2010

Human-black bear interactions in Missoula Montana

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Recommended Citation

Merkle, Jerod A., "Human-black bear interactions in Missoula Montana" (2010). *Graduate Student Theses, Dissertations, & Professional Papers*. 533.
https://scholarworks.umt.edu/etd/533

HUMAN-BLACK BEAR INTERACTIONS IN MISSOULA MONTANA

by

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B.S., University of Arizona, Tucson, Arizona, 2006

Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Wildlife and Fisheries Biology

The University of Montana
Missoula, MT

February 2011

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Human-black bear interactions in Missoula Montana

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The increasing frequency and distribution of human-wildlife interactions is a direct result of a growing human footprint worldwide. Specifically, the effects of urbanization can be significant for many species, including American black bears (*Ursus americanus*). Human-black bear interactions (HBI) resulting in property damage, injury or death to humans, or fear of injury or death to humans are increasing in number and extent throughout North America, and wildlife management agencies are interested in reversing this trend. Using a case study of HBI in Missoula, Montana, my objectives were to examine temporal patterns of human behaviors and attitudes regarding HBI, develop a model capable of predicting the spatial distribution of HBI, and determine forage-related variables that predict use of the urban landscape by bears. Based upon questionnaires sent to a sample of residents in 2004 and 2008, the prevalence of outdoor garbage storage decreased, and support for management actions used to deal with HBI increased. These results suggest that human behaviors and attitudes in urban areas exposed to HBI may be changing. Based on phone complaints regarding HBI recorded by Montana Fish, Wildlife & Parks from 2003 to 2008, the probability of HBI is highest when residents live close to large forest patches, close to rivers and streams, and in intermediate housing densities (approx. 7 houses/ha). These results provide a wildlife management tool and a repeatable statistical framework that can be used to predict future HBI in areas where the potential for development is high. Using GPS collared black bears and a time-to-event modeling framework, the probability of an individual black bear being located within the urban landscape was driven by anthropogenic forage availability (i.e., urban green-up, apple availability) as opposed to wildland forage scarcity. Black bears will forage within the urban areas even when wildland foods are available outside the urban area, suggesting that bears shift their behavior in response to the availability of multiple anthropogenic food items (e.g., fruit trees, garbage). Wildlife managers developing management plans for HBI should incorporate possible changes in human dimensions, models that can predict where HBI will occur in the future, and bear populations that are becoming increasingly reliant on anthropogenic food items.

ACKNOWLEDGMENTS

I thank, Paul R. Krausman, my advisor, for his tireless encouragement, support, advice, friendship, and research expertise. Without Paul, I would not be where I am, or who I am, today. I am especially indebted to Vickie Edwards, Jamie Jonkel, Bob Wiesner, Erin Edge, and Mike Thompson from Montana Fish, Wildlife & Parks, for their guidance, logistical support, accepting personalities, patience, and knowledge of the study area. Thank you to all volunteers who helped with field and office work, especially Ben Jimenez, who provided me never-ending knowledge, guidance and support both in the field and out. I am grateful for my graduate committee, Mike Mitchell and Joel Berger, who provided excellent guidance on scientific inquiry and feedback regarding study design and writing style. My sincere thanks go to Jeanne Franz for logistical support within the Wildlife Biology Program, Nick DeCesare, Jamie Jonkel, Melinda Booth, Hugh Robinson, and Paul Alaback for their interest in collaboration within different aspects of this project, and cooperating landowners of the North Hills neighborhoods in Missoula. Finally, without the support of my family, especially Bethann Garramon Merkle, this process would not have been so much fun! This study was funded and supported by the Longwell Family Foundation, Boone and Crockett Program in Wildlife Conservation, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, and Montana Fish, Wildlife & Parks.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 2

CHAPTER 3

LIST OF FIGURES

CHAPTER 2

CHAPTER 3

CHAPTER 4

CHAPTER 1

INTRODUCTION

BACKGROUND

As the human population continues to grow and expand worldwide, more space will be needed to live, cultivate food, and gather water. Urbanization, which is the conversion of land into residential, industrial, or commercial uses (Niemela 1999), is an important consequence of human population growth. Literature examining the effects of urbanization on wildlife is available, and is commonly analyzed through an urban-rural gradient framework (Nilon and Pais 1997, Pckett et al. 2001, Randa and Yunger 2006). In general, species composition and richness can be profoundly different along the urban-rural gradient (McKinney 2002), and usually the center of urbanization harbors the highest habitat fragmentation (Medley et al. 1995, Collins et al. 2000), highest number of nonnative species (Kowarik 1995, Blair and Launer 1997), lowest species richness, and the lowest species diversity (Blair 2001, Marzluff 2001).

Although urbanization can be attributed to endangering more species than any other anthropogenic activity (Czech et al. 2000), increased numbers of human-wildlife interactions as a result of urbanization is also an important consideration for wildlife management and conservation (Adams et al. 2006). Interactions are a consequence of varying responses to human development (e.g., attraction, habituation, avoidance; Whittaker and Knight 1998) among taxonomic groups and even individuals (Savard et al. 2000). The issues are most profound when the species interacting with humans can cause property damage, or present a threat to human safety (Conover 2002). This is the case with large carnivores, such as bears (*Ursus* spp.), where individuals can cause thousands of dollars worth of property damage (Madison 2008), and maul or kill a person (Herrero and Fleck 1989).

Human-black bear (*U. americanus*) interactions (HBI) resulting in property damage, injury or death to humans, or fear of injury or death to humans in North America have been increasing in number over the last few decades (Beckmann and Berger 2003, Baruch-Mordo et al. 2008). Wildlife management agencies are interested in reversing this trend to preserve human safety (Perry and Rusing 2000), reduce resources spent dealing with conflicts (Garshelis 1989), and avoid controversial management (e.g., lethal control; Hristienko and McDonald 2007). Over the last 8 years, there has been a spike in research concerning HBI. Investigations can be categorized into 4 distinct groups: human dimensions of wildlife management based on proactive education efforts (Peine 2001, Gore et al. 2006, Gore et al. 2008), spatiotemporal models of HBI themselves (Zack et al. 2003, Baruch-Mordo et al. 2008, Kretser et al. 2008), biological changes associated with bear populations near urban areas (Beckmann and Berger 2003*a*, 2003*b*, Lyons 2005, Beckmann and Lackey 2008, Breck et al. 2008, Thiemann et al. 2008), and effectiveness of management actions (Beckmann et al. 2004, Leigh and Chamberlain 2008, Landriault et al. 2009, Mazur 2010). The underlining goal of many of these studies is to provide a knowledge base so wildlife managers can make better decisions and reduce the number of HBI in the future. For example, Gore et al. (2008) tested the efficacy of an education effort to reduce the number of attractants available to black bears in New York. They found that education efforts have few positive short term effects on human behavior, and integrating evaluation measures is essential to implementing education efforts (Gore et al. 2008). Baruch-Mordo et al. (2008) used the date and location of phone call complaints in Colorado to develop state-wide models of HBI. Clusters of HBI occur near urban areas adjacent to high quality black bear habitat, and that the occurrences of HBI in Colorado are increasing in number. Beckmann and Berger (2003*a*) recorded life history characteristics of 2 black bear populations (1 urban and the other wildland) over 12 years in the Lake Tahoe Basin of California and Nevada. They found that bear populations conform to an ideal-despotic distribution model, suggesting population redistribution from wildland areas into urban areas without an overall population increase. Beckmann et al. (2004) relocated 62 bears and applied multiple types of aversive conditioning in the Lake Tahoe Basin. Ninety-two percent of all bears returned to the urban areas, and 70% returned within 40 days, suggesting that nonlethal deterrents are not effective at reducing HBI for periods > 1 month.

My thesis directly addresses knowledge gaps in the first 3 categories of HBI research: human dimensions, modeling of HBI, and biological changes of black bears. For human dimensions of wildlife management, I am not aware of any study that has assessed changes in human behaviors and attitudes using a long term (> 1 year) framework. An understanding of long-term adjustment in the social aspects of humans provides bear managers with a temporal framework for expecting human change. Next, I am not aware of any study that has assessed the probability of HBI across urban areas specifically to identify future areas of high probability of conflict. Managers dealing with a growing interface between urban and wildlands need tools at the urban scale to be successful in predicting the frequency of HBI in the future. Finally, I could not find any study in the literature that has examined the use of the urban landscape by bears as it relates to anthropogenic and wildland food availability. Information about whether the availability of foods within or outside the urban area influence bear use of urban areas, will help managers decide which vegetative or non-vegetative features are important to monitor or eliminate to reduce the prevalence of HBI.

For wildlife managers to be successful in reducing the number of HBI, a wide variety of knowledge and tools must be considered (Spencer et al. 2007). This science-based information, whether based at local or regional scales, must be framed so that findings have applicability to every manager. This thesis contains research based on a case study in Missoula, Montana, although the patterns, analysis and statistical framework, and some conclusions can be extrapolated to other areas where HBI occur. Missoula is a city of approximately 65,000 people (US Census Bureau 2000), lying in a valley surrounded by multiple mountain ranges. Montana Fish, Wildlife and Parks is the state agency responsible for managing wildlife within Missoula, and they receive approximately 130 phone calls about HBI annually. They respond with reactive bear management actions (e.g., trapping efforts) to an average of 30 HBI annually.

OBJECTIVES

My objectives were 3-fold, but generally they fall under a main goal of providing knowledge about black bear ecology and HBI to wildlife managers. The results and implications from each chapter can be applied differently (e.g., chapter 2 investigates social issues regarding humans and bears, and chapter 4 examines biological patterns of black bears), however all can inform proactive management of HBI. In chapter 2, I described the diversity of anthropogenic attractants available to black bears based on self-reported behaviors of residents, and tested for changes in resident behaviors and attitudes over a 4 year period. In chapter 3, I used Montana Fish, Wildlife & Park's bear-related phone call complaint database to develop a model capable of predicting the spatial distribution of HBI. In chapter 4, I identified forage-related variables that predict use of the urban landscape by bears, and tested the validity of the model by describing food items at actual urban feeding sites.

THESIS FORMAT

Chapters 2, 3, and 4 were written and formatted as individual manuscripts ready for publication in specific peer-reviewed scientific journals. Chapters 2 and 3 have been submitted to *Ursus* and *The Journal of Wildlife Management*, respectively, and are under review. Chapter 4 will be submitted to *The Journal of Wildlife Management*. Because my work is a collaboration among several other people and entities, co-authors are listed at the start of each chapter. I also shift from the singular “I” to the collective “we” throughout the remainder of the thesis.

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CHAPTER 2

BEHAVIORAL AND ATTITUDINAL CHANGE OF RESIDENTS EXPOSED TO HUMAN-BEAR INTERACTIONS

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ABSTRACT

Human-black bear (*Ursus americanus*) interactions (interactions resulting in property damage, injury or death to humans, or fear of injury or death to humans; hereafter referred to as HBI) have been increasing in frequency and magnitude in North America since the 1960s, and many wildlife management agencies are turning to proactive management actions to reverse this trend. Information and education efforts (IEE) are the most common proactive management actions used, however, few studies monitor behaviors and attitudes of residents exposed to HBI and IEE. We used a case study in the Rattlesnake Valley of Missoula, Montana to describe the diversity of anthropogenic attractants available to black bears based on self-reported human behaviors, and test for changes in resident behaviors and attitudes over a 4 year period of exposure to HBI and IEE. We identified > 5 non-vegetative attractants, and >12 species of native and non-native vegetation available to black bears. Comparing the responses from mail questionnaires in 2004 (n = 369, response rate = 74%) and 2008 (n = 560, response rate = 60.1%), we found that the prevalence of 1 important behavior (i.e., outdoor garbage storage) decreased, and support for management actions used to deal with HBI increased, suggesting behaviors and attitudes of residents changed from 2004 to 2008. We suggest that bear managers developing proactive management plans for HBI must incorporate the varying affects of reducing the prevalence of 1 or numerous attractants, the changing dynamics of human behaviors and attitudes, and the importance of incorporating monitoring and evaluation procedures.

INTRODUCTION

As the number of humans continues to increase globally, interactions with bears (*Ursus* spp.) will persist as an important conservation and management issue. Human-black bear (*U. americanus*) interactions (HBI) have been increasing in frequency and magnitude in North America since the 1960s (Conover and Decker 1991, Beckmann and Berger 2003). Human-black bear interactions can be defined minimally as an occurrence when both a human and a bear are aware of each other’s presence, but can also include human-bear conflicts where a bear makes physical contact with a person or displays a stress-related behavior (Hopkins et al. 2010). Wildlife management agencies are interested in reducing the number of HBI because of limited resources and the mandate to manage wildlife populations. Unfortunately, interactions are often associated with numerous stakeholder groups, intense political scrutiny, and limited biological data, creating complex decision-making situations for bear managers.

Most management of HBI relies on reactive management, where managers respond immediately and directly to individual bears involved in interactions (Hopkins et al. 2010). However, implementing reactive management actions can be time consuming (Garshelis 1989), so many wildlife management agencies are turning to proactive management actions (Spencer et al. 2007), where preventative management is implemented to deter bears from getting involved in future HBI (Hopkins et al. 2010). The main proactive management action used by agencies is Information and Education Efforts (IEE) directed towards the public, where a variety of interested organizations (e.g., community associations, government agencies; Gore et al. 2006) work together to promote responsible behavior (Disinger 1983), increase knowledge regarding bear biology and management, and change attitudes regarding management of human-bear interactions (Zint et al. 2002).

Essential to successful wildlife management, and especially proactive management involving black bears, is a thorough understanding of human dimensions (Decker and Enck 1996). Monitoring human attitudes and behaviors will aid in the understanding of diverse stakeholder groups (Decker and Enck 1996), and provide information for IEE development and reorganization (Gore et al. 2006). For example, managers may alter their IEE curriculum when the recipients of the curriculum change their attitudes (e.g., increase their support) regarding a certain management action (e.g., lethal control). To our knowledge, few studies monitor human behaviors and attitudes in areas where HBI occur to provide information for proactive human-black bear management (Gore et al. 2008).

We used a case study in Missoula, Montana, where an increase in HBI and a subsequent increase in IEE, created a scenario where potential changes in self-reported human behaviors and attitudes could be monitored. Significant increases in HBI in the mid to late 1990s instigated a movement to develop IEE in the Rattlesnake Valley neighborhood of Missoula. Led by the Missoula Bear Task Force (a community-based bear awareness program) and Montana Fish Wildlife & Parks (MFWP), IEE were developed and implemented by 2004. The goal of this IEE was to decrease the prevalence of human-created bear attractants (i.e., anthropogenic foods, garbage, pet food, chicken coops, compost piles, bird seed, barbecue grills [BBQ], orchards, gardens), and to increase human awareness of bears, bear biology, and management. Information pamphlets, newsletters, door hangers, signs, kiosks, posters, annual bear fairs, and a website, along with door to door contacts, and presentations at local interest group meetings were all used to disseminate information to the public (J. J. Jonkel, MFWP, personal communication). We monitored human behaviors and attitudes by comparing public surveys implemented in the initial stages of IEE and 4 years later.

Our objectives were to describe the diversity of anthropogenic attractants available to black bears within the Rattlesnake Valley of Missoula based on self-reported behaviors, and test for changes in resident behaviors and attitudes in an area where residents were exposed to HBI and IEE. We defined trends in human behaviors and attitudes as positive, when residents reported a decrease in behaviors that provide bear attractants or an increase in support for any bear management action. We expected resident knowledge of bear biology, conflicts, and management would be enhanced, resulting in more responsible behavior and higher support for management actions used to deal with HBI.

