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Spatio-Temporal Factors Affecting Human-Black Bear Interactions in Great Smoky Mountains National Park

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**SPATIO-TEMPORAL FACTORS AFFECTING HUMAN-BLACK BEAR
INTERACTIONS IN GREAT SMOKY MOUNTAINS NATIONAL PARK**

A Thesis Presented

by

NATHAN K. BUCKHOUT

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

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Environmental Conservation

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DEDICATION

I dedicate this to my family – Mom, Dad and Will – who have supported me and encouraged me throughout my journey. I love you all. This is also dedicated to the bears, the reason for this paper.

“In wildness is the preservation of the world.”

-Henry David Thoreau

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ABSTRACT

SPATIO-TEMPORAL FACTORS AFFECTING HUMAN-BLACK BEAR INTERACTIONS IN GREAT SMOKY MOUNTAINS NATIONAL PARK

SEPTEMBER 2014

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Wildlife managers use models to aid in predicting high risk areas for human and black bear (*Ursus americanus*) interactions (HBI). These tools help managers implement management strategies to minimize HBI. Over 3,000 incidents of HBI were compiled from management reports at Great Smoky Mountains National Park (GSMNP) during 1998-2011, a park with 9-10.2 million visitors per year and a black bear population of about 1,600 bears.

We used data from bear management reports along with annual visitor use, mast and bear abundance data to develop a series of generalized linear models to assess the spatial and temporal factors affecting HBI. Although HBI occurred throughout the GSMNP, 50% of all HBI occurred in five areas. The best predictor variables of HBI across four subsets of models included interaction between mast production and number of park visitors, month, vegetation cover, visitor activity, and bear abundance. Although there was not a clear relationship between visitor use and mast abundance, the number of park visitors was always relatively high and HBI increased substantially in poor mast

years. HBI was more frequent during summer months when park visitation rates and more people and food were present overnight in frontcountry and backcountry camping areas. Over 43% of HBI in hemlock forests were serious. Bear abundance data were not a strong predictor of HBI, and bear bait stations may not provide a sensitive index to bear abundance.

GSMNP uses different strategies for managing HBI to protect visitors and bears. In 1991, bear proof waste disposal containers and food storage devices were placed in camping and picnic areas. In combination with aversive conditioning, HBI decreased in some areas of the park. We recommend that proactive bear management programs including education, enforcement of park regulations, and aggressive aversion conditioning of bears be implemented at the identified HBI high risk areas to provide a safer environment for both people and bears in GSMNP.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	v
ABSTRACT.....	vi
LIST OF TABLES	x
LIST OF FIGURES	xii
CHAPTER	
1. INTRODUCTION	1
2. METHODS	3
Study Area	3
Data Compilation.....	4
Human-Bear Interactions (HBI)	4
Visitor Use	5
Acorn Abundance	6
Bear Relative Abundance and Distribution	6
Landcover and HBI Location.....	7
Data Analyses	7
3. RESULTS	10
Human-Black Bear Interactions.....	10
Distribution	10
Model Selection	10
Model Validation	12
4. DISCUSSION	13
5. MANAGEMENT IMPLICATIONS	17

APPENDICES

A. BEAR MANAGEMENT REPORT USED IN GSMNP	60
B. BEAR WARNING SIGN	61
C. FOOD CABLE SYSTEM FOR BACKCOUNTRY CAMPSITES IN GSMNP.....	62
BIBLIOGRAPHY	63

LIST OF TABLES

Table	Page
1. Description of the 9 response variables that were combined to make the single response variable “Conflict.”.....	22
2. Yearly visitor and camping totals for GSMNP, 1998-2011.....	23
3. Acorn mast abundance index (percent of visible crown with mast) for white and red oaks, GSMNP, 1998-2010.....	24
4. Percent of bait-stations visited by bears by year at GSMNP, 2002-2011.....	25
5. Numbers of HBI by vegetation type (“Vital_Name”) at GSMNP, 1998-2011.....	26
6. Descriptions of the 17 different predictor variables used in the GLMs.....	27
7. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 1 st subset (0 observations dropped), including dAIC and model weights.....	28
8. Deviance, AIC and probability values of parameters of the best glm model (Model 48.f) describing the locations of human-black bear interactions in GSMNP for the 1 st subset (0 observations dropped).....	29
9. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 2 nd subset (425 observations dropped), including dAIC and model weights.....	30
10. Deviance, AIC and probability values of parameters of the best generalized linear model (Model M38.g) describing the locations of human-black bear interactions in GSMNP for the 2 nd subset (425 observations dropped).....	31
11. Variance inflation factors for the model interaction between mast and yearly visitation for the 2 nd subset (425 observations dropped) describing the locations of human-black bear interactions in GSMNP.....	32
12. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 3 rd subset (857 observations dropped), including dAIC and model weights.....	33

13. Deviance, AIC and probability values of parameters of the best glm (model M41.f) describing locations of human-black bear interactions in GSMNP for the 3 rd subset (857 observations dropped).....	34
14. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 4 th subset (1,282 observations dropped), including dAIC and model weights.....	35
15. Deviance, AIC and probability values of parameters of the best glm (M45.fs.B) describing locations of human-black bear interactions in GSMNP for the 4 th subset (1,282 observations dropped).....	36
16. Variance inflation factors for the model interaction between mast and yearly visitation for the 4 th subset (1,282 observations dropped) describing the locations of human-black bear interactions in GSMNP.....	37
17. Four best models using an optimum threshold value derived using percent correctly classified (PCC), sensitivity, specificity, highest Kappa value and area under the curve (AUC) metrics based on presence-absence accuracy measure.....	38
18. Year, mast, abundance, visitation and HBI data for GSMNP, 1998-2011.....	39

LIST OF FIGURES

Figure	Page
1. Great Smoky Mountains National Park study area showing campsites, shelters, trails and other human access areas.....	40
2. Average monthly visitation over 14 year period from 1998 to 2011.....	41
3. Number of human visitors at GSMNP by year, 1998-2011.....	42
4. Numbers of total human-black bear interactions (HBI) at GSMNP by year, 1998-2011.....	43
5. Numbers of serious human-black bear interactions (HBI) at GSMNP by year, 1998-2011.....	44
6. Average number of total human-black bear interactions (HBI) at GSMNP by month, 1998-2011.....	45
7. Numbers of serious human-black bear interactions (HBI) at GSMNP by month, 1998-2011.....	46
8. Distribution of HBI locations in GSMNP, 1998-2011.....	47
9. Distribution of serious HBI locations in GSMNP, 1998-2011.....	48
10. Five areas of highest HBI concentration in GSMNP, 1998-2011.....	49
11. Backcountry campsite HBI locations including the three campsites with the highest concentration of HBI in GSMNP, 1998-2011.....	50
12. Model M38.g plot of the interaction between mast (x-axis) and yearly visitation (y-axis) in GSMNP, 1998-2011. Larger circles represent more occurrence of HBI.....	51
13. Model M45.fs.B plot of the interaction between mast (x-axis) and yearly visitation (y-axis) in GSMNP, 1998-2011. Larger circles represent more occurrence of HBI.....	52
14. Average number of total human-bear interactions (HBI) at GSMNP by month, 1998-2011.....	53
15. Average monthly visitation over 14 year period from 1998 to 2011.....	54

16. HBI termplots of visitor activity for model M48.f, M38.g and M41.f, respectively.....	55
17. HBI termplots vegetation cover for models M41.f and M48.f, respectively.....	56
18. HBI termplots of vegetation cover for models M38.g and M45.fs.B, respectively.....	57
19. HBI termplots of relative bear abundance for models M41.f and M45.fs.B respectively.....	58
20. Hypothetical diagram of the progression of a wild night active bear to a nuisance day active bear through anthropogenic rewards (GSMNP Resource Management, unpubl data).....	59

CHAPTER 1

INTRODUCTION

More than 20 states across the United States report a growing number of human-black bear interactions (HBI) (Baruch-Mordo et al., 2008). Since 1900, at least 63 people were killed by black bears and hundreds more have been injured, and there is a positive linear relationship between human population size and number of fatal black bear attacks (Herrero et al. 2010). Many of these deaths resulted in litigation and a reactionary change in policy by the U.S. Forest Service (Perry and Rusing, 2001).

The ability to predict HBI provides wildlife managers a tool to identify high-risk areas and implement management efforts to minimize HBI (Wilson et al. 2006, Merkle et al., 2011). HBI predictive models were developed for black (Baruch-Mordo et al. 2008, Merkel et al., 2011) and grizzly (*U. arctos*) bears (Wilson et al. 2006) using bear sightings, records of HBI, and reactive management actions such as law enforcement, education and removal of the animal (Merkle et al., 2011). These models were developed to identify spatio-temporal factors affecting HBI and predict areas with high probability of HBI. Landscape variables (i.e. distance to forest patches, riparian areas and animal density) and anthropogenic variables (i.e. housing/human densities, distances to roads and structures and human-use areas) are the two major categories used in HBI models (Merkle et al., 2011).

There are more than 1,600 black bears (*Ursus americanus*) in Great Smoky Mountains National Park (GSMNP), a park that hosts nearly 10 million visitors each year (GSMNP, 2002). Between 1998 and 2011, there were 3,059 incidents involving conflicts

between humans and black bears reported within the park, including nine human injuries and nearly \$34,000 in property damage (GSMNP Resource Management, unpubl data). Tate (1983) reported that food and trash from park visitors in GSMNP heavily influenced the foraging behaviors of black bears and caused bears to associate human scent with food. Bears readily exploited garbage cans, backpacks, dumpsters, tents, vehicles and people as sources of food.

Park managers use several strategies to reduce the potential for food-conditioning in bears and human-bear interactions (HBI) in GSMNP, including: enforcement of regulations that restrict the distance (46 m) that visitors can approach wildlife; bear-proof waste disposal containers at front-country (vehicle-accessible) campgrounds and picnic areas; and cable systems to raise food and garbage up out of reach of bears at all back-country campsites. Yet despite these efforts by park managers, HBI increased in the park over the past 15 years (GSMNP Resource Management, unpubl data).

The objectives of this study were to 1) identify areas with high HBI, 2) evaluate a variety of spatio-temporal factors associated with HBI, and 3) develop management strategies to minimize HBI in GSMNP. This information will provide wildlife managers a tool for identifying where and what actions may be needed to implement proactive management efforts to minimize HBI in GSMNP.

