of bears from the HRA at 2 week

intervals were: October 1-14 (1,288 $\pm$ 324) ($\bar{x}$ $\pm$ SE) and October 15-31 (1,283 $\pm$ 209)

($\bar{x}$ $\pm$ SE).

Results for the BMA Restricted
Period (Den Emergence to June 30)

During the restricted period, grizzly bears locations were more likely to be within

the HRA compared to random locations. Consequently 10% of bear locations were

within the HRA during the restricted period, compared to 5.5% of random locations. The

odds of a bear being within the HRA during the restricted period were 2.0 times more

likely (95% CI = 1.81 to 2.14, $P \leq 0.001$) than random (Fig. 2.6A).

During the restricted period, grizzly bears were more likely to be within the HRA

when people were projected to be inactive compared to when people were projected to be

active. While 10.12% of bear locations were within the HRA when BMAs were

restricted, 9.36% were found during the human active period and 10.77% when people

were inactive (Fig. 2.6A). However, the odds were near equal and were consistent at 100

m intervals away from the HRA. This suggests that bears showed scant time of day

preference when people were absent from the study area. The 95% CI for the odds ratios

overlapped 1 at 100-200m, 300-400 m and 400-500m (Fig. 2.7). The odds of a bear

being within the HRA while humans were projected to be inactive was 1.18 times higher

than when people were projected to be active (95% CI $= 1.06$ to 1.31, $P = 0.002$). The

odds at 0-100 m were 1.l7 times higher (95% CI $= 1.01$ to 1.36, $P = 0.035$). The odds at

100-200 m significantly did not differ from 1 and were 1.14 times higher (95% CI $= 0.98$

to 1.33, $P = 0.098$). The odds at 200-300 m were 1.18 times higher (95% CI $= 1.00$

to1.39, $P = 0.045$). The odds at 300-400 m and 400-500m statistically did not differ from

1 at 1.14 (95% CI $= 0.96$ to 1.36, $P = 0.132$) and 0.96 times higher (95% CI $= 0.83$ to

1.14, $P = 0.585$), respectively.

Results for the BMA Unrestricted
Period (July 1 to September 30)

Grizzly bears were more likely than random to be within the HRA during the

unrestricted BMA period as well. Consequently, 6.9% of bear locations were within the

HRA when BMAs were unrestricted compared to 5.2% of random locations. The odds or

a bear being within the HRA were 1.35 times more likely (95% CI $= 1.27$ to 1.44, $P \leq$

0.001) than random (Fig. 2.6B).

During the unrestricted period, grizzly bears were more likely to be within the

HRA when people were inactive compared to when people were active. While 6.92% of

bear locations were within the HRA during the unrestricted period, only 4.35% were

found during the human active period and 9.05% when people were inactive (Fig 2.6B).

The odds of a bear being located within the HRA during the human inactive period was

2.15 times higher than the human active period (95% CI = 1.96 to 2.37, $P \leq 0.001$).

However, at 100m intervals the odds decreased incrementally, suggesting that the

presence of people may influence bear behavior, but only within a short distance of

places people frequent. The 95% CI intervals for the odds ratios were significantly

greater than 1 until a distance of 300-400 m and 400-500 m from the HRA (Fig. 2.7). The

odds of a bear being within 0-100 m of the HRA during the human inactive period was

1.89 times higher than the active period (95% CI = 1.64 to 2.17, $P \leq 0.001$). The odds of

a bear being within 100-200 m of the HRA during the human inactive period was 1.63

times higher than the active period (95% CI = 1.41 to 1.89, $P \leq 0.001$). The odds of a

bear being within 200- 300 m of the HRA during the human inactive period was 1.21

times higher than the active period (95% CI = 1.06 to 1.37, $P = 0.004$). We found no

significant difference between the human inactive and active periods starting at 300-400

m and 400-500 m with 0.99 odds (95% CI = 0.84 to 1.15, $P = 0.847$) and 0.99 odds (95%

CI = 0.84 to 1.15, $P = 0.847$), respectively.

Discussion

Seasonal movement patterns agreed with our hypothesis that grizzly bears would

be near areas of human use in the spring and early summer, further away in the mid to

late summer, and closer again in the fall. This coincides with the evidence that bears

showed a preference in use for the HRA while the BMAs were restricted. After the BMA

restrictions were lifted, bears were still more likely to use the HRA compared to random locations, however there was a measurable change in temporal use. Grizzly bears were more likely to use the HRA during hours when people were inactive, compared to when they were active. However, this time of day preference changed incrementally as bears moved away from the HRA, where bears showed an equal preference in locations during human active and inactive time periods after 300-400m. This pattern of temporal use did not occur when BMAs were restricted and people were largely off the landscape. During the restricted period, bears showed a consistent spatial preference at varying distances from the HRA, regardless of the time of day. Contrasting these two time periods we found that bears were likely showing an avoidance response to the presence of people. Consequently, if BMA restrictions were lifted and people were allowed open access to the same places in April, May, and June, an increase in human-bear overlap is likely to occur. Our results suggest that the outcome of this increase in human-bear overlap, during the BMA restricted period, may result in an avoidance response of bears to people.

Since this was an observational study, we can only describe an association between human presence and bear movement. This study does not draw a cause and effect relationship. However, previous research has suggested a similar avoidance response of bears to recreational users and hikers (Mclellean and Shackleton 1989, Gunther 1990, Kasworm and Manley 1990, Mace et al 1996, Graves 2002). Our research compliments this work, yet we were able to establish an avoidance response in a remote backcountry setting, with non-motorized recreational users, over a relatively large area, and over a 3 year time span. Furthermore, we were able to provide specific times and

locations of potential human-bear interaction and establish a distance where a response of bears to people was no longer likely to occur.

We considered the possibility that bears were simply avoiding mid-day heat during the BMA unrestricted period and that the response to warm temperatures lead to the appearance of avoidance away from people. This was important to consider because, during our study, July and August were the two warmest months throughout each year in Yellowstone Park (Western Regional Climate Center 2010). In addition, daily recreational use tracked daily temperature fluctuations. However, we did not believe bears were just responding to fluctuating temperatures because at 300-400m from the HRA, bear locations were at equal odds during the human active and inactive times. It is unlikely temperatures within the HRA were higher than temperatures 300m away during the human active period. Also, the 6 BMAs and the HRA was densely forested and provided ample cover for day beds. Overall, Yellowstone Park is covered in approximately 80% forested cover types (Despain 1990). Using the same classification system as Despain 1990, we found that the HRA was 18.1% non-forested. Therefore, the HRA provided adequate thermal cover and we believe that grizzly bears could find cover directly within the HRA. As a result, it is unlikely that bears were moving away from the HRA during daylight hours to seek cover from direct sunlight.

A research study by Rode et al. 2007, related human presence to bear food sources and found that bears can lose foraging opportunities because of human presence, but that they were often able to compensate by adjusting their spatiotemporal patterns of resource use. While our research did not directly evaluate the influence of food resources

in the same manner, we did find evidence that bears may lose day time foraging

opportunities within the HRA during the BMA unrestricted period. This may be

problematic, especially since we found that bears were twice as likely to be in the HRA

during the restricted period, compared to random locations. Also, during this period, we

found that bears showed a near equal day and night selection to the HRA. In addition,

other research has shown that grizzly bears in the GYE are more day active in April and

May, compared to July and August (Schwartz et al. 2010). As noted in Rode et al. 2006

and Rode et al. 2007, foraging opportunities lost during times when people were present

could possibly be offset by altering spatiotemporal foraging patterns. This may not be a

safe assumption in our study area, especially during April, May, and June. Since the

decrease in spawning cutthroat trout around Yellowstone Lake, ungulate meat has

become an increasingly important food source during April, May, and June (Haroldson et

al. 2005, Fortin 2011). In addition, ungulate meat is a widely obtained and critical food

source in Yellowstone Park, compared to other bear populations (Jacoby et al. 1999).

Ungulate meat from elk calves and winter kill is primarily obtained during the BMA

restricted period (Gunther and Renkin 1990, Mattson 1997, Barber-Meyer et al. 2008).

In addition, ungulate meat obtained from usurped wolf kills is available any time of the

year (Gunther and Smith 2004). Ungulate meat is often obtained opportunistically during

day and night hours (Herrero 1985, Gunther and Renkin 1990, Gunther and Smith 2004).

When meat is obtained, grizzly bears often stay on or near the carcass for many hours to

several days. During our study we confirmed 2 circumstances where grizzly bears were

displaced from an ungulate meat source because of a close proximity to hikers (~120m),

(unpublished data). If bears abandon ungulate carcasses because of human interference, they may lose out on foraging opportunities due to inter and intraspecific competition (Mattson 1997, Gunther and Smith 2004). We cannot assume that a lost opportunity to forage on a meat source can be regained at night, when people are absent. Furthermore, if bears do not abandon a carcass when encountered by people, they can be very aggressive, increasing the probability of an attack (Herrero 1985).

Grizzly bears are apex predators in the GYE and, outside of mortalities from other bears and people, they face no predation risk. Grizzly bears are not hunted in the GYE yet evidence from this study and many others suggests that bears still perceive humans as a threat and will consistently avoid them when possible (Mattson et al. 1987, Mclellean and Shackleton 1989, Kasworm and Manley 1990, Mace et al. 1996, Sundell et al. 2006). If bears perceive humans as predators, or display a type of anti-predator response, there is evidence that this type of activity can carry costs related to survival and reproduction (Ruxton 1997, Creel et al. 2007, Pangle et al. 2007). If this is the case, it is important to provide grizzly bears with ample opportunities free of constant human disturbance. Conversely, when human-bear interactions occur on a very frequent basis, some grizzly bears can become habituated to human presence (Jope 1979, Herrero 1985). Habituation can lead to a loss of fear and may result in bears interacting with people in very close situations (Herreo et. al 2005, Smith et al. 2005, Gunther and Wyman 2008). When this happens, bears have an increased chance of obtaining human foods and can become food conditioned (Gunther and Wyman 2008). Historically, habituated and food conditioned bears were responsible for the majority of bear management problems in Yellowstone

Park, including bear-caused human injuries (Herrero 1985, Schullery 1992, Gunther 1994, Wondrack-Biel 2006).

Management Implications

Yellowstone BMAs were designed to limit continual human-bear interaction that may lead to a loss of foraging opportunities, an increased risk of habituation, or dangerous situations for people. We found that grizzly bears did show an avoidance response to people when in close proximity. We also found that bears will avoid human overlap if BMAs are closed during the time period specified in our study (April, May, and June). Bear Management Areas do restrict potential encounters and thus limit harmful situations for bears and people. We found that the BMA restrictions and timelines considered in this study did provide protection for bears and people, and did restrict human-bear interaction for a substantial part of the year.

Acknowledgements

Fig. 2.1. Yellowstone National Park, Wyoming, USA. Highlighted areas display all 16 Bear Management Areas (BMAs), including the 6 study area BMAs.
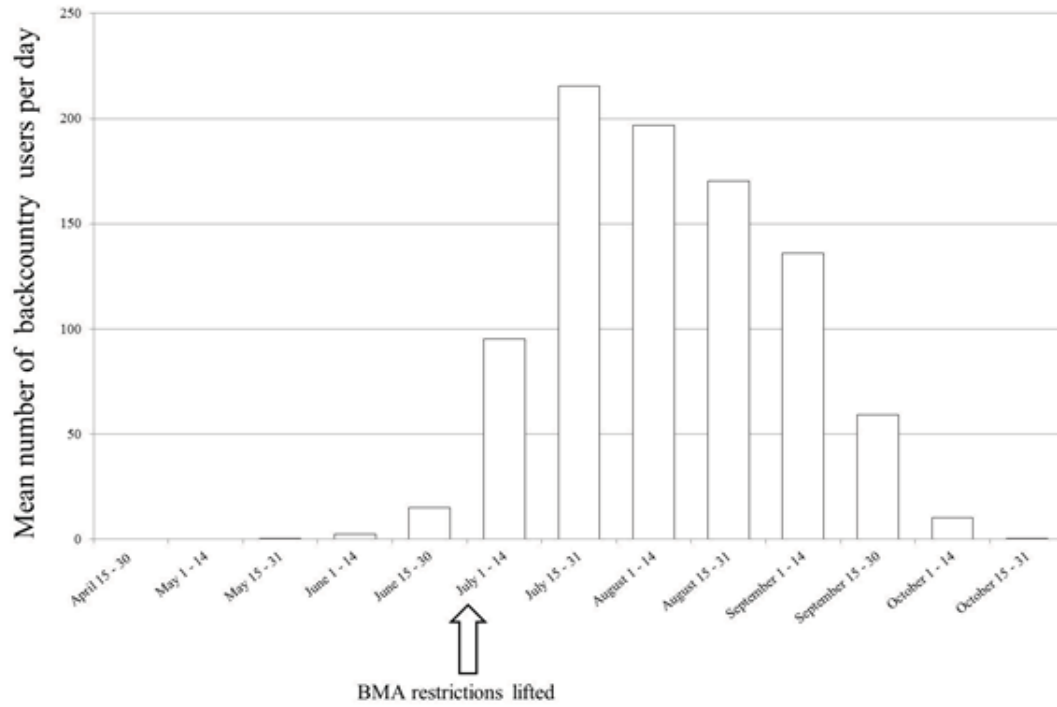
Fig. 2.2. Backcountry users in the 6 study area Bear Management Areas (BMAs). Each two week period = the mean number of day and overnight users per day. The BMA restricted period was defined as mid-April (den emergence) to June 30. The BMA unrestricted period was defined as July 1 to September 30.
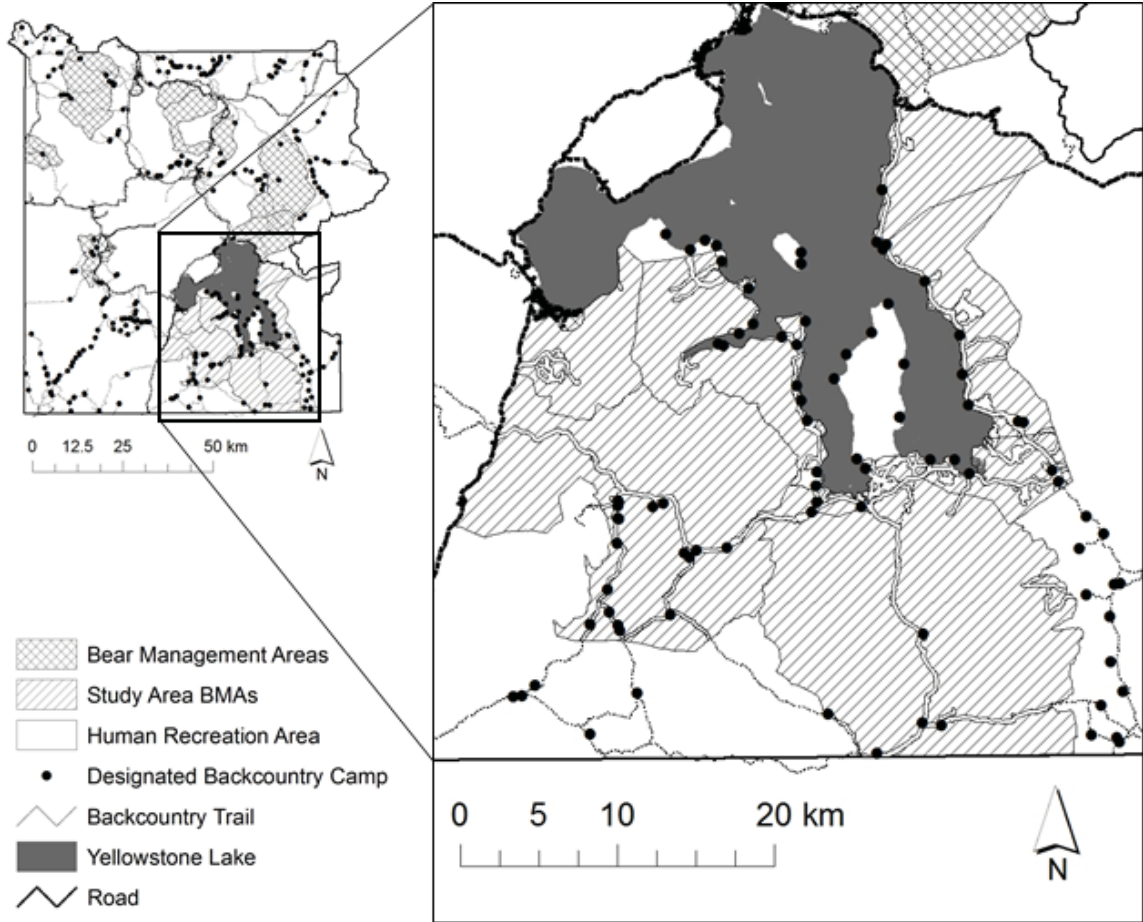
Fig. 2.3. Human Recreation Area (HRA) within the 6 study area Bear Management Areas (BMAs). The HRA was 6,251.4 ha and 7.7% of the 6 study area BMAs. The HRA was centered on maintained backcountry trails, but also included various off trail travels up to 3 km, and a buffer around designated backcountry camps. Also shown is the additional park BMAs, designated backcountry camps, park roads and maintained backcountry trails.
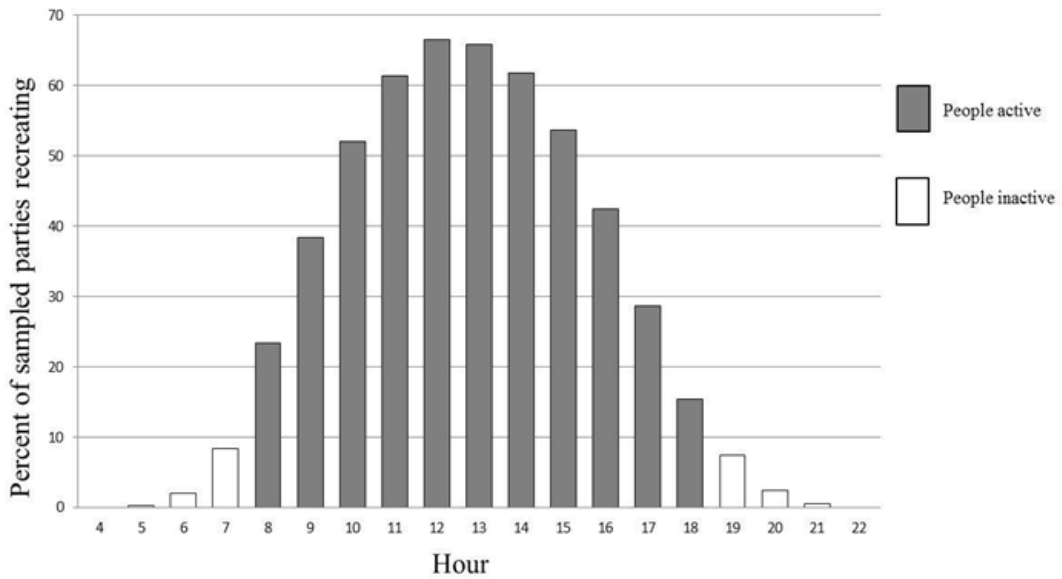
Fig. 2.4. Distribution of people recreating during the day. Each hour represents the percentage of sampled parties actively recreating per hour throughout the duration of the study. A human active period (gray shaded area) was defined as 0800-1859 hrs, and the inactive period was from 1900-0759 hrs.
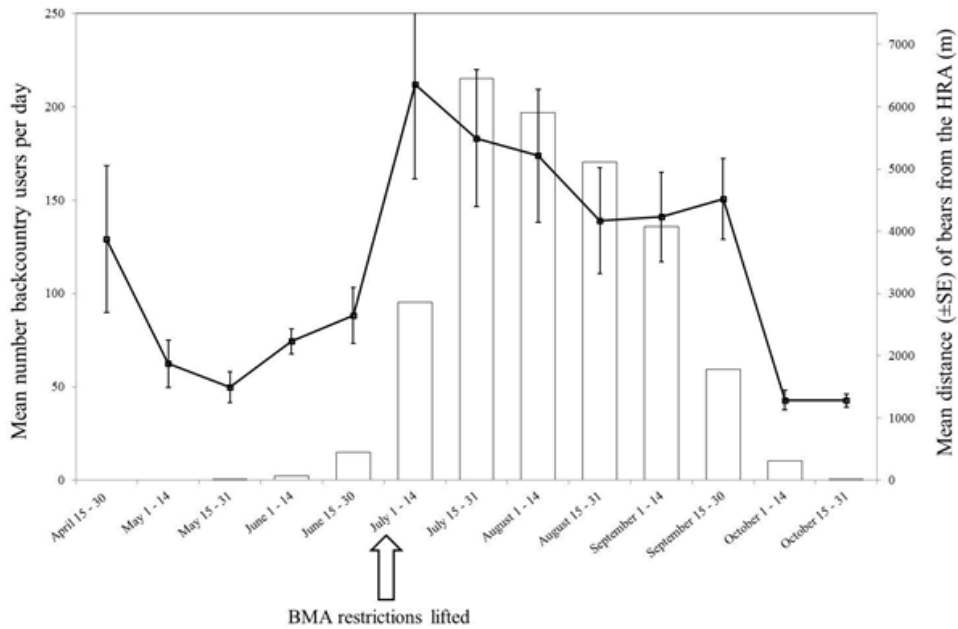
Fig. 2.5. Mean weighted distance ($\bar{x} \pm$ SE) of bears from the Human Recreation Area. Each distance is categorized in 2 week time