STUDY AREA

Missoula, Montana was inhabited by approximately 65,000 people, spanning 62 km² (U.S. Census Bureau 2000). Average human density was approximately 1,046 people/km², and average housing density was 407.5 housing units/km². Gender ratio of residents was approximately 1:1, and the median age was 30.3 years (U.S. Census Bureau 2000). The city lies in a valley bottom at 978 m in elevation, where the Clark Fork and Bitterroot rivers converge. The Bitterroot Mountains abut the city to the west, and the Garnet Mountains to the east. The surrounding land owners were private ranchers and the U.S. National Forest Service. The mountains that surround Missoula rise to 2,766 m. Most urban development lies in the flat valley bottom, whereas the surrounding mountains are characterized by steep slopes and canyons of coniferous forest.

Most HBI occur in the wildland urban interface (WUI) of Missoula; few occur in the city core. The majority of HBI reported in the WUI are from the Rattlesnake Valley; it is 8 km long, 0.5-1.5 km wide, and a northern protrusion of the city core with >2,000 residents. Before 1950, the valley attracted bears with orchards, a mink (*Neovision vison*) and fox (*Vulpes vulpes*) farm, and a slaughterhouse (Booth 2005). Prior to 1997 approximately 15 reactive bear management actions were carried out annually in response to human-bear incidents (i.e., occurrences where bears cause property damage, obtained anthropogenic food, killed livestock or pets, or were involved in a human-bear conflict; Hopkins et al. 2010) in Missoula. The number of reactive bear management actions increased since 1997 and by 2004, Missoula residents reported 275 HBI and incidents, and MFWP addressed > 50 of those incidents with reactive bear management actions. Since 2004, residents report approximately 130 HBI and incidents annually, and MFWP responds to > 30 of those incidents with reactive bear management actions.

METHODS

The University of Montana Institutional Review Board for human subject research approved this research (Protocol ID# 162-04 in 2004, ID# 170-08 in 2008).

Sampling and Implementation

We distributed mail surveys in 2004 and 2008 to Rattlesnake Valley residents with comparable questions regarding human-black bear incidents, sightings, attractants, and management. In the 2004 survey, we selected 500 residences in the Rattlesnake Valley, Missoula, Montana to receive the questionnaire. We randomly selected these residents after numbering each property using a Missoula county zoning map. Surveys and a self-addressed and stamped return envelope were delivered in person and left with a household member >18 years of age. Two in-person delivery attempts were made; if no one answered the door on the second attempt, the survey was left with a hand written note requesting participation. A postcard reminder was mailed to each non-respondent within 2 weeks after delivery (Booth 2005). We received 369 returned surveys for a 74% response rate.

In the 2008 survey, we randomly selected 1,000 residents in the Rattlesnake Valley using a sampling firm (Survey Sampling, Inc., Fairfield, Connecticut). They accessed samples from a computer database of telephone and address listings categorized by census neighborhood block groups. Neighborhood block groups are the smallest geographical unit in which census data are published (U.S. Census Bureau 2000). We modified Dillman's (2007) 5-part mail process, and sent 3 mailings. We sent an introduction letter, the survey along with a self-addressed return envelope 1 week later, and a reminder postcard 4 weeks after the survey was sent. We received 560 completed surveys, and 68 incomplete surveys because of failed addresses, for a 60.1% response rate. Non-response was assessed by attempting to contact 10% of non-respondents by phone and asking 7 representative questions from the survey. We successfully contacted 32 non-respondents.

The Questionnaire

All questions used in this study were presented in a multiple choice format. Both the 2004 and 2008 surveys contained identical questions regarding resident demographics, behaviors that produce bear attractants, and attitudes towards a variety of management actions. However, the 2008 survey included additional questions regarding the diversity of attractants. We tracked demographic variables to test for sampling bias between sampling periods including gender, age (18-25, 26-35, 36-45, 46-55, 56-65, >65), and highest level of education achieved (some high school, high school, some college, bachelor's degree, graduate degree).

To test for changes in self-reported behaviors, respondents in both surveys were asked a variety of questions regarding their direct or indirect contribution of human-created bear attractants, including the presence of bird feeders, outdoor BBQ grills, outdoor compost piles, and the location of pet food and garbage container storage. Additionally, questions regarding the presence of outdoor chicken coops, gardens, berry bushes (i.e., raspberry, holy, blueberry, strawberry, grape, service berry [*Amelanchier alnifolia*], elderberry [*Sambucus* spp.], mountain ash [*Sorbus* spp.]), and fruit-bearing trees (apple, pear, cherry, peach, other) were included only in the 2008 survey and were used to assess the diversity of anthropogenic attractants available to bears.

We developed 4 hypothetical HBI scenarios from which 4 possible management actions could be implemented to test for changes in resident attitudes toward different management actions. These scenarios included, when a bear is frequently sighted in neighborhood, repeatedly disturbs and dumps garbage, destroys personal property, and attacks and injures your neighbor. The 4 management actions used to deal with the scenario in question were no action, use of cracker shells to deter bears, capture and relocation, and lethal removal. We estimated acceptance based on a 5-point acceptance scale of strongly disagree, disagree, undecided, agree, and strongly agree with each management action. We developed a mean support value based on the average number of positive (1; agree and strongly agree), negative (-1; disagree and strongly disagree), and neutral (0; undecided) attitudes to limit the effect of extreme cases and to more intuitively depict attitudes.

Data Analysis

We used Pearson's chi square tests to examine differences in the frequency of behaviors between 2004 and 2008 to test whether resident behaviors that produce attractants changed. We used independent samples *t*-tests assuming unequal variances (Zar 1999) to test for changes in mean support values for different management actions. We tested non-response bias in the 2008 survey by comparing responses of respondents and non-respondents using Pearson's chi square tests for behaviors and independent samples *t*-tests assuming unequal variances for attitudes. To test for sampling bias between surveys, we used a chi-square test of homogeneity (Ott and Longnecker 2001) to test differences in gender, age, and education of respondents. When respondent demographics differed significantly between surveys, we weighted mean support values from the 2008 survey to reflect demographic sampling proportions in the 2004 survey and analyzed them separately. We used a significance level of 0.05 for all statistical tests.

RESULTS

A non-response bias was not detected in the 2008 survey (Table 2.1). However, respondent demographics varied between the 2004 and 2008 surveys (Table 2.2). The 2008 survey was skewed towards males, older respondents, and lower education levels, when compared to the 2004 survey (Table 2.2). Patterns of change using weighted responses between the 2004 and 2008 surveys did not differ from un-weighted responses for frequency of bird feeders ($\chi^2_1 = 0.920$; $P = 0.338$), BBQ grills ($\chi^2_1 = 0.231$; $P = 0.631$), compost piles ($\chi^2_1 = 1.706$; $P = 0.191$), garbage storage ($\chi^2_1 = 8.571$; $P = 0.003$), and pet food storage ($\chi^2_1 = 1.390$; $P = 0.238$), and mean support values averaged across scenarios for no action ($t_{888} = 2.06$; $P = 0.053$),cracker shells as a deterrent ($t_{777} = 5.23$; $P < 0.0001$), capture and relocation ($t_{730} = 6.97$; $P < 0.0001$), and lethal removal ($t_{978} = 6.09$; $P < 0.0001$). Therefore, we report non-weighted results hereafter for more intuitive interpretation.

Attractants available to bears within the study area were diverse. From the 2008 survey, 63.9% of residents had ≥ 1 fruit tree and 64.7% of residents had ≥ 1 berry bush, representing > 3 different varieties of fruit trees and 8 different species of berry bushes. Apple was the most prevalent fruit tree, and mountain ash (*Sorbus sitchensis*) was the most prevalent berry bush (Table 2.3). Bird feeders, BBQ grills, compost piles, garbage containers, and pet food (Table 2.4), and gardens (44.9%), and outdoor chicken coops (1.3%) also occurred on resident properties.

Between 2004 and 2008, frequencies of self-reported human behaviors that produce available bird feeders, pet food, compost, and BBQ grills did not change significantly, but the frequency of outdoor garbage storage did change ($\chi^2 = 8.677$; $P < 0.003$), and it decreased by 7.6% (Table 2.4). The number of residents who reported they stored their garbage outdoors decreased by 33% from 2004 to 2008 (Table 2.4).

Acceptance based on mean support values across all conflict scenarios increased between 2004 and 2008 for the use of cracker shells as a deterrent ($t_{813} = 4.67$; $P < 0.0001$), capture and relocation ($t_{796} = 6.46$; $p < 0.0001$), and lethal removal ($t_{886} = 7.07$; $P < 0.0001$) (Figure 2.1e). The proportion of residents responding with positive attitudes increased, depending on bear incident scenario, by 9-21% for cracker shells, 0-25% for capture and relocation, and 6-27% for lethal removal (Figure 2.1a, b, c, d), but did not change significantly for no action ($t_{852} = 1.89$; $P = 0.058$) (Figure 1e). Mean support values were highest for capture and relocation (ranging from 47-89% of residents supporting relocation) depending on conflict scenario. Mean support values were lowest for lethal removal (ranging between 3-55% of residents supporting lethal removal) depending on conflict scenario (Figure 2.1a, b, c, d).

DISCUSSION

Monitoring trends in human behaviors and attitudes is an important aspect of successful wildlife management (Decker and Enck 1996). Indeed, monitoring is fundamental to understanding shortcomings and the usefulness of proactive management actions (i.e., IEE) to manage the increasing prevalence of HBI (Gore et al. 2006). The results of our case study have provided a quantitative description of the diversity of attractants based on self-reported behaviors, and 1 of the only temporal examinations of behaviors and attitudes of residents exposed to HBI and an IEE. In general accordance with our expectations, the prevalence of one important behavior (i.e., outdoor garbage storage) decreased, and support for management actions used to deal with HBI increased, suggesting some behaviors and attitudes of residents changed from 2004 to 2008. Implications herein suggest that proactive management plans for HBI must embrace the diversity of attractants available to bears and the shifting dynamics of human behaviors and attitudes.

The diversity and abundance of bear forage located in our study area supports how difficult it is for bear managers to reduce the availability of attractants. In addition to non-vegetative anthropogenic attractants such as garbage, bird feeders, and BBQ grills, native and non-native black bear forage were widespread. Apple trees were the most prevalent bear-attracting vegetation species in our study area. In addition, >4 species of native berry and >7 other fruit producing species also had a presence (Table 3). Because black bear foraging dynamics are closely related to seasonal shifts in available food (Rogers 1987), proactive management plans to eradicate specific attractants (e.g., only garbage) may not actually affect the frequency of HBI. However, if proactive management plans are indeed successful in substantially reducing the availability of numerous anthropogenic foods, little or no information is available on the biological response of bears. When garbage dumps (i.e., the only anthropogenic food source for bears) were eliminated in Yellowstone National Park, human-grizzly bear (*U. arctos*) interactions increased and numerous bears were euthanized, which played a role in a significant population decline and redistribution (Knight and Eberhardt 1985, Eberhardt et al. 1986). We recommend that the diversity of attractants and the biological effects of eliminating multiple attractants be incorporated into proactive management plans, and suggest researchers should assess the impacts of the removal of anthropogenic food (e.g., garbage or apple trees) on bear habitat use, movements, and population dynamics.

Underlining the presence of anthropogenic food sources is human behavior (Baruch-Mordo et al. 2009), where residents carry out intended or unintended behavioral actions (e.g., decide to put out their garbage the night before garbage pick-up) that provide anthropogenic food sources to bears. One of the main goals in proactive bear management is to preventatively reduce the prevalence of anthropogenic food sources. To our knowledge, the authors of only 1 other study monitored behaviors of residents exposed to HBI. Gore et al. (2008) found no differences in self-reported prevalence of unsecured garbage, outdoor feeding of pets, outdoor storage of BBQ grills, compost piles, bird feeders, and failure to harvest fruit from trees over the period of 1 year after the implementation of an IEE in New York. Our results are consistent with some of these findings, where no changes in human behaviors were reported for the presence of outdoor bird feeders, composts, gardens, and pet food storage. However, in contrast to the findings in New York, we found a decrease in self-reported change in the frequency of garbage containers stored outside (Table 4). Discrepancies between self reported behavioral change in New York and this study, may be the result of differing measurement time-frames (i.e., 1 year in New York versus 4 years in this study) or differences in resident exposure to IEE or other bear-related information.

It seems clear that North American public attitudes have become more protectionist and less utilitarian (Manfredo et al. 1999), emphasized by public disapproval of black bear hunting techniques (Teel et al. 2002) and ballot initiatives limiting hunting seasons and methods (Manfredo et al. 1998). Our results suggest an alternate trend, where support for the use of cracker shells, relocation, and lethal removal as management tools for dealing with HBI have increased over time. Our findings correspond more closely to results reported in a 17 year meta-analysis of studies in New York, where no clear patterns support a general trend across demographic segments towards a more protectionist society, and that more research is necessary to identify mechanisms of change (Butler et al. 2003). Regardless, our results do reemphasize that non-lethal management tools, especially relocation, have high overall support (Figure 1e), and that lethal management tools are relatively unsupported (Figure 1e) except in situations where a human life has been compromised by injury (Figure 1d). We are not suggesting however, that relocation is the best reactive management tool; we are merely reporting public support. It is clear that relocation is not always successful, and may only temporarily delay reoccurrence of HBI (Landriault et al. 2009).

We propose 2 reasons for the positive trends observed in this study, where 1 human behavior and numerous attitudes have changed. First, IEE were being developed in the Rattlesnake Valley between 2000 and 2004, and were consistently being implemented from 2004 to 2008 (during our study period; J. J. Jonkel, Montana Fish, Wildlife & Parks, Personal Communication). Educational efforts, such as IEE implemented in the Rattlesnake Valley, have played a role in successful implementation of policy directed towards minimizing other human-wildlife interactions (Piene 2001, McCarthy and Seavoy 1994) and have been suggested as a means of altering human attitudes (Coluccy et al. 2001; Enck and Brown 2002; Teel et al. 2002). The IEE implemented in our study area may have been successful in changing resident knowledge of bear biology, conflicts, and management, resulting in more responsible behavior and higher support for management actions used to deal with HBI. Second, the process of mere exposure also affects behavioral and attitudinal change (Zajonc 1968, Petty and Wegner 1998). Residents may have received information from non-IEE avenues, such as articles in local newspapers, frequent bear sightings, and discussions with neighbors. Changes in self-reported behaviors and attitudes may have also come from exposure to specific conflicts, such as bears getting into individual respondent's garbage containers.

To identify the mechanism for change, future research monitoring human behaviors and attitudes and assessing IEE, should incorporate 2 important components. First, studies should include a spatial control, along with a longitudinal framework, to compare resident exposure to treatments such as IEE (Gore et al. 2008, Baruch-Mordo et al. 2009). With this type of study design the identification of patterns in human behaviors and attitudes can be improved and the reason for change (e.g., effectiveness of IEE) can be specified. Second, receptivity to educational messages (e.g., IEE) has been linked to risk perception (Knuth et al. 1992), where people intuitively assess a risk (Slovic, 1987). For HBI, risk can be classified by threats to human safety and property damage. This perceived threat (i.e., threats to human safety and property damage) must be evident for a risk reducing behavior to be carried out (Witte 1992). When monitoring behaviors and attitudes of residents exposed to HBI and IEE, covariates intended to identify risk perception must be included in the analysis. For example, although no changes were observed due to an IEE in New York, risk perception increased, providing some evidence that IEE was the mechanism for change (Gore et al. 2008). Optimal study designs for monitoring human behaviors and attitudes and evaluating IEE will include controls and antecedents for risk perception (Gore et al. 2008), generating the most informative information for developing, modifying, and evaluating proactive management actions for reducing HBI.