CHAPTER 2

METHODS

Study Area

Great Smoky Mountains National Park is located on the Tennessee-North Carolina border, roughly oriented north to south and spanning 2,080 km² (Fig. 1). It is part of the Unaka Mountain Range located in the Southern Appalachian Highlands. Large peaks and steep narrow drainages, ranging in elevation from 270 to 2,024 m, characterize the terrain. The park is bordered mostly by private land on the Tennessee side as well as Cherokee National Forest. Nantahala and Pisgah National Forests border most of the North Carolina side of the park. There are six major forest types in the park, including: oak (*Quercus sp.*), eastern hemlock (*Tsuga canadensis*), oak-pine (*Quercus sp.*, *Pinus sp.*), northern hardwood, cove hardwood and spruce-fir forests (*Abies sp.*, *Picea sp.*). The average rainfall ranges from 140 cm in the lower elevations to 215 cm in the higher elevations (Clark, 2005).

The park contains 10 front-country (vehicle-accessible) campgrounds, providing 1,000 sites. It also has over 100 back-country campsites and shelters. There are 11 picnic areas with 1,050 sites. The park also has five horse camps that include 27 individual sites as well as four park stables that allow for visitor horseback riding. GSMNP also includes more than 1,280 km of hiking trails (Clark, 2002). It is the most visited park in the country, with more than double the visitation of the second most visited park, Yellowstone National Park. More the 9.4 million people visited Great

Smoky Mountains National Park in 2010. Around 1,600 black bears (1.3 bears per km²) inhabit the park (GSMNP, 2002).

Data Compilation

Human-Bear Interactions (HBI)

Incidents of HBI were identified from GSMNP bear-related management reports for 1998 to 2011. Each report represents a single HBI that we was classified by year (“*Year*”), month (“*Month*”), GPS location (“*X_COORD*” and “*Y_COORD*”), and mapped in ArcGIS (ESRI, 2010). Each HBI was classified into one of three categories, including a significant observation, an incident report, and a management action (Appendix A). Several different bear behaviors constitute a significant observation. The first occurs when a bear enters a developed area, such as a picnic area, campsite, or shelter. The second occurs when a bear harasses a visitor, such as approaching or following. The third occurs when there is any unusual behavior from a bear, such as a bear that looks sick, has numbered tags in its ears from a previous capture, or when bears are seen in groups. The fourth is any observation that does not directly include a bear but involves one, such as a tipped dumpster (GSMNP, 2002).

An incident report occurs when there is any property damage by a bear, injuries to a human or a bear, a bear is fed by a human, dead bears killed by illegal hunting, or if the bear obtains any anthropogenic-related food source such as garbage or a cooler. Typically, park staff attempt to estimate the monetary value of any property damage (GSMNP, 2002).

The third type of bear-related report occurs when there is any type of management action, including: captured bears, attempted capture, resolving traffic jams caused by

people stopping to watch bears, car-bear collisions, campsite closures or monitoring programs initiated in response to bears, posting of warning signs about bears, or aversive conditioning and euthanization of bears. When possible, wildlife resource managers also record the size, sex and age of bears involved with any bear report (GSMNP, 2002).

We also classified each HBI as a single binary response variable termed “Conflict”. If the bear behavior associated with a HBI was one of nine bear behaviors (Table 1), we considered this a “serious” HBI (1=occurrence, 0=non-occurrence). Additionally, for all serious HBI incidents, we determined if bear cubs (“*assoc_Cubs*”), yearlings (“*assoc_Yearlings*”) or other adult bears (“*assoc_Bears*”) occurred in association with the incident. We also grouped all age groups into one category (“*assoc_Bears_All*”), representing a single variable when other bears were present during a serious HBI.

Visitor Use

We compiled numbers of total recreational use park visitors per year (“*Yearly_Visitation*”) (Table 2) and month (“*Monthly_Visitation*”) (Fig. 2.) for 1998-2011 (IRMA, 2013). Monthly visitation numbers were averaged over the 14-year period and also grouped into seasonal categories (“*Season*”), including spring (March-May), summer (June-August), fall (September-November) and winter (December- February). Numbers of visitors using picnic areas were not available.

For our analyses, we identified seven types of activities that a visitor was engaged with when a HBI occurred. These activities included camping (backcountry), camping (frontcountry), dayhiker, motorist, picnicker, other, and none. Camping (frontcountry) occurred in campgrounds accessible by vehicle. Camping (backcountry) occurred at

campsites or shelters that were only accessible by hiking. All seven of these activities are represented in the variable entitled, "Visitor Activity".

Acorn Abundance

The availability and distribution of hard mast acorns were estimated via visual trail surveys each year during August (Whitehead, 1969). The same 6.4-km long mast survey routes and marked trees were used each survey year, and only oak trees were surveyed because they are considered the most important mast producing trees for black bears (Nicholas and White, 1984). For each tree sampled, we recorded a GPS location, diameter at breast height, and species. Using binoculars, the crown of each tree is surveyed for approximately 30 sec and estimated percent of visible crown with mast. Mast survey indices were calculated following Greenberg and Warburton (2007). Index values ≤ 2.00 were classified as poor, 2.01 to 3.00 fair, and ≥ 3.00 good (Wentworth, 1989) and included in a variable titled, "*Mast*" (Table 3).

Bear Relative Abundance and Distribution

Annual bait-stations surveys were used to monitor annual black bear relative abundance and distribution (Johnson, 1982) and general population trends (Salinas, 2003). Bait-stations consisted of three partially-opened cans of sardines hung approximately 3 m from the ground with string. Bait-stations were placed at approximately 0.8-km intervals along roads and trails throughout the park. Location, elevation, overstory and understory vegetation, and distance from the nearest trail or road was recorded at each bait-station location (GSMNP Resource Management, unpubl data).

After five days, bait-stations were checked for bear visits. Claw marks on trees and/or large tooth-holes in cans constituted evidence of a bear visit. Activity was recorded for each bait-station and percent of stations visited was calculated by dividing the number of bait-stations visited by the total number of bait-stations established and included in a variable titled “*Bear_Density*” (Table 4).

Landcover and HBI Location

A vegetation cover layer of GSMNP was used to assign vegetative cover at each HBI location. Fifteen vegetative cover types (Table 5) were coded into a variable entitled, “*VitalName*”, for each HBI location. The variable “*General_location*” refers to the name of the exact point of an HBI, including the GPS points. Additionally, to decrease the number of general locations, we grouped HBI into a variable entitled, “*Grouped_Locations*”, based on general proximity to each other.

Data Analyses

We used generalized linear models (GLMs) to assess what variables affected the occurrence of HBI at GSMNP using our single response variable of “*Conflict*”. We used a binomial error distribution because our response variable was either presence or absence. We assessed 17 predictor variables (Table 6).

Our first step was to evaluate each predictor variable individually; however,

Model = glm(Response Variable ~ Predictor Variable(s), data = Data, family=binomial)

Mast” could not be grouped with the other variables because 695 observations were “dropped due to missing values. “*Month*” was analyzed as a category and a factor

(“*fMonth*”), and “*Bear_Density*” was analyzed as a category and numerically (“*nBear_Density*”). “*nBear_Density*” dropped 857 observations and was put into a different subset of models.

We next evaluated different combinations of predictor variables using the GLMs. We used the Akaike Information Criterion (AIC) to evaluate the models based on goodness of fit. When variable combinations dropped missing values, we grouped models accordingly. For example, AICs from models with 425 dropped observations could not be compared with AICs from models that dropped 857 observations. Eventually, we ended up with four subsets of models. The first subset included variables and variable combinations that dropped zero observations from the dataset. The second subset included variables and variable combinations that dropped 425 (14%) observations. The third subset included variables and variable combinations that dropped 857 (28%) observations. The fourth subset included variables and variable combinations that dropped 1,282 (42%) observations.

We evaluated 58 different GLMs based on AIC values and significance. We selected the best models from each subset with the lowest AIC values. We plotted the residuals and the fitted values for each of these selected models. Next, we examined the variables for each model using the “drop1” function in R using a Chi^2 test for significance (R 2010). We chose the model with the lowest AIC value from each subset to model the response variable using the predictor variables. We used presence-absence accuracy to validate the effectiveness of each model. The optimum threshold value for each model was calculated using R (R 2010) to determine the threshold that provided the highest percent correctly classified (PCC), sensitivity, specificity, the Kappa and area

under the curve (AUC).

CHAPTER 3

RESULTS

Human-Black Bear Interactions

Between 1998 and 2011, there were 3,059 incidents involving conflicts between humans and black bears reported within the park (Fig. 3), including 9 human injuries and nearly \$34,000 in property damage. Both total HBI and serious HBI gradually increased since 1998 (Fig. 2). The park averaged over 9 million visitors each year, with visitation at its highest in 1999 (Fig. 4). Visitation peaks in the summer months (Fig. 5) as does HBI (Fig. 6) and serious HBI (Fig. 7).

Distribution

Although HBI were located throughout the park (Fig. 8), serious HBI tended to more concentrated in certain areas (Fig. 9). Five areas (Cades Cove, Laurel Falls, Elkmont, Cosby and Chimneys Picnic area) accounted for nearly 50% (n=1,498) of the total HBI and 43% (n=292) of serious HBI incidents (Fig. 10). Backcountry campsite areas and shelters accounted for 16% (n=495) of the total HBI and 22% (n=151) of the serious HBI. Campsites 10, 13 and 24 accounted for 22% (n=108) of the total backcountry campsite HBI and 20% (n=30) of serious HBI incidents (Fig. 11).

Model Selection

We divided our models into four different subsets based upon the number of HBI

observations that were dropped due to missing values, including the 1st subset with no missing values, the 2nd with 425, the 3rd with 857, and the 4th with 1,282 missing values.

The best model for the first subset (M48.f) (Table 7) used the variables of vegetation, visitor activity and yearly visitation totals for explaining the locations for serious HBI (Table 8). Serious HBI occurred in areas containing eastern hemlock (*Tsuga sp.*), in backcountry campsites and shelters, and decreased as visitation increased.

Our best model for the second subset (M38.g) (Table 9) indicated that month, visitor activity, vegetation and the interaction between mast and yearly visitation best explained locations for HBI (Table 10). However this subset dropped 425 observations (14% of total HBI, 15% of serious HBI) due to missing mast data. Mast surveys were not available for 2011. Serious HBI occurred in areas of hemlock, in backcountry campsites and shelters, and in late spring and early fall. However, the variance inflation factor (vif) showed mast, yearly visitation and the interaction between the two variables to be highly inflated. Consequently, we are uncertain about the effects of these three individual variables (Table 11).

Our best model for the third subset (M41.f) (Table 12) indicated that vegetation, visitor activity and bear abundance best explained locations for serious HBI (Table 13). This subset dropped 857 observations (28% of HBI, 21% of serious HBI) due to missing bear abundance data. Bear abundance surveys were not available for 1998, 1999, 2000, 2001 and 2010. Serious HBI occurred in areas of hemlock, in backcountry campsites and shelters, and in years of higher bear abundance.