Fig. 2.6. Distribution of grizzly bear locations within the Human Recreation Area (HRA) during the restricted period (A) and unrestricted period (B). The Bear Management Area (BMA) restricted period was defined as mid-April to June 30, while the BMA unrestricted period was defined as July 1 to September 30. Gray shaded areas denote the human active period. During the restricted period (A) 10% of all bear locations were within the HRA (horizontal black line), while 5.5% of random locations were within the HRA. While people were projected to be active (gray shaded area) 9.4% of all bear locations were within the HRA. While people were projected to be inactive (white or blank area) 10.8% of all bear locations were within the HRA. During the unrestricted period (B) 6.9% of all bear locations were within the HRA (horizontal black line), while 5.2% of random locations were within the HRA. While people were active (gray shaded area) 4.4% of all bear locations were within the HRA. While people were inactive 9.1% (white or blank area) of all bear locations were within the HRA.

(A) Bear Management Area restricted

(B) Bear Management Area unrestricted
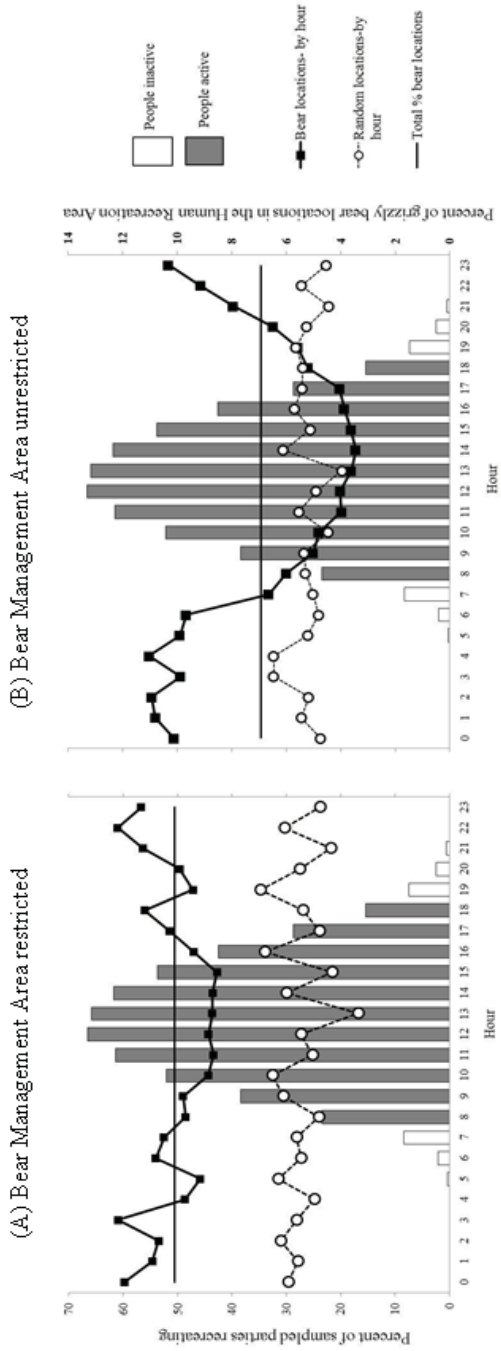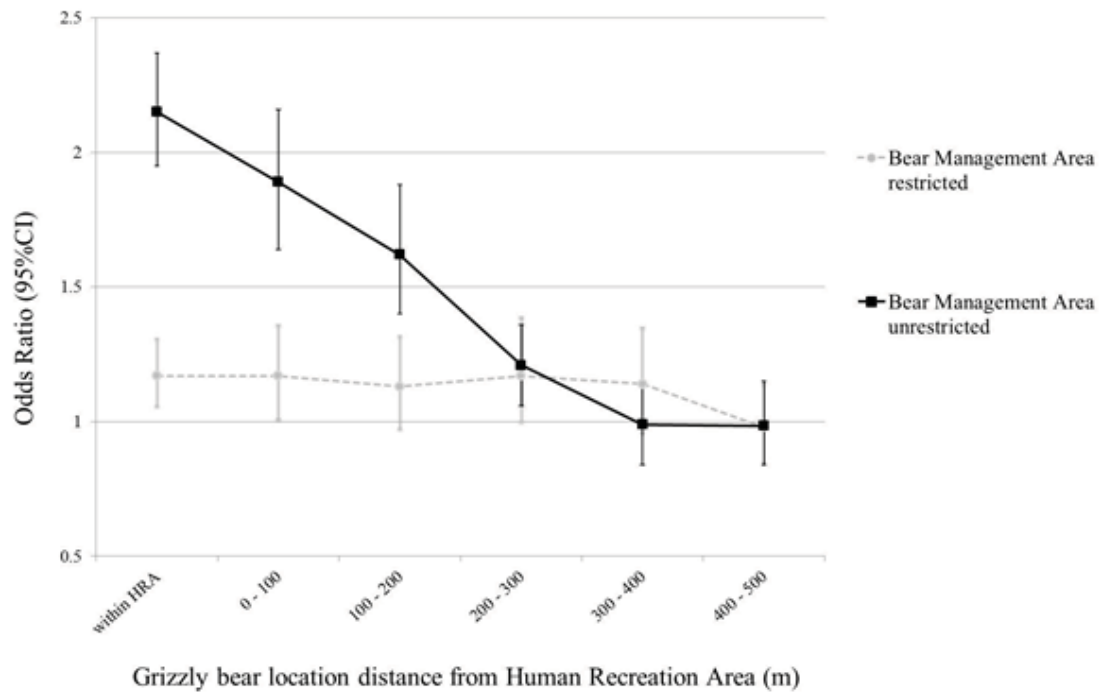
Fig. 2.7. Odds ratios (95% CI) for bear locations within the Human Recreation Area (HRA) during the human inactive period compared to the active period. When Bear Management Areas (BMAs) were restricted (dashed gray lines) the odds of a bear being within the HRA during the times when people were projected to be inactive was 1.18 times higher (95% CI = 1.06 to 1.31, P = 0.002) compared to when people were projected to be active. When BMAs were unrestricted (black lines) the odds of a bear being within the HRA during the times when people were inactive was 2.15 times higher (95% CI = 1.95 to 2.37, $P \leq 0.001$) compared to when people were active. Also given are the odds ratios and 95% CI at 100 m intervals from the edge of the Human Recreation Area.

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CHAPTER THREE

INFLUENCE OF OVERNIGHT RECREATOIN ON GRIZZLY BEAR MOVEMENT
AND BEHAVIOR IN YELLOWSTONE NATIONAL PARK

<u>Contribution of Authors and Co-Authors</u>

Manuscripts in Chapters 2, 3, 4, and 5

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<u>Manuscript Information Page</u>

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Abstract

Interaction among recreational users and grizzly bears (*Ursus arctos*) are a

continuous challenge for bear managers. Yellowstone National Park, WY uses a system

of designated backcountry campsites to manage overnight use and provide bear-resistant

food storage devices for recreational users. Few studies have evaluated how this type of

management and recreation influences grizzly bear spatial and temporal behavior. We

used Global Positioning System (GPS) data for humans and bears to determine how

overnight use influenced grizzly bear behavior. We used GPS data to determine when

campsites were occupied and contrasted grizzly bear locations to random locations near

campsites. We conducted a similar analysis ignoring campsite occupancy to assess the

utility of including a temporal variable. Our results suggested that grizzly bears were

0.35 times as likely to be within 200 m of an occupied campsites, compared to random

locations (95% CI = 0.19 to 0.62, $P \leq 0.001$) . Conversely, when human occupancy or a

temporal variable was ignored, our results suggested bears were attracted to campsites

because bears were 2.11 times more likely to be ≤ 200 m from campsites compared to

random locations (95% CI = 1.85 to 2.41, $P \leq 0.001$). We conclude that overnight

backcountry camping can displace grizzly bears. Our study also suggested that, to avoid

confounding results, a temporal variable is important to consider in studies of human-

bear interaction.

Introduction

In areas of the United States where humans are encroaching on wildlife habitat, land managers must balance recreational opportunities and conservation for threatened and endangered animals. In Yellowstone National Park, Wyoming, USA (hereafter, Yellowstone Park) visitors can recreate in areas that are critical to the survival and recovery of grizzly bears (*Ursus arctos*). Yellowstone grizzly bears were listed as "threatened" by the U.S. Fish and Wildlife Service in 1975. Since then Yellowstone Park officials have been challenged with accommodating an increasing number of visitors while supporting grizzly bear conservation. Yellowstone Park is considered critical to grizzly bear recovery, yet backcountry recreation is an important part of the visitor experience (USFWS 1993). Overnight backcountry use has remained consistently high with an average of 42,000 user nights/year from 1972 to 2011 (National Park Service 2012*c*). To help accommodate these backcountry users Yellowstone Park created a system of designated backcountry campsites to concentrate use and provide campers with bear-resistant food storage devices. Created in 1973, designated backcountry campsites (hereafter backcountry campsites) were placed along trails and lakeshores (National Park Service 1995).

In the years following the creation of backcountry campsites, Yellowstone Park implemented policies to provide additional protection for grizzly bears (Gunther 1994).

A synthesis of these management policies (National Park Service 1982) outlined a plan for preserving critical grizzly bear habitat and proactively preventing human-bear conflict. Following guidelines of Craighead (1980) the park set aside areas considered critical for grizzly bear recovery and identified them as Bear Management Areas (BMAs). Sixteen individual BMAs comprised of 188,032 hectares (21% of Yellowstone Park) were delineated with unique management guidelines (Gunther 2003). Bear Management Areas seasonally restricted recreation in pre-determined areas of the park with high concentrations of grizzly bears and bear foods. Several BMAs seasonally close backcountry campsites and trails because they were within approximately 500 m of food sources considered critical to grizzly bear recovery. Backcountry campsites outside of BMAs generally had no limitations. Campsite closures and restrictions were based on the assumption that backcountry campsites displaced foraging grizzly bears or placed backcountry campers in harm's way. However, since the creation of the designated backcountry camp system in 1973, and the subsequent seasonal closures of some campsites by the BMA program in 1982, little research has been done to determine how bears behave around occupied backcountry campsites.

Evidence suggests that non-motorized backcountry users can displace grizzly bears and potentially hinder foraging opportunities (Mclellean and Shackleton 1989, Kasworm and Manley 1990, Mace and Waller 1996, Rode et al. 2007). However, this research has mostly taken place during daylight hours involving groups of people actively moving. In Yellowstone Park, thousands of backcountry users stay overnight in grizzly bear habitat, yet there is little empirical evidence that bears are attracted to, or are

deterred by, this type of use. One study (Gunther 1990) suggested that bears avoided

backcountry campsites when occupied. However, this study occurred during daylight

hours, in an open valley, with a limited number of campsites ($n = 13$). Other research has

focused on large camps or permanent developments such as, paved campgrounds,

outfitting camps, or multi-group sites (Mattson et al. 1987, Ruth et al. 2003). Most land

management agencies, surrounding Yellowstone Park, require backcountry users to stay

in multi-group campsites or allow people to freely pick a camp location (USDA Forest

Service 2012, National Park Service 2012a, National Park Service 2012b, USDA Forest

Service 2012). Consequently, there is a lack of quantitative research on the effect of

small party backcountry camping on grizzly bear behavior.

In Yellowstone Park, grizzly bears rarely attack hikers or overnight backcountry

campers. When attacks do occur, they most often involve recreational parties with group

sizes ≤ 2 (Gunther and Hoekstra 1998). Grizzly bear attacks after dark often involve

food-conditioned bears (*sensu* Hopkins et al. 2010).   However, there are records of

grizzly bear attacks on small overnight backcountry parties involving bears with no

known management status (Gunther and Hoekstra 1998, Herrero 2002). This suggests

that biologists and park managers may need more information about how grizzly bears

respond to backcountry campers at night in remote locations.

Opposing forces can influence bear behavior around backcountry campsites.

Grizzly bears are capable of associating a negative experience with people at a location or

situation and thus avoid backcountry campsites (Herrero 2002). Alternatively, bears can

be attracted to backcountry campsites because many are near trails and other natural

travel corridors. In addition, natural or anthropogenic food sources can attract bears to backcountry campsites. Scraps left behind by campers provide a human food attractant. Many backcountry campsites are near open meadows and riparian areas which provide water for campers, but also green succulent vegetation for bears (Despain 1990). Years of hooved stock (horses, mules, and llamas) use have allowed protein-rich exotic vegetation such as clover (*Trifolium spp*.) to grow near campsites historically used by horse and mule packers (Mealey 1980, Mattson 1991). Also, backcountry campsites are located in remote portions of the park, are difficult to access, and may be vacant a lot of the summer.

As part of a study investigating behavior and diet of grizzly bears around Yellowstone Lake in Yellowstone Park, we had the opportunity to evaluate bear behavior around backcountry campsites within and around 6 Bear Management Areas. Global Positioning System (GPS) data of bears and people allowed us to assess effects of backcountry camping on bear behavior in a variety of locations, including forested and open cover types, on trails, and on lakeshores. These data allowed us to determine if seasonal backcountry campsite closures provided foraging opportunities for grizzly bears and some justification for continuation of the BMA program.

We used two different approaches to evaluate our research questions. We investigated bear behavior around backcountry campsites when humans were known to occupy them in addition to an analysis where campsite occupancy was ignored. A comparison of these two tests allowed us to determine if bears were responding to the presence of people or the campsites themselves. In this study, we examined 1) patterns of

recreation; including backcountry campsite occupancy, departure and arrival times, 2) GPS locations of sampled grizzly bears in areas with a large number of backcountry campsites, 3) the odds of a grizzly bear location being near occupied backcountry campsites, compared to random locations 4) the odds of a grizzly bear location being near backcountry campsites, compared to random locations when occupancy was ignored, 5) the distance bears responded to backcountry campsites, compared to random locations, and 6) the distance bears responded to backcountry campsites, compared to random locations when occupancy was ignored. Based on previous evidence that backcountry users can displace bears and that night time bear attacks on backcountry campers are very rare, we hypothesized that bears avoid occupied backcountry campsites but avoidance behavior diminishes incrementally as distance from occupied campsites increases. Also, because campsites are usually vacant, and some food attractants do exist in backcountry campsites, we hypothesized that when occupancy is ignored, grizzly bears show a spatial preference to backcountry campsites.

Study Area

Geography, Vegetation, and Climate

We conducted our study from April 2007 to October 2009 in an area of Yellowstone Park that contained 6 Bear Management Areas and 88 backcountry campsites (Fig. 3.1). The study area encompassed the southeast portion of Yellowstone Park, which is within in the core of the Greater Yellowstone Ecosystem (GYE). The GYE is geographically defined as the Yellowstone Plateau and the surrounding mountain

ranges above 1,500 m to 3,600 m. Grizzly bears used habitats within this range

throughout the GYE (Schwartz et al. 2002). The main geographic and recreational

characteristic of the study area was Yellowstone Lake. Yellowstone Lake was a high

elevation (2,359 m) oligotrophic lake that covered 35,391 ha, and had a mean depth of 42

m. The east and southeast drainage of Yellowstone Lake was dominated by larger stream

tributaries draining from high mountain topography, closed canopy mixed forest, and

subalpine meadows. The west and north drainages were characterized by smaller streams

draining from low relief plateau topography, lodgepole pine (*Pinus contorta*) forest, and

alluvial meadows. The 10-year (1998–2008) mean high and low temperatures were -5.4 º

C and -17.0º C, respectively, in January and 23.3º C and 4.6º C, respectively, in July at

Yellowstone Lake (Western Regional Climate Center 2010). Approximately 80% of

precipitation typically fell as snow (Reinhart and Mattson 1990, Fortin 2011).