Wildlife managers and researchers should take caution when interpreting the results of this study, because we recognize 2 issues related to study design that may have affected our data. First, methods for implementing the 2004 and 2008 surveys were different. Although we randomly selected households in both cases, and we ran our analysis using demographically weighted data, other demographic differences (e.g., whether the resident owns or rents the property) may have played a role in the patterns we observed. Second, we did not assess non-response bias in 2004, and our non-response assessment in 2008 did not evaluate important demographic variables nor did it have a large sample size (n = 32).

MANAGEMENT IMPLICATIONS

Based on our results, bear managers should consider 3 important components when developing and implementing proactive management plans for reducing HBI. First, the diversity of anthropogenic attractants within local areas may be high (>10 different vegetative or non-vegetative food sources), making it difficult to reduce HBI by only decreasing the prevalence of a single attractant. Managers should systematically investigate the diversity and prevalence of attractants within their respective management area, and investigate the impacts of reducing the availability of a single or multiple attractants. Second, managers should assess the possibility that human behaviors and attitudes are changing within areas exposed to HBI and IEE, and incorporate those changes into proactive management initiatives. Third, to identify shortcomings and evaluate effectiveness of proactive management plans (i.e., IEE), managers must develop monitoring protocols using longitudinal and treatment-control study designs (Gore et al. 2008, Baruch-Mordo et al. 2009). These monitoring protocols along with a suite of other information such as harvest numbers, removal numbers from conflict mortality and relocations, natural forage availability, weather, and basic biological data, will greatly assist in interpreting IEE outcomes in the future (Gore et al. 2006).

ACKNOWLEDGMENTS

We thank the Missoula, Montana residents who took the time to fill out the surveys, as well as M. Bruns-Dubois, and the Institute for Tourism and Recreation, University of Montana. We thank Montana Fish, Wildlife and Parks for cooperation and logistical support, particularly M. Thompson, J. J. Jonkel, V. Edwards, and B. Wiesner. B. Kohl, and S. M. Smith assisted in data collection. J. Berger, M. S. Mitchell, and E. Edge provided information and comments related to earlier drafts of the manuscript. This study was supported by the Boone and Crockett Program in Wildlife Conservation, and the Harry Longwell Family Foundation.

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Table 2.1. Non-response analysis for a questionnaire sent to residents in Rattlesnake Valley, Missoula, Montana in 2008 to determine behaviors and attitudes related to human-black bear interactions. Variables are presented as the percentage of respondents, and the mean support value is for a scenario where a bear attacks and injures your neighbor.

Survey question	Respondents (n = 560)	Non-respondents (n = 32)	Test statistic
Presence of bird feeders			$\chi^2_1 = 0.339$, $P = 0.560$
Yes	35.5	40.6	
No	64.5	59.4	
Presence of peach tree			$\chi^2_1 = 1.429$, $P = 0.232$
Yes	2.6	6.1	
No	97.4	93.9	
Presence of cherry tree			$\chi^2_1 = 1.433$, $P = 0.231$
Yes	16.2	24.2	
No	83.8	75.8	
Mean support value			
No action	-0.84	-0.76	$t_{26} = -0.585$, $P = 0.564$
Cracker shells	0.30	0.24	$t_{22} = 0.296$, $P = 0.770$
Relocation	0.74	0.86	$t_{34} = 1.259$, $P = 0.217$
Lethally remove	0.09	-0.23	$t_{27} = .1.606$ $P = 0.119$

Table 2.2. Respondent demographics from mail questionnaires implemented in 2004 and 2008 to Rattlesnake Valley residents, Missoula, Montana to test for changes in human behaviors and attitudes. Data are represented as percentage of respondents reporting the corresponding demographic parameter.

	Survey			
Variable (n = 2004, 2008)	2004	2008	Overall	Test statistic (2004 vs. 2008)
Gender (366, 558)				$\chi^2_1 = 24.32$, $P < 0.0001$
Male	48	65	59	
Female	52	35	41	
Age (366, 563)				$\chi^2_5 = 40.41$, $P < 0.0001$
18-25	5	1	2	
26-35	12	8	9	
36-45	16	12	14	
46-55	28	21	24	
56-65	18	29	25	
> 65	20	29	26	
Education (363, 563)				$\chi^2_4 = 9.439$, $P < 0.0001$
Some high school	2	0	1	
High school	4	6	5	
Some college	20	17	18	
Bachelor's degree	33	37	36	
Graduate degree	41	40	40	

Table 2.3. Occurrence frequency of available vegetation attracting black bears on resident properties, Rattlesnake Valley, Missoula, Montana. Values based on self-reported behaviors from a mail questionnaire implemented in 2008.

Fruit trees		Berry bushes			
		Native		Non-native	
Type	%	Type	%	Type	%
Apple	50.4	Mountain Ash	33.6	Raspberry	26.3
Cherry	16.2	Serviceberry	23.1	Strawberry	13.7
Pear	11.3	Elderberry	9.0	Grape	6.4
Peach	2.6			Holly	6.4
Other	24.1			Blueberry	2.6

Table 2.4. Frequency of outdoor and available black bear attractants based on self-reported resident behaviors in the early stages of Information and Education efforts (2004) and 4 years later (2008) in the Rattlesnake Valley, Missoula, Montana. Reported *p*-values based on a chi-square test of homogeneity of frequencies between surveys.

	Bird feeder	BBQ grill	Compost pile	Garbage storage	Pet food storage
Survey					
2004	38.9	77.7	19.5	22.7	0.3
2008	35.5	74.2	16.6	15.1	0.7
Test statistic					
χ^2_1	1.06	1.32	1.25	8.68	0.33
P -value	0.302	0.250	0.263	0.003	0.565

Figure 3.1a. Support values based on the mean of positive (1 = agree and strongly agree), neutral (0 = neutral), and negative (-1 = disagree and strongly disagree) attitudes for different management actions to reduce HBI between 2004 (triangles) and 2008 (circles) in the Rattlesnake Valley, Missoula, Montana. Results are stratified by conflict scenario: a) bear frequently sighted in neighborhood; b) bear repeatedly disturbs and dumps garbage; c) bear destroys personal property; d) bear attacks and injures your neighbor; and e) all scenarios combined. Error bars denote 95% confidence intervals around the mean.

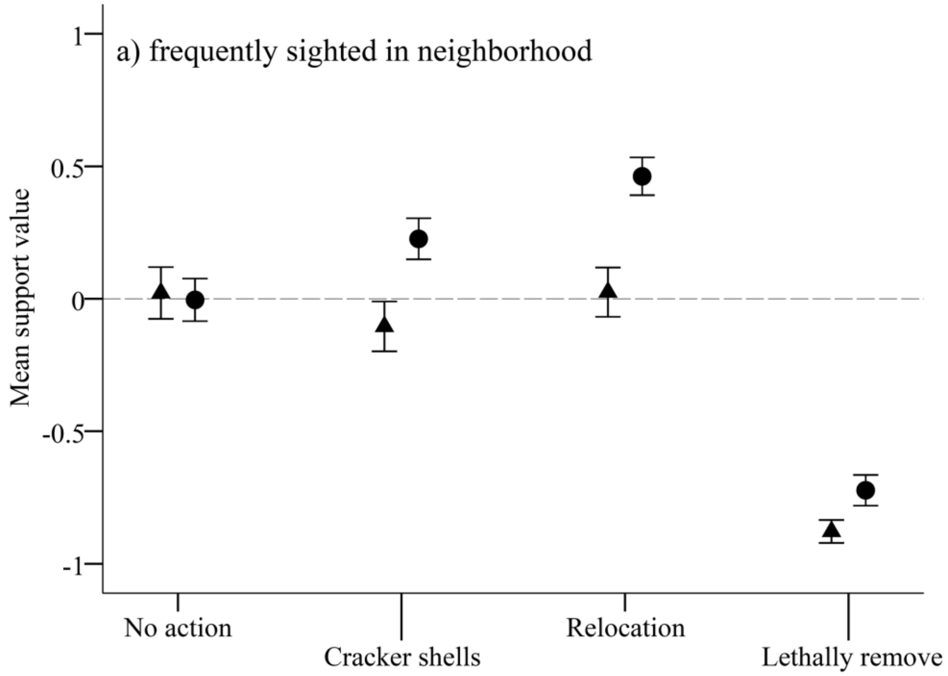


Figure 3.1b. Support values based on the mean of positive (1 = agree and strongly agree), neutral (0 = neutral), and negative (-1 = disagree and strongly disagree) attitudes for different management actions to reduce HBI between 2004 (triangles) and 2008 (circles) in the Rattlesnake Valley, Missoula, Montana. Results are stratified by conflict scenario: a) bear frequently sighted in neighborhood; b) bear repeatedly disturbs and dumps garbage; c) bear destroys personal property; d) bear attacks and injures your neighbor; and e) all scenarios combined. Error bars denote 95% confidence intervals around the mean.

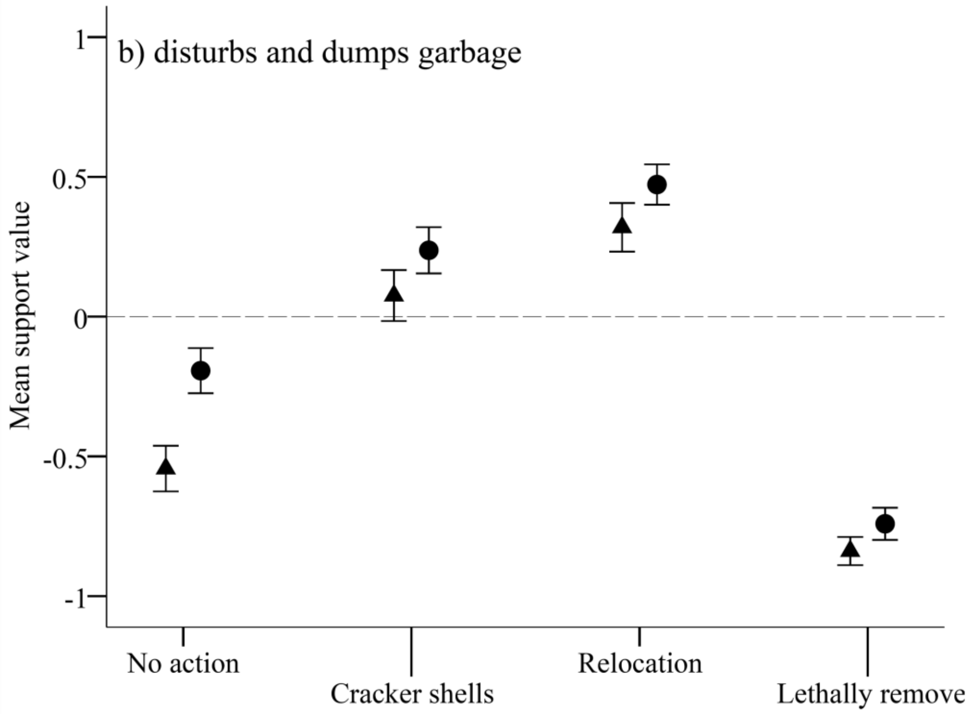


Figure 3.1c. Support values based on the mean of positive (1 = agree and strongly agree), neutral (0 = neutral), and negative (-1 = disagree and strongly disagree) attitudes for different management actions to reduce HBI between 2004 (triangles) and 2008 (circles) in the Rattlesnake Valley, Missoula, Montana. Results are stratified by conflict scenario: a) bear frequently sighted in neighborhood; b) bear repeatedly disturbs and dumps garbage; c) bear destroys personal property; d) bear attacks and injures your neighbor; and e) all scenarios combined. Error bars denote 95% confidence intervals around the mean.

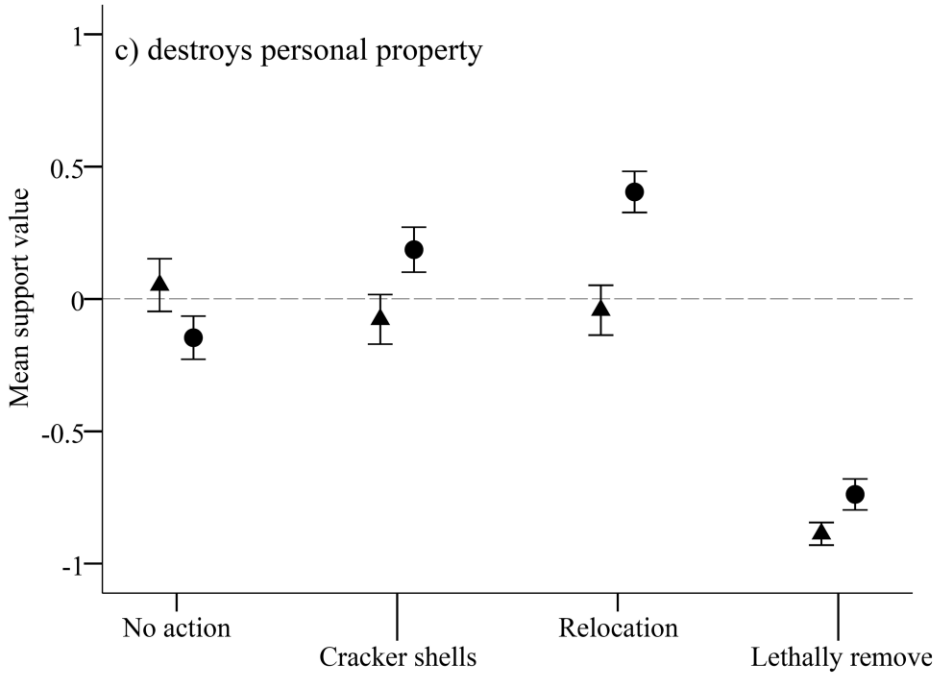


Figure 3.1d. Support values based on the mean of positive (1 = agree and strongly agree), neutral (0 = neutral), and negative (-1 = disagree and strongly disagree) attitudes for different management actions to reduce HBI between 2004 (triangles) and 2008 (circles) in the Rattlesnake Valley, Missoula, Montana. Results are stratified by conflict scenario: a) bear frequently sighted in neighborhood; b) bear repeatedly disturbs and dumps garbage; c) bear destroys personal property; d) bear attacks and injures your neighbor; and e) all scenarios combined. Error bars denote 95% confidence intervals around the mean.