Our best model for the fourth subset (M45.fs.B) (Table 14) indicated month, bear abundance, vegetation and the interaction between mast and yearly visitation best explained locations for serious HBI (Table 15). This subset dropped 1,282 observations (42% of HBI, 36% of serious HBI) due to missing mast and bear abundance data. Serious HBI occurred in areas of hemlock, in years of high bear abundance, and in late spring and early fall. However, the variance inflation factor (vif) showed mast, yearly visitation and the interaction between the two variables to be highly inflated. Consequently, we are uncertain about the effects of these individual variables (Table 16).

Model Validation

The Kappa, PCC and area under the curve (AUC) values were the highest for model M38.g from the 2nd subset and model M.45fs.B from the 4th subset, indicating that these were the two best models for predicting serious HBI. Whereas, these values were lower for model M48.f from the 1st subset and model M41.f from the 3rd subset, indicating that these models were less accurate for predicting serious HBI locations (Table 17).

CHAPTER 4

DISCUSSION

The two top models among our four model subsets included three of the same predictor variables for serious HBI, including the interaction between mast production and number of park visitors per year (*Mast*Yearly_Visitation*), month (*fMonth*), and vegetation cover type (*VitalName*). In addition, one of the top models (M38.g) included visitor activity (*Visitor_Activity*), and the other top model (M45.fs.B) included bear abundance (*nBear_Density*) as predictor variables.

Overall, we expected serious HBI to be high in years when mast production was low compared to years with high mast production. Similarly, the number of park visitors might be expected to affect the occurrence of HBI, with HBI increasing with increased numbers of park visitors. Yet, for model M38.g, HBI was consistently high no matter the level of mast production or the numbers of visitors, except for two relatively low HBI years in 1998 and 1999 when visitor numbers were near their highest (Fig. 12).

Similarly, model M45.fs.B suggested that the occurrence of HBI was intermediate when mast was fair or poor at multiple park visitation numbers (Fig. 13). With the very large numbers of visitors to GSMNP each year (9.0 to 10.2 million people), it appears that changes in numbers of visitors probably has little effect on the number of HBI. In other words, there are always high numbers of park visitors, providing bears much opportunity to interact with visitors. Further, high numbers of HBI can occur in low, fair and high mast years. This low association between HBI and mast production may indicate that bears potentially prefer anthropogenic over natural food sources once they begin using anthropogenic food sources. However, low mast years may exacerbate the occurrence of

HBI in GSMNP. From 2005 to 2009, HBI increased substantially in association with poor mast production and increased proportion of bait stations visited by bears (Table 18). Thus, we caution that the proportion of bait stations visited by bears may not provide a sensitive index to bear abundance, but rather possibly increased attraction to bait stations by bears in years with low food availability, such as mast. Similarly, Clark et al. (2005) reported that bait station indices (BSI) in GSMNP do not improve the ability to explain changes in bear population. They suggested that higher BSI values may simply reflect increased bear movements and attraction to bait stations in low mast years.

Bears are ecologically adapted to food fluctuations. When food is scarce, fewer cubs are produced and bears tend to enter den sites earlier in the fall to expend less energy (Clark 2004). Additionally, during periods of poor mast productions, non-hunting fatalities for bears tend to increase. Vaughn et al. (2002) reported increased bear movements during poor mast years, which put them into more frequent contact with roads and anthropogenic food sources.

Month was selected as a predictor variable for the two top models. As expected, the highest numbers of HBI occurred during summer months (Fig. 14) when park visitation rates were typically the highest (Fig. 15), increasing the potential for bears to interact with people. Further, visitor activity (*Visitor_Activity*) was selected in three of the top models in the first three subsets (M48.f in subset 1, M38.g in subset 2, M41.f in subset 3). Frontcountry and backcountry camping, where people and food are present overnight, were significant predictor variables in each of these models (Fig. 16). Similarly, motorists were a significant factor in two of the models (M48.f and M41.f) (Fig. 16). Motorists are able to cover large areas of the park, visiting areas where wildlife

are frequently observed. When bears are spotted, cars stop for pictures and people exit their cars, putting bears and people in close contact. Further, roadway corridors allow for more sunlight, encouraging growth of plants fed on by bears, such as highbush blueberry (*Vaccinium corymbosum*), wild red raspberry (*Rubus idaeus*), highbush blackberry (*Rubus allegheniensis*) and common dandelions (*Taraxacum officinale*). Baruch-Mordo et al. (2008) reported that vehicle accidents with bears accounted for more than 25% of the HBI in Colorado. In Yosemite National Park, black bears broke into 908 vehicles over a 7-year period and bears disproportionately targeted minivans (Breck et al., 2009). The authors hypothesized that minivans were more likely to emit odors of food from spills caused by children, contain larger coolers with more food than other vehicles, or may be easier to break into than other vehicles. Day hiking was also significant in three models (M48.f, M38.f, M41.f) (Fig. 16). Day hikers have the potential to cover large distances on trails and move quietly, increasing the potential for increased human-bear encounters. Further, bears are often spotted using trails as travel routes due to their ease of movement, and trails, like roads, can also allow in more sunlight encouraging plants that bears utilize for food.

Vegetation type (*VitalName*), in particular hemlock forested areas, was significant in all of the models (Fig. 17). Over 43% (38 out of 87) of serious HBI in backcountry campsites was associated with hemlock. Additionally, the low visibility in hemlock forests may also lead to increased HBI. Montane alluvial areas were also significant in two models (M38.g and M45.fs.B) (Fig. 18). With their many waterfalls and streams, these areas are reliable water sources for bears and also attract hikers and fishermen who picnic and clean fish, two activities that can attract bears.

Bear abundance (*nBear_Density*) was highly significant in two models (M41.f and M45.fs). HBI increased as the relative abundance of bears increased (Fig. 19) with a higher likelihood of contact between visitors and bears. At high bear abundance, we might also expect increased competition between bears for limited resources, forcing bears to seek out other food options, such as anthropogenic sources. Alternatively, as discussed above, increased proportion of bait stations visited by bears may simply indicate increased attraction to bait stations by bears in years with low food availability rather than actual increases in bear abundance.

CHAPTER 5

MANAGEMENT IMPLICATIONS

Interactions with humans or human property that lead to food rewards are the root cause of HBI (Hunt, 1984; Howe et al., 2003). With a strong sense of curiosity and high mobility, bears are opportunistic feeders (Herrero, 2002) that begin entering human-use areas at night, and over time and without negative stimuli, begin to approach people closer during the day, losing their natural fear of humans (Hunt, 2003). A lack of negative reinforcement develops a loss of fear in black bears towards humans (Hopkins, 2010). To help reduce and prevent conflict between humans and black bears, anthropogenic food sources must be eliminated and negative or aversive conditioning applied in certain situations to help affirm or reestablish a feeling of fear for humans (McCullough, 1982) (Fig. 20).

Education is the first step to successful management of human-bear interactions. By teaching employees and visitors about black bear behavior and biology, many of the conflicts can be avoided or prevented. The Division of Resource Education in GSMNP post bulletin boards, fliers, pamphlets, signs, and newspaper articles discussing bear management efforts, visitor conduct, park regulations, food storage and proper waste disposal. Warning signs are also posted in areas where there is a high potential for conflict based on previous bear encounters or sightings (Appendix B).

Limiting the access of bears to anthropogenic food sources through use of bear-proof waste disposal containers and proper use of food storage devices is critical for reducing HBI. In 1991, GSMNP began a bear-proof garbage system with bear-proof dumpsters and garbage cans placed in picnic areas, motorist pull-offs, parking areas and

frontcountry campsite areas. At all backcountry campsites and shelters, the park installed cable systems away from sleeping areas that allow campers to store their packs and food above ground out of reach of bears (Appendix C).

Aversive conditioning is also an important tool to reduce HBI, including: capture/release/relocation, pepper spray, chasing/yelling, and projectiles. At GSMNP, bears were captured using culvert traps, snares and immobilization darts with bears ear-tagged and lip tattooed for identification. At GSMNP, Clark et al. (2002) reported that this procedure was 73% successful in deterring bears from returning to the capture site, and bears caught and released during night activity were four times less likely to return and 7.6 times less likely to have to be re-located. Additionally, the earlier the intervention with a problem bear (i.e. less food reward), the less likely a bear would return to the capture site. Projectiles used to change bear behaviors at GSMNP included throwing rocks, paintball guns, and shotguns that shoot noise rounds, beanbag rounds, rubber slugs and rubber pellets.

Although it is not possible to quantify the individual effects of reducing access to food and the various aversive conditioning methods used at GSMNP, cumulatively they significantly reduced HBI at an area (Chimneys Picnic Area) with frequent HBI. From 1988 to 1990, 24 black bears were captured at Chimneys and relocated 35 times (11.6 bears/yr) and three bears were euthanized. In 1991, small garbage cans were replaced with larger bear-proof garbage cans, a strict 2000 hours closing time was instituted, and the area was cleaned after visitors left. Additionally, park wildlife managers began an aggressive aversive conditioning and capturing program. After these bear management actions, 55 bears were captured 93 times (5.4/yr) at Chimneys between 1991 and 2008

with bears released on site 72 times and relocated 21 times. During this period, no bears were euthanized and there were no significant human injuries (GSMNP Resource Management, unpubl data). Similarly, Mazur (2010) reported that 58% of bears that were using anthropogenic food sources in Sequoia National Park abandoned this behavior after the application of aversive conditioning using rubber slugs, rock throwing, pepper spray and chasing. They also reported that conditioning was more effective when the techniques were applied soon after the undesired behavior, more successful on adults than yearlings, and rubber slugs were more effective than lower impact projectiles.

In Florida, Wooding et al. (1988) reported that only 14% of 66 nuisance black bears captured and released on site at bee yards returned to the bee yards causing additional apiary damage. Returning bears were mostly adult males, with two returning after 3-4 captures, which were eventually relocated. Similarly, Landriault (2009) reported that male bears were more likely to return than females, and juvenile males were least likely to return to capture areas in Ontario. When bears were relocated, the younger the age of the bear and the greater distance a bear was moved from a capture site reduced the probability of a bear returning to the original capture site.

In summary, it is as important to change the behaviors of humans and bears alike to reduce HBI at GSMNP. This study identified high-risk HBI areas in GSMNP where proactive bear management programs (education, enforcement of park regulations, and aggressive aversion conditioning of bears) need to be implemented to reduce HBI and to provide a safer environment for both people and bears. It is also important that bears have suitable habitats with sufficient resources to meet their life history needs. Further, visitors and park staff need to report all HBI so that proactive and rapid bear management

responses can be initiated, which will increase the probability of management success and reduce the occurrence of future HBI.