Patterns of precipitation and temperature produced predictable vegetation patterns

(Marston and Anderson 1991). Low elevations (<1,900 m) supported foothill grasslands

or shrub-steppe communities. With increasing moisture, open stands of Rocky Mountain

juniper (*Juniperus scopulorum*), limber pine (*Pinus flexilis*), and Douglas-fir

(*Pseudotsuga menziesii*) occurred. Lodgepole pine dominated mid-elevations where poor

soils formed from rhyolite predominated. With increasing elevation, spruce-fir or

subalpine forests dominated. Engelmann spruce (*Picea engelmannii*) and whitebark pine

(*Pinus albicaulis*) formed the upper tree line. Alpine tundra occurred at the highest

reaches of all major mountain ranges (Patten 1963, Waddington and Wright 1974,

Despain 1990).

Human Recreation and
Designated Backcountry Campsites

Our study area covered all backcountry campsites extending from the southeast

boundary of Yellowstone Park to the main park roads north and west of Yellowstone

Lake (Fig. 3.1). The area ranged in elevation from the shores of Yellowstone Lake at

2,380 m to Eagle Peak, the highest point in Yellowstone Park at 3,462 m. The study area

was approximately 99% "recommended wilderness", which prohibited or restricted

motorized equipment and any type of road building (The 1964 U.S. Wilderness Act).

The area was accessible by man-powered watercraft, foot, hooved stock, and motorboats

in limited circumstances. Other forms of transportation or recreation were prohibited.

Access for recreational users was via foot or hooved stock trailheads or from the

Yellowstone Lake shoreline. Yellowstone Lake had 177 km of shoreline, which provided

near continuous access to the backcountry campsites on the Lake. The study area had 3

major trailheads which provided foot or hooved stock access for overnight users (Nine-

mile, Heart Lake and South Boundary trailheads). The study area had 293 km of

maintained backcountry trails and 88 designated backcountry campsites (26 accessible by

boat only, 10 accessible by boat, foot, or hooved stock, and 52 accessible by foot or

hooved stock only); twenty five and 63 were located in forested and open habitats,

respectively. Mean party size for the 88 backcountry campsites was 3.6 ± 2.7 ($\bar{x} \pm$ SD), a

median and mode of 2, and a range of 1 to 15 people (2007–2009). Occupancy was

relatively light because the area was geographically remote with long winters and cool

summers and averaged 26 reservations/camp/year (April through October, 2007–2009).

On average 7 of 88 camps/day were occupied (April through October, 2007–2009).

However, 36 campsites were closed in all or part of April, May, and early July due to BMA regulations. Most backcountry campsite use occurred during July-September with 92% of the annual use.

Methods

Human Recreation Sample

We sampled overnight backcountry users during May, June, July, August, and September from 2007–2009. We selected our sample of overnight users using data from the Yellowstone Park backcountry permit reservation system. We applied a stratified random sample design with proportional allocation among three strata: private users, outfitters, and administrative users (National Park Service or research groups). The sampling frame for overnight users was a list of the recreational parties that had reserved at least one designated backcountry campsite which required travel through the study area into the 6 surrounding BMAs. We attempted to sample approximately 20% of users from each strata per week based on the list provided from the backcountry permit system. We were unable to contact parties before their departure date. Thus we met sampled parties at their designated trailheads or boat access points on the morning of their departure. One member of each party was asked to carry a hand-held Garmin 12 XL or Garmin e-Trex GPS on their trip (Montana State University Institutional Review Board-Human Subjects Committee, protocol approval number = TC042606-EX). We programmed GPS units to obtain 1 location/minute for trips $\leq$ 2 days, and 1 location/2minutes for trips > 2 days . We asked individuals to leave GPS units on all day and record when they arrived at

backcountry campsites in the evening and when they departed in the morning. Upon

completion of their trip, we asked parties to return GPS units to Yellowstone Park staff

via inter-park mail. All units were successfully received in good condition. If a party

failed to accurately record their campsite location, arrival, or departure time we removed

that night or time from our analysis. We used Garmin Map Source 4.0 (Garmin Inc.,

Olathe, KS) to download all GPS units to a laptop computer. The GPS units provided a

UTM location, date, and time for each fix. For each party we recorded the number of

individuals and recreation type (hooved stock, foot, or boat).

Bear Trapping and Collaring

We trapped and radio collared grizzly bears from September of 2006 to mid-

summer 2009. The Interagency Grizzly Bear Study Team conducted all trapping under

procedures approved by the Animal Care and Use Committee of the United States

Geological Survey, Biological Resources Division and conformed to the Animal Welfare

Act and United States Government principles for the use and care of vertebrate animals

used in testing, research and training. The team used culvert traps placed within 1 km of

Yellowstone Lake to capture grizzly bears that utilized the 6 BMAs around the Lake and

surrounding areas. The team fitted all captured bears with Telonics Spread Spectrum

GPS collars (Telonics, Inc., Mesa, AZ) with a biodegradable canvas spacer and a CR2-A

programmable remote drop-off device set at a specific release date. Collars obtained a

position fix every 30 or 60 minutes. Collars shut off during denning season (Nov 15 to

Apr 14). We flew telemetry flights weekly from late-April through mid-October to

retrieve collar data. We calculated fix success and excluded collars that malfunctioned due to antenna fatigue.

Backcountry Camp Analysis

To evaluate how bears respond to backcountry campsite occupancy we needed to determine the dates and times when campsites were occupied. Since it was not feasible to sample all recreational users in all 88 campsites we used the data gathered from our GPS sample, combined with the Yellowstone Park backcountry permit system database to empirically estimate dates and times campsites were occupied. All overnight users were required to obtain a permit, fill out a trip plan, and reserve all of their backcountry campsites prior to leaving on their trip. Backcountry campsite reservation information was annually compiled into a database by park staff and was used to determine campsite occupancy when we lacked direct GPS data from recreational users in our sample.

Occasionally, backcountry campers stayed at a campsite that did not agree with their permit and thus did not agree with the Yellowstone Park backcountry database. This occurred for several reasons, but most likely reasons include; fatigue, weather, insects, a data entry error by park staff, or a change of plans (I. Kowski, Yellowstone Park Central Backcountry Office, personal communication). Since we wanted to use the park database to determine campsite occupancy, our first objective was to evaluate the backcountry database for accuracy. We evaluated it by comparing our GPS samples to their paired records in the backcountry database. We used the GPS sample to determine exact campsite locations and then compared them to their reserved campsite and calculated an accuracy percentage.

Our second objective was to determine a cutoff time when people were most likely to be arriving and leaving a backcountry campsite. We did this to provide a campsite occupancy time for parties that were not in our sample. We used the GPS location data from our sample to create a distribution of times when campsites were vacated in the morning and occupied in the evening. We considered campsites vacant when at least 25% of sampled parties had left in the morning, and occupied when at least 75% of sampled parties had arrived for the evening. We wanted to be conservative with the estimate of campsite occupancy times to avoid the possibility of committing a type 1 error (e.g. suggesting a campsite was occupied when it was not). When we detected a bear location near an occupied campsite, we wanted a reasonable degree of certainly that it was occupied by people. Finally, if a recreational party reserved a campsite for multiple days we considered the campsite continuously occupied.

Bear Distribution versus
Backcountry Campsite Analysis

To evaluate the relationship between backcountry campsites and bear behavior we compared bear locations and random locations to campsite occupancy in space and time. To evaluate the relationship spatially, we measured the distance of locations to the nearest occupied and vacant backcountry campsite. We created random locations, for each individual bear within the outer boundary of its defined home range. We created home ranges using the k nearest neighbor convex hull method (k-LoCoh) with $k = \sqrt{\frac{n}{2}}$ (Getz and Wilmers 2004). We used the k-LoCoh method because it adequately delineated the shoreline of Lake Yellowstone, where several campsites were located. We created the

home range shapefiles using the LoCoh home range generator for ArcGIS 9.x (University

of California, LoCoh home range generator for ArcGIS 9,

http://nature.berkeley.edu/~alvons/locoh, Accessed 21 April 2011). We chose 100%

isopleths as a boundary. We generated an equal number of random locations to GPS

locations per bear. We generated random locations using the Alaska Pak Toolkit in

ArcGIS 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA). To

evaluate the relationship between backcountry campsites and bear behavior temporally,

we used the times associated with each GPS radio collared bear location. We compiled

times associated with each bear location and randomly attached these to random locations

for each individual bear resulting in a list of random locations with a time equivalent in

number to the GPS fixes, but in a random order. This allowed us to contrast occupancy

status of a campsite to a bear or random location at given distances from campsites.

We compared the times and distances (≤ 1 km) of the bear and random locations

to occupied and unoccupied backcountry campsites. We categorized locations into 5

ordinal distance bins (0–200 m, >200–400 m, >400–600 m, >600–800 m, and >800–1000

m). We chose a distance of 200 m to provide an adequate sample for each category. We

generated statistics for 4 different datasets: 1) bear locations within a given ordinal

distance of an occupied campsites, 2) bear locations within a given ordinal distance of a

vacant campsites, 3) random locations within a given ordinal distance of an occupied

campsites, 4) random locations within a given ordinal distance of a vacant campsites. We

created 2X2XK contingency tables with K = individual bear, to control for individual

bear effects. Finally, we generated similar statistics using these 5 ordinal distances of bear and random locations to backcountry campsites ignoring campsite occupancy.

For both analyses we used an exact inference procedure to estimate odds ratios in the 3-way contingency tables (campsite occupancy, bear or random location, individual bear) and (within or beyond the distance bin, bear or random location, individual bear). We conditioned our test on fixed-strata marginal totals and used an exact small-sample alternative to the Cochran-Mantel-Haenzel test (Agresti 2007:114). Our null hypothesis was that the odds ratios were = 1 (equal odds). We accepted the alternative hypothesis for any odds ratio where the 95% CI did not overlap 1. A key assumption was that individual bears share a common odds ratio. We evaluated this by fitting log-linear models corresponding to this assumption and plotting fitted values with observed values. The plots allowed for a visual assessment of the reasonability of common odds ratio assumption (Haroldson et al. 2004). We conducted our analysis using the statistical program R (R version 2.12.2, www.r-project.org, accessed 2 September 2011).

Results

Bear Sample

We deployed 16 collars on 12 individual grizzly bears (9 M, 3 F). Our GPS collars successfully obtained 92.4% of 71,535 fix attempts.

Human Sample

We sampled 233 overnight parties, including 1,101 reserved camp nights. In our sample, 11 parties (4.7%) failed to record their campsite locations on their entire trip, 53

parties failed to record a portion of campsite locations (22.7%), and 169 (72.6%) parties

successfully recorded campsite locations on their entire trip. Therefore, our backcountry

campsite reservation accuracy, arrival and departure times were determined by 222

parties, including 799 camp nights.

Backcountry Campsite Results

The 222 recreational parties stayed in backcountry campsites that agreed with the

Yellowstone Park reservation database in 701 out of 799 circumstances (87.7%

accuracy). Of the 98 times an error occurred, 43 (44%) were when campsites were

vacated because a party abandoned a trip, or never left on their trip and failed to notify

park staff. The other errors, 55 (56%) included 15 parties that failed to locate the correct

campsite. Based on these statistics, we concluded that the park reservation database was a

suitable measure of campsite occupancy for our analysis.

Campsite arrival times and departure times in our sample were consistent with

modest variability (Fig. 3.2). We determined that the lower quartile, median, and upper

quartile for campsite departure and arrival times were 0826 hours, 0932 hours, and 1054

hours ($n = 701$) and 1527 hours, 1653 hours, and 1814 hours ($n = 668$), respectively.

Since we defined campsite occupancy when at least 75% of people had arrived in the

evening or at least 25% of sampled people had left in the morning, cutoff times for

campsite occupancy were between 1814 to 0826 hours. We used data from our GPS

sample and the park database to establish occupancy, departure, and arrival times for

9.4% and 90.6% of campsites used in our analysis, respectively.

Bear and Occupied Campsite Results

      Our results showed that grizzly bears were less likely to be near occupied

backcountry campsites, compared to random locations. Bears avoided occupied

campsites within 400 m, where the odds ratio was significantly less than 1 at $\leq$ 200 m and

>200–400 m. Beyond 400 m, we did not detect a significant difference between bear

locations and random locations (Fig. 3.3). Grizzly bear locations were 0.35 times as

likely to be within 0–200 m of occupied campsites, compared to random locations (95%

CI = 0.19 to 0.62, $P \leq 0.001$). Grizzly bear locations were 0.56 times as likely to be

within 200–400 m of occupied campsites, compared to random locations (95% CI = 0.38

to 0.82, $P = 0.002$). At 400–600 m grizzly bear locations were 0.88 times as likely to be

near occupied campsites (95% CI = 0.67 to 1.17, $P = 0.375$). At 600–800 m grizzly bear

locations were 1.09 times as likely to be near occupied campsites (95% CI = 0.86 to 1.37,

$P = 0.487$). At 800–1000 m grizzly bear locations were 1.2 times as likely to be near

occupied backcountry campsites (95% CI = 0.97 to 1.5, $P = 0.093$).

Bear and Backcountry Campsite
Results (Occupancy Ignored)

      When we did not consider campsite occupancy, results were different. Grizzly

bears were more likely to be near backcountry campsites compared to random locations

when occupancy was ignored. This likely occurred because campsites were most often

vacant. On average 81 out of the 88 campsites were unoccupied each day. Bears selected

areas within 600 m of backcountry campsites, where the odds ratio was significantly

greater than 1 at $\leq$ 200 m, >200–400 m, and > 400–600 m. Beyond 600 m bears were

less likely to be near backcountry campsites, compared to random locations (Fig. 3.4).

Grizzly bear locations were 2.11 times more likely to be within 0–200 m of campsites,

compared to random locations (95% CI = 1.85 to 2.41, $P \leq 0.001$). Grizzly bear locations

were 1.38 times more likely to be within 200–400 m of backcountry campsites,

compared to random locations (95% CI = 1.27 to 1.51, $P \leq 0.001$). Grizzly bear locations

were 1.11 times more likely to be within 400–600 m of backcountry campsites, compared

to random locations (95% CI 1.03 to 1.20, $P = 0.005$). After 600 m there was a shift in

preference and the odds were less than 1. Grizzly bear locations were 0.86 times as likely

to be within 600–800 m of backcountry campsites, compared to random locations (95%

CI 0.80 to 0.92, $P \leq 0.001$). Grizzly bear locations were 0.90 times as likely to be within

800–1000 m of backcountry campsites, compared to random locations (95% CI 0.85 to

0.96, $P \leq 0.001$).

Discussion

We found evidence that bears avoid backcountry campsites when occupied. This

supports our hypothesis that bears avoid backcountry campsites occupied by humans.

This avoidance response diminished beyond 400 m. We also found that bears tended to

be closer to backcountry campsites when occupancy was ignored. This was not

surprising because on average 81 of the 88 backcountry campsites were unoccupied each

night. Therefore, campsites were most often vacant so an odds ratio in the opposite

direction corresponds with our evidence of bear avoidance of camps when humans were

present. These results provide further evidence that bears respond negatively to the presence of people and not just the campsites themselves.

Previous research has also found that bears avoid non-motorized recreational users in remote areas (Jope 1985, Gunther 1990, Kasworm and Manley 1990). This study further confirms that bears will continue to avoid humans, even when they are inactive and in predictable locations. Our results also provide evidence that backcountry campsites around Yellowstone Lake are, in general, preferred bear habitat unless occupied by people. This is likely due to the location of campsites near natural travel corridors (e.g. trails and streams), and preferred vegetal foods for bears (Mealey 1980, Despain 1990, Mattson et al. 1991). Also, bears have been known to frequent backcountry campsites after they have been vacated by people. Many backcountry campsites have fire rings which are sometimes used by campers to burn trash. Evidence of bear digging in fire rings has been documented. Also, despite best efforts, many campers do leave behind small food scraps which attract bears to campsites shortly after people leave.

Global Positioning System technology allows wildlife researchers to consider temporal aspects when evaluating animal behavior near human presence (Cagnacci et al. 2010). When time of day is considered in studies of human-bear interaction a significant effect is often observed (Gibeau et al. 2002, Graves 2002, Graham et al. 2010). It has also been suggested that studies of bear habitat selection should include a temporal component to avoid biased results (Moe et al. 2007). Results of this study provide additional support for including a temporal component when evaluating studies of

human-bear interaction. This study also showed that if we had no knowledge of campsite

occupancy and merely tested effects of backcountry campsites on bear behavior, results

would have led us to conclude bears were attracted to these sites. Including a temporal

component allowed us to determine effects of human presence on bears.

Management Implications

Based on our results we feel the Yellowstone backcountry database is accurate

and can be used to assess campsite occupancy and human-wildlife interaction. We also

found that a temporal component in our analysis led to very different conclusions then

when one was not considered. We therefore recommend future studies consider time as a

covariate. We also found that human occupancy can displace bears from habitat out to

400 m and that campsite closures may enhance foraging opportunities for bears. We

conclude that BMA restrictions on backcountry campsites around Yellowstone Lake are

effective at providing bears additional foraging opportunities and thus increase habitat

effectiveness.