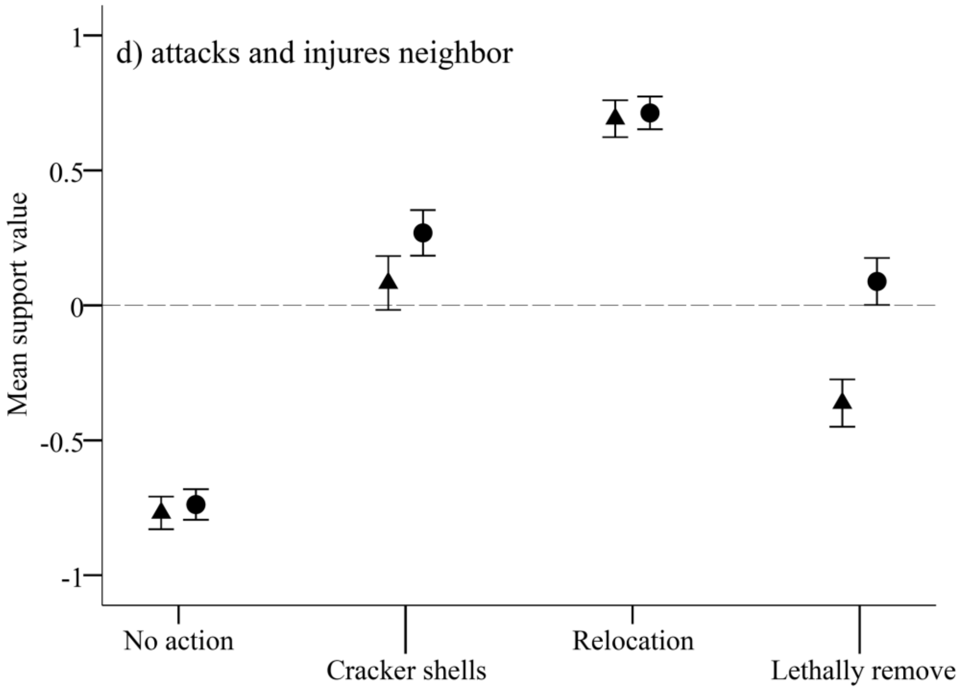
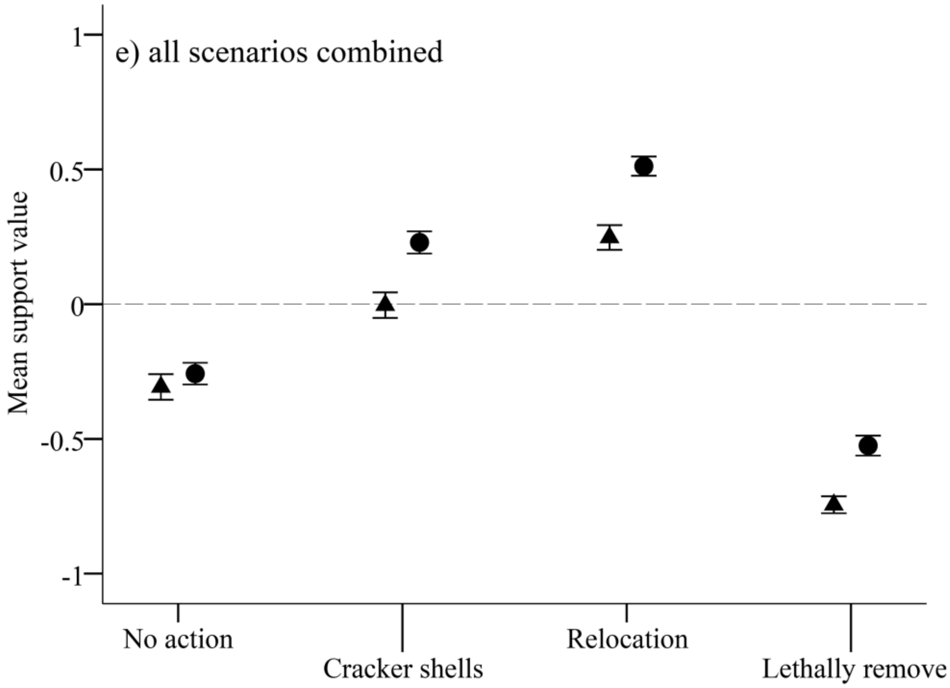


Figure 3.1e. Support values based on the mean of positive (1 = agree and strongly agree), neutral (0 = neutral), and negative (-1 = disagree and strongly disagree) attitudes for different management actions to reduce HBI between 2004 (triangles) and 2008 (circles) in the Rattlesnake Valley, Missoula, Montana. Results are stratified by conflict scenario: a) bear frequently sighted in neighborhood; b) bear repeatedly disturbs and dumps garbage; c) bear destroys personal property; d) bear attacks and injures your neighbor; and e) all scenarios combined. Error bars denote 95% confidence intervals around the mean.



CHAPTER 3

PREDICTING SPATIAL DISTRIBUTION OF HUMAN-BLACK BEAR INTERACTIONS IN URBAN AREAS

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ABSTRACT

Human-wildlife interactions are often associated with a myriad of stakeholder groups, intense political scrutiny, and limited biological data, creating complex decision-making situations for wildlife management agencies. Limited research exists on the development and testing of tools (e.g., models to predict the spatial distribution of interactions) to reduce human-black bear (*Ursus americanus*) interactions (HBI). Available models predicting the spatial distribution of HBI are usually developed at scales too large to predict across urban areas, are rarely tested against independent data sets, and usually do not incorporate both landscape and anthropogenic variables. We developed a predictive modeling tool to identify areas of high conflict potential across urban areas. We compiled phone complaint and conflict data related to black bears recorded by Montana Fish, Wildlife & Parks in Missoula, Montana from 2003 to 2008, which included sightings (*n* = 284), other incidents (e.g., bear was seen feeding on garbage; *n* = 530), and sites where reactive management actions occurred (*n* = 103). We compared the location of interactions to 5,000 random locations using logistic regression and 3 spatial explanatory variables: distance to forested patches, distance to major rivers and streams, and housing density. We tested how well the model predicted the locations of interactions in Missoula using *K*-folds cross validation, and the locations of HBI from a second and independent study area. The final model discriminated the relative spatial probability of HBI within Missoula well, and the second study area moderately. The probability of HBI in Missoula increased when residents lived close to forested patches and major rivers and streams, and in intermediate housing densities (approx. 6.59 houses/ha). Our results provide a wildlife management tool and a repeatable statistical framework, which predicts the spatial distribution of HBI using only a small set of variables.

INTRODUCTION

Resolving human-wildlife interactions can be complex (Conover 2002) because interactions can be real or perceived, social or political, economic or aesthetic, and include vehicle-wildlife collisions, disease, agricultural and timber damage, and property damage (Messmer 2009, Peterson et al. 2010). Wildlife management agencies are faced with an increasing trend in the number of human-wildlife interactions (Messmer 2000), along with the challenges of a growing wildland-urban interface (Theobald 2001). Most agencies are interested in decreasing the number of interactions to preserve human safety

(Perry and Rusing 2000), reduce resources spent dealing with interactions (Garshelis 1989), and avoid controversial management (e.g., lethal control; Hristienko and McDonald 2007).

Although research investigating human-wildlife interactions is available (Conover 2002), managers dealing with human-black bear (*Ursus americanus*) interactions (e.g., bear sightings, and interactions resulting in property damage, injury or death to humans, or fear of injury or death to humans; hereafter referred to as HBI) still develop management plans without rigorous development and testing of certain management practices (Beckmann et al. 2004, Ferraro and Pattanayak 2006, Gore et al. 2008). For example, the authors from only 1 study systematically developed an education effort with the goal of reducing the number of HBI, and tested its efficacy on changing human behavior (Gore et al. 2008). Education efforts have few short term effects on human behavior, and integrating evaluation measures is essential to implementing education efforts (Gore et al. 2008). These results, along with the increasing trend in HBI over the last few decades in North America (Beckmann and Berger 2003, Zack et al. 2003, Baruch-Mordo et al. 2008), exemplify the need to develop and test best management practices to reduce HBI.

To successfully reduce the number of HBI, managers should have a suite of tools that allow them to spatially identify developed areas (Sitati et al. 2003, Wilson et al. 2006) and areas scheduled for development with high probability of conflict (Kretser et al. 2008). The ability to predict interactions across urban areas is essential to successfully identify where to implement proactive management efforts and plan urban development that minimizes HBI. Researchers have recently demonstrated the value of spatial modeling to investigate the distribution of human-wildlife interactions for species other than black bears (Sitati et al. 2003, Bradley and Pletscher 2005, Michalski et al. 2006). Similarly, prediction models in rural areas and at statewide scales have been developed for black and grizzly (*U. arctos*) bears using locations of bear sightings, incidents, and reactive management actions collected by state management agencies (Wilson et al. 2006, Baruch-Mordo et al. 2008, Ambarli and Bilgin 2008, Kretser et al. 2008). No studies however, have tested the validity of their models using independent data sets in adjacent study areas (Verbyla and Litvaitis 1989), which would be beneficial for managers to predict human-wildlife interactions in areas considered for development.

A clear pattern exists regarding the spatial predictive variables used in studies predicting HBI and other human-wildlife interactions. Variables used in all studies are explicably linked to 2 distinctive categories: landscape variables (e.g., distance to habitat feature), and anthropogenic variables (e.g., housing density, grazing regime). Few research studies however, include both landscape and anthropogenic variables within the same predictive model (Wilson et al. 2006). Important variables to predict HBI include distance to black bear habitat (Baruch-Mordo et al. 2008), distance to riparian areas (Wilson et al. 2006), and housing density (Kretser et al. 2008). No studies have incorporated all 3 suggested variables into a single model to predict the spatial distribution of HBI, and have developed prediction models across urban areas where most HBI occur (Spencer et al. 2007).

Our objective was to develop a model that can predict the spatial distribution of HBI. To meet our objective we asked what variables are important predictors of the location of HBI across an urban area. We tested whether distance to forest patches, distance to major rivers and streams (i.e., a surrogate for riparian areas), and housing density were significant predictors of HBI in Missoula, Montana, and tested the portability of the model with locations of HBI from an adjacent study area (Seeley Lake, MT). Based on previous research (Kleckner 2001, Wilson et al. 2006, Baruch-Mordo et al. 2008), we expected a negative relationship between probability of HBI and distance to forest patches, distance to major rivers and streams, and housing density. The purpose of our research was to provide wildlife managers with a tool that is broadly applicable, practical and repeatable, and would allow them to predict the spatial arrangement of future HBI across urban areas in western Montana.

STUDY AREA

Missoula, Montana (61.9 km^2) was inhabited by approximately 64,801 people. There were 25,225 housing units at a mean density of 4.08/ha, with 10.46 people/ha (US Census Bureau 2000). The town lies in a valley bottom, where the Clark Fork and Bitterroot rivers converge. Landownership in surrounding parcels was a mix of private and public (i.e., USDA Forest Service) lands. The topography is diverse with elevations ranging from 978 to 2,766 m. Most urban development is on the valley floor and steep slopes and canyons in the surrounding mountains (Figure 1). The highest annual temperatures occurred in July (average max = 28.4ºC, min = 10.6 ºC), and the coolest month was December (average max = 0.1 ºC min= -7.2 ºC; Western Regional Climate Center 2008). Average annual precipitation was 43.3 cm evenly distributed throughout the seasons except for May and June when rain was more common (Western Regional Climate Center 2008).

Seeley Lake, Montana (28.6 km^2) was 50 km northeast of Missoula, and was inhabited by approximately 1,436 people. There were 938 occupied housing units at a mean density of 0.33/ha, with 0.50 people/ha (US Census Bureau 2000). The town lies in the Clearwater River Valley at 1228 m in elevation. The spatial dynamics of urban development in Seeley Lake were similar to Missoula, with a concentrated central area and multiple radiating protrusions of housing development. Landownership in surrounding parcels was a mix of private and public (i.e., USDA Forest Service) lands. The highest annual temperatures occurred in July (average max = 27.8ºC, min = 6.4 ºC), and the coolest month was January (average max = -1.1 ºC min= -12.8 ºC; Western Regional Climate Center 2008). Average annual precipitation was 50.8 cm evenly distributed throughout the seasons except December, January, May and June when precipitation is more common (Western Regional Climate Center 2008).

In both study areas, rain ordinarily falls April–October and snow from November–March. Human-black bear interactions occur in both study areas, and Montana Fish, Wildlife & Parks (MFWP) is responsible for managing these interactions. Attractants related to HBI in both areas include garbage, fruit trees, bird seed, composts, chickens, and barbeque grills (Booth 2005).

METHODS

From 2003 to 2008, MFWP systematically recorded HBI in 2 databases. The first database included phone calls concerning human-black bear incidents and sightings unrelated to black bear hunter harvest. Information from each phone call included date, address, nature of interaction (e.g., sighting only, bear getting into trash, bear getting into bird feeders), attractant related to interaction, and physical appearance of the bear. The second database included all reactive management actions carried out by MFWP personnel. Reactive management actions occurred when MFWP personnel respond to an individual bear through immediate and direct action, using methods such as capturing, aversive conditioning, translocating, or removing individuals from the population (Hopkins et al. 2010). Information for each reactive management action included date, mailing address where interaction took place, nature of interaction, attractant related to interaction, and action taken (e.g., aversive conditioning, set trap). We combined these 2 databases into a pooled spatial data set of HBI and categorized records into sighting only, other interaction, and reactive management action. We omitted all records that did not explicitly fall into these categories.

We used Google Earth Free (Google, Mountain View, CA) as a geocoding software to obtain Universal Transverse Mercator (UTM) coordinates from the mailing address of each record. To improve geocoding data, we adjusted coordinates given by Google Earth to consistently mark the centroid of the dwelling's roof centerline (Goldberg et al. 2008). We also employed 2 other methods to minimize error in location approximation. First, when we obtained a geocoded location in the middle of a street, we used the convention of odd-even addresses being associated with north-south and east-west properties, respectively, to obtain more precise UTM coordinates. Second, we contacted the MFWP manager who recorded the phone call or reactive management action to verify questionable locations. We omitted coordinates given by Google Earth that were ambiguous or incomprehensible, not associated with a property, or not recalled by the manager. We assumed a negligible effect on sampling bias by omitting locations, because the omitted locations constituted <6% of all locations.

Modeling

We used 6 years (2003–2008) of HBI data, and compared locations of HBI to 5,000 locations randomly selected across Missoula using a use-available sampling framework (Manly et al. 2002). The available extent for selecting random locations included all areas within 100 m (roughly the width of an average city block within the study area) of an occupied dwelling or business parcel, where HBI could occur. We buffered center locations of parcels with residential dwellings and businesses (Montana Natural Resources Information System 2009) by 100 m, and drew random locations within this buffered zone of availability. We omitted privately owned parcels classified as vacant and agricultural to limit our inferences within occupied urban areas.

We developed models using logistic regression to discriminate between HBI and random locations, analogous to resource selection function techniques (Hosmer and Lemeshow 2000, Manly et al. 2002). We used multi-variable models to derive a relative probability of a human-black bear interaction using the formula:

$$\hat{\omega}(x) = \exp\left(\hat{\beta}_1 x_1 + \hat{\beta}_2 x_2 + \dots + \hat{\beta}_n x_n\right) \qquad (1)$$

where $\hat{\omega}(x)$ is the relative probability of a sighting or incident (i.e., low to high) as a function of an array of covariates x_n, and variable coefficients $\hat{\beta}_n$ (Hosmer and Lemeshow 2000, Manley et al. 2002, Keating and Cherry 2004, Johnson et al. 2006). In developing our models, we assumed that, 1) HBI reported by the public reflect the actual distribution of all HBI that occur within our study area (reported or not reported); 2) there were no biases in data collection, recording, or geocoding; 3) each HBI location was an independent event; and 4) errors in the location of HBI are normally distributed.