Table 1. Description of the 9 response variables that were combined to make the single response variable “Conflict.”

Response Variable	Description
Property_Damage	any park or visitor property damaged by a bear
Personal_Injury	any injury to a person by a bear
Bear_Got_Pack	any backpack taken by a bear
Bear_Entered_Vehicle	any vehicle entered or attempted to be entered by a bear
Bear_Entered_Tent	any tent entered or attempted to be entered by a bear
Bear_Entered_Structure	any human structure entered or attempted to be entered by a bear
Vocalize_Charge_or_SwatGround	the bear vocalized, bluff charged or swatted the ground
BearSpray_Deployed	a visitor deployed bear spray during an HBI
Food_Garbage_Bin	a bear attempted or succeeded in getting food or garbage

Table 2. Yearly visitor and camping totals for GSMNP, 1998-2011.

Year	Recreation Visitors	Tent Campers	RV Campers	Backcountry Campers	Misc Campers
1998	9,989,395	191,418	141,109	101,486	25,096
1999	10,283,598	191,169	133,961	92,994	25,459
2000	10,175,812	177,170	128,172	80,654	24,379
2001	9,197,697	146,724	125,147	76,919	21,428
2002	9,316,420	154,853	129,195	77,816	20,222
2003	9,366,845	154,490	126,815	73,124	19,931
2004	9,167,046	136,228	122,959	73,787	17,283
2005	9,192,477	135,132	120,448	69,985	19,461
2006	9,289,215	136,994	120,825	70,193	23,169
2007	9,372,253	163,489	134,112	70,215	26,741
2008	9,044,010	142,849	118,981	71,381	23,492
2009	9,491,437	154,852	134,115	79,182	21,699
2010	9,463,538	154,504	128,991	79,480	19,560
2011	9,008,830	145,077	108,732	90,444	23,316

Table 3. Acorn mast abundance index (percent of visible crown with mast) for white and red oaks, GSMNP, 1998-2010.

Year	White Oak	Red Oak	Total Oak
1998	1.73 (81)*	3.77 (171)	3.33 (252)
1999	1.23 (105)	1.29 (150)	1.35 (255)
2000	0.78 (87)	1.61 (163)	1.42 (250)
2001	1.05 (92)	5.10 (165)	3.92 (257)
2002	0.97 (188)	2.38 (317)	1.99 (503)
2003	0.99 (214)	0.80 (312)	0.94 (526)
2004	2.62 (177)	2.25 (331)	2.52 (508)
2005	0.48 (201)	2.24 (329)	1.70 (530)
2006	0.80 (198)	1.33 (315)	1.21 (513)
2007	2.00 (207)	1.67 (321)	1.91 (528)
2008	0.99 (204)	2.10 (319)	1.79 (523)
2009	0.64 (210)	2.61 (330)	1.99 (540)
2010	3.07 (209)	2.90 (320)	3.13 (529)

* Number in parentheses = sample size for each tree species.

Table 4. Percent of bait-stations visited by bears by year at GSMNP, 2002-2011.

Year									
2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
71%	68%	66%	73%	80%	77%	75%	83%	-	74%

Table 5. Numbers of HBI by vegetation type (“*Vital_Name*”) at GSMNP, 1998-2011.

Vegetation Type	Total HBI
Cove	408
Grass	127
Heath	84
Hemlock	87
High Hardwood	376
Human Influence	447
Montane Alluvial	147
Oak	652
Pine/Oak	299
Spruce/Fir	93
Successional	319

Table 6. Descriptions of 17 predictor variables used in the GLMs.

Predictor Variable	Description
assoc_Bears	other adult bears were present with the bear involved in the HBI
assoc_Cubs	cubs were present with the bear involved in the HBI
assoc_Yearlings	yearlings were present with the bear involved in the HBI
assoc_Bears_All	another bear(s) present with the bear involved in the HBI (a combination of the previous three variables)
Year	the year the incident occurred in
Month	the month the incident occurred in
Season	the season the incident occurred in (Spring, Summer, Fall, Winter)
Mast	the estimated hard mast for the year
Bear_Density	the estimated bear abundance for the year
Visitor_Activity	the activity the visitor was participating in when the HBI occurred
Yearly_Visitation	total human visitation per year from 1998-2011
Monthly_Visitation	average monthly human visitation in the park from 1998-2011
VitalName	vegetation cover
General_Location	the name of the location based on X and Y coordinates (420 locations)
Grouped_Locations	locations grouped by areas of the park (41 locations)
X_COORD	the X coordinate
Y_COORD	the Y coordinate

Table 7. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 1st subset (0 observations dropped), including dAIC and model weights.

Model	Variables	AIC	dAIC	df	Weight
M48.f	VitalName+Visitor_Activity + Yearly_Visitation	3045.3	0	18	1
M49	Yearly_Visitation	3124.6	79.3	2	<.001
M21	VitalName+Visitor_Activity + poly(X_COORD,2) * poly(Y_COORD,2)	3137.1	91.8	25	<.001
M17	VitalName+Visitor_Activity + Grouped_Locations	3138.9	93.6	57	<.001
M10	Grouped_Locations	3140.3	95	41	<.001

Table 8. Deviance, AIC and probability values of parameters of the best generalized linear model (Model 48.f) describing the locations of human-black bear interactions in GSMNP for the 1st subset (0 observations dropped).

Parameter	df	Deviance	AIC	LRT	Pr (>Chi)	
<none>		3009.3	3045.3			
VitalName	10	3048.7	3064.7	39.4	2.18E-05	***
Visitor_Activity	6	3066.7	3090.7	57.4	1.53E-10	***
Yearly_Visitation	1	3145.3	3179.3	136.0	2.20E-16	***

Table 9. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 2nd subset (425 observations dropped), including dAIC and model weights.

Model	Variables	AIC	dAIC	df	Weight
M38.g	Mast*Yearly_Visitation+fMonth+Visitor_Activity+VitalName	2384.5	0	31	1
M38.f	Mast+fMonth+Visitor_Activity+Yearly_Visitation+VitalName	2552.6	168.1	30	<.001
M34.f	Mast+Grouped_Locations+fMonth+Visitor_Activity	2650.2	265.8	59	<.001
M36.f	Mast+Grouped_Locations+fMonth+Visitor_Activity+VitalName	2654.3	269.8	69	<.001
M33	Mast+Grouped_Locations	2681.4	311	42	<.001

Table 10. Deviance, AIC and probability values of parameters of the best generalized linear model (Model M38.g) describing the locations of human-black bear interactions in GSMNP for the 2nd subset (425 observations dropped).

Parameter	df	Deviance	AIC	LRT	Pr(>Chi)	
<none>		2322.5	2384.5			
fMonth	11	2355.2	2395.2	32.7	0.0005854	***
Visitor_Activity	6	2355.6	2405.6	33.1	1.02E-05	***
VitalName	10	2366.7	2408.7	44.2	3.00E-06	***
Mast:Yearly_Visitatio n	1	2492.6	2552.6	170.1	2.20E-16	***

Table 11. Variance inflation factors for the model interaction between mast and yearly visitation for the 2nd subset (425 observations dropped) describing the locations of human-black bear interactions in GSMNP.

	GVIF	Df	$\text{GVIF}^{(1/(2 \cdot \text{Df}))}$
Mast	1548.9	1	39.4
Yearly_Visitation	11.7	1	3.4
fMonth	1.4	11	1.0
Visitor Activity	2.1	6	1.1
VitalName	2.2	10	1.0
Mast*Yearly_Visitation	1638.8	1	40.5

Table 12. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 3rd subset (857 observations dropped), including dAIC and model weights.

Model	Variables	AIC	dAIC	df	Weight
M41.f	VitalName+Visitor_Activity + nBear_Density	2248.4	0	18	1
M42.f	nBear_Density	2319.3	70.9	2	<.001

Table 13. Deviance, AIC and probability values of parameters of the best glm (model M41.f) describing locations of human-black bear interactions in GSMNP for the 3rd subset (857 observations dropped)

Parameter	Df	Deviance	AIC	LRT	Pr(>Chi)	
<none>		2212.4	2248.4			
VitalName	10	2258.9	2274.9	46.5	1.18E-06	***
Visitor_Activity	6	2257.8	2281.8	45.3	4.08E-08	***
nBear_Density	1	2341.8	2375.8	129.4	2.20E-16	***

Table 14. Models tested and selected by AIC values to explain the locations of human-black bear interactions in GSMNP for the 4th subset (1,282 observations dropped), including dAIC and model weights

Model	Variables	AIC	dAIC	df	Weight
M45.fs.B	Mast*Yearly_Visitation+nBear_Density+fMonth+VitalName	1730.1	0	26	0.9983
M45.fs	Mast+nBear_Density+fMonth+Yearly_Visitation+VitalName	1743.5	13.4	25	0.0012
M43.f	Mast + fMonth + Visitor_Activity + nBear_Density + VitalName	1745.3	15.2	30	<.001
M47.keep	Mast + nBear_Density + Grouped_Locations	1784.5	54.4	42	<.001
M44.f	Mast + nBear_Density	1850.6	120.4	3	<.001

Table 15. Deviance, AIC and probability values of parameters of the best glm (M45.fs.B) describing locations of human-black bear interactions in GSMNP for the 4th subset (1,282 observations dropped).

Parameter	df	Deviance	AIC	LRT	Pr(>Chi)	
<none>		1678.1	1730.1			
nBear_Density	1	1684	1734	5.817	1.59E-02	*
fMonth	11	1705.2	1735.2	27.1	4.45E-03	**
VitalName	10	1738.8	1770.8	60.7	2.68E-09	***
Mast:Yearly_Visitation	1	1693.5	1743.5	15.4	8.78E-05	***

Table 16. Variance inflation factors for the model interaction between mast and yearly visitation for the 4th subset (1,282 observations dropped) describing the locations of human-black bear interactions in GSMNP.

	GVIF	Df	$GVIF^{1/(2*Df)}$
Mast	41987.2	1	204.9
Yearly_Visitation	127.9	1	11.3
nBear_Density	4.1	1	2.0
fMonth	1.6	11	1.0
VitalName	1.2	10	1.0
Mast:Yearly_Visitation	41537.3	1	203.8

Table 17. Four best models using an optimum threshold value derived using percent correctly classified (PCC), sensitivity, specificity, highest Kappa value, and area under the curve (AUC) metrics based on presence-absence accuracy measures.