Acknowledgements

Fig. 3.1. Yellowstone National Park, Wyoming, USA. Highlighted areas display 6 Bear Management Areas and 88 designated backcountry campsites
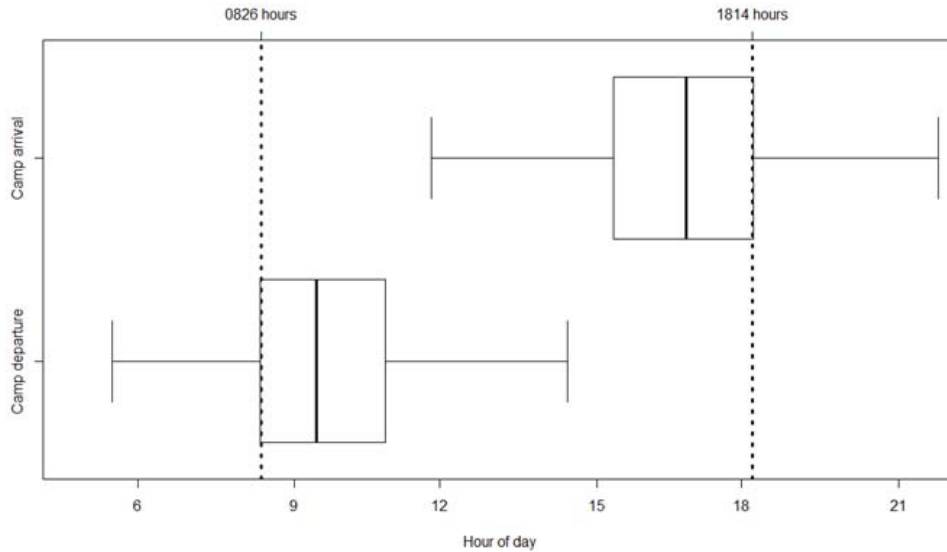
Fig. 3.2. Box and whisker plot of backcountry campsite arrival ($n = 701$) and departure times ($n = 668$). We used the hours between the 75th percentile of arrival times and 25th percentile of departure times to determine backcountry campsite occupancy in cases where we had no direct information of occupancy from our GPS sample. The dashed lines represent the estimated arrival time (1814 hours) and departure time (0826 hours). For the arrival time, the median was 1653 hours, with an inter-quartile range (IQR) of 2 hours and 46 minutes. For the departure time, the median was 0932 hours, with an IQR of 2 hours and 28 minutes. The whiskers extend to 1.5 x IQR.
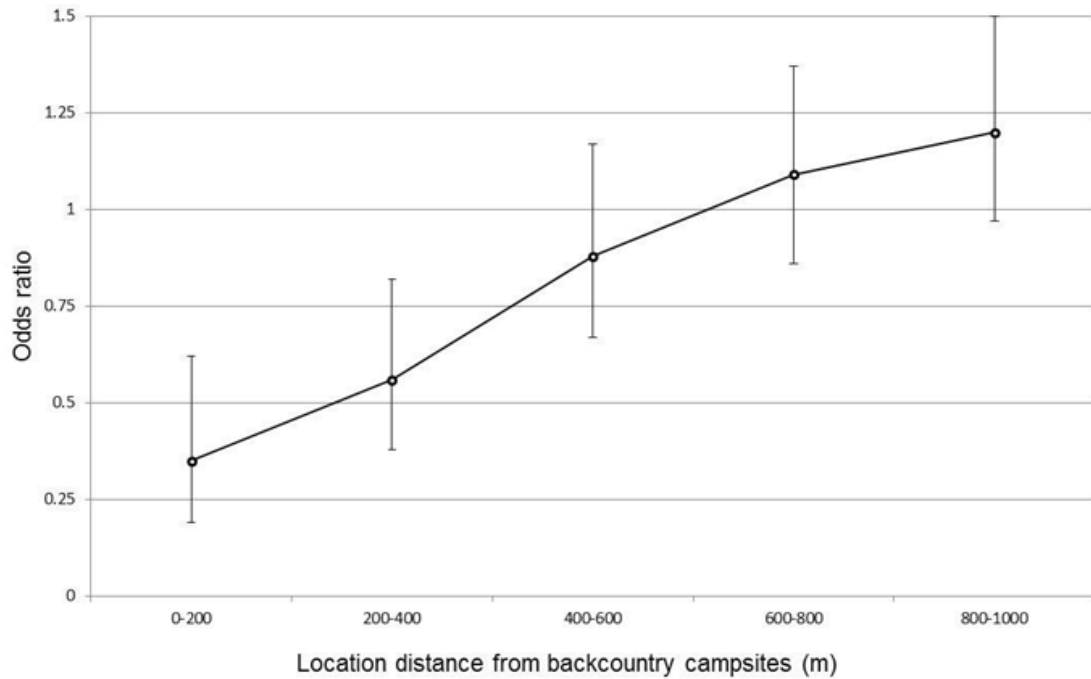
Fig. 3.3. Odds ratios (95% CI) for grizzly bear locations within given distances to occupied backcountry campsites, compared to random locations. At ≤ 200 m, grizzly bear locations were 0.35 times as likely to be near occupied backcountry campsites, compared to random locations (95% CI = 0.19 to 0.62, $P \leq 0.001$). At 200–400 m, grizzly bear locations were 0.54 times as likely to be near occupied backcountry campsites, compared to random locations (95% CI = 0.38 to 0.82, $P = 0.002$).
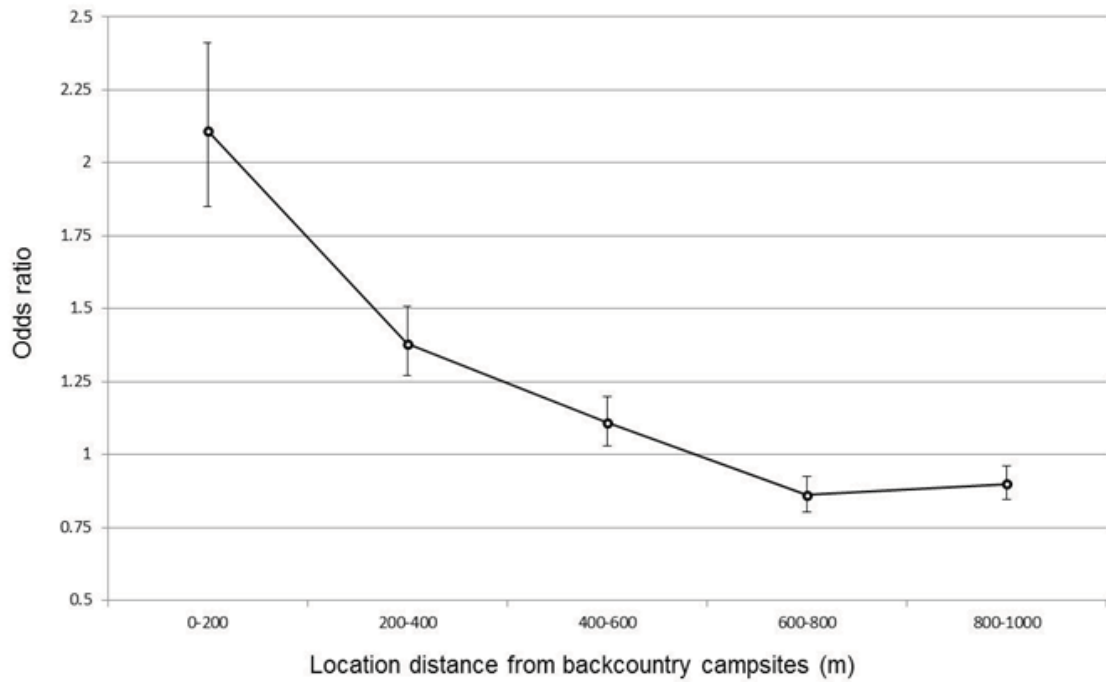
Fig. 3.4. Odds ratios (95% CI) for grizzly bear locations within given distances to backcountry campsites, compared to random locations. At ≤ 200 m, grizzly bear locations were 2.11 times more likely to be near backcountry campsites, compared to random locations (95% CI = 1.85 to 2.41, $P \leq 0.001$). At 200–400 m grizzly bear locations were 1.38 times more likely to be within 200–400 m of backcountry campsites, compared to random locations (95% CI = 1.27 to 1.51, $P \leq 0.001$).

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CHAPTER FOUR

DISPLACEMENT BEHAVIOR OF GRIZZLY BEARS FOLLOWING DIRECT
INTERACTIONS WITH BACKCOUNTRY USERS IN YELLOWSTONE NATIONAL
PARK

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4, and 5

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Contributions: Conceived and implemented the study design. Collected and analyzed
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Co-Author: Dr. Scott Creel

Contributions: Provided feedback on the study design. Provided statistical advice and
comments on the manuscript.

Manuscript Information Page

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Abstract

The consequences of human recreation on grizzly bear (*Ursus arctos*) behavior is not fully understood. Evidence suggests that grizzly bears avoid people when possible and often move away quickly when the two interact. However, more research has been needed to understand the specific conditions that lead to an avoidance response by a bear and what occurs following a close interaction. In this study, we tracked human movements with Global Positioning System (GPS) units and grizzly bear movements with GPS radio collars in Yellowstone National Park, USA. We identified circumstances of direct human-bear overlap and documented 86 interactions where a grizzly bear and a group of people were within 750 m of one another at the same time. We measured the distance between the bear, the group of people and a suite of environmental covariates. We also measured the distance each bear moved following an interaction with people and categorized the movements as an avoidance response or nonresponse. We determined that the closer a bear was to a group of people, the more likely it would show an avoidance response, regardless of environmental variables, age or sex. The mean distance between a bear and group of people for interactions that led to an avoidance response was 217 m $\pm$ 130 ($\bar{x} \pm$ SD), and a median of 192 m. The mean distance between a bear and a group of people for interactions that did not lead to an avoidance response was 482 m $\pm$ 167 ($\bar{x} \pm$ SD), and a median of 508 m.

Introduction

Grizzly bears (*Ursus arctos*) that inhabit areas of Yellowstone National Park, USA are surrounded by consistent recreational activity. To help manage recreational users in grizzly bear habitat, Yellowstone National Park (hereafter, Yellowstone Park) implemented a Bear Management Area (BMA) program which was designed to provide space and unhindered foraging opportunities for grizzly bears (National Park Service 1982). The program was created in 1982 and delineating areas of the park where human access was restricted. The BMA program was partly based on the idea that grizzly bears avoid people and can be displaced from foraging opportunities. Previous research has indicated that grizzly bears in Yellowstone Park avoid areas of human presence (Mattson et al. 1987, Gunther 1990, Coleman et al. in review *a,b*). Yet, work focused on direct human-bear interaction in Yellowstone Park has been hampered by small sample sizes and dated technology (Schleyer 1983, Haroldson and Mattson 1985, Gunther 1990). Thus far, it has been difficult to quantify individual interactions and assess conditions that lead to an avoidance response of bears to people.

Multiple studies have shown that grizzly bears avoid recreational users (Mclellean and Shackleton 1989, Gunther 1990, Kasworm and Manley 1990, Mace et al 1996, Graves 2002). There is evidence that bears often display an avoidance response when a person is within their overt reaction distance (ORD). Overt reaction distance can be

defined as the distance at which a bear visibly responds to a person during a human-bear interaction (Herrero et al. 2005, Hopkins et al. 2010). The measured distance can be site specific and may change depending on various biological and environmental factors (Smith et al. 2005, Rode et al. 2006, Sundell 2006, Greve 2008). A bear's individual history, the density of bears in an area, sex, age, available food resources, and immediate surroundings may all contribute to how an individual animal behaves around a group of people. Habituated or food-conditioned bears often have a diminished ORD and may tolerate humans in close proximity (Herrero 2002, Herrero et al. 2005). Also, bears that come in constant contact with other bears are sometimes less responsive to people (Smith et al. 2005). Age, sex, and reproductive status must also be considered. Females with cubs may be more prone to a defensive attack and younger bears may have limited experience interacting with people (Herrero 2002). Certain individual bears can have different dietary requirements and may tolerate people in order to gain access to prime foods (Rode et al. 2006). Dominant male grizzly bears in Yellowstone are more successful at obtaining meat when compared to females (Mattson 1997, Hilderbrand et al. 1999, Jacoby et al. 1999). Grizzly bears consuming meat may respond differently in an interaction with a person, compared to bears consuming vegetal food sources.

Grizzly bears can also respond differently to people depending on the amount of forested cover. In dense forests, bears may interact with people at close distances because they may not have the ability to see, smell, or hear people approaching. This type of interaction can trigger a quick and defensive response from a bear or, at other times, may prompt a bear to quickly leave an area (Herrero 2002). Conversely, bears

may react to people at much longer distances in non-forested areas. Interactions in non-forested areas allow humans and bears to be mutually aware of one another at a further distance, thus increasing the likelihood of an avoidance response by the bear. Finally, there is evidence that a grizzly bear's response to people depends on the number of people in a group. Grizzly bears may perceive people as threatening, and determine that it is better to avoid larger groups of people. Empirical evidence suggests that bears are more likely to avoid groups of ≥ 3 people (Herrero 2002, Gunther and Hoekstra 1998, National Park Service 2012*b*). Various factors often contribute to the behavior of a bear near a group of people. Therefore, it is important to consider each case individually and assess as many variables as possible.

Previous research has found that grizzly bears will avoid people over relatively large distances in Yellowstone Park (Gunther 1990, Coleman et al.in review *a*), yet this work involved small sample sizes, or focused on larger scale human-bear interactions. In Yellowstone Park, there has been little research done which evaluates individual human-bear interactions, especially involving the general public, and with bears that have a known age, sex, and management status. Finally, there is evidence that bears travel far distances following an interaction (Schleyer 1983, Haroldson and Mattson 1985, Gunther 1990). However, this has been difficult to determine unless a bear is closely monitored or remains within a visible range.

In this study we used Global Positioning System (GPS) data for people and bears to identify and evaluate circumstances when the two interacted directly. We utilized human GPS movement data from a group of sampled recreational parties in Yellowstone

Park. In addition, we used GPS units to track the movements of a group of biologists

performing bear research in our study area. Our approach was to combine human

movement data with GPS radio collar information from grizzly bears to identify direct

interactions and classify outcomes. Our objectives were to 1) identify circumstances

when a radio collared grizzly bear and a group of people were within close proximity to

one another, 2) determine the distances that led to an avoidance response by a bear, 3)

evaluate how far bears moved following close interactions, and 4) determine

environmental factors that influenced the response of a bear to humans. To address our

questions we used model selection with Akaike's Information Criterion (AIC_c) to

compare a set of a priori logistic regression models. This included a group of models

with the near-distance between a bear and a group of people and a set of different

environmental covariates. Our study approach allowed us to determine what type of

conditions led to an avoidance response of a bear to people and provided more

information about the energetic demands of this behavior.

Study Area

Geography, Vegetation, and Climate

We conducted our study from April 2007 to October 2009 in the southeastern

portion of Yellowstone Park (Fig. 4.1). Yellowstone Park is within the core of the

Greater Yellowstone Ecosystem (GYE). The GYE is geographically defined as the

Yellowstone Plateau and the surrounding mountain ranges above 1,500 m and 3,600 m.

Grizzly bears used habitats within this range throughout the GYE (Schwartz et al. 2002).

The main geographic and recreational characteristics of the study area was Yellowstone

Lake. Yellowstone Lake was a high elevation (2,359 m) oligotrophic lake that covered

35,391 ha and had a mean depth of 42 m. The east and southeast drainage of

Yellowstone Lake was dominated by larger stream tributaries draining from high

mountain topography, lodgepole pine (*Pinus contorta*) forest, and alluvial meadows. The

10-year (1998–2008) mean high and low temperatures were -5.4 º C and -17.0º C,

respectively, in January and 23.3º C and 4.6º C, respectively, in July at Yellowstone Lake

(Western Regional Climate Center 2010). Approximately 80% of precipitation typically

fell as snow (Reinhart and Mattson 1990, Fortin 2011).

Patterns of precipitation and temperature produced predictable vegetation patterns

(Marston and Anderson 1991). Low elevations (<1,900 m) supported foothill grasslands

or shrub-steppe communities. With increasing moisture, open stands of Rocky Mountain

juniper (*Juniperus scopulorum*), limber pine (*Pinus flexilis*), and Douglas-fir

(*Pseudotsuga menziesii*) occurred. Lodgepole pine dominated mid-elevations where poor

soils formed from rhyolite predominated. With increasing elevation, spruce-fir or

subalpine forests dominated. Engelmann spruce (*Picea engelmannii*) and whitebark pine

(*Pinus albicaulis*) formed the upper tree line. Alpine tundra occurred at the highest

reaches of all major mountain ranges (Patten 1963, Waddington and Wright 1974,

Despain 1990).

Human Use and Recreation

The study area covered approximately 375,000 hectares of non-developed terrain

with a system of maintained backcountry trails (Fig. 4.1). Permitted methods of

recreation within the study area were foot travel, hooved stock (horses, mules, and llamas) travel, and personal watercraft use on Yellowstone Lake. The study area offered trail and hooved stock access from 8 trailheads and off-trail access from Yellowstone Lake. Recreational users had access to over 500 km of trail and over 100 designated backcountry campsites. Backcountry campsites allowed recreation users overnight access to wilderness and road less areas. All areas greater than approximately 500 to 1000 m from roads and park developments were considered recommended wilderness. Recommended wilderness prohibited or restricted motorized equipment from being used and any type of road from being built (The 1964 U.S. Wilderness Act). Therefore, the study area was only accessible by man-powered watercraft, foot, hooved stock, and motorboats in limited circumstances. No other forms of transportation or recreation were allowed.

Recreation was restricted in portions of the study area due to annual Bear Management Area restrictions (Fig. 4.1). The BMA restrictions included pre-determined area closures, backcountry campsite closures, limited off-trail travel, and time of day restrictions. Bear Management Areas restricted human use in April, May, and June. Following early July, most restrictions were lifted and people were allowed access to all areas of the study area, including all backcountry campsites and off-trail travel.

Methods

Bear Trapping and Collaring

We trapped and radio collared grizzly bears from September 2006 to July 2009. Trapping was performed by the Interagency Grizzly Bear Study Team under the procedures approved by the Animal Care and Use Committee of the United States Geological Survey, Biological Resources Division and conformed to the Animal Welfare Act and United States Government principles for the use and care of vertebrate animals used in testing, research and training. The team used culvert traps placed within approximately 1 km from the shoreline of Yellowstone Lake to capture grizzly bears that utilized the Lake and surrounding areas. The team fitted all captured bears with Telonics Spread Spectrum (SS) Global Positioning System (GPS) collars (Telonics, Inc., Mesa, AZ) with a biodegradable canvas spacer and a CR2-A programmable remote drop-off device set a specific release date. Collars obtained a position fix every 30 or 60 minutes. Collars shut off during the expected denning season (Nov 15 to Apr 14) and programmed a release date of October 1 of the 1st or 2nd year. We flew telemetry flights weekly from late April through mid-October to retrieve collar data.

Human Use Sample

We obtained human GPS movement data from two sources. First, we randomly sampled overnight and day recreational users that were accessing the 6 BMAs surrounding the southern and eastern portion of Yellowstone Lake (Fig. 4.1). We randomly sampled overnight backcountry users from May through September in 2007,

2008, and 2009 by using a list of people generated from the Yellowstone Park backcountry permit system database. We attempted to sample approximately 20% of the overnight recreational users per week. Day users were not required to obtain a backcountry permit, therefore; we sampled day users by randomly selecting hiking parties at two commonly used trailheads that provided access to the 6 BMAs south and east of Yellowstone Lake. We sampled day users 1 day/week during July, August, and September from July 1, 2007 to September 30, 2009. We stationed a crew member at a randomly selected trailhead from 0700–1800 hours on sample days and randomly selected every other hiking group. For day and overnight users one member of each sampled recreational party was asked to carry a hand-held Garmin XL or Garmin e-Trex GPS unit on their trip (Montana State University Institutional Review Board-Human Subjects Committee, protocol approval number = TC042606-ES). We asked individuals to leave GPS units on all day and record all of their movements while on or off backcountry trails, except when boating and or in designated backcountry campsites. We programmed GPS units to obtain 1 location/minute for trips $\leq$ 2 days, and 1 location/2 minutes for trips > 2 days. Upon completion of their trip, we asked recreational parties to return their GPS units to Yellowstone park staff via inter-park mail.