Spatial Explanatory Variables

We selected potential spatial explanatory variables based on 2 conditions. First, variables must have been publicly available, and easy and inexpensive to obtain (Sitati et al. 2003), so our modeling framework could be replicated by managers and researchers in other areas. Second, variables must have been supported by previous literature and biological relevance. The variables we included stemmed from a combination of landscape and anthropogenic factors, and were distance to major rivers and streams (i.e., riparian vegetation; Wilson et al. 2006), housing density (Kleckner 2001, Kretser et al. 2008), and distance to forest patches (i.e., suitable bear habitat; Baruch-Mordo et al. 2009). We divided forest patches into 2 categories based on land use planning (Soulé 1991) and foraging theory (Pyke et al. 1977). We assumed that the relationship between the locations of HBI and forested areas large enough to sustain a bear home range (meeting all life history requirements for black bears, similar to core habitats; Larkin et al. 2004) and small forest patches used intermittently throughout the year (similar to high human disturbance land cover types; Larkin et al. 2004) would be different.

We used TIGER 2000 Census data (http://www.census.gov/geo/www/tiger/) to delineate water bodies for measuring distance to major rivers and streams (i.e., riparian vegetation). We omitted artificial waters, man-made ditches and diversion canals from the database, and calculated the distance to major rivers and streams (km) for each location using ArcGIS 9.2 (ESRI, Redlands, CA).

We estimated spatial housing density from parcel information accessed from the Montana Cadastral Mapping Project (Montana Natural Resources Information System 2009). We estimated a centroid location within each parcel containing an occupied residential dwelling or business, omitting privately owned parcels classified as public, vacant, or undeveloped. We then used the density function in ArcGIS 9.2 to create a housing density (houses/ha) raster.

To delineate forested areas we used landcover data from the Vegetation Mapping Project (VMAP) geospatial database (USDA Forest Service, Missoula, MT, USA). We merged all vegetation classes that were dominated by a forest-related tree species and had ≥25% canopy cover to develop a single forest layer. We then calculated the area of each contiguous forest patch, and characterized patches as large (>100 km^2; based on 95% fixed kernel estimator [Worton 1989] of a male bear collared in the study area; J. A. Merkle and P. R. Krausman, unpublished data) or small (≤100 km^2). We calculated distance to each large and small forest patch for each location using ArcGIS 9.2.

Analysis

We developed multi-variable logistic regression models that included distance to large and small forest patches, distance to major rivers and streams, housing density, and interactions between housing density and all other variables. The response variable was whether or not interaction occurred at the specified location, coded as 1 for HBI, and coded as 0 for random locations. We screened all variables for colinearity (based on a cutoff threshold value of $r = 0.5$) and used univariate logistic regression to identify candidate variables ($P < 0.25$) for inclusion in multi-variable modeling (Hosmer and Lemeshow 2000). We then followed a manual forward stepping model selection approach, using likelihood ratio tests to assess variable significance and considering additional polynomial and interaction terms (Hosmer and Lemeshow 2000). This approach resulted in a single, final model, which was the most parsimonious model including only predictive explanatory variables. We used Stata 10 (StataCorp, College Station, TX) for all analyses.

Model Validation

We tested the validity of our model first by generating predictions used to create the final model from where the data were collected (i.e., Missoula), and second by applying the final model predictions across Seeley Lake for a more unbiased validation of the final model (Verbyla and Litvaitis 1989). First, we used *K*-folds cross validation to partition the data into model training and model testing datasets, based on 5 random divisions ($k = 5$) of 80 and 20% training and testing data, respectively (Huberty 1994, Boyce et al. 2002). We assessed predictive power of the final model by comparing 5-fold training model predictions to the observed distributions of withheld locations (Boyce et al. 2002). Predicted values from testing data were partitioned into 10 equal-area ranked bins representing low to high training data predictions. We then used Spearman rank correlations (r_s) to compare the number of withheld locations within each standardized bin to the respective bin ranking (Boyce et al. 2002).

Second, we obtained other interactions, and reactive management action locations ($n = 79$) collected between 2003 and 2008 in Seeley Lake, MT. Databases compiled for Seeley Lake were similar to Missoula because information was collected by the same regional office within MFWP. Using coefficients from the final model developed in Missoula, we predicted the relative spatial probability of HBI in Seeley Lake based on the same spatial variables used in Missoula. We then tested the predictive power of the model by comparing Missoula training model predictions to Seeley Lake testing locations. We used Spearman rank correlations (r_s) to compare the number of HBI from

Seeley Lake that fell within 10 standardized ranked bins produced from the Missoula training model predictions (Boyce et al. 2002).

RESULTS

We geocoded 917 HBI in Missoula, Montana (284 sightings, 103 reactive management actions, 530 other incidents) from 2003 to 2008 (*n* = 132, 257, 150, 160, 105, 113, respectively). Most other incidents and reactive management actions (72%) involved anthropogenic attractants, such as garbage (*n* = 284), fruit trees (*n* = 72), bird feeders (*n* = 52), freezers (*n* = 16), livestock grain (*n* = 6), barbeque grills (*n* = 6), chickens (*n* = 6), pet food (*n* = 6), and compost piles (*n* = 5).

Landscape and anthropogenic variables, including distance to large forest patches, housing density, distance to major rivers and streams, and an interaction between housing density and distance to large forest patches, had predictive power in the final model (Table 1). Correlations among variables ranged from $r = 0.045$ to $r = 0.495$. Distance to major rivers and streams and housing density were non-linear predictors so quadratic relationships (i.e., squared terms) were included in the model for these variables. Distance to small forest patches was a significant univariate predictor ($Z = -11.67$, $P < 0.001$), but did not contribute significantly to the final multivariate model. The final model described the spatial distribution of interactions ($\chi^2_6 = 1105.08$, $P < 0.00001$), and the probability of a HBI was negatively associated with distance to large forested patches, and distance to major rivers and streams, and positively associated with intermediate housing densities (approx. 6.59 houses/ha; Table 1) in Missoula. Spatial predictions from the final model portrayed patterns of high probability of HBI in all valleys protruding from the city core and in most housing developments associated with the western wildland-urban interface of Missoula (Figure 2).

Spearman rank correlations between the frequency of HBI and the 10 standardized bins suggested good models for the *K*-folds cross validation ($r_s = 0.8776$, SE = 0.0296, $P < 0.01$; Figure 3). We also successfully applied the final model developed in Missoula to Seeley Lake (Figure 4), and the model predicted the locations of HBI recorded in study area 2 moderately ($r_s = 0.6524$, $P = 0.041$; Figure 3). All model testing procedures supported the final model, where residents who lived close to major rivers and streams, close to large forest patches, and in intermediate housing densities were at a higher risk of HBI.

DISCUSSION

Urban expansion into natural landscapes has affected biotic integrity, species composition, and wildlife behavior (Kretser et al. 2008), resulting in increasing trends in the number of reported human-wildlife interactions (Conover 2002). Managers responsible for reducing HBI need an array of information (from public education programs to best aversive conditioning practices) to be successful in dealing with this complex issue. The ability to predict the spatial distribution of HBI will focus proactive management by allowing for efficient identification of areas with high and low conflict potential. Our results provide a wildlife management tool and a repeatable statistical framework, which predicts the spatial distribution of HBI using only a small set of variables.

In accordance with our expectations, we observed a negative relationship between probability of HBI and distance to large forest patches (linear relationship) and distance to major rivers and streams (non linear relationship). However, the probability of HBI was not negatively associated with housing density, but negatively quadratic in form, where higher probabilities of HBI were positively associated with intermediate housing densities in Missoula. Results from our model selection procedure also suggested an interaction between housing density and distance to large forest patches (Table 1), meaning that residents living in intermediate housing densities (with respect to our study area) that are located near large forested areas have the highest risk of HBI. Our final model developed in Missoula was moderately effective in identifying the locations of HBI in Seeley Lake, MT (Figure 4), suggesting that these variables and this type of modeling procedure can be used across study areas. Specific variable coefficients however, may need to be refined because of the diversity of housing densities in western Montana and other urban areas in North America.

Although the scale at which habitat-related studies is an important consideration when developing models (Wiens 1989), we found similar predictive variables to studies examining HBI at larger scales (i.e., across states or rural areas; Wilson et al. 2006, Baruch-Mordo et al. 2008, Kretser et al. 2008). This is not surprising when considering the parallels between the variables used in our model and variables known to be important predictors of black bear habitat use. Forested areas and riparian zones are vegetation associations used by black bears across their range (Jonkel and Cowan 1971, Young and Beecham 1986, Fecske et al. 2002, Brodeur et al. 2008), and housing density may be a surrogate for factors that affect mortality (e.g., road kill; Baruch-Mordo et al. 2008, Fecske et al. 2002), anthropogenic resources (e.g., abundance of garbage; Badyaev 1998, Beckmann and Berger 2003), and travel permeability (Larkin et al. 2004).

Together though, and regardless of scale, these 3 variables integrate landscape and anthropogenic variables into a model, which can successfully predict the spatial distribution of HBI in Missoula.

The only variable not incorporated into the final multivariate model was distance to small forested areas (Table 1). In our study area, these areas mostly encompassed small forest patches on the edge of town and naturally forested parks within city limits, similar to high human disturbance lands noted for its medium resistance to bear permeability (Larkin et al. 2004). Our assumption that these small forest patches would contribute to the location of HBI differently than large patches was correct; however, we assumed that these forest patches would be important escape cover (Pelton 2000) in between foraging bouts within the urban area, thus a significant predictor of HBI. Our hypothesis was not supported, and small forest patches have less effect on HBI relative to other explanatory variables. The impacts of this finding suggest that land planners developing urban areas may not need to take into account HBI when developing semi-natural, urban parks or reserves near urban areas (Niemela 1999), unless those small areas are connected to large forest patches. Features such as housing density and proximity to large forest patches and major rivers and streams however, are more important when planning urban areas.

The ability to identify areas (or clusters) with high probability of human-wildlife conflict, have enabled appropriate management and mitigation methods to be applied strategically (Tourenq et al. 2001). With this information, specifically for HBI, wildlife managers can deploy different proactive management strategies depending on the area. In areas with a relatively low probability of interaction, education programs can be developed to increase awareness and biological knowledge regarding bears. In areas with a relatively medium probability of interaction, education programs can be developed with specific attractant reducing goals (e.g., use bear resistant dumpsters, use bird feeders seasonally, pick ripe fruit off of trees; Gore et al. 2006, Gore et al. 2008). Finally, in areas with a relatively high probability of interaction, managers can implement not only education programs but ordinances outlawing human behaviors that provide available attractants including garbage, fruit trees and bird feeders (Peine 2001). The ability to strategically direct different management options in different areas, contributes to efficient allocation of resources to proactively minimize human-wildlife interactions.

Although internal validation tests suggest our final model is good (Figure 3, 4), we recognize that all of our model assumptions may not have been fully met based on 2 issues with using non-invasive, public phone call data. First, there are errors associated with geocoding residential mailing addresses into GPS coordinates (Rushton et al. 2006). For example, geocoding error is inversely related to population density, and 95% of errors can be as far as 152 m from true locations (Cayo and Talbot 2003). Second, data collection and entry inconsistencies can exist, also integrating error into estimates. Records sometimes are not screened by the same administrator prior to being entered, and interactions are documented by a variety of managers who record information differently. Assuming these errors are normally distributed and thus not biased, we are confident in our findings. Furthermore, we minimized errors by collecting data from only 1 regional office of MFWP (i.e., 1 bear manager, < 3 biologists, and < 3 game wardens) minimizing the number of people entering and collecting information, and we manually reviewed all records in the database minimizing error from mistakes during data entry.

MANAGEMENT IMPLICATIONS

Our modeling framework and selected variables can be used to estimate the probably of HBI in developed and undeveloped areas. In developed areas, our model parameters can be estimated to stratify into sections of low to high probability of interaction, allowing strategic implementation of different proactive management activities (from promoting awareness to creating ordinances to eliminate attractants) across the areas of conflict opportunity. In undeveloped areas, wildlife managers involved in planning community development can integrate proposed housing development information into a future model, allowing estimation of the relative probability of future HBI. Hypothetical changes to housing development proposals can be incorporated, and the development plan with the lowest probability of HBI can be recommended. Management agencies should also systematically record human-bear sightings and interactions reported by the public. Current protocols may need to be strengthened, but these monitoring efforts are not difficult to develop (Gore et al. 2006, Baruch-Mordo et al. 2008). Information specific to developing spatially explicit models should be carefully documented such as the actual location of the sighting, not just the resident's address. With careful data collection, precise estimates of the relative probability of HBI will allow for more efficient and strategic management directives in the future.

ACKNOWLEDGMENTS

We thank B. Kohl for geocoding all human-black bear interaction locations. We thank Montana Fish, Wildlife and Parks for cooperation and logistical assistance, particularly M. Thompson, J. J. Jonkel, V. Edwards, and B. Wiesner. M.S. Mitchell and

J. Berger reviewed earlier versions of the manuscript. This study was supported by the Boone and Crockett Program in Wildlife Conservation, and the Harry Longwell Family Foundation.

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Table 3.1. Parameter estimates for a logistic regression model based on locations of human-black bear interactions in Missoula, Montana, USA. The model includes anthropogenic and landscape variables, and estimates the relative probability of human-black bear interactions.

Variable	Coefficient	S.E.	*P*	95% CI for coefficient	
				Lower	Upper
Distance to large forest patches (km)	-0.496	0.054	<0.001	-0.602	-0.390
Housing density (houses/ha)	0.553	0.047	<0.001	0.462	0.645
Housing density^2 (houses/ha)	-0.022	0.005	<0.001	-0.031	-0.012
Distance to water bodies (km)	-2.074	0.298	<0.001	-2.659	-1.490
Distance to water bodies^2 (km)	0.766	0.194	<0.001	0.384	1.147
Housing density x distance to forest	-0.140	0.018	<0.001	-0.175	-0.104
Constant	-0.969	0.092	<0.001	-1.150	-0.788

Figure 3.1. The spatial distribution of urban development with respect to major rivers and streams, and forested areas in and around Missoula, Montana, USA. Areas in white include agricultural and industrial lands, and grassland and shrub dominated vegetation.