Model	Threshold	PCC	Sensitivity	Specificity	Kappa	AUC
M48.f	0.31	0.73	0.36	0.84	0.21	0.7
M38.g	0.33	0.76	0.47	0.84	0.31	0.8
M41.f	0.3	0.7	0.51	0.77	0.26	0.7
M45.fs.B	0.33	0.73	0.6	0.78	0.34	0.8

Table 18. Year, mast, abundance, visitation and HBI data for GSMNP, 1998-2011.

Year	Mast	Abundance	Visitation	HBI
1998	3.33	NA	9989395	109
1999	1.35	NA	10283598	111
2000	1.42	NA	10175812	286
2001	3.92	59%	9197697	293
2002	1.99	71%	9316420	164
2003	0.94	68%	9366845	100
2004	2.52	66%	9167046	160
2005	1.7	73%	9192477	155
2006	1.21	80%	9289214	191
2007	1.91	77%	9372253	245
2008	1.79	75%	9044010	285
2009	1.99	83%	9491436	173
2010	3.13	NA	9463538	358
2011	NA	74%	9008830	429

Figure 1. Great Smoky Mountains National Park study area showing campsites, shelters, trails and other human access areas.

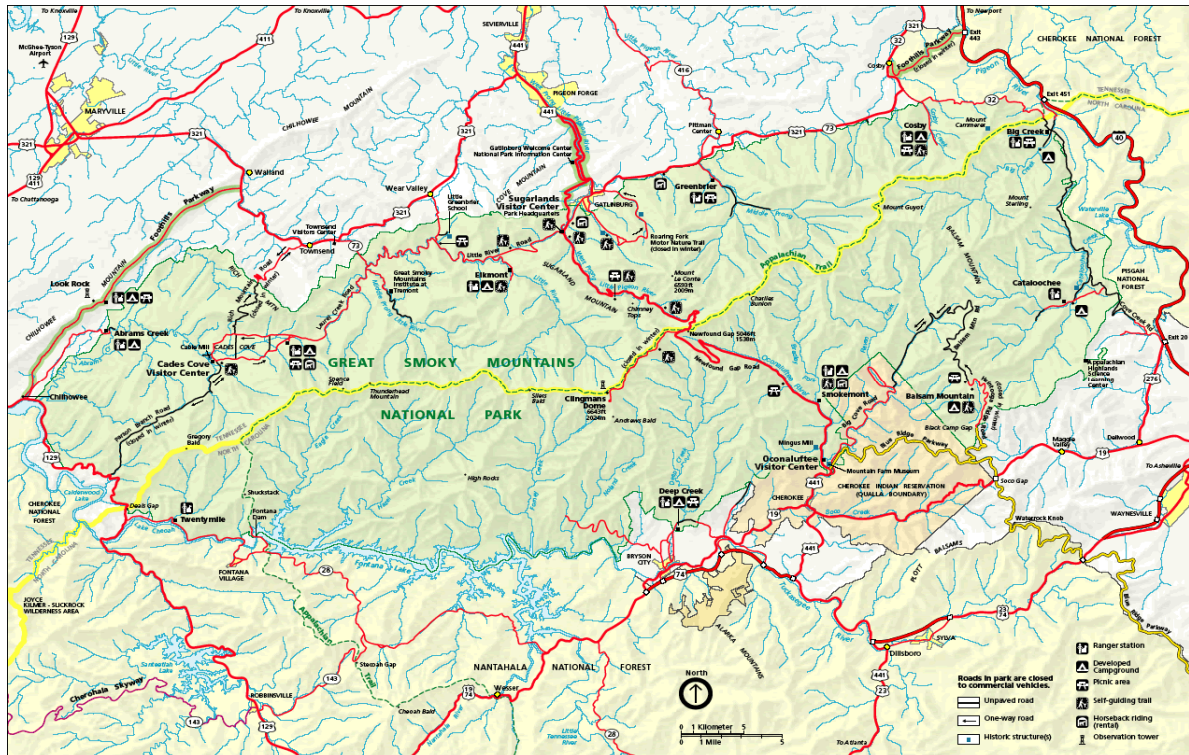


Figure 2. Average monthly visitation over 14 year period from 1998 to 2011.

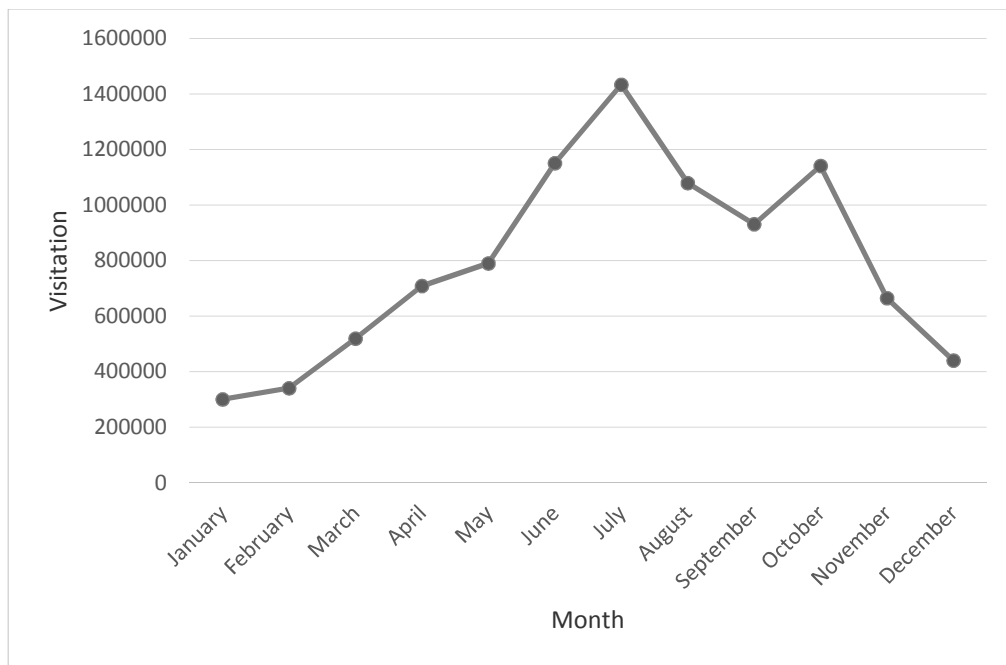


Figure 3. Number of human visitors at GSMNP by year, 1998-2011.

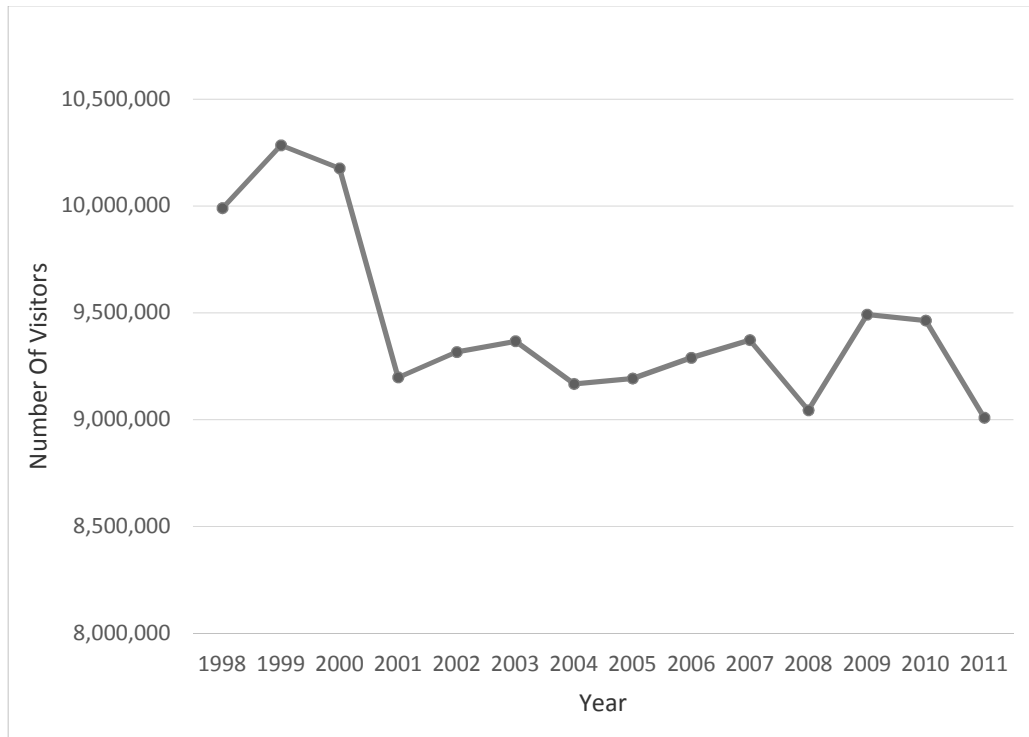


Figure 4. Numbers of total human-black bear interactions (HBI) at GSMNP by year, 1998-2011.

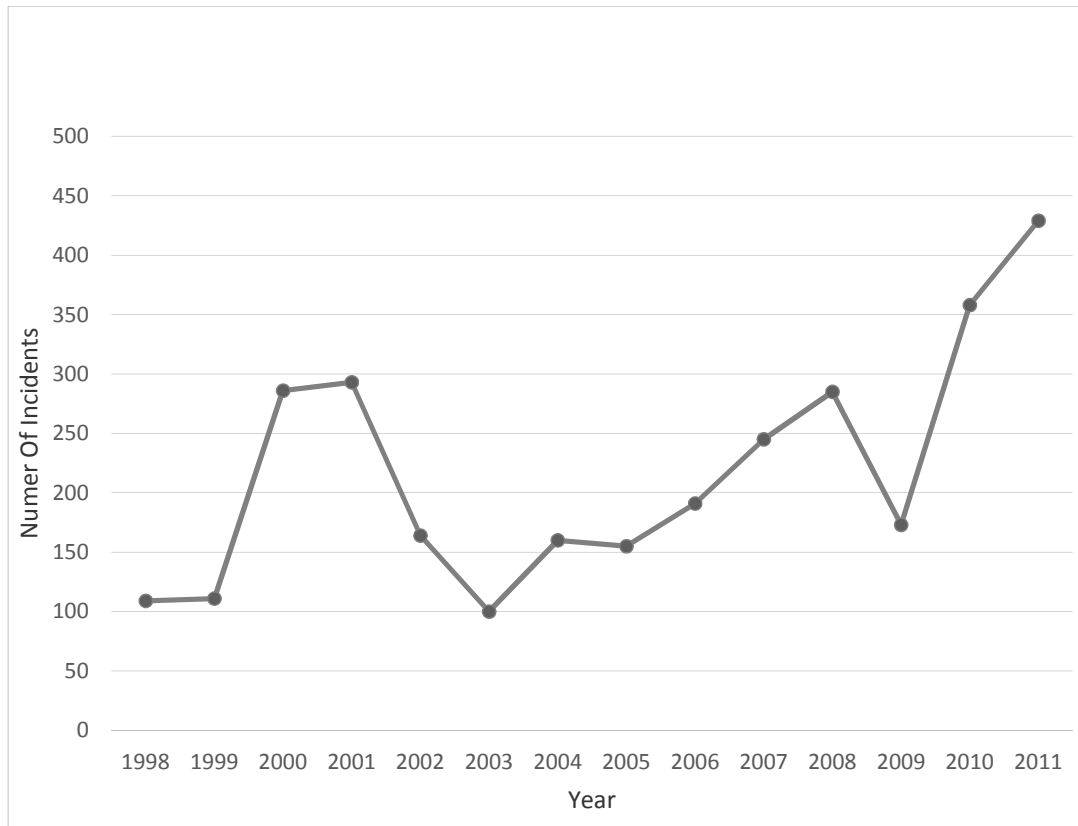


Figure 5. Numbers of serious human-black bear interactions (HBI) at GSMNP by year, 1998-2011.