We also obtained human GPS movement data from a bear research crew. The bear research crew was performing work in areas surrounding Yellowstone Lake, focusing on the lake tributaries and drainage areas. The research crew had access to all areas of the study area with few exceptions. Furthermore, they were allowed to access the seasonal BMA closures normally prohibited to the general public. The research crew

worked in groups of 2-4 people and often travelled both on-trail and off-trail to perform

daily tasks. They also travelled along stream corridors to perform visual counts of

spawning Yellowstone cutthroat trout (*Oncorhynchus clarki*). They were also asked to

use a Garmin e-Trex GPS units and track all movements while performing field work.

The GPS units were programmed to obtain a fix every 1 or 2 minutes, depending on trip

duration. To avoid bias, we only considered GPS locations that were taken when the

research crew was traveling from point to point or surveying a spawning stream. We did

not consider GPS locations when the research crew was actively pursuing a bear using

radio telemetry. We used Garmin Map Source 4.0 (Garmin Inc., Olathe, KS) to download

all GPS units to a laptop computer. The GPS units provided a UTM location, a date, and

time for each fix. We recorded group size for the all sampled recreational parties and the

research crew.

Human-Bear Interaction Analysis

To extract direct interactions for our analysis we queried all human and bear

locations that were within 750 m, with the same date and time. We considered each

paired human and bear GPS location as an individual interaction. We chose our query

distance because grizzly bears have been documented responding to, or acknowledging,

human presence at distances up to and over 500 m (Mclellan and Shackleton 1989,

Gunther 1990, Herrero 2002, Coleman et al. in review *a,b*). The 750 m query distance

allowed for additional space for people that were not carrying a GPS unit and may have

been closer to a bear. It also allowed us to incorporate any aberrant human movements

that occurred between sequential GPS locations.

We considered each paired individual interaction as our sample unit, but to maintain independence we only considered interactions that occurred between one individual bear and one group of people per day. If an interaction occurred between a certain group of people and a certain bear more than once in a day, we only considered the first interaction. We only considered more than one interaction per bear, per day, if it occurred with two different groups of people. We used ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, CA) to identify all interactions and analyze all spatial and temporal locations of bears and people.

We evaluated all human-bear interactions and determined 1) the near-distance between a group of people and a bear, 2) the direction a bear moved following the interaction relative to the people, 3) the time recorded by the human GPS units and the bear radio collars, 4) the straight line movement distance between sequential bear locations (30 or 60 minutes) following an interaction, and 5) the bear movement distances between sequential locations that occurred at the same time interval for 15 days prior and 15 days following each interaction. For all bears with a radio collar programmed at a 30 minute fix rate, we included measurements at the 30 and 60 minute time scale. We calculated the mean, median, and upper 90th percentile of movement distances for the matching time intervals and the 31 days surrounding each interaction. If a bear's movement distance, following an interaction, was in the upper 90th percentile we assumed it was responding to the presence of people. If the bears movement was not in the upper 90th percentile, we assumed it was not responding to the presence of people. We chose a breakpoint of 90 a priori, using a wildlife flight response criteria similar to

Preisler et al. 2006. We classified all human-bear interactions into one of two categories.

Interactions that produced an avoidance response from the bear and those that did not.

We used logistic regression models with a binary response to evaluate our

research question. The response variable in our models was coded as a 1 for an

interaction that resulted in an avoidance response, and a 0 for an interaction that did not.

We compared models with a number of environmental variables to estimate effects of

different covariates on an avoidance response. We considered the near-distance between

a bear and people in all models. In addition to near-distance, other covariates were; bear

sex (categorical), bear age (continuous), group size (continuous), and cover type

(categorical). We determined the cover type for each interaction by using the 2006

Yellowstone Park cover type layer, the 2009 Yellowstone Park burn layer, and 2006

satellite imagery from the National Agricultural Imagery Program compiled by the

Yellowstone Park, Spatial Analysis Center. We categorized the cover type for each

interaction as "cover" or "open-cover". Cover was considered a forested area, and we

considered an interaction in cover if both the bear and the people were in a forested cover

type, or if the bear alone was in a forested cover type. Open-cover was considered a non-

forested cover type, a sparsely forested cover type, or a recent burn. We considered an

interaction in open-cover if both the bear and the people were in the non-forested cover

type.

We used Akaike's Information Criterion , with a small sample size adjustment

(AIC_c), to rank and compare models with a combination of different explanatory

variables. We started with an intercept only model and a model with the near-distance

variable alone. We then considered a suite of basic models that included the near-

distance variable and a combination of other covariates identified from the literature and

personal knowledge (Haroldson and Mattson 1985, Herrero 2002, Mclellan and

Shackleton 1989, Gunther and Hoekstra 1998, Rode et al. 2006). We considered models

of increasing complexity and only considered statistical interactions that allowed for

biological interpretation. We considered the best approximating models, from the

candidate list, as the model with the smallest AIC_c score and any other models within 2

ΔAIC_c units of the top model. We also calculated the AIC_c weights for each model. The

weights represent the relative likelihood of the model, given the data and other models

considered (Burnham and Anderson 2002). We checked model assumptions by checking

for linearity. Linearity was assessed by plotting empirical logits against each explanatory

variable.

Results

We radio collared 21 grizzly bears during the 3 years of the study (n =13 M, n = 8

F). We sampled 389 recreational users from our random sample at trailheads and boat

access points. In total, 349 recreational users traveled by foot (via trailhead or boat

access) and 40 traveled on horseback. We collected 223,302 individual GPS locations

from hiking parties. This included 1,154 hikes and 55 horse rides.   We collected 291,167

GPS locations from the bear research crew including 565 individual days of hiking.

We identified 86 human-bear interactions from our GIS output, with 67 and 19

interactions that did not cause or caused an avoidance response from a bear, respectively.

We did not detect a situation where a bear approached a person. All bear movements were in the opposite direction from people or they were within the horizontal error for a GPS radio collar, 5.9 m to 30.6 m, D'Eon et al. 2002). We determined that 18 grizzly bears were involved in interactions with groups of people (n =11 M, n = 7 F). The sampled recreational users were involved in 30 interactions and the research crew was involved in 56 interactions. Of the interactions that led to an avoidance response, 9 involved recreational users and 10 involved the research crew. We did not detect an interaction with anyone traveling on horseback or with hooved stock. Therefore, all interactions occurred between a bear and a group of people on foot. Interactions that occurred when people and bears were ≤ 200 m apart usually led to an avoidance response by the bear. Two interactions occurred at ≤ 100 m and both produced avoidance responses. At a near-distances between 100-200 m, 10 of 13 interactions produced an avoidance response. Beyond a near-distance of 200 m, fewer interactions led to an avoidance response. Between 200-300 m only 3 of 13 interactions led to an avoidance response, between 300-400 m only 1 of 10 led to an avoidance response, and between 400-500 m only 3 of 14 led to an avoidance response. No interactions greater than 500 m produced an avoidance response from a bear (0/34) (Fig. 4.2). Differences were apparent between bears that displayed an avoidance response to humans, compared to those that did not (Fig. 4.2), suggesting that these differences were quite distinct and insensitive to our a priori breakpoint of 0.9.

Group size was larger for interactions which led to an avoidance response from a bear. The mean group size for all people involved in interactions was 2.7 ± 1.4 ($\bar{x}$ ± SD),

with a median of 2. The mean group size for those involved in interactions that led to an avoidance response was 3.4 ± 2.3 ($\bar{x} \pm$ SD), with a median of 3. The mean group size for those involved in interactions that did not lead to an avoidance response was 2.5 ± 0.9 ($\bar{x} \pm$ SD), with a median of 2. The near-distance between a bear and a group of people was shorter for interactions that produced an avoidance response. The mean near-distance between a bear and group of people for interactions that led to an avoidance response was 217 m ± 130 ($\bar{x} \pm$ SD), with a median of 192 m. The mean distance between a bear and a group of people for interactions that did not result in an avoidance response was 482 m ± 167 ($\bar{x} \pm$ SD), with a median of 508 m. The movement distance, following an interaction, was longer for bears that showed an avoidance response. At the 30 minute fix rate, the mean movement distance from bears that did not display an avoidance response was 93 m ± 183 ($\bar{x} \pm$ SD), with a median of 20 (n = 20). At the 60 minute fix rate, the mean movement distance resulting from bears that did not display an avoidance response was 179 m ± 239 ($\bar{x} \pm$ SD), with a median of 56 (n = 68). At the 30 minute fix rate, the mean movement distance from bears that displayed an avoidance response was 969 m ± 459 ($\bar{x} \pm$ SD), with a median of 830 m (n = 6). At the 60 minute fix rate, the mean movement rate resulting from bears that displayed an avoidance response was 1,501 m $\pm 1,434$ ($\bar{x} \pm$ SD), with a median of 846 m (n = 18) (Table 4.1).

The AIC_c model selection process indicated that the most supported model only contained the near-distance variable (Table 4.2). The only other model within 2 ΔAIC_c units of the top model included near-distance and the group size variable. The coefficient

estimates for the top 2 models suggested that the near-distance variable was significant in both cases, however party size was not (Table 4.3).

The most supported model suggested that for every one meter increase in distance between a recreational party and a bear the estimated odds of an avoidance response decreased 1.13% (95% CI 1.67% to 0.58%, $P \leq 0.001$). The estimated odds of an avoidance response was 3.1 times higher at a near-distance of 100 m compared to 200 m (95% CI = 3.09 to 3.12). The estimated odds of an avoidance response was 9.6 times higher at a distance of 100 m compared to 300 m (95% CI = 9.58 to 9.68). The second most supported model included the near-distance and group size variable. The near-distance coefficient estimate was very similar to the top model (Table 4.3). The group size variable was not statistically significant at the 0.05 level. The odds of an avoidance response increased 21.3% for every one person increase in group size (95% CI = -32.8% to 74.4%, $P = 0.424$). Also, for every one person increase in group size the odds of an avoidance response increased 1.24 times (95% CI = 0.73 to 2.11).

Discussion

The logistic regression model with near-distance between a bear and a group of people as the sole variable was the top ranking model in our set. We did include near-distance in all other models, yet various combinations of environmental variables did not improve model fit.   The only model within 2 ΔAIC_c units of the top model included the group size variable, and it was not significant at the 0.05 level. However, we found that the median group size for interactions that caused an avoidance response was 3, while

other types of interactions had a group size of 2. We determined that most interactions within 200 m did produce an avoidance response and were within the ORD for most bears, regardless of environmental conditions. These findings support Yellowstone Park policy which prohibits any person from "willfully approaching, remaining, viewing, or engaging in any activity within 100 yards (91.4 m) of bears" (Yellowstone 2012 Code of Federal Regulations). Overall, other factors appear less important than actual proximity of a group of people to a bear.

We did not determine a strong effect from the age and sex variables. This does not mean they are not important variables to consider. When interacting with people, females with cubs are often considered the most unpredictable and are often more prone to attack (Herrero 2002). However, only one female with cubs was involved in our analysis. The female had two cubs of the year and had an interaction with people at near-distances of 348 m, 417 m, and 601 m. None of these interactions produced an avoidance response, but she did not approach the people either. This individual female bear also had a history of habituated behavior which may have diminished her ORD.

Our data also suggests that bears often moved very far distances following an interaction. We failed to link other factors with these movements. Nevertheless, there is evidence that close interactions can lead to bears moving distances far beyond their mean and median movement distances. An increased energetic demand and loss of foraging opportunities may be a consequence of these movements. We confirmed 2 circumstances where we believe a grizzly bear was displaced from an ungulate carcass because of its proximity to people (117 m and 121 m). It is difficult to determine if this displacement

impacted the bear, but it was unlikely beneficial because ungulate carrion is a valuable food source for bears in Yellowstone Park (Jacoby et al. 1999). Our study did not address this question directly, but other research has shown that continuous avoidance of a threat or anti-predator behavior can lead to decreased fitness (Ruxton 1997, Creel et al. 2007, Pangle et al. 2007).   Outside of the rare occurrence where a person is attacked by a bear, it appears that bears often carry the burden of human-bear interactions.

We did not document any movement towards people or an aggressive act by a collared bear that was in close proximity to people. Excluding members of the bear research crew, we were also informed that most people had no knowledge when a bear was in close proximity. In addition, all of the bears considered in this study were captured in research traps. Very few of the individuals in our bear sample had a management history and none were documented as being food-conditioned. Therefore, we can assume that none of the bears in this study were associating humans with food. This fact may have contributed to the consistent avoidance response shown by these bears.

Management Implications

Our study highlights the importance of the Yellowstone Bear Management Area program which seeks to reduce human-bear interaction by restricting recreation access. We found that bears consistently respond to people following a close interaction. Often these responses led to movement distances well beyond a normal movement distance for a bear. Separating bears and people is a reliable way to ensure that bears are given adequate foraging opportunities and that bears are not subjected to the energetic demands

that accompany an avoidance response. We also found some evidence that larger party sizes will increase the odds of an avoidance response. While this behavior is not beneficial to bears, it does suggest that bears acknowledge additional people in a group. Yellowstone Park policy requiring hiking in large numbers is likely beneficial for human safety.

Acknowledgements

Table 4.1. Descriptive statistics for all interactions resulting in an avoidance response
[a]Near-distance between people and grizzly bear
[b]Time interval for each bear GPS radio collar
[c]Mean movement distance of each bear following an interaction
[d]Median movement distance for the same 30 or 60 minute time period 15 days prior and 15 days following an interaction
[e]This radio collar failed to take a location at the 60 minute time interval

Bear age (sex)	Date	Time	Party size	Near-distance (m)[a]	Time interval in minutes[b]	Movement distance (m)[c]	Median movement distance (m)[d]	Mean movement distance ± SD
19 (m)	8/13/2009	0930	3	202	30	502	125	279 ± 393
					60	503	218	439 ± 550
19 (m)	8/31/2009	1400	2	468	30	1701	130	207 ± 325
					60	3063	132	396 ± 317
9 (m)	8/3/2007	1100	1	197	30	1325	17	109 ± 261
					60	2109	18	142 ± 387
17 (m)	9/16/2009	1100	3	192	30	625	65	207 ± 492
					60	946	188	265 ± 346
18 (m)	7/20/2007	1800	2	433	30	916	192	285 ± 269
					60	2179	378	514 ± 69
17 (m) [e]	9/23/2009	1300	3	81	30	743	125	183 ± 196
					60	NA	NA	NA
19 (m)	7/27/2009	1200	6	117	60	522	13	74 ± 136
19 (m)	7/27/2009	1530	8	121	60	343	24	94 ± 158
15 (m)	9/11/2007	900	5	344	60	661	18	259 ± 550
4 (f)	9/2/2008	1200	10	71	60	1127	249	472 ± 493
4 (f)	8/4/2008	1500	2	184	60	746	167	358 ± 526
5 (m)	7/20/2008	1500	2	111	60	5846	11	222 ± 1027
11 (m)	6/27/2009	1400	3	113	60	731	32	343 ± 658
5 (f)	9/19/2009	1100	2	228	60	1212	431	563 ± 528
5 (f)	8/25/2009	1100	2	195	60	2811	349	552 ± 594
14 (f)	7/1/2009	1200	4	276	60	246	10	32 ± 76
14 (f)	7/26/2009	1300	2	127	60	427	9	31 ± 78
13 (f)	8/23/2008	1800	2	166	60	2894	137	340 ± 559
19 (m)	7/14/2009	1300	3	499	60	656	18	85 ± 153

Table 4.2. Model selection results for a priori models investigating the effects of human proximity and associated environmental factors on bear movement

Variables	*k*	AIC$_c$	ΔAIC$_c$	Weight
Near-distance	3	60.69021	0	0.359
Near-distance + group size	4	62.06524	1.375028	0.1803
Near-distance + cover	4	62.78126	2.091051	0.126
Near-distance + sex + age	5	63.67991	2.989701	0.08041
Near-distance + group size+ cover	5	64.04059	3.350375	0.0671
*Near-distance + group size+ near-distance*group size*	5	64.20975	3.519538	0.061695
*Near-distance + cover + near-distance*cover*	5	64.91292	4.222708	0.04341
Near-distance + sex + age + group size	6	65.4125	4.722286	0.03381
Near-distance + sex + age + cover	6	65.85713	5.166916	0.02707
Near-distance + sex + age + cover + group size	7	67.51205	6.821835	0.01835
*Near-distance + sex + age + cover + group size + near-distance*cover*	8	69.45762	8.767408	0.004473
*Near-distance + sex + age + cover + group size+ near-distance*group size*	8	69.75014	9.059929	0.003865
*Near-distance + sex + age + cover + group size + near-distance*group size + near-distance*cover*	9	71.65473	10.964515	0.00149
Intercept	2	92.83024	32.14003	3.76E-08

Table 4.3. Model output, coefficient estimates, and 95% CI's for the top two models from our a priori model set

Variable		95% lower CI	95% upper CI	SE	*P*-value	ΔAIC$_c$
Top Model						
Near-distance	-0.0113	-0.0168	-0.0058	0.0027	0.001	0
Second Model						
Near-distance	-0.0109	-0.0164	-0.0054	0.0028	0.001	1.375
Group size	0.2134	-0.3179	0.7447	0.2670	0.424	
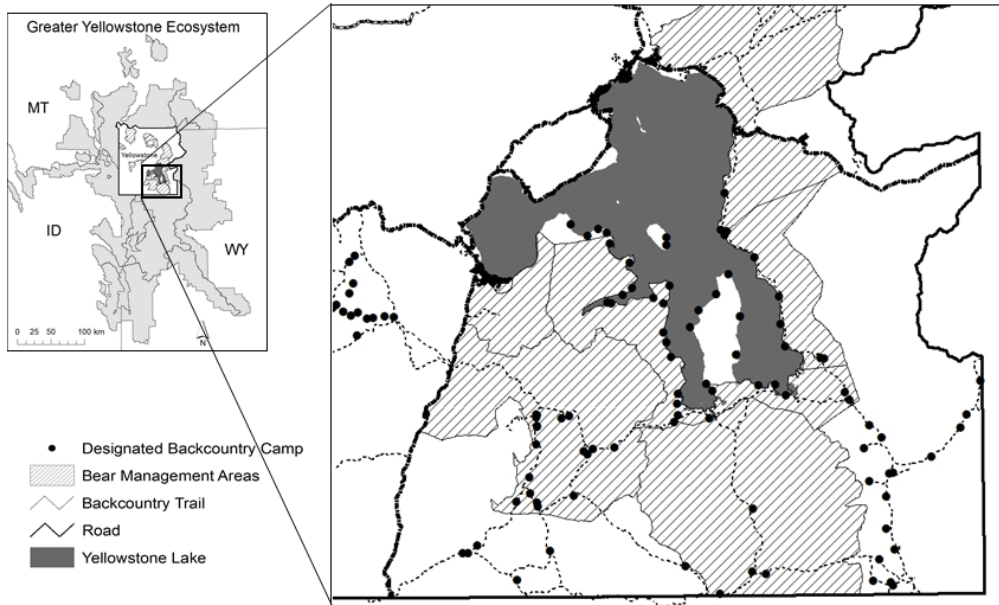
Fig. 4.1. Map of the study areas within the Greater Yellowstone Ecosystem and Yellowstone Park.