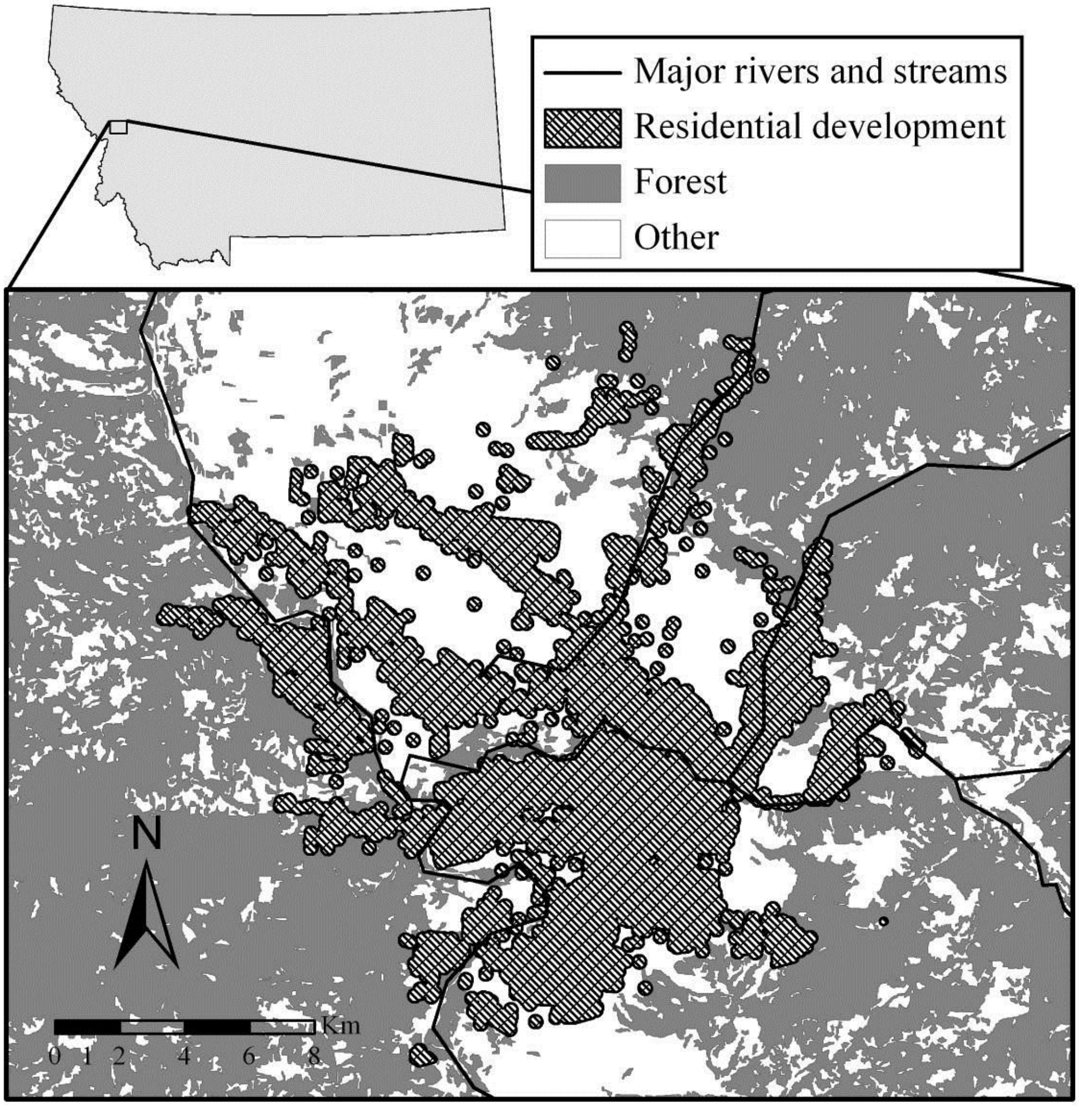


Figure 3.2. Distribution of human-black bear interaction probabilities based on final estimated logistic regression model from human-black bear interaction locations in Missoula, Montana, USA.

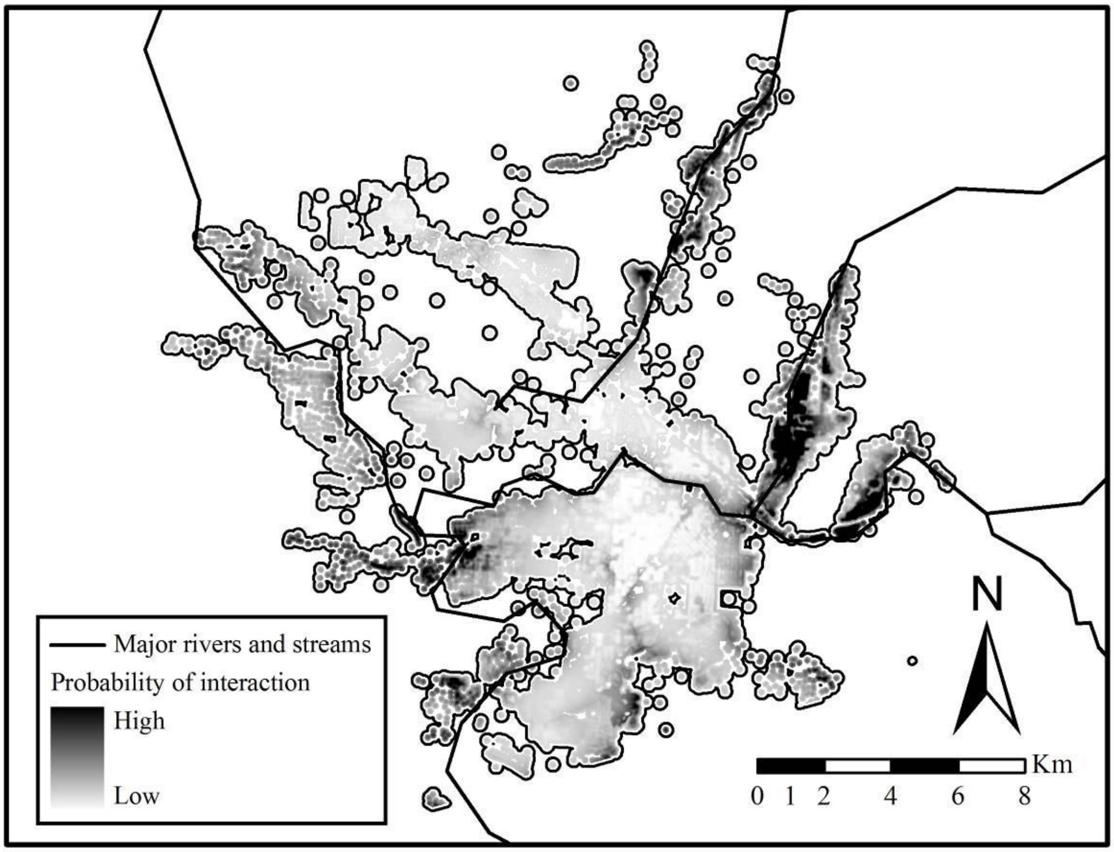


Figure 3.3. Frequency of human-black bear interaction locations across 10 equal-area (i.e., percentile classification) ranked bins of relative probability of interaction scores for *K*-folds cross validation and the external (human-black bear incidents in Seeley Lake, MT) independent data set.

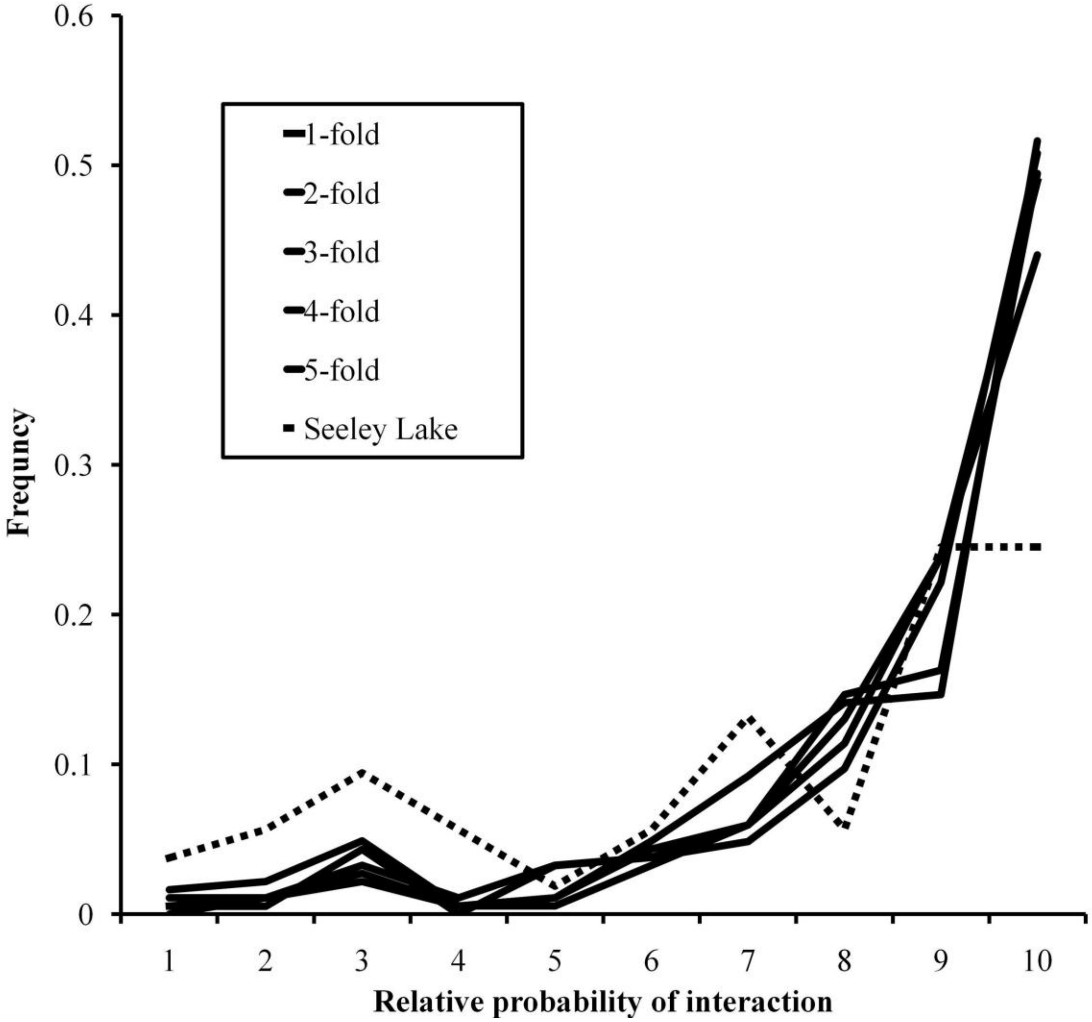
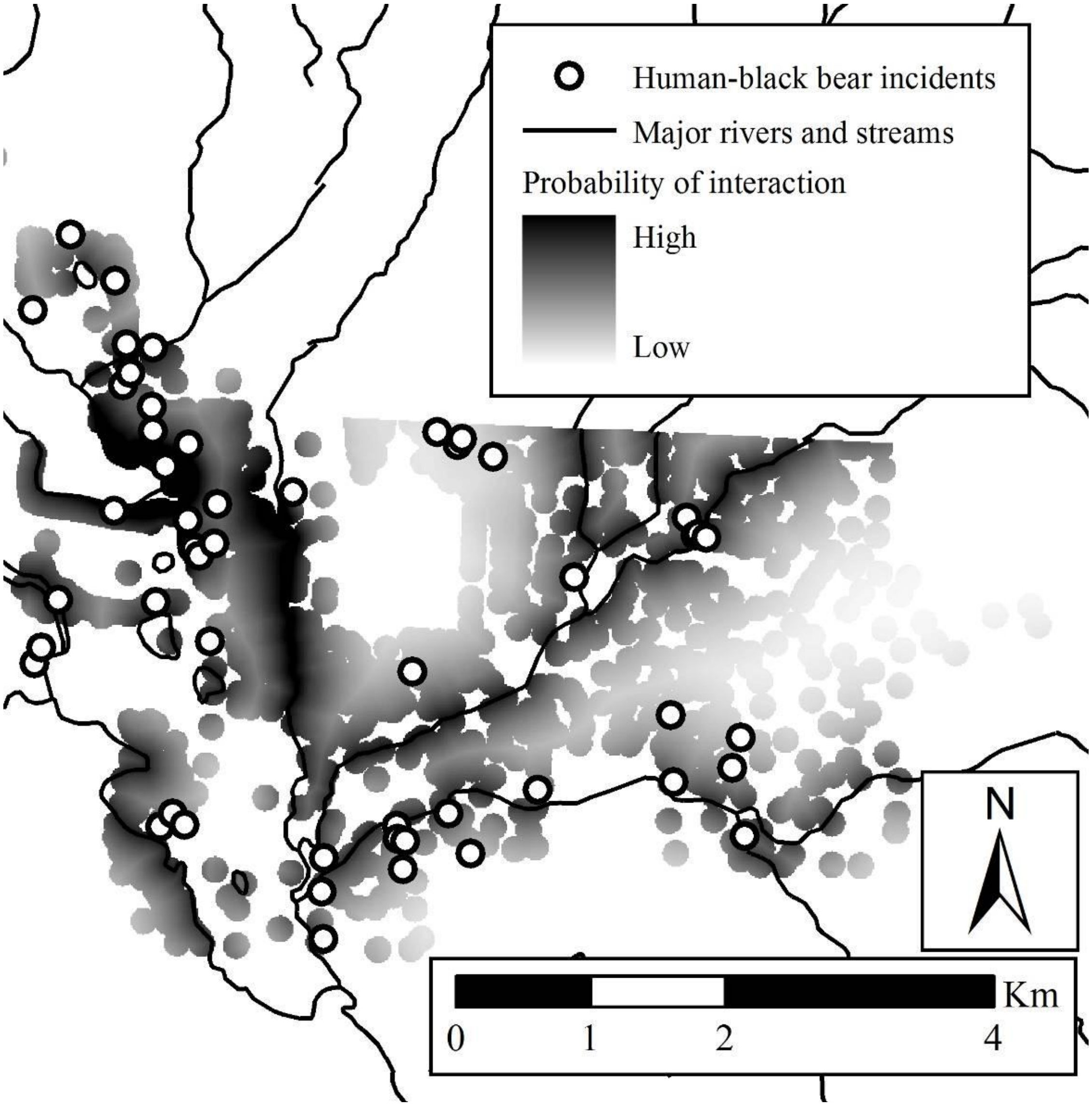


Figure 3.4. Location of human-black bear incidents (other interactions and reactive management actions) recorded from 2003 to 2008 in Seeley Lake, Montana, USA, and distribution of human-black bear interaction probabilities based on best estimated logistic regression model from human-black bear interactions in Missoula, MT.



CHAPTER 4

INFLUENCE OF FORAGE AVAILABILITY ON USE OF THE URBAN LANDSCAPE BY BLACK BEARS

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ABSTRACT

American black bears (*Ursus americanus*) living near urban areas forage on anthropogenic foods, increasing the chances of negative human-black bear interactions (i.e., bear conflicts). Wildlife managers are interested in reducing the frequency of bear conflicts, but little research has identified how the relative availability of anthropogenic and wildland foods influence use of the urban landscape by bears. We used 2 years of telemetry data from 16 black bears fitted with global positioning system collars, and employed a time-to-event modeling framework to determine forage-related variables that explain the probability of a bear being located within the urban area of Missoula, Montana. We also visited feeding sites located near houses to quantify diet and examine the validity of our models. We monitored the availability of green vegetation and 5 native berry producing species outside the urban area, and the availability of green vegetation, apples, and garbage inside the urban area, as surrogates for wildland and anthropogenic foods, respectively. Use of the urban landscape differed for male and female bears, and was driven by anthropogenic variables. The probability of a bear being located within the urban landscape, increased for males, and increased during apple season, garbage night, and the urban green-up. Fruit trees (50%) and garbage (35%) accounted for most of the forage items at urban feeding sites, and <10% of all forage items were wildland foods. Black bears in Missoula used the urban landscape to forage on anthropogenic foods, even when wildland foods were still available, suggesting that the absence of wildland foods does not drive use of the urban landscape by bears. Additionally, alternative attractants (e.g., fruit trees) within urban landscapes may be more important than the availability of garbage in influencing bear conflicts.

INTRODUCTION

Interactions between humans and wildlife resulting in costs (e.g., monetary, safety, mortality) to humans or wildlife are a major issue facing global wildlife management and conservation (Conover 2002). These interactions can be broad and include wildlife-vehicle collisions (Allen and McCullough 1976, Reed et al. 1982, Bashore et al. 1985), crop-raiding (Naughton-Treves 1998, Osborn and Parker 2003), and depredation on livestock (Oakleaf et al. 2003, Kissui 2008). Of particular concern is when humans inhabit landscapes occupied by large carnivores, because outcomes of human-wildlife interactions in these areas can result in property damage, and injury or death to humans (Loe, and Roskaft 2004, Gurung et al. 2008).