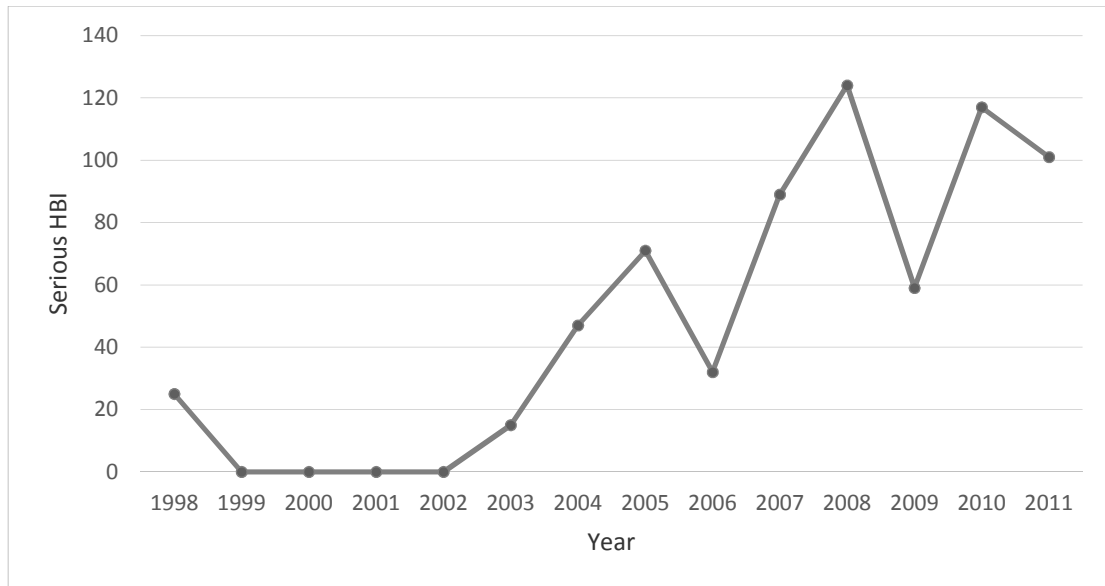


Figure 6. Average number of total human-black bear interactions (HBI) at GSMNP by month, 1998-2011.

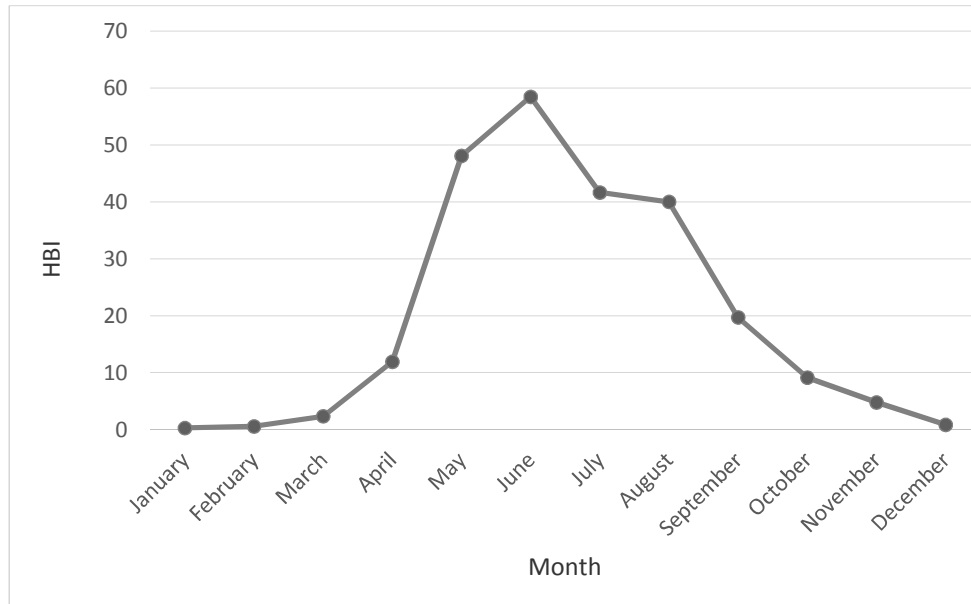


Figure 7. Numbers of serious human-black bear interactions (HBI) at GSMNP by month, 1998-2011.

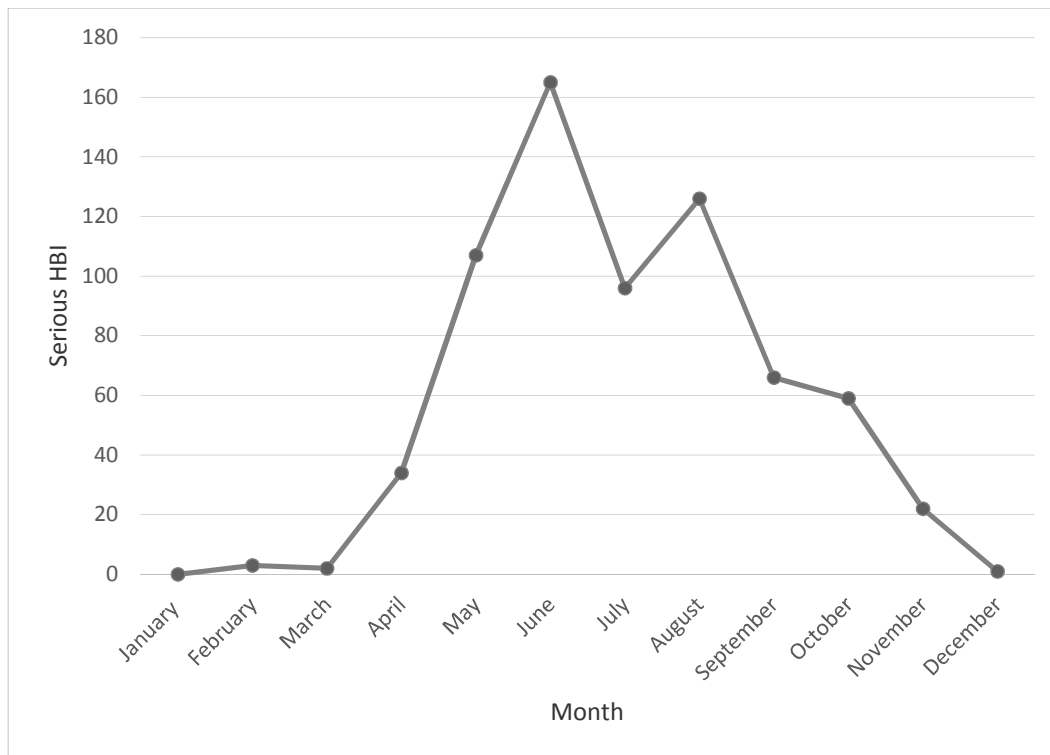


Figure 8. Distribution of HBI locations in GSMNP, 1998-2011.

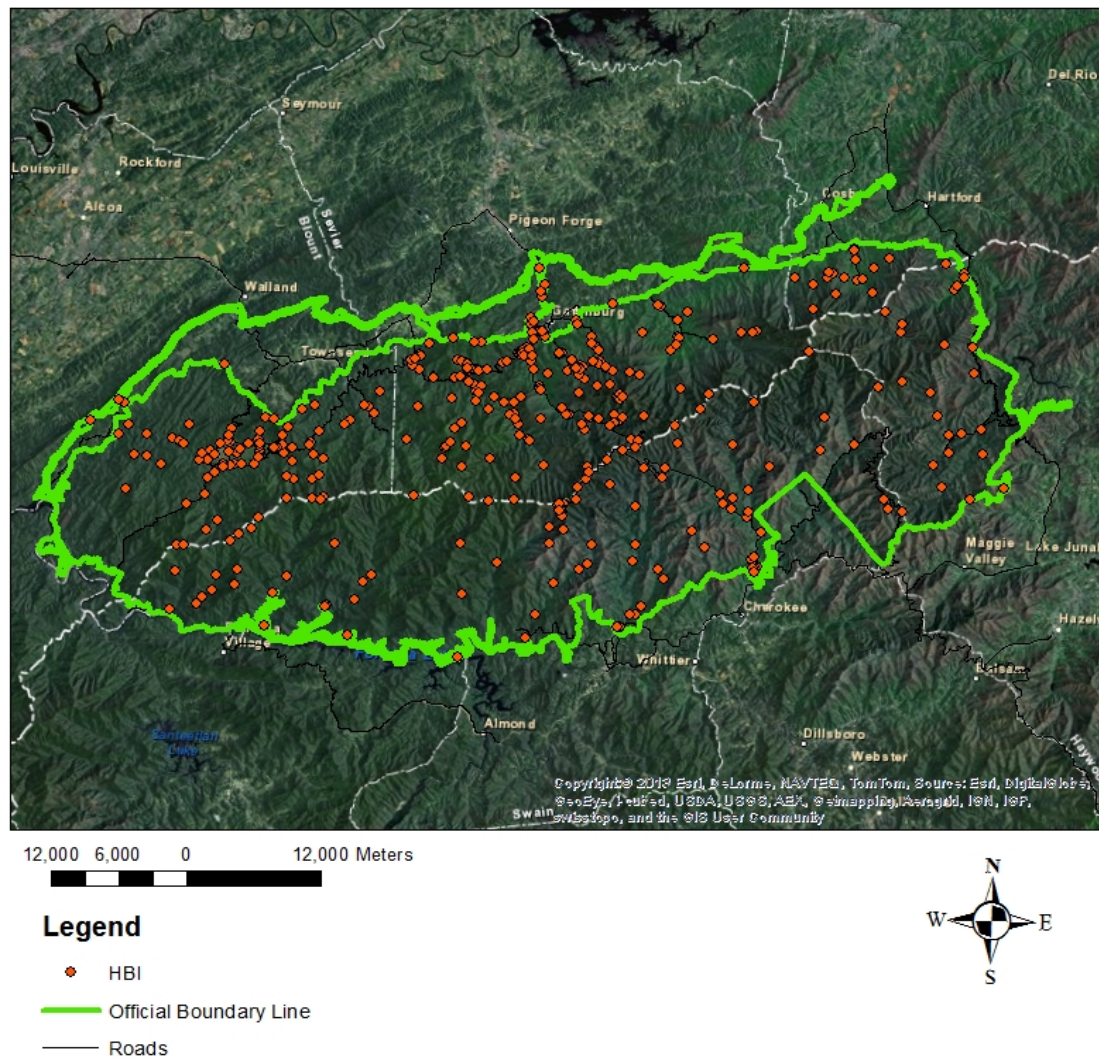


Figure 9. Distribution of serious HBI locations in GSMNP, 1998-2011.