Fig. 4.2. All human-bear interactions ($n = 86$). The solid black line represents the median movement distance for each bear for the 15 days prior and 15 days following an interaction. The dashed line represents the 90th percentile movement distance. The "x" represents interactions that were classified as an avoidance response ($n = 19$), and the "o" represents all other interactions ($n = 67$).

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CHAPTER FIVE

GRIZZLY BEAR ACTIVITY PATTERNS AND THE INFLUENCE OF HUMAN PRESENCE

Contribution of Authors and Co-Authors

Manuscripts in Chapters 2, 3, 4, and 5

Author: Tyler H. Coleman

Contributions: Conceived and implemented the study design. Collected and analyzed data. Wrote first draft of the manuscript.

Co-Author: Dr. Charles C. Schwartz

Contributions: Helped conceive the study design. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Kerry A. Gunther

Contributions: Helped conceive and implement the study design. Provided field expertise and funding. Provided feedback on early drafts of the manuscript.

Co-Author: Dr. Scott Creel

Contributions: Provided feedback on the study design. Provided statistical advice and comments on the manuscript.

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Manuscript Information Page

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 x   Prepared for submission to a peer-reviewed journal
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Abstract

Most studies that have detailed the effects of human presence on grizzly bears (*Ursus arctos*) have focused on the spatiotemporal response of bears to people. Grizzly bears are often displaced by human presence and occupy areas with little human impact. However, some bears may occupy areas near humans because they are avoiding larger, more dominant bears or acquiring food sources not available elsewhere. When this occurs, little is known about the resulting behavioral changes. We used global positioning system (GPS) collars to track bear activity and hand-held GPS units to track human activity in remote portions of Yellowstone National Park, USA (YNP). Our objective was to compare bear activity in areas of human use to areas with little known human use to determine the influence of recreation on bear activity. We also evaluated bear activity patterns in areas where human recreation was restricted or prohibited in YNP. We found that bears were significantly less day active and more night active when near areas of human use. Conversely, bears were more day active and less night active when in places with little human use. Finally, when human recreation was prohibited, bears were significantly more day active in places people may frequent if allowed access. We conclude that human presence can influence bear behavior by decreasing mid-day activity and increasing night activity. Our study also suggested that areas of YNP currently closed to human recreation may see an increase in human-bear conflict if immediately opened to human recreation.

Key Words: bear management, grizzly bear, human-bear interaction, *Ursus arctos*,

Yellowstone National Park

Introduction

Numerous studies have explored the non-consumptive interaction between people

and grizzly bears (*Ursus arctos*). It has been documented that grizzly bears often avoid

areas of human development and occupation (Mattson 1990, Gibeau et al. 2002, Apps et

al. 2004, Johnson et al. 2005, Nellemann et al. 2007). Also, more benign forms of human

presence can influence bear movement, behavior, and habitat selection. Grizzly bears

have been shown to avoid motorized backcountry users (Graves 2002), wildlife viewers

(Olson et al. 1998, Nevin and Gilbert 2005, Rode et al. 2006*a*), and hikers or campers

(McLellan and Shackleton 1989, Gunther 1990, Kasworm and Manley 1990, Mace and

Waller 1996). In addition, some grizzly bears may alter their activity and foraging

patterns in the presence of people or human developments (Mattson 1987, Rode et al.

2006*b*, Rode et al. 2007). This phenomena has been studied in a variety of others species

and has been shown to contribute to an increase in physiological stress (Creel et al. 2002,

Barja et al. 2007), reduced reproductive output (Ellenberg et al. 2007), survival (Ruhlen

et al. 2003), and foraging time (Steidl and Anthony 2000).

National Parks provide a unique opportunity to study human-bear interaction

because they often have few human developments and rarely allow consumptive

recreational use. Yellowstone National Park, USA (hereafter; Yellowstone Park) fits this

criteria because it is a popular destination for tourists, backcountry recreationists, and

wildlife watchers but also contains a stable population of protected grizzly bears (USFWS 1993, Schwartz et al. 2006). Yellowstone Park visitation has steadily increased to 3.5 million people in recent years (National Park Service 20102). However, much of this visitation occurs during the summer months, placing a potential strain on the park's bear population.

Previous work on human-bear interaction in Yellowstone Park has focused on the spatial or temporal response of a bear to the presence of people (Schleyer 1983, Haroldson and Mattson 1985, Gunther 1990, Coleman et al. in review *a,b*). However, certain circumstances suggest that some bears will stay near areas frequented by people and not entirely avoid them. Grizzly bears that are consuming high quality food resources may tolerate people at a close distances, and younger bears or females with cubs may occupy areas near humans to avoid larger adult males (Mattson et al. 1987, Nevin and Gilbert 2005, Rode et al. 2006*b*). Also, wildlife may choose to forage near humans when resources near people cannot be accessed elsewhere (Gill et al. 2001) For bears that occupy areas near people, little is known about the resulting behavioral changes. Recent research done by Schwartz et al. 2010, in Grand Teton National Park, provided evidence that grizzly bears become less day active and more night active when near areas of human developments. Conversely, they documented that bears further away from developments were more day active and less night active. Little research has been done to address how humans influence bear activity patterns in more remote areas, away from permanent developments.

In this study, we addressed the influence of human recreation on grizzly bear activity patterns in remote, backcountry areas of Yellowstone Park. We were able to compare and contrast activity patterns for grizzly bears by using annual Bear Management Area (BMA) closures. These closures have been in place since 1982 and were established to restrict recreational use in areas of Yellowstone Park with high seasonal concentrations of bears and bear foods (National Park Service 1982). The BMAs considered in our study had annual use restrictions for the first half of the tourist season (April, May, and June) and essentially no restrictions during the second half of the tourist season (July, August, and September). The restricted and unrestricted time periods allowed us to assess how the presence of people influenced bear activity patterns within the BMA boundaries. The 2 time periods also allowed us to determine what may occur if humans were allowed unrestricted access to areas currently closed or restricted. Our objectives were to 1) directly measure human recreational patterns, 2) evaluate bear activity patterns while BMAs were closed to recreational users, 3) evaluate bear activity patterns while BMAs were open to recreational users, and 4) identify how bear behavior could be influenced if BMA restrictions were lifted and people were allowed unrestricted access. We hypothesized that when humans were no present on landscape, bears would be more day active and less night active in areas that may otherwise be used by people (i.e. trails, campsites and non-forested areas). We also hypothesized that when humans were on the landscape, bears would be less day active and more night active in areas used by people. To address these questions we used Global Positioning System (GPS) units to track human movements while BMAs were unrestricted and identify areas and times of

common human use. We used bear GPS radio collars with activity counters to evaluate how bear activity patterns changed with proximity to places commonly used by humans.

Study Area

Geography, Vegetation, and Climate

We conducted our study from April 2007 to October 2009 in the southeast portion of Yellowstone Park. Yellowstone Park is within in the core of the Greater Yellowstone Ecosystem (GYE). The GYE is geographically defined as the Yellowstone Plateau and the surrounding mountain ranges above 1,500 m to 3,600 m (Fig. 5.1). Grizzly bears used habitats within this range throughout the GYE (Schwartz et al. 2002). The main geographic and recreational characteristic of the study area was Yellowstone Lake. Yellowstone Lake was a high elevation (2,359 m) oligotrophic lake that covered 35,391 ha, and had a mean depth of 42 m. The east and southeast drainage of Yellowstone Lake was dominated by larger stream tributaries draining from high mountain topography, closed canopy mixed forest, and subalpine meadows. The west and north drainages were characterized by smaller streams draining from low relief plateau topography, lodgepole pine (Pinus contorta) forest, and alluvial meadows. The 10-year (1998-2008) mean high and low temperatures were -5.4º C and -17.0º C, respectively, in January and 23.3º C and 4.6º C, respectively, in July at Yellowstone Lake (Western Regional Climate Center 2010). Approximately 80% of precipitation typically fell as snow (Reinhart and Mattson 1990, Fortin 2011).

Patterns of precipitation and temperature produced predictable vegetation patterns (Marston and Anderson 1991). Low elevations (<1,900 m) supported foothill grasslands or shrub-steppe communities. With increasing moisture, open stands of Rocky Mountain juniper (Juniperus scopulorum), limber pine (Pinus flexilis), and Douglas-fir (Pseudotsuga menziesii) occurred. Lodgepole pine dominated mid-elevations where poor soils formed from rhyolite predominated. With increasing elevation, spruce-fir or subalpine forests dominated. Engelmann spruce (Picea engelmannii) and whitebark pine (Pinus albicaulis) formed the upper tree line. Alpine tundra occurred at the highest reaches of all major mountain ranges (Patten 1963, Waddington and Wright 1974, Despain 1990, Schwartz et al. 2002).

Bear Management Areas and Human Recreation

Our study area consisted of 6 of the 16 Bear Management Areas surrounding the southern and eastern portions of Yellowstone Lake. Collectively the 6 BMAs were 81,176 ha or 9.0% of Yellowstone Park (Fig. 5.1). The 6 study area BMAs ranged in elevation from the shoreline of Yellowstone Lake at 2,380 m to the top of Two Ocean Plateau at 3,062 m. The 6 BMAs were 97.3% "recommended wilderness", which prohibited or restricted motorized equipment and any type of road building (The 1964 U.S. Wilderness Act). The area was accessible by man-powered watercraft, foot, hooved stock (horses, mules, and llamas), and motorboats in limited circumstances. Other forms of transportation or recreation were prohibited.

Access for recreational users was via foot and hooved stock trailheads or from the Yellowstone Lake shoreline. Yellowstone Lake had 177 km of shoreline, which provided

near continuous entry into the 6 BMAs. Yellowstone Lake provided access for backcountry trips via commercial boat drops, personal watercraft, or hiking from a designated backcountry campsite on the shoreline. The 6 BMAs had 4 major trailheads which lead into and through the study area. These trailheads provided access for foot and hooved stock travel, including day and overnight users. In total, the 6 BMAs contained 160 km of maintained trail. All day users could access the study area BMAs without informing Yellowstone Park. However, all overnight users were required to fill out a trip plan in advance and use a designated backcountry campsite. The designated backcountry campsite system allowed for use of pre-determined campsite locations by backcountry parties. The system was in place since 1973 and has had minimal changes to site locations since. The study area BMAs contained 54 designated backcountry campsites (14 accessible by boat only, 12 accessible by boat, foot or hooved stock and 28 accessible by foot or hooved stock only).

The 6 BMA restrictions differed slightly, but in general human use in the area was mostly restricted before July 1 and mostly unrestricted after July 1. From early spring to July 1 human recreation was limited to a subset of backcountry campsites, off-trail travel was restricted and several trail segments were closed. The result was a mean of 4.5 recreational users per day in the study area during this time period (2007–2009). Following July 1, the study area showed a sharp increase in human use. July, August, and September reflected the peak of seasonal recreation. The increase was the result of improved weather, open Yellowstone Lake fishing starting June 15th, permitted hooved stock use starting July 1, and employee entrance for trail and backcountry patrol cabin

maintenance. By July 15th all 6 BMAs were completely open and unrestricted. From July

1 to September 30 the study area had a mean of 146.7 recreational users per day (2007–

2009). By October 1, human use dropped off substantially due to inclement weather and

the closing of park facilities. During October there was a mean of 10.9 recreational users

per day in the study area (2007–2009).

Methods

Human Recreation Sample

We sampled overnight backcountry users during July, August, and September

from 2007–2009. We based our sample of overnight users using data from the

Yellowstone Park backcountry permit reservation system. We applied a stratified

random sample design with proportional allocation among four strata: private users,

outfitters, park employees or research groups staying at a designated backcountry

campsite, and park employees or research groups staying in a backcountry cabin. The

sampling frame for overnight users was a list of any recreational party that had reserved

at least one designated backcountry campsite which required travel through one of the 6

study area BMAs, including any park employee or researcher with overnight business

which required travel through the BMAs. We attempted to sample approximately 20% of

users from each strata per week based on the list provided from the backcountry permit

system. We were unable to contact parties before their departure date. Thus we met

sampled parties at their designated trailheads or boat access points on the morning of

their departure. One member of each party was asked to carry a hand-held Garmin 12

XL or Garmin e-Trex GPS on their trip (Montana State University Institutional Review Board-Human Subjects Committee, protocol approval number = TC042606-EX). We programmed GPS units to obtain 1 location/minute for trips $\leq$ 2 days, and 1 location/2 minutes for trips > 2 days. We asked individuals to leave GPS units on all day and record all movements.

Day users were not required to obtain a backcountry permit. Thus, we measured day use by randomly selecting recreational parties at two commonly used day-use trailheads. We sampled day users by randomly selecting one of the two study area trailheads frequently used by day users. We sampled day users 1 day/week during July, August, and September from July 1, 2007 to September 30, 2009. We stationed a crew member at the selected trailhead from 0700–1800 hours on sample days and randomly selected every other hiking group. One member from each group was asked to take a GPS unit and record all movements during the day. The GPS units were programmed to obtain 1 location/minute.

Upon completion of their trip, we asked all sampled recreational parties to return their GPS units to park staff via inter-park mail. All units were successfully received in good condition. We used Garmin Map Source 4.0 (Garmin Inc., Olathe, KS) to download all GPS units to a laptop computer. The GPS units provided a UTM location, a date, and time for each fix. If a GPS unit failed to obtain a satellite connection or did not receive data at the 1–2 minute rate, we removed those days from analysis. For each party, we recorded the number of individuals and recreation type (hooved stock or foot). We considered any party that accessed the BMAs by boat would be travelling on offshore on

foot and any party that started a trip with hooved stock would always travel on horseback (Coleman et al. in review *a*).

<u>Human Spatial and Temporal Use</u>

To evaluate how people used the landscape, we created a Human Recreation Area (HRA) layer by adding a buffer to GPS locations from individual recreational parties. Each GPS location received a buffer equal to the mean distance a backcountry user traveled per minute, plus 1 SD, plus 10 m to incorporate typical GPS error (Wing et al. 2005). We used this formula because it provided enough space to incorporate any aberrant movement for a hiking or hooved stock party between sequential GPS locations. We separated all GPS locations into two distinct groups; on-trail users and off-trail users. Off-trail use was defined as any hike that occurred >100 m beyond a maintained backcountry trail for >15 minutes. All other GPS locations were considered on-trail. A "hike" was defined as a continuous walking or horse riding path with no intentional break in GPS locations. Some recreational parties recorded more than 1 hike/day, most being those who traveled by boat and repeatedly going to shore to recreate. We used two methods to select GPS locations that were associated with areas of primary human use and removed locations that were associated with atypical human travel. First, we categorized all on-trail and off-trail hikes into 1 km sections. We calculated the total number of hikers in each 1 km segment for on-trail users only. We created a distribution of all 1 km on-trail sections and the 1 km trail buffers with the fewest overall number of hikers were removed (the lowest 10th percentile). Second, we analyzed all 1 km sections of off-trail hikes and categorized them by the maximum distance from a maintained trail

or backcountry campsite. Approximately 90% of all off-trail hikers occurred within 3 km of the nearest maintained trail or campsite. Therefore, any off-trail buffer that occurred beyond 3 km was truncated beyond that distance and eliminated from analysis. All designated backcountry campsites received the same buffer size as 1 GPS location. All on-trail, off-trail, and campsite buffers were merged together to create the single HRA layer (Coleman et al. in review *a*).

To evaluate times of the day when people were actively recreating in the BMAs we used the time associated with each GPS location. We pooled all GPS location times from all years and calculated the percentage of hikers that were actively moving (away from a campsite or trailhead) at sequential 1 hour categories for a 24 hour period. We summarized activity patterns by the percentage of people recreating per hour, throughout the course of the study (Coleman et al. in review *a*).

Bear Trapping and Collaring

We trapped and radio collared grizzly bears from autumn 2006 to mid-summer 2009. The Interagency Grizzly Bear Study Team conducting all trapping under the procedures approved by the Animal Care and use Committee of the United States Geological Survey, Biological Resources Division and conformed to the Animal Welfare Act and United States Government principles for the use and care of vertebrate animals used in testing, research and training. The team used culvert traps placed within 1 km from the shoreline of Yellowstone Lake to capture grizzly bears that utilized the BMAs. Bears that immediately dispersed after capture and did not frequent the BMAs were not included in the sample and were not considered for analysis. The team fitted all captured

bears with Telonics Spread Spectrum (SS) Global Positioning System collars (Telonics, Inc., Mesa, AZ) with a biodegradable canvas spacer and a CR2-A programmable remote drop-off device set a specific release date. Collars obtained a position fix every 30 or 60 minutes. Collars shut off during denning season (Nov 15 to Apr 14). We flew telemetry flights weekly from late April through mid-October to retrieve collar data.

Each SS radio collar also contained an activity switch. The activity switch was activated by movement of the bear's head through a plane 15˚ below the horizon. The activity switch tallied the number of seconds that showed a switch closure that was then accumulated during a 15-minute interval just prior to the GPS collar fix attempt. The number returned was a percentage of total seconds of switch closure during the collect interval at 0.5% resolution. Activity counts were reflective of a bear's head-up head-down movement just prior to each attempted GPS collar fix (Schwartz et al. 2009).

Bear Distribution and Activity Analysis

We used two seasonal time periods for our analysis. The "BMA restricted" season was defined as den emergence to June 30. The "BMA unrestricted" season was defined as July 1 to September 30. These two seasons reflect times when people were mostly off the landscape vs. on the landscape (Coleman et al. in review *a*) We used bear-year as our sample unit. We defined bear-year as one individual bear's data collected for one BMA season (BMA restricted or BMA unrestricted). We considered bear-year as an independent sample unit and evaluated this by plotting the hourly mean activity for each bear-year for every available month, against the overall mean. We evaluated if repeated measures from the same bear were grouped across multiple years or if they showed a

more random pattern among bears (Schwartz et al. 2010). We found that the activity

means were randomly dispersed for each bear-year, per hour. We concluded that using

bear-year as the sample unit did not bias our mean activity estimates.