Bears (*Ursus* spp.) are one of the few large carnivores that, when occupying areas near human dominated landscapes, regularly exploit anthropogenic foods (Mattson 1990). Because of a well-documented movement of humans from low density areas to cities in North America (Population Reference Bureau 2010), urban areas are critical to understanding the mechanisms influencing human-bear interactions. Negative human-American black bear (*U. americanus*) interactions (e.g., interactions resulting in property damage, injury or death to humans, or fear of injury or death to humans; hereafter referred to as bear conflicts) are increasing in number and extent in North America (Hirstienko and McDonald 2007), and most bear conflicts are a direct consequence of bears foraging on anthropogenic resources (e.g., garbage).

Wildlife management agencies are interested in reducing the frequency of bear conflicts to preserve human safety (Perry and Rusing 2000), reduce resources spent dealing with conflicts (Garshelis 1989), and avoid controversial management (e.g., lethal control; Hristienko and McDonald 2007). Research on bear conflicts has shown that bears use urban landscapes (Lyons 2005), that garbage is an important attractant (Rogers et al. 1976, Badyaev 1998, Thiemann et al. 2008), and that behavior and population dynamics of bear populations living in and near urban areas has changed (Beckmann and Berger 2003*a*, *b*, Beckmann and Lackey 2008).

These findings are not surprising given that food influences use of landscapes by bears (Lindsey and Meslow 1977, Rogers 1987, Powell et al. 1997), and that urban areas support a variety of alternative food sources (e.g., garbage, fruit trees; Merkle et al. 2011). For example, because of human population growth in the wildland-urban interface of California and Nevada and the associated increase in availability of anthropogenic bear foods (assumed to be garbage), behavioral characteristics such as activity patterns and den chronology have changed (Beckmann and Berger 2003*b*). However, tests of how the availability of different wildland and anthropogenic food items affects use of the urban landscape by bears are lacking. An understanding of how multiple measures of anthropogenic and wildland forage influences bear conflicts would provide a direction (e.g., how much resources should be invested into reducing the availability of different types of bear attractants) for wildlife managers to develop management plans that will reduce the number of bear conflicts in the future.

Our objective was to determine forage-related variables that predict use of the urban landscape by bears. We modeled the daily probability of an individual black bear being located within the urban area of Missoula, Montana, and visited Global Positioning System (GPS) locations from collared bears near houses. We tested 2 competing hypotheses that identify whether fluctuations in wildland or anthropogenic forage availability is related to use of the urban landscape by bears. The first hypothesis states that use of the urban landscape by bears increases when the availability of forage items associated with landscapes outside the urban area fall below some level. If this hypothesis is supported, we would expect that wildland forage items (e.g., green-up, fleshy fruit availability) with negative coefficients would predict bear use of the urban landscape. The second hypothesis states that use of the urban landscape by bears increases when forage items associated with the urban area are available, regardless of the wildland forage availability. If this second hypothesis is supported, we would expect that anthropogenic forage items (i.e., urban green-up, apple season, garbage night) with positive coefficients would predict bear use of the urban landscape. Assuming that use of the urban landscape by bears is proportional to the probability of a bear conflict, results from this study provide important information for wildlife managers who manage wildland forage and urban attractants to reduce bear conflicts.

STUDY AREA

Our study was conducted in the northern periphery of Missoula, Montana, including urban and exurban development in Butler, Grant, Rattlesnake, and Marshall Creeks. Missoula lies in a gravelly glacial outwash plain where the Blackfoot and Bitterroot rivers empty into the Clark Fork watershed. During our study, the city of Missoula (61.9 km^2) was inhabited by approximately 65,000 people. There were approximately 25,000 housing units, and mean human density in Missoula was approximately 1,000 people/km^2, and mean housing density was approximately 400 housing units/km^2 (U.S. Census Bureau 2000). The city is surrounded by a mix of private and public (i.e., city, county, state, and USDA Forest Service) lands. The topography is diverse with elevations ranging from 978 to 2,766 m. Most urban development is on formerly grassland and agricultural lands on the valley floor and associated foothills. Steep slopes and canyons with forest vegetation characterize the surrounding mountains. Annually, the warmest month was July ($\bar{x}$ max = 28.4ºC, min = 10.6 ºC), and the coolest month was December ($\bar{x}$ max = 0.1 ºC min= -7.2 ºC; Western Regional Climate Center 2008). Average annual precipitation was 43.3 cm evenly distributed throughout the seasons except for May and June when rain was more common (Western Regional Climate Center 2008). Rain ordinarily falls from April–October and snow from November–March.

Native vegetation is dominated by mixtures of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menzesii*) on hillslopes, bunchgrass prairie dominated by wheatgrasses (*Agropyron* spp.) and fescues (*Festuca* spp.) on the valley bottom, and riparian areas dominated by black cottonwood (*Populus balsamifera*) and willow species (*Salix* spp.). Common wildflowers include silky lupine (*Lupinus sericeus*), larkspur (*Delphinium bicolor*), arrowleaf balsamroot (*Balsamorhiza saggittata*), and penstemon (*Penstemon wilcoxii*). Fruit bearing vegetation include serviceberry (*Amelanchier alnifolia*), huckleberry (*Vaccinium caspitosum*, *V. globulare*), strawberry (*Fragaria virginiana*), gooseberry and current (*Ribes* spp.), tatarian honeysuckle (*Lonicera tatarica*), chokecherry (*Prunus virginiana*), blue elderberry (*Sambucus cerulea*), and barberry or Oregon grape (*Berberis and Mahonia* spp.). Within Missoula, vegetation is variable including exotic and native species, and outside of Missoula native species predominate. Common fruit trees in Missoula include a broad variety of apple and crabapple, plum, pear, cherry, and peach. Other anthropogenic attractants include garbage, fruit trees, bird seed, composts, domestic chickens, and barbeque grills (Booth 2005).

METHODS

We opportunistically captured bears from September 2008 until November 2009 using culvert traps (Teton Welding, Choteau, Montana, USA) set on private lands where bears had recently been sighted. We chose trap sites that would minimize the chance of public detection by selecting fenced yards in dense vegetation. We immobilized captured bears using a syringe pole containing Telazol at a dosage of 8 mg/kg (Jonkel 1993). We fitted a Global Positioning System (GPS) radiocollar (Globalstar DD-cell wildlife GPS radiocollar, North Star Science and Technology, LLC, King George, Virginia) to the neck of bears ≥ 36 kg, and recorded body mass, age (subadults [1.5-3 years old] or adults [> 3 years old]), general body condition, and notes on appearance (for field identification). Collars were programmed to collect 8 evenly distributed locations per day, fixed with a Very High Frequency (VHF) motion sensory unit, and fitted with a release mechanism programmed to drop 10 October 2010. This research was approved by the University of Montana Institutional Animal Care and Use Committee (Animal Use Protocol # 004-08 PKECS-072508).

Defining Urban Cover Type

To spatially categorize the urban landscape within the study area, we manually digitized every residential dwelling within the study area in a Geographic Information System (GIS). We obtained National Agriculture Inventory Program (NAIP) imagery (U.S. Department of Agriculture – Farm Service Agency, Aerial Photography Field Office, Salt Lake City, Utah, 2005, 1m resolution) and used ArcGIS 9.2 (ESRI, Redlands, CA) to locate the centroid of the roofline of each residential dwelling (Goldberg et al. 2008). Because an urban cover type has never been defined with respect to bear conflicts, we analyzed our data using multiple definitions: buffers of 25, 50, 75, 100, 200, 300, 400, and 500m around each house location.

Time-to-Event Modeling

We used a parametric Time-to-Recurrent-Event model to quantify the effect of forage-related variables on the probability of a bear being located within the urban cover type (Hosmer et al. 2008). We characterized variables as related to wildland or anthropogenic food availability.

Variables –We developed 2 variables as proxies for wildland food availability outside of the urban cover type. First, to monitor wildland vegetation conditions (i.e., availability of green vegetation or green-up) we used the Enhanced Vegetation Index (EVI) calculated from Moderate Resolution Imaging Spectroradiometer (MODIS) data. We used EVI because most of the study area was forested and most forage used by bears grows below the forest canopy, and EVI was developed to improve sensitivity in high biomass regions by clearing away the canopy background signal (Huete et al. 2002). We developed a 100% minimum convex polygon (White and Garrott 1990) of all bear locations collected during the study, and spatially subtracted the urban covertype from this polygon. We calculated mean EVI values for all EVI pixels (250m resolution, 16 day periods) that fell within the resulting polygon. We associated each published 16 day mean EVI value with the previous 16 days to create a continuous (i.e., 16 day intervals) wildland green-up (EVI_WILDLAND) variable (Table 4.1).

Second, because EVI is more closely related to phenological variables such as photosynthetic activity (Justice et al. 1998), green-up and dormancy dynamics (Zhang et al. 2003) and berries are and important food source for bears within our study area (Holcroft and Herrero 1991, Jonkel and Cowan 1971), we monitored wildland berry availability along a 2 km transect adjacent (< 1 km) to the study area. This transect has been monitored weekly since 1996 as a part of a larger study on plant phenological dynamics and climate change (P. Alaback, unpublished data). We noted the date of first fruiting (i.e., presence of ≥ 3 ripe fruits/shrub), peak fruiting (i.e., presence of > 50% of berrys/shrub ripe), and end of fruiting (i.e., > 50% of berries dispersed) for 5 fleshy fruited woody shrub species: serviceberry, chokecherry, blue elderberry, tartarian honeysuckle, and waxy currant (*R. cereum*). We developed a berry index of availability (BERRY_INDEX; Table 4.1) by summing the number of species in which ripe berries were available (i.e., from date of first fruiting until end of fruiting) on each day throughout the study period.

We identified 3 anthropogenic-related variables measuring urban food availability: a) urban green-up, b) garbage availability, and c) apple availability. To obtain an index of urban green-up, we calculated mean EVI values for all EVI pixels (250m resolution, 16 day periods) that fell within the urban covertype polygon. As with the areas outside the urban area, we associated each published 16 day mean EVI value with the previous 16 days to create a continuous (i.e., 16 day intervals) urban green-up (EVI_URBAN) variable (Table 4.1).

We developed an indicator variable that represents periods of time when garbage is available, coded as 1 when available, and 0 when not available. Garbage pick-up occurs on Tuesday in western neighborhoods or Thursday in eastern neighborhoods within our study area. Using GIS, we assigned each bear location as exposed to Tuesday garbage or Thursday garbage based on the closest house to the location. We created the indicator variable GARBAGE (Table 4.1), and assumed garbage would be available to bears (coded as 1) from 1800 hours the evening before garbage day until 1800 hours on garbage day and unavailable (coded as 0) other times during the week.

We established a phenology based estimate of apple availability within the study area. We selected 10 representative apple trees in the study area in 2009 and 2010, and sampled them weekly from 15 August to 31 October. Three replicates (i.e., apples) were picked from each sample each week. Apples were then pressed using a Jack LaLanne vegetable juicer (Tristar Products Inc., Fairfield, New Jersey, USA). We recorded the mass of juice produced per apple and the percent sugar per apple using a common hydrometer. We noted the date of peak amount of sugar per apple content for each apple tree monitored. We developed the variable APPLES (Table 4.1), and characterized apples as being available (coded as a 1; Table 4.1) from the date the earliest tree was at peak fruiting until the date the latest tree was at peak fruiting, and unavailable otherwise (coded as 0). We buffered our dates by 6 days to account for variation in peak ripeness of apples (Peirs et al. 2005). Finally we included sex (SEX, coded as 1 for male) because of the difference between urban foraging strategies of males and females (Beckmann and Berger 2003*a*).

Analysis – To convert black bear relocation data into a time-to-event framework, we condensed GPS locations into a daily response variable that identified whether ≥ 1 bear GPS collar location was (outcome = 1) or was not (outcome = 0) inside the urban cover type (i.e., based on multiple definitions of the urban cover type). We characterized our time scale as a biological year based on when bears were active, 1 March to 30 November (275 days).

Because most of our variables varied with time equally for each individual (e.g., all animals are exposed to apple season at the same time), we could not use a more traditional Cox model and instead used a parametric time-to-event modeling framework (Hosmer et al. 2008). The parametric proportional hazards model summarizes the times to an event (in this case, ≥ 1 bear location per day within the urban cover type) as a baseline hazard (parameterized by some functional form) multiplied by the effects of a set of variables (Hosmer et al. 2008). Variables can be time-varying (e.g., EVI values) or can be fixed (e.g., sex). We chose a Weibull distribution (Weibull 1951) because of its versatility and wide application. The hazard model takes the form,

$$h(t \mid \mathrm{X}_{\mathrm{j}}) = p\, t^{p-1} \exp\left(\beta_{0} + \mathrm{X}_{j} \beta_{x}\right) \quad (1)$$

where p is an ancillary shape parameter estimated by the data, t is time (days), exp (β_0) is a scale parameter, and β_x are coefficients based on X_j set of covariates. Hazard ratios are calculated from e^{β_x}, and constitute the relative effect of each covariate. If the exponential term is < 1 the daily probability of a bear located within the urban area is reduced, and if the exponential term is > 1 the bear conflict tendency is increased. For example, for a continuous variable, a hazard ratio equal to 1.6 indicates that for every unit increase in the variable the daily probability of a bear located within the urban area increases 1.6 times (i.e., 60%). The baseline hazard can be estimated when all covariates are equal to 0 (Hosmer et al. 2008).

Model building and selection – We initially tested a null hypothesis, that the probability of a bear being located within the urban cover type is constant throughout the year. We tested whether the shape parameter (p) in all Wiebull models (when the urban area was defined as a 100m buffer from a house) was different from 1 using a Wald's test, where a significant difference would allow us to reject our null hypothesis and assume that probability of bear in the urban cover type varies over time (Hosmer et al. 2008). Next, we used an information theoretic approach (Burnham and Anderson 2002) to test the predictions of our 2 hypotheses. We developed 2 categories of models: wildland (6 models) and anthropogenic (14 models). The first supported hypothesis 1, where the probability of a bear being located within the urban cover type was negatively associated with the availability of food sources located outside of the urban area (i.e., wildland variables with negative coefficients; Table 4.1). The second supported hypothesis 2, where the probability of a bear being located within the urban cover type was positively associated with the availability of food sources located within the urban area (i.e., anthropogenic variables with positive coefficients; Table 4.1). We compared the ability of each set of models, at each urban cover type definition, to predict the probability of a bear being located within the urban cover type using Akaike's information criterion (AIC; Burnham and Anderson 2002). We defined variables included in models within 4 ΔAIC units as important (Arnold 2010). We used Pregibon's Link Test (Pregibon 1980) on the model (i.e., when urban cover type was defined as 100m buffer around houses) with the lowest AIC value, to test whether all models were correctly parameterized. All analyses were conducted using Stata 10 (StataCorp, College Station, TX).

Feeding Site Analysis

The GPS collar technology we used resulted in ~75% of successful GPS fixes available in real time via an internet website. We projected those bear locations over satellite imagery using Google Earth Free (Google, Mountain View, CA; imagery date: 19 April 2006) on a daily basis. We traveled to every location that was <100m from a house and was located on a road, on a house, or within a private yard (i.e., assessed by typical urban landscaping such as manicured lawns, hedgerows, or fence lines) within 24 hours to document sign of bear behavior.