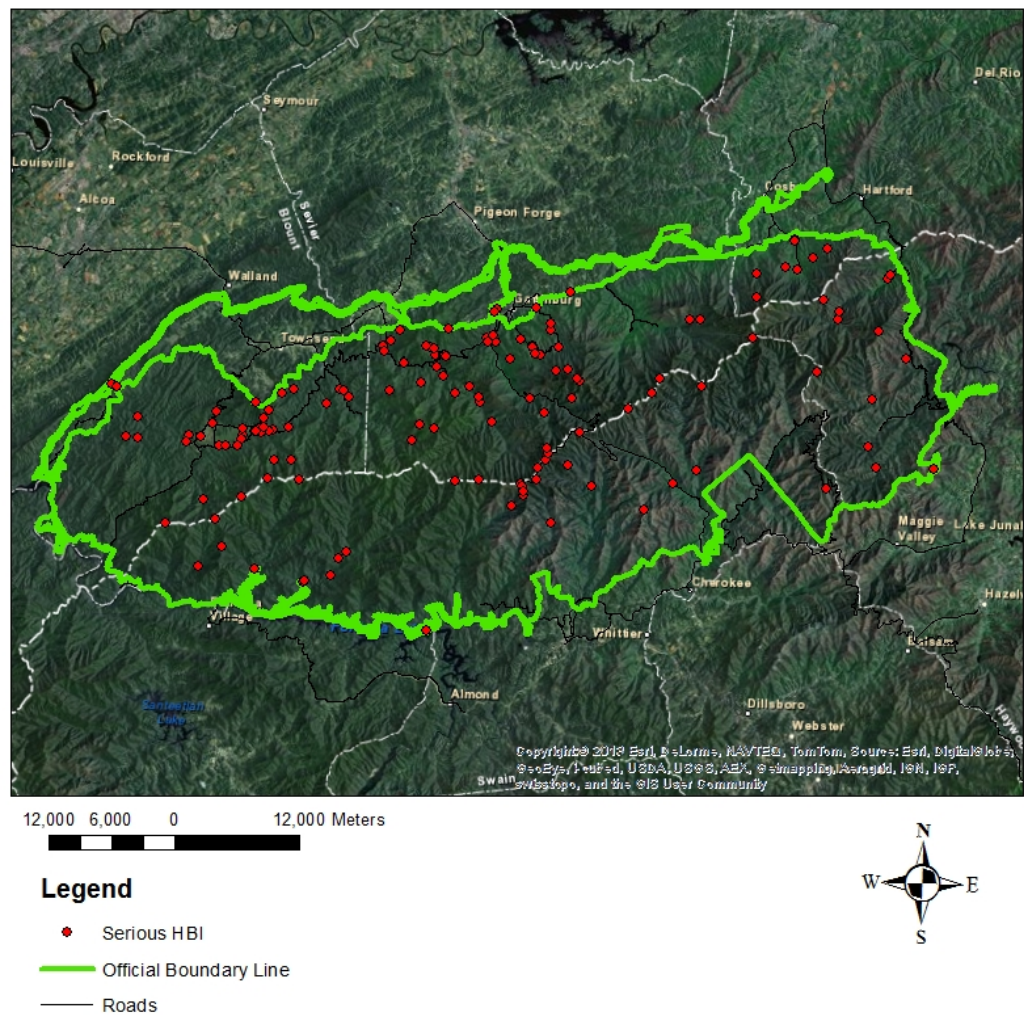


Figure 10. Five areas of highest HBI concentration in GSMNP, 1998-2011.

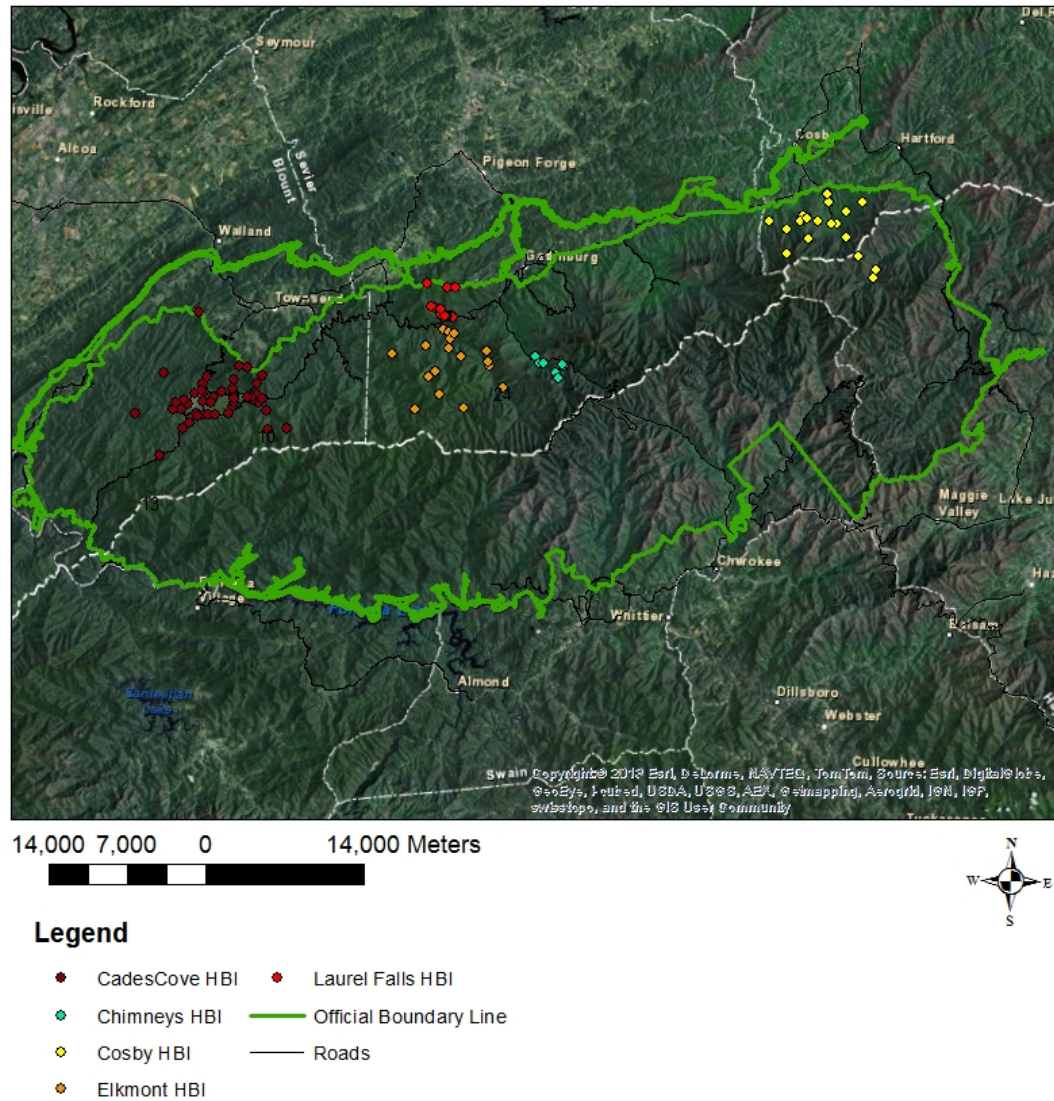


Figure 11. Backcountry campsite HBI locations including the three campsites with the highest concentration of HBI in GSMNP, 1998-2011.

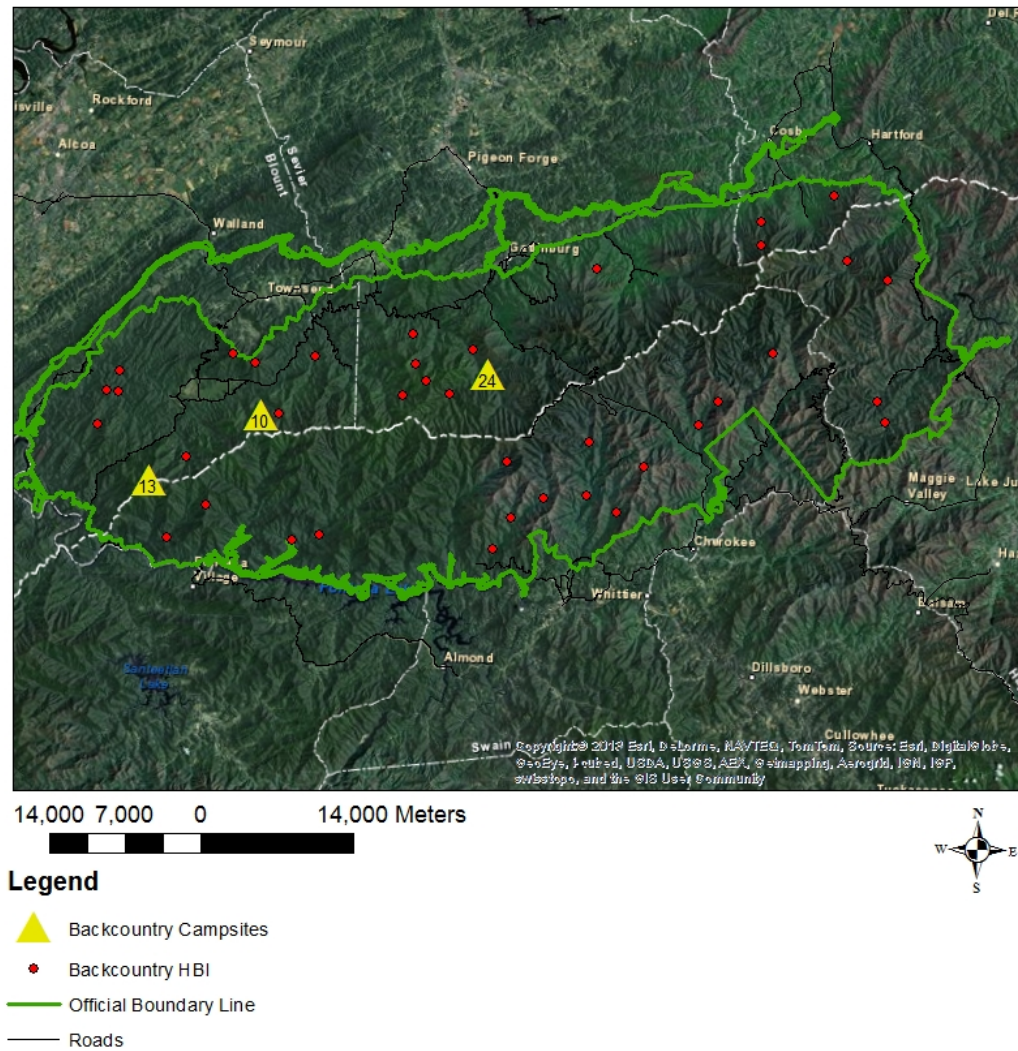


Figure 12. Model M38.g plot of the interaction between mast (x-axis) and yearly visitation (y-axis) in GSMNP, 1998-2011. Larger circles represent more occurrence of HBI.