We used the mean activity counts from the radio collars to compare activity

patterns for bears at varying distances to the HRA during the BMA restricted and

unrestricted time periods. We measured the distance of each telemetry location to the

HRA layer for each BMA season. For each season, we combined all individuals in our

sample that were radio collared for at least 6 weeks. We did not have an adequate sample

size to separate sex or age class. All individuals used in the sample had to have at least

one 24 hour cycle within the HRA layer to be considered.   To avoid influence from

human developments, we excluded all bear locations that were > 1 km from any park

road or development. We used the near tool in ArcGIS 10.1 to measure and categorize

all telemetry locations (Environmental System Research Institute, Inc., Redlands, CA).

We used the regression approach from Murtaugh 2007, and fit no intercept

models to activity count. The resulting coefficients estimates were sample mean activity

counts and standard errors for each bear-year for each hour. We summarized the results

for each bear-year, in each time period, using the weighted average of the bear-year-

specific regression coefficients, with weights proportional to reciprocals of squared

standard errors for individual fits (Murtaugh 2007, Schwartz et al. 2010). To determine

the influence of human recreation on bear activity we tested the difference in activity

patterns of bears that were within a distance of the HRA + 200 m to those that were

beyond 1 km from the edge of the HRA layer. We selected the HRA + 200 m distance

category because previous work, from this study, determined that this distance is likely to have a measurable influence on a bear's spatial use pattern (Coleman et al. in review *a*). We selected a distance of at least 1 km from the HRA as a comparison because less than 2% of our human GPS locations occurred beyond this distance. Therefore, we assumed that human influence beyond 1 km from the HRA was minimal.

We compared bears within the HRA + 200 m to bears beyond 1 km from the HRA in 2 time periods; during the BMA restricted period and during the BMA unrestricted period. We also compared bears within the HRA + 200 m during June and July directly. We felt like a direct comparison between June and July was reasonable because in nearby Grand Teton National Park, grizzly bear activity patterns in June and July were very similar (Schwartz et al. 2010). To further evaluate similarities among months we contrasted bears beyond 1 km from the HRA during June and July. Because collars recorded activity regardless of fix success we had several activity counts with no associated location. We were unable to use most of these locations in our analysis, but we made one exception to increase our sample size. If a radio collar failed to obtain a fix, we used the activity count if a straight line between subsequent locations did not stray from either of our category distances. Also, if a radio collar failed >1 sequential fix attempts, we excluded those activity counts. Finally, one key assumption in our analysis was the ability to apply the HRA layer to the BMA restricted period, when people were not permitted access. A subsample of recreational users from this study and personal communications with Yellowstone Park officials suggested this was a reasonable assumption (Coleman et al. in review *a*).

We used two methods of comparison to address our questions. First, we wanted to determine if the overall activity patterns between the two groups differed (ie. Bears within 200 m of the HRA and those beyond 1 km from the HRA). We fit 4 different regression models for each comparison following Schwartz et al. (2010). The response variable in each model was the difference between the weighted mean activity count, per hour, for both groups. The first model fit the mean with uncorrelated errors. The model formula was

$$y_t = \beta_0 + \varepsilon_t$$

where y_t was the difference in mean activity count at time t, $t = 0,\ldots,23$, β_0 was the overall true mean difference, and ε_t were independent and normally distributed with mean 0 and variance $= \sigma^2$.

The second model was identical to model 1, but adjusted for correlated error terms. It followed the first-order autoregressive AR(1) process. The formula was

$$\varepsilon_t = \rho\varepsilon_{t-1} + \mu_t$$

Where $|\rho| < 1$ and μ_t are independent and identically normally distributed with mean 0 and variance $= \sigma^2$.

The third and fourth models treated hour as a circular variable by transforming each hour to radians and taking the sine and cosine (Fisher 1993). The third and fourth models were identical, however the fourth model adjusted for correlated errors, as shown in model 2. The model formula was

$$y_t = \beta_0 + \beta_1 \sin(hour) + \beta_2 \cos(hour) + \varepsilon_t$$

We compared all 4 models using Akaike's Information Criterion, adjusted for small sampled size (AIC_c) (Burnham and Anderson 2002). We determined that there was no difference in the overall shape of the activity curve, between the two groups, if the AIC_c scores were the lowest for models 1 or 2. Conversely, we considered low scores for models 3 or 4 as evidence that there was a difference in the overall shape of the activity curves. Model diagnostics were evaluated by using normalized residuals, which should be independent and identically distributed as standard normal random variables (Pinheiro and Bates 2000).

We also wanted to compare and test individual hours between the two groups to evaluate how activity changed on an hourly basis. We used the weighted means and standard errors used in the regression approach from Murtaugh 2007, and described above. We summarized the activity curves for each of the four comparisons with the weighted means and associated 95% confidence intervals for each hour. We identified significant differences at the $P < 0.05$ level. We contrasted the hourly mean activity counts to the percentage of humans recreating per hour. This allowed for a direct contrast between bear activity and human activity. We conducted our analyses using the statistical program R (R version 2.14.1, www.r-project.org, accessed 1 April 2012). We fit models using the gls function in the R, nlme package.

Results

Human Use and Activity

We sampled 385 recreational parties. This included 286 overnight users from the 4 sample strata, and 99 day users from selected trailheads. In our sample, 345 parties traveled by foot (via trailhead or boat access) and 40 traveled on horseback. Party size had a range from 1 person to 15 people with a mean of 3.48 ± 2.87 ($\bar{x} \pm$ SD). Within the study area BMAs, the sampled parties recorded a total of 827 usable individual foot hikes and 140 individual horse rides. On-trail use was common with foot hikers including 554 (67.0%) staying on-trail the entire time, 220 (26.6%) going off and on-trail during the same hike, and 53 (6.4%) going completely off trail for an entire hike. No hooved stock users traveled off trial. The Human Recreation Area (HRA) was created by adding 102 m (66 m + 26.3 m+ 10 m), ($\bar{x}$ + SD + 10 m GPS error) around each GPS location and backcountry campsite. The HRA was 6,251.4 hectares or 7.7% of the 6 study area BMAs. The HRA layer was a near continuous polygon because many GPS locations were stacked upon one another (Fig. 5.2).

We found that human activity times followed a predictable pattern of use. A small number of people began recreating in the early morning, 0500–0600 hrs. The peak of activity occurred between 1000 hrs and 1500 hrs when more than 50% of all sampled recreational parties were active. The peak of activity was at 1200 hrs when 66.6% of all people were actively recreating, followed by 1300 hrs with 65.8%. Activity diminished by 2100 hrs when few people were still active (Figs. 5.3, 5.4, 5.5, and 5.6).

BMA Restricted Period (Den Emergence to June 30)

During the BMA restricted period 9 bears were ($n = 6$ M, $n = 3$ F) available for analysis, including 13 bear-years ($n = 7$ M bear-years, $n = 6$ F bear-years). We had 3,362 successful fix attempts within the HRA + 200 m, and included 203 failed attempts that we considered to be likely within this distance. We had 5,340 successful fix attempts beyond 1 km from the HRA and included 526 failed attempts that were likely within this distance. We determined that there was a significant difference between the shape of the two activity curves. Model 3 had the lowest AIC_c score, followed by model 4 (Table 5.1). When people were off the landscape bears within the HRA + 200 m were more day active, compared to bears that were beyond 1 km from the HRA. Mean activity counts had non-overlapping 95% confidence intervals between 10 and 16 hours, indicating that bears were consistently more day active when people were projected to be active. During night hours and during the crepuscular period, there was not a significant difference in mean bear activity counts (Fig. 5.3).

BMA Unrestricted Period (July 1 to September 30)

During the BMA unrestricted period 13 bears were ($n = 8$ M, $n = 5$ F) available for analysis, including 19 bear-years ($n = 11$ M bear-years, $n = 8$ F bear-years). We had 5,427 successful fix attempts within the HRA + 200 m, and included 513 failed attempts that we considered to be likely within this distance. We had 15,203 successful fix attempts beyond 1 km from the HRA and included 1,876 failed attempts that were likely this distance. We determined that there was a significant difference between the shape of the 2 activity curves. Model 4 had the lowest AIC_c score, followed by model 3 (Table

5.1). Mean activity counts had non-overlapping 95% confidence intervals during the middle of the day and during the middle of the night. When people were most active, bears within the HRA + 200 m were significantly less active (1200–1500 hrs), compared to bears beyond 1 km from the HRA. During night hours bears within the HRA + 200 m were more active compared to bears beyond 1 km from the HRA. There was a significant difference in mean activity between the two groups at 0–0500 hrs and 2100–2300 hrs (Fig. 5.4).

June and July Comparison

During June and July 8 bears were ($n = 4$ M, $n = 4$ F) available for analysis, including 10 bear-years ($n = 6$ M bear-years, $n = 4$ F bear-years). During June we had 1,800 successful fix attempts within the HRA + 200 m and included 113 failed attempts that we considered likely within this distance. During July we had 2,999 successful fix attempts with the HRA + 200 m and included 360 failed attempts likely within this distance. During June we had 3,494 successful fix attempts beyond 1 km from the HRA and included failed 385 attempts. During July we had 5,299 successful fix attempts beyond 1 km from the HRA and included 554 failed attempts. When bears were within the HRA + 200 m we did not detect a significant difference between the shape of the 2 activity curves. Model number 2 had the lowest AIC_c score, followed by model 4 (Table 5.1). However, activity counts with non-overlapping 95% CI's occurred during the peak of human activity at 12–15 hrs (Fig. 5.5). We did not detect a significant difference in activity curves for bears that were beyond 1 km of the HRA. The lowest AIC_c score was

for model 1, followed by model 2. There was no significant difference in activity counts per hour (Fig. 5.6).

Discussion

We found evidence that human presence and recreation influenced bear activity. When BMAs were unrestricted we detected a significant decrease in bear's mid-day activity occurring in places people frequent. Conversely, bears were significantly more night active in the same places. A direct comparison of activity patterns during June and July produced similar results. The AIC_c results did not suggest a significant difference in the shape of the overall activity curves, yet we found that grizzly bears showed a sharp decrease in mid-day activity in July, shortly after people were allowed on the landscape. These findings agree with our hypothesis that bears would show a decrease in activity near humans, but only when people are active. Previous work from this study, done by Fortin (2011), determined a modeled activity breakpoint of 17.3. Counts below 17.3 were most likely from inactive bears, while counts above 17.3 more most likely from active bears. Mean activity counts for bears were often below this threshold when in areas occupied by active people. When bears were 1 km away from places with active humans, mean activity was above this threshold.

We also found evidence that grizzly bears were much more day active in areas within 200 m of the HRA when BMAs were restricted. This agrees with our hypothesis that bears would be more active when people were off the landscape. This suggests that if BMAs were unrestricted to human recreation in the first half of the year, an increase in

human-bear overlap would likely occur. The outcome may be an increase in human-bear conflict, a decrease in bear activity, or both. Beyond the absence of people, others reasons may contribute to the increase in day activity during the BMA restricted period. The HRA layer was mainly centered around trails, backcountry campsites and non-forested areas that allowed for easy travel (Fig. 5.2). This likely contributed to high activity counts associated with bear movement (Fig. 5.3). The HRA layer was also lower in elevation, near the shore of Yellowstone Lake, and along stream corridors. These lower elevation places melt sooner in April and May and allowed bears access to high quality foods such as; green succulent vegetation and winter-killed ungulate carcasses (Despain 1990, Mattson et al. 1991, Fortin 2011). In addition, during April and early May bears were emerging from dens. In the GYE, grizzly bear dens are usually located in elevations higher than the HRA layer (Haroldson et al. 2002). Shortly after den emergence bears may be less active for a short period of time (Nelson 1983). A brief period of low activity, near dens, may have contributed to the activity patterns shown for bears beyond 1 km from the HRA.

Our comparison of June and July also helped illustrate the effect of human presence on bear activity. The lowest activity counts recorded in our study were in July, during peak human activity times (Fig. 5.5). We considered the influence of daily high temperatures on bear activity patterns during these two months because grizzly bears can become less active when temperatures exceed 20° C (Schwartz et al. 2010). Therefore, temperature should be considered in our direct comparison between June and July. During our study, the high temperatures averaged 15.9° C in June, and 23.1° C in July

(Western Regional Climate Center 2010). However, bears that were beyond 1 km of the HRA during June and July, would have been exposed to the same temperature trends and did not have a significant difference in mid-day activity (Fig. 5.6).

When BMAs were unrestricted we determined that bears were more night active when they were within areas used by people (Fig. 5.4). This may have been the result of bears utilizing maintained backcountry trails and traveling during cool night hours. Yet, we also found some evidence that bears may have displayed some compensatory foraging behavior (e.g. foraging at night when people were inactive, as opposed to the day). During our study, we documented a circumstance of an adult male grizzly bear leaving an ungulate carcass twice during peak hours of human activity and remaining on the carcass during hours when people were less active. This interaction is of interest because ungulate meat is a preferred and important food source for Yellowstone grizzlies, especially adult males (Mattson et al. 1997, Hildebrand et al. 1999, Jacoby et al. 1999). Also, ungulate meat is opportunistic and cannot immediately be accessed elsewhere. Our data suggested that the bear located a carcass at 0300 hrs and did not leave the site until a close encounter with people at 1100 hrs. The bear returned to the carcass by 1300 hrs and left shortly again at 1400 hrs, following another encounter with a group of people. The bear returned to the carcass again at 1800 hrs and did not vacate the carcass until 1200 hrs the following day. This detailed encounter, which occurred in late July within 200 m of the HRA, suggests that the bear had an unhindered foraging opportunity during night hours yet was disrupted twice during the day time. Both encounters with people resulted in the bear moving several hundred meters into dense cover, where the

subsequent activity counts were all ≤ 11. Conversely, the bear remained on the carcass

and mostly active during night hours, when people were inactive. We cannot determine if

the bear's behavior was typical or if other factors contributed to the movement patterns,

but the interaction corresponds with the overall activity pattern detailed when the BMAs

were unrestricted.

Management Implications

Our results provide two important considerations for grizzly bear management in

Yellowstone Park and surrounding areas. Grizzly bears appear to show an overall

decrease in activity when near the presence of backcountry recreational users. This is

important to consider in places where land management agencies have some control over

the places and times that people recreate. It is difficult to determine if this activity

response has a consequence for a bear population, but our results provide evidence that

sustained separation from people may allow for increased foraging opportunities.

Furthermore, it is difficult to determine if bears can offset lost foraging opportunities

during night hours. Many vegetal food sources are continuously available and can likely

be accessed throughout a 24 hour period. However, carrion is more opportunistic and is

often aggressively defended by bears. Defensive activities may be more difficult or costly

during night hours.

We also determined that the BMA program in Yellowstone Park is effective at

separating people and bears when both are active. If people were allowed on the

landscape during the BMA restricted period, bears and people would interact at times

when both were highly active. The consequence of these interactions could be more bear attacks or missed foraging opportunities for bears. While BMAs were unrestricted, bears that were within areas commonly used by people were active during night and crepuscular hours. This suggests that time of day restrictions can provide some temporal separation of humans and bears and may decrease potential conflicts. The provided activity graphs can be used to recommend time of day closures or restrictions on recreational use.

Table 5.1. AIC$_c$ results for group comparisons.

The lowest AIC$_c$ score for model 1 or 2 should be interpreted as no significant difference in activity pattern. The lowest AIC$_c$ score for models 3 or 4 should be interpreted as a significant difference in activity pattern between the two categories.

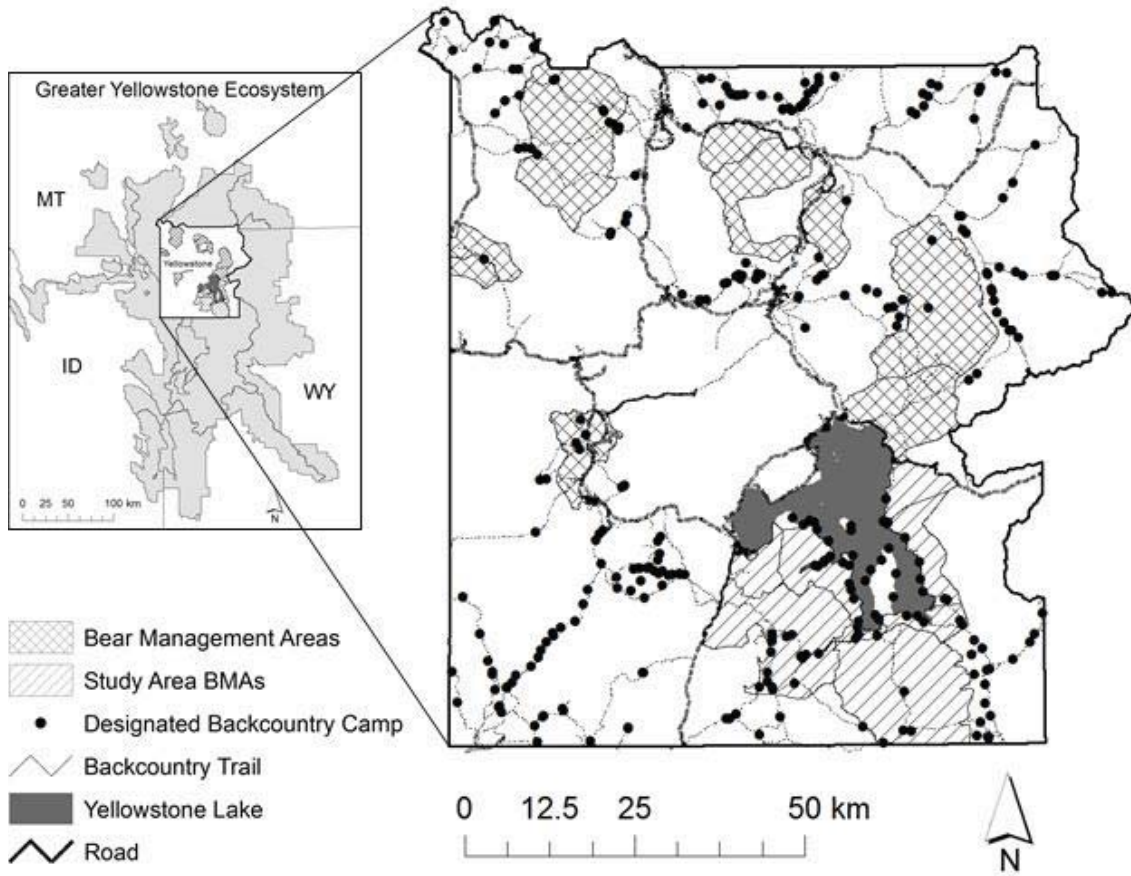| BMA season and comparison	AIC$_c$ scores			
	Model 1	Model 2	Model 3	Model 4
BMA restricted: bears within the HRA + 200 m vs. beyond 1000 m	155.78	141.63	128.59	131.76
BMA unrestricted: bears within the HRA + 200 m vs. beyond 1000 m	188.20	144.68	143.11	131.37
Bears within HRA + 200 m in June vs. July	190.28	167.16	186.75	170.75
Bears beyond 1000 m in June vs. July	115.91	116.39	116.62	119.20