Bear activity at each site was described as feeding, bedding, passing through or unknown/other, and assessed our confidence by documenting whether we were absolutely (i.e., definitive signs of activity), probably (i.e., sign is apparent, but not definitive), or were not (i.e., cannot decipher bear activity at location) sure of our assessment. We searched for sign of bear activity (e.g., broken branches in berry bushes or fruit trees, garbage containers tipped over, bird feeders destroyed, fresh scratching on trunks and stems, digging) within approximately 30 m (allowing for GPS error) of each location. We classified food items at feeding sites as fruit tree, garbage, bird feeder, natural berry bush, or other (e.g., garden, barbeque grill, grain, pet food). Bedding sites were identified by searching for fresh beds containing bear hair. Sites where bears were passing through were identified based on observed fresh tracks. We analyzed feeding sites only when we were absolutely or probably sure of identification, using percent frequency of occurrence (PFO). We summed all food items documented (i.e., >1 food item was identified at some feeding sites), and divided each food item by the total occurrence of all food items.

RESULTS

We captured and fit GPS collars on 16 individual bears (10 F, 6 M), amassing 14,292 relocations (range 185-2,812 locations per individual) between 1 March 2009 and 10 October 2010. These records condensed into 2,380 monitoring days ($\bar{x}$ = 97.39, range = 26-398 per individual), and within those monitoring days, between 260-1433 days were recorded where ≥ 1 bear location per individual was located within the urban cover type.

Peak EVI_WILD occurred on 26 June for 2009 and 2010. Peak EVI_URBAN occurred on 9 May 2009 and 26 June 2010. Apples were available from early September until late October in 2009, and from mid September until 10 October in 2010 (Table 4.2).

The first available berries were from waxy current on 10 June in 2009 and 20 June in 2010. The last berries available were from elderberry and they were no longer available starting 18 October 2009 and 10 October in 2010 (Table 4.2). Peak NATURAL_BERRY availability occurred from 4 August to 20 August in 2009 (4 of 5 species available), and only on 14 August in 2010 (4 of 5 species available; Table 4.2).

The Weibull shape parameter (p) for all models was > 1 (range = 1.88-2.26, Wald test statistic range = 11.51-18.62, $P < 0.0001$), suggesting that the daily probability of a bear located within the urban area was not constant and was increasing throughout the year. Without the influence of variables, the smooth hazard function, increased throughout the year with peaks in mid June and late September (see Figure 4.1 for example when urban cover type is defined as 100m buffer around each house).

For each urban cover type definition, variables included in models within 4 ΔAIC units were all anthropogenic variables (i.e., APPLES, EVI_URBAN, GARBAGE) and sex (Table 4.3). Models that included wildland variables (i.e., wildland green up, berry index) were unsupported at all definitions of the urban covertype. Apple season was a significant predictor of bear use of the urban cover type at all definitions. Sex was a significant predictor at definitions closer than 400m of a house. Urban green-up (i.e., EVI_URBAN) was a significant predictor at definitions between 100 and 300m. Finally, garbage was a significant predictor at urban cover type definitions between 25 and 75m from a house (Table 4.3). The probability of a bear being located within the urban cover type, at any definition, increased for males, and increased during apple season, garbage night, and the urban green-up (Table 4.3). The top model when the urban cover type was defined at 100m was properly parameterized ($Z = 0.04$, $P = 0.965$), and included SEX, APPLES, and EVI_URBAN (Table 4.3).

We visited 265 GPS locations (*n* = 9 bears) from March 2009 until October 2010. We documented 173 feeding, 19 passing through, 1 bedding, and 72 unknown/other sites. We documented 187 food items at feeding sites (Table 4.4). Percent frequency of occurrence of forage items varied by month for fruit trees (0-57.1%), garbage (18.9-100%), bird feeders (0-14.3%), wildland berries (0-13.2%), and other (0-13.2%). Overall, anthropogenic foods accounted for 90.9% of bear foraging sites near houses (Table 4.4).

DISCUSSION

Although bears use urban areas to forage (Lyons 2005), and the food within urban areas affects bear behavior (e.g., den chronology, activity patterns; Beckmann and Berger 2003*b*), little information exists identifying how the availability of different wildland and anthropogenic forage items affects use of the urban landscape by bears. In Missoula, Montana, use of the urban landscape by black bears was not constant throughout the year, and was positively associated with the availability of forage (i.e., urban green-up, apple season, garbage night) located within the urban area (i.e., consistent with hypothesis 2). Hypothesis 1 was not supported because use of the urban landscape by bears was not associated with lower levels of wildland forage (e.g., wildland green-up, berry availability) availability. These patterns were reinforced by a high proportion (>90%) of urban feeding sites being associated with anthropogenic foods, and few associated with wildland forage (<10%) items (Table 4.3). Results suggest that the anthropogenic food available within the urban area was an attractant to black bears regardless of forage availability outside of Missoula, Montana during 2009 and 2010.

Use of the urban landscape by bears differed based on sex (Figure 4.1). Males were between 1.14 and 3.14 times more likely to be located inside the urban cover type at definitions of a buffer between 25 and 300m from a house (Table 4.3). This is consistent with other studies that reported a higher proportion of males using urban areas (Beckmann and Berger 2003*a*), and other human facilities (e.g., garbage dumps; Mattson 1990). For example, of 126 bears captured at dumps, campgrounds, and residential areas in the upper peninsula of Michigan, 67% were male (Rogers et al. 1976). Two hypotheses have been discussed in explaining this pattern. The first is based on social factors (Erickson et al. 1964), where male bears are acting as despots and precluding females from urban areas (Beckmann et al. 2003*a*). The second is that male bears have larger home ranges than females so the probability of encounter with urban areas is higher (Bunnell and Tait 1985).

Our top models explaining use of the urban landscape (at all definitions) by bears included anthropogenic variables only (Table 4.3), suggesting that the probability of bear conflicts in urban areas is strongly influenced by the availability of anthropogenic forage regardless of wildland forage availability. Support for hypothesis 2 contradicts other findings about when bears forage on anthropogenic foods (Knight et al. 1988, Mattson 1990, Peine 2001). For example, adult female grizzly bear (*U. arctos*) mortality rates were inversely related to annual habitat productivity from 1977 to 1982 in Yellowstone National Park (Knight et al. 1988). This contradiction brings up 2 important observations which need further testing. First, although we used 2 years (2009 and 2010) of data, our analysis examined bear use of the urban landscape within a year, whereas many other studies consider bear use of anthropogenic landscapes among years (Knight et al. 1998).

For example, the influence of temporal availability might influence bear use of the urban landscape more within years, than among years, leading to biased predictions of when bear conflicts will occur.

Second, the definition of a bear conflict and an urban landscape must be considered when identifying the factors predicting use of urban areas by bears. Our analysis did not take place during years of extreme good or bad berry crops, and we found that during late summer and autumn months, male bears living near Missoula have >50% chance of being located within 100m of a house. Thus, if the probability of bears being close to houses is high, even during years with an average berry crop, there must be a reason why state management agencies still see significant fluctuations in the number of phone calls and human-bear conflicts over time (Baruch-Mordo et al. 2008). Our assumption that use of the urban landscape by bears is proportional to the probability of a bear conflict may be incorrect, and some aspect of bear behavior prevents them from getting involved in bear conflicts even when they are close to a house. We suggest a few explanations to be tested in the future, such as changes in day and nighttime movement rates (Beckmann and Berger 2003*b*), and switching between anthropogenic forage items. For example, if black bears switch from foraging on apples during average berry years to garbage during poor berry years, bears may be attracted closer to houses, increasing their susceptibility to involvement in bear conflicts. Garbage containers are usually located closer to houses than fruit trees, which can be growing at any distance from a house. This issue emphasizes the importance of defining the urban landscape (e.g., defining the scale of the urban landscape), because anthropogenic forage items are not always located at similar distances to houses, and the importance of forage availability affects bear use of urban landscape at different definitions of the urban cover type (Table 4.3).

Apple season was the best forage-related predictor of bear use of the urban landscape. When apples were available the probability of a bear being located within any definition of the urban area was between 1.22 and 2.62 times more likely (Table 4.3). Furthermore, during the 1-2 month period when apples are available, the daily probability of a male bear in our study area being located within 100m of a house can be >80% (Figure 4.1). This result has important implications for the management of anthropogenic forage within urban areas. Formerly, although apples are a significant food source for some bear populations (Servheen 1983), foraging on apples has been observed to coincide with years when native foods are in short supply (Slobodyan 1976). Based on our time-to-event models and feeding site analysis, apples are the most important food source for bears foraging within Missoula during 2009 and 2010. This result also supports a hypothesis proposed in Yosemite National Park, California where foraging on apples by black bears may be the mechanism for developing habituated and food-conditioned individuals (Greenleaf et al. 2009). In study areas where there are multiple important attractants (e.g., garbage and avocado trees; Lyons 2005), wildlife managers managing bears may need to evaluate the magnitude of bear dependence on garbage relative to alternative attractants when developing proactive management plans.

Garbage, although secondary to apples, was also influential in the probability of a bear being located within the urban landscape when the urban cover type was defined as a buffer < 100m from a house. In those cases, the probability of a bear being located within the urban area was between 1.24 and 1.45 times more likely during garbage night

(Table 4.3). Furthermore, garbage made up 35% of annual food items at feeding sites, but in some parts of the year (e.g., May and July), garbage made up 100% of food items at feeding sites (Table 4.4). However, there may be some issues when comparing the two variables across space and time. First, garbage is usually only available within 100m of a house, perhaps confounding our modeling results. Bears may not need to be within 100m of a house to forage on a fruit tree, however, bears are very likely to be within 100m of a house to forage on garbage. Second, there are residents within the study area who do not secure their garbage anytime of the week (approx 15% do not properly store their garbage; Merkle et al. 2011). Therefore, garbage can be found at anytime during the week, not just during garbage night, again confounding our ability to detect true differences between the effect of garbage and apples.

MANAGEMENT IMPLICATIONS

Our results regarding the identification of forage-related variables predicting use of the urban landscape by bears provide a hypothesis framework to understanding why bears use urban landscapes, a methodology to identify the variables that drive the probability of bear conflicts, and insights into how important garbage and other attractants are compared to natural forage availability. Based on 2 years of data in Missoula, Montana, monitoring wildland food availability may not be necessary when developing management plans for bear conflicts, because use of urban areas by bears is related to anthropogenic food availability only. Even when wildland foods are available, it is possible that bears will use the urban landscape and, thus, be susceptible to involvement in bear conflicts. In wildlife management units with an alternative attractant (e.g., fruit trees in our study area), garbage may not be the most important attractant influencing the frequency of bear conflicts. Consequently, proactive management actions (in some cases ordinances) may need to incorporate methods to eliminate the alternative attractant as well as garbage.

ACKNOWLEDGMENTS

We thank Montana Fish, Wildlife and Parks for cooperation and logistical assistance, particularly M. Thompson, J. J. Jonkel, V. Edwards, and B. Wiesner. M.S. Mitchell and J. Berger reviewed earlier versions of the manuscript. This study was supported by the Boone and Crockett Program in Wildlife Conservation, and the Harry Longwell Family Foundation.

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Table 4.1. Variables used in parametric proportional hazards models describing the annual probability bears using the urban landscape in Missoula, Montana from 2009 to 2010.

Variable	Type	Description
Wildland		
EVI_WILD	Continuous	Mean enhanced vegetation index (EVI) values inside minimum convex polygon of all bear locations subtracted by urban covertype, resolution = 250m, 16 day
BERRY_INDEX	Continuous	Based on the availability of berries from 5 berry-producing species; ranges from 0-4 depeding on the number of berry species available
Anthropogenic		
EVI_URBAN	Continuous	Mean EVI values in pixels intersecting a buffer of 100m from houses, resolution = 250m, 16 day
GARBAGE	Indicator	Available = 1; from 6pm the night before garbage pick-up to 6pm on garbage day
APPLES	Indicator	Available = 1; date earliest tree was at peak fruiting (based on sugar content) until the date the latest tree was at peak fruiting, buffered by 6 days
Other		
SEX	Indicator	Male = 1

Table 4.2. Availability dates of 5 species of natural berries and apples collected during weekly sampling periods during 2009 and 2010 in Missoula, Montana.

	2009 avaiability		2010 Availability	
Species	Start	End	Start	End
Serviceberry	9 Jul	20 Aug	30 Jun	14 Aug
Chokecherry	4 Aug	20 Sep	14 Aug	10 Oct*
Elderberry	27 Sep	18 Oct	7 Sep	10 Oct*
Honeysuckle	9 Jul	27 Sep	14 Aug	10 Oct*
Waxy currant	10 Jun	20 Sep	20 Jun	14 Aug
Apples	3 Sep	21 Oct	16 Sep	10 Oct*

*Fruit still available at end of study (10 October 2010)

Table 4.3. Parametric proportional hazards models describing the annual probability of black bear use of the urban landscape (at multiple definitions) in Missoula, Montana, based on 16 GPS collared black bears from 2009 to 2010. All models were within 4 ΔAIC units from the top model.

Definition of urban cover type[a]	SEX			APPLES			EVI_URBAN			GARBAGE		
	Hazard ratio	SE	*Z*	Hazard ratio	SE	*Z*	Hazard ratio	SE	*Z*	Hazard ratio	SE	*Z*
25m	3.14	0.39	9.21 ***	2.62	0.40	6.29 ***	1.00	0.00	-0.20	1.45	0.23	2.29 *
50m	2.42	0.22	9.64 ***	2.19	0.25	6.99 ***	1.00	0.00	0.77	1.32	0.16	2.27 *
75m	1.87	0.15	7.76 ***	1.82	0.17	6.22 ***	1.00	0.00	1.81	1.24	0.13	1.98 *
100m	1.61	0.12	6.30 ***	1.61	0.14	5.32 ***	1.00	0.00	2.07 *	1.13	0.12	1.22
200m	1.33	0.09	4.21 ***	1.37	0.11	4.02 ***	1.00	0.00	2.89 **	1.04	0.10	0.45
300m	1.14	0.07	2.06 *	1.28	0.09	3.40 **	1.00	0.00	2.80 **	1.08	0.09	0.90
400m	1.07	0.07	1.06	1.28	0.09	3.57 ***	1.00	0.00	0.74	1.09	0.09	1.06
500m	1.03	0.06	0.55	1.22	0.08	2.98 **	1.00	0.00	1.00	1.11	0.09	1.41

[a] Size of buffer around houses

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 4.4. Percent frequency of occurrence of food items identified at black bear feeding sites within the yards of residents in Missoula, Montana in 2009 and 2010. Feeding site locations were identified within 24 hours after locations of 9 GPS collared black bears were identified.

Month	*n*	Fruit tree	Garbage	Bird feeder	Other	Wildland berries
May	8	0.0	100.0	0.0	0.0	0.0
June	7	0.0	85.7	14.3	0.0	0.0
July	3	0.0	100.0	0.0	0.0	0.0
Aug	18	38.9	55.6	0.0	5.6	0.0
Sept	53	52.8	18.9	1.9	13.2	13.2
Oct	98	57.1	28.6	1.0	3.1	10.2
Total	187	48.7	34.8	1.6	5.9	9.1

Figure 4.1. Smoothed hazard function based on whether male or female black bears spent time in the urban cover type (defined as within 100m of a house) on any given day between 1 March and 30 November. Data obtained from 16 GPS collared black bears living in and adjacent to Missoula, Montana from 2009 to 2010.