Fig. 5.1. Yellowstone National Park, Wyoming, USA. Map includes all 16 Bear Management Areas (BMAs), including the 6 study area BMAs.
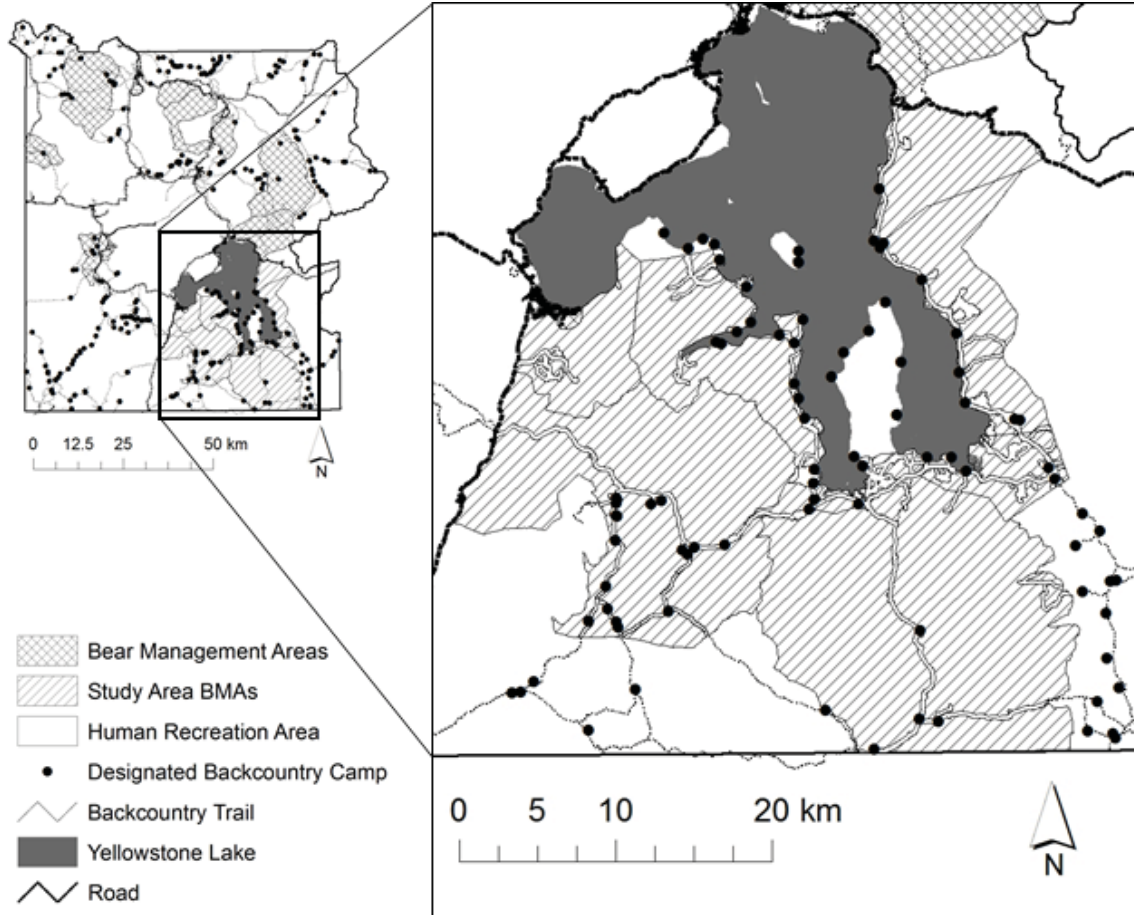
Fig. 5.2. Human Recreation Area (HRA) layer within the 6 study area Bear Management Areas (BMAs). The HRA was 6,251 ha and 7.7% of the 6 study area BMAs. The HRA was centered on maintained backcountry trails, but also included various off trail travels up to 3 km, and a buffer around designated backcountry campsites. Also shown is the additional park BMAs, designated backcountry campsites, park roads, and maintained backcountry trails.
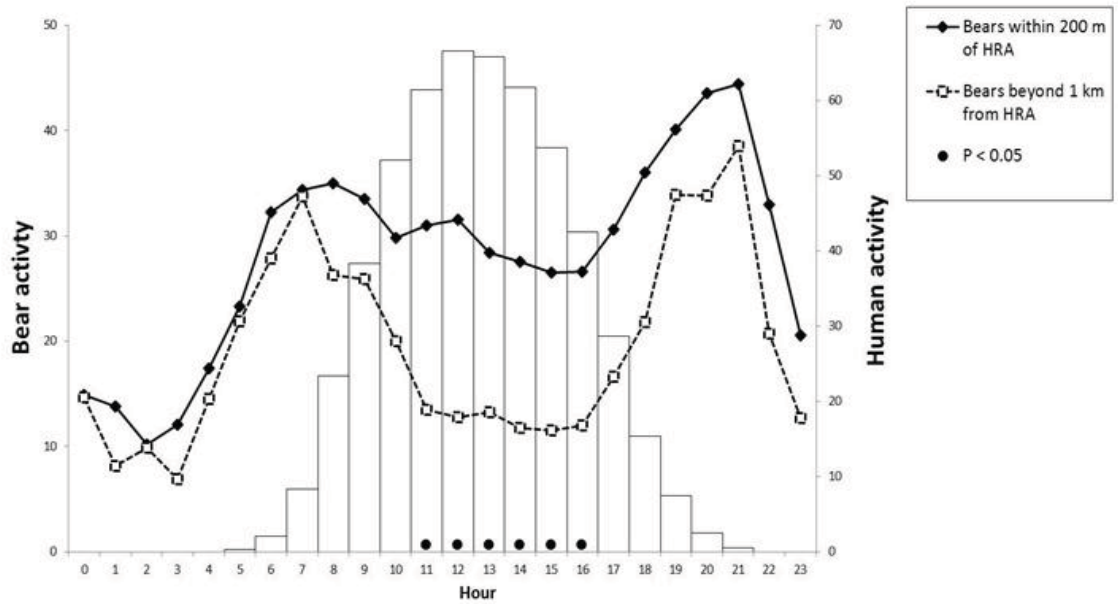
Fig. 5.3. Comparison of activity curves during the BMA restricted period, when people were mostly off the landscape (den emergence to June 30). The activity curves represent bears within the HRA (Human Recreation Area) + 200 m and bears beyond 1 km from the HRA. Mean weighted activity counts are displayed per hour and the black dots indicate a difference in mean activity where the 95% confidence intervals do not overlap. The bar graph represents human activity which is displayed as the percentage of people actively recreating per hour. Data is summarized by bear-year (n = 7 M bear-years and n = 6 F bear-years).

Fig. 5.4. Comparison of activity curves during the BMA unrestricted period when people were allowed access to the study area (July 1 to September 30). The activity curves represent bears within the HRA (Human Recreation Area) + 200 m and bears beyond 1 km from the HRA. Mean weighted activity counts are displayed per hour and the black dots indicate a difference in mean activity where the 95% confidence intervals do not overlap. The bar graph represents human activity which is displayed as the percentage of people actively recreating per hour. Data is summarized by bear-year ($n = 11$ M bear-years and $n = 8$ F bear-years).
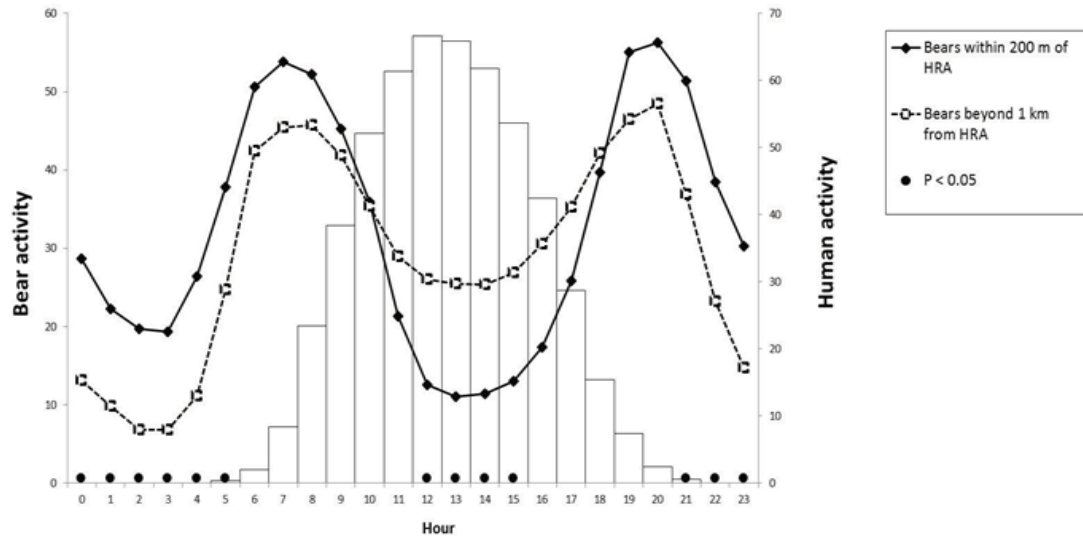
Fig. 5.5. Comparison of activity curves during June when people are mostly off the landscape and July when people are allowed in the study area. The activity curves represent bears within the HRA (Human Recreation Area) + 200 m. Mean weighted activity counts are displayed per hour and the black dots indicate a difference in mean activity where the 95% confidence intervals do not overlap. The bar graph represents human activity which is displayed as the percentage of people actively recreating per hour. Data is summarized by bear-year ($n = 6$ M bear-years and $n = 4$ F bear-years).
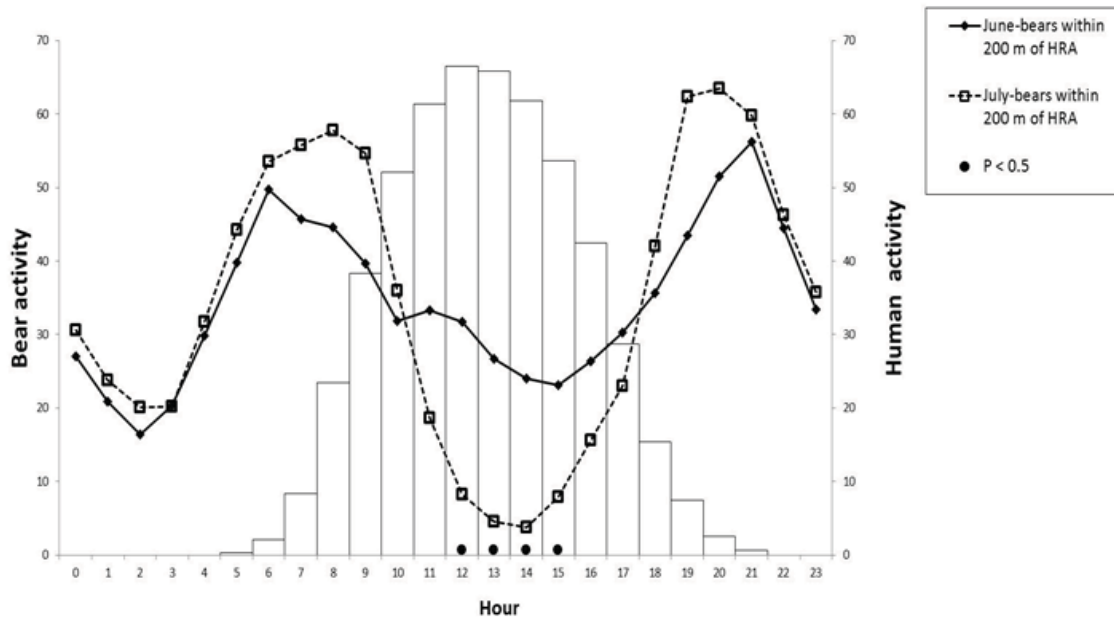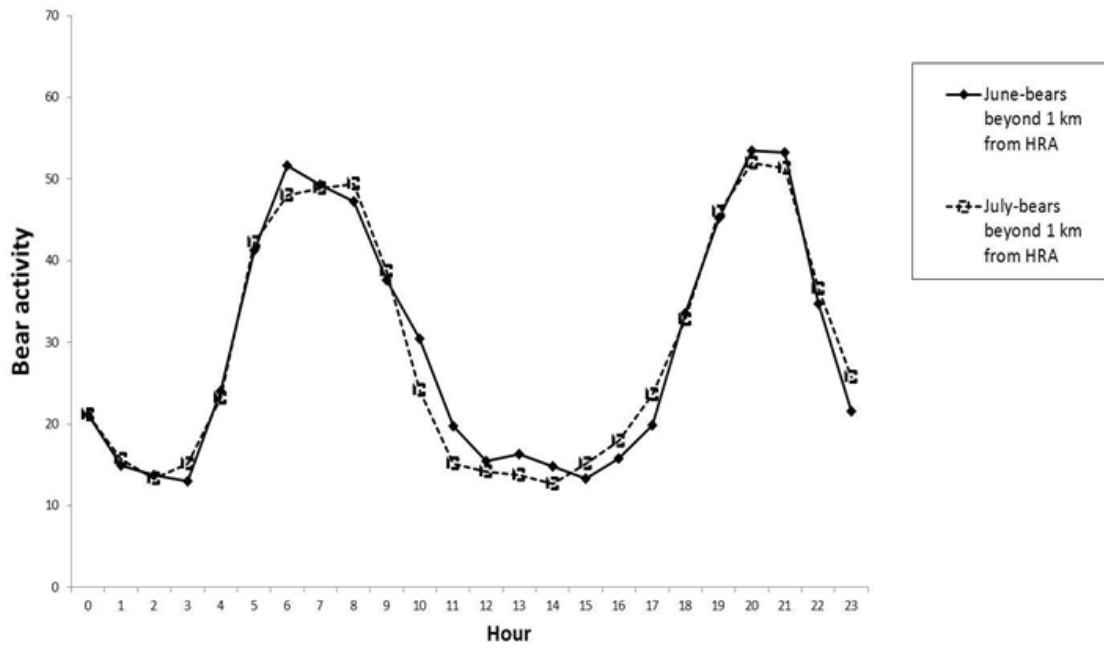
Fig. 5.6. Comparison of activity curves during June when people are mostly off the landscape and July when people are allowed in the study area. The activity curves represent bears beyond 1000 m from the HRA (Human Recreation Area). Mean weighted activity counts are displayed per hour. No activity mean activity counts were statistically different at $P < 0.05$. Data is summarized by bear-year (n = 6 M bear-years and n = 4 F bear-years)

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CHAPTER SIX

CONCLUSIONS

General Conclusions

Results from this study confirm what others have found regarding the influence of human presence on grizzly bears. Grizzly bears generally avoid human contact when possible and can, at times, be displaced from foraging opportunities or preferred habitats based on human presence (Mclellean and Shackleton 1989, Gunther 1990, Kasworm and Manley 1990, Mace et al 1996, Graves 2002, Rode et al. 2006*a*, Rode et al. 2007). However, this research is unique in a couple of ways. First, we were able to utilize the BMA closures in a type of treatment and control setting. We were able to examine bear behavior when human use was primarily restricted, thus providing a unique opportunity to contrast the effects of human presence. This also allowed us to investigate what type of overlap may occur if people were allowed access. Second, this research occurred in a place with little human use. The study area was relatively remote and received only a small proportion of the annual backcountry use in Yellowstone National Park. Nevertheless, we found that bears still showed a significant avoidance to the presence of people, even in a remote location with infrequent human contact.

In Chapters Two and Three we were able to assess the overall premise of Yellowstone National Park's Bear Management Area program. We found that 6 of the BMAs that restricted large portions of the park were effective at separating bears and people in space and time. We also determined that when people were allowed on the

landscape, bears show a significant avoidance response. However, this avoidance only occurred during times when people were active and diminished after approximately 400 m. We were also able to investigate the premise of backcountry campsite closures and determine if restricting human use diminished the possibility of displacement behavior by grizzly bears. We found that, generally, bears were attracted to designated backcountry campsites locations. However, when we considered human occupancy, bears showed a significant avoidance, up to 400 m. This suggested that bears were avoiding the presence of people in camps and that campsite closures were effective at preventing displacement. It also suggests that future studies should consider a temporal variable in measurements of human use to avoid misleading results.

In Chapter Four we investigated the outcome of direct interactions between grizzly bears and humans. This chapter allowed us to augment the argument that bears were avoiding close contact with people (i.e. Chapters Two and Three). It also allowed us to consider other variables that may trigger an avoidance response by a grizzly bear. We found that bears consistently avoided people when in close proximity. This occurred regardless of other environmental factors such as; hiking party size, bear sex, bear age, and forest cover type.

In Chapter Five we investigated the behavioral and activity adaptations of bears near people. We found that in certain circumstances bears still occupy areas near people, or near places that people frequent. Other studies have shown that bears may do this to avoid larger, more dominant bears or to acquire food sources that cannot be found elsewhere (Mattson et al. 1987, Rode et al. 2006*b*, Rode et al. 2007). Previous research

has also shown that grizzly bears may alter their activity patterns near areas of human developments (Schwartz et al. 2010). We found that bears altered their activity patterns near people by becoming more night active and less day active when near places that people frequented. We also found that if BMA rules did not exist, bears and people would interact during times when both were highly active.

In conclusion, we found compelling evidence that the Bear Management Area program in Yellowstone National Park is effective and does help separate grizzly bears and people, thus reducing overlap or potential conflict. We found empirical evidence that bears can be displaced by humans, however further research should focus on the potential loss of foraging opportunities or the potential energetic consequences that result from interacting with humans. This research could be replicated in Yellowstone's remaining BMAs or other closures. However, it is imperative to gain a full and complete understanding of human use. Understanding fine scale human use allowed us to detect more discrete behavioral and spatial changes by bears that might go undetected on a larger scale.

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