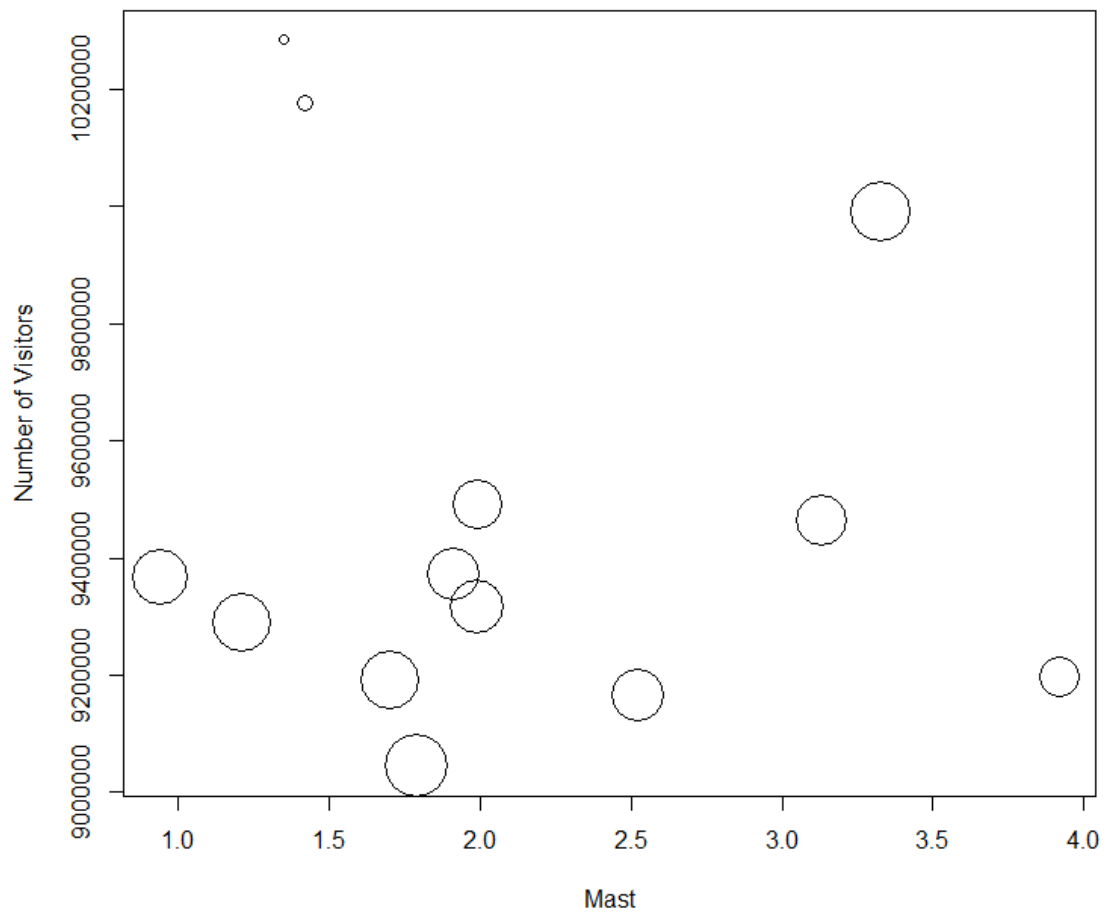


Figure 13. Model M45.fs.B plot of the interaction between mast (x-axis) and yearly visitation (-axis) in GSMNP, 1998-2011. Larger circles represent more occurrence of HBI.

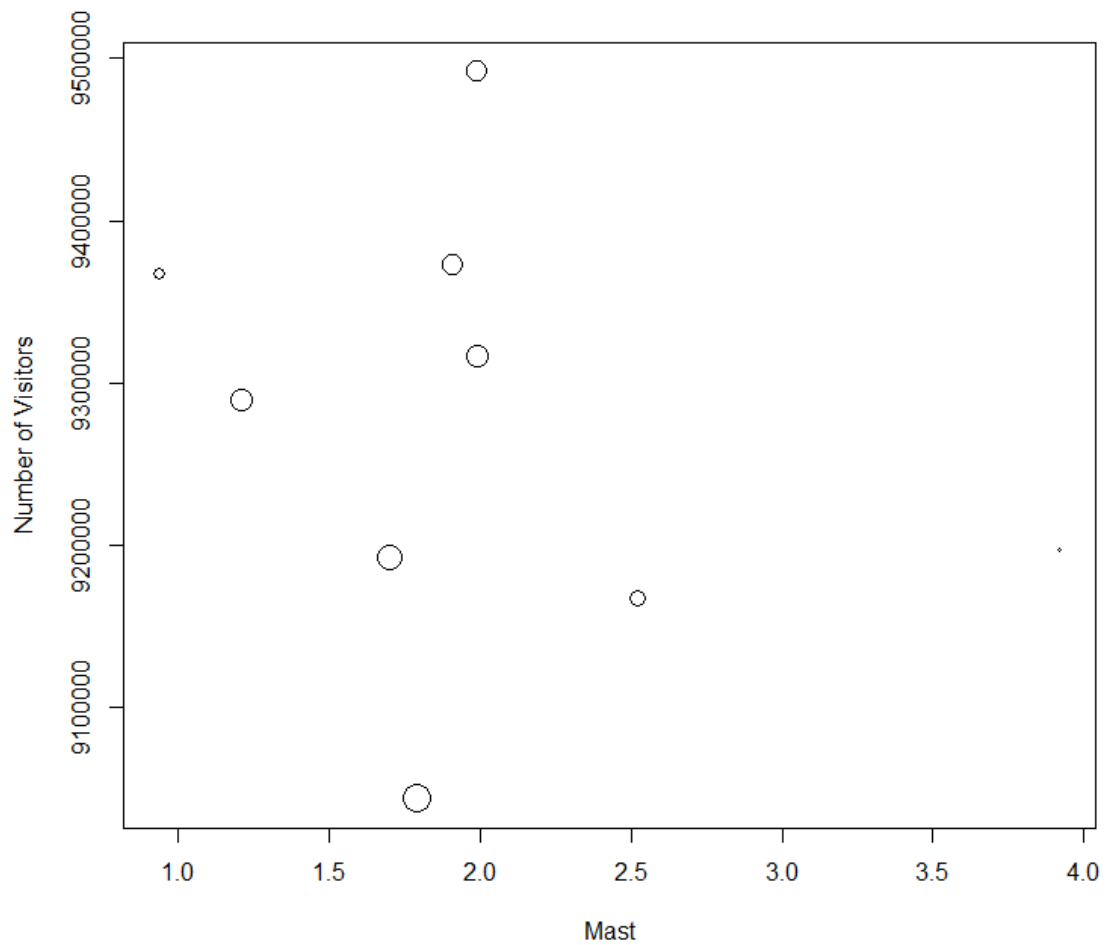


Figure 14. Average number of total human-bear interactions (HBI) at GSMNP by month, 1998-2011.

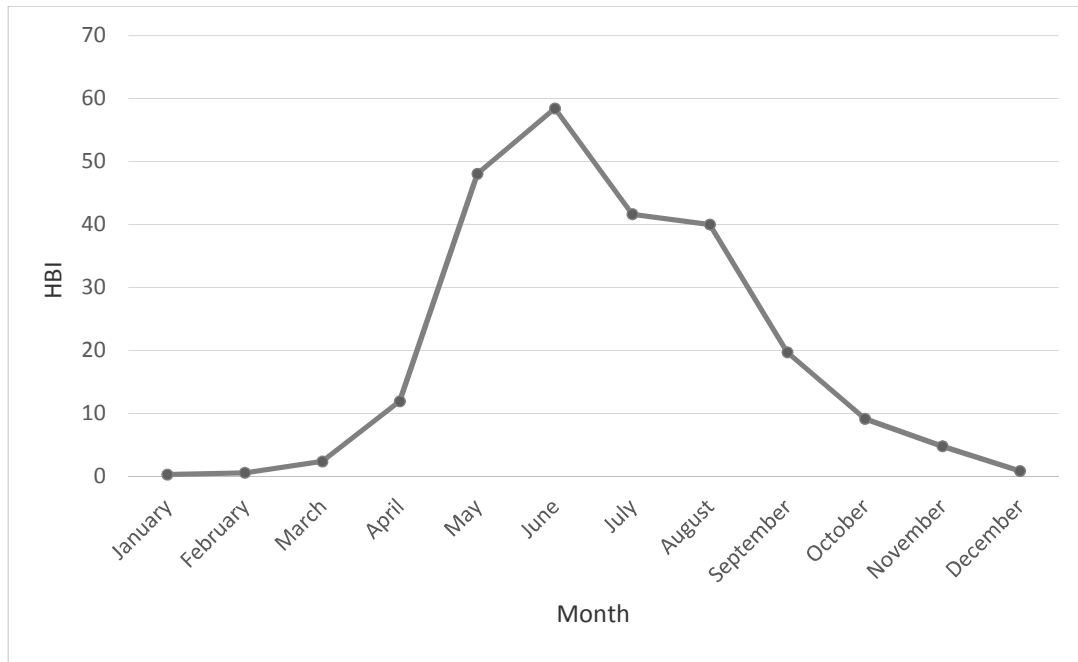


Figure 15. Average monthly visitation over 14 year period from 1998 to 2011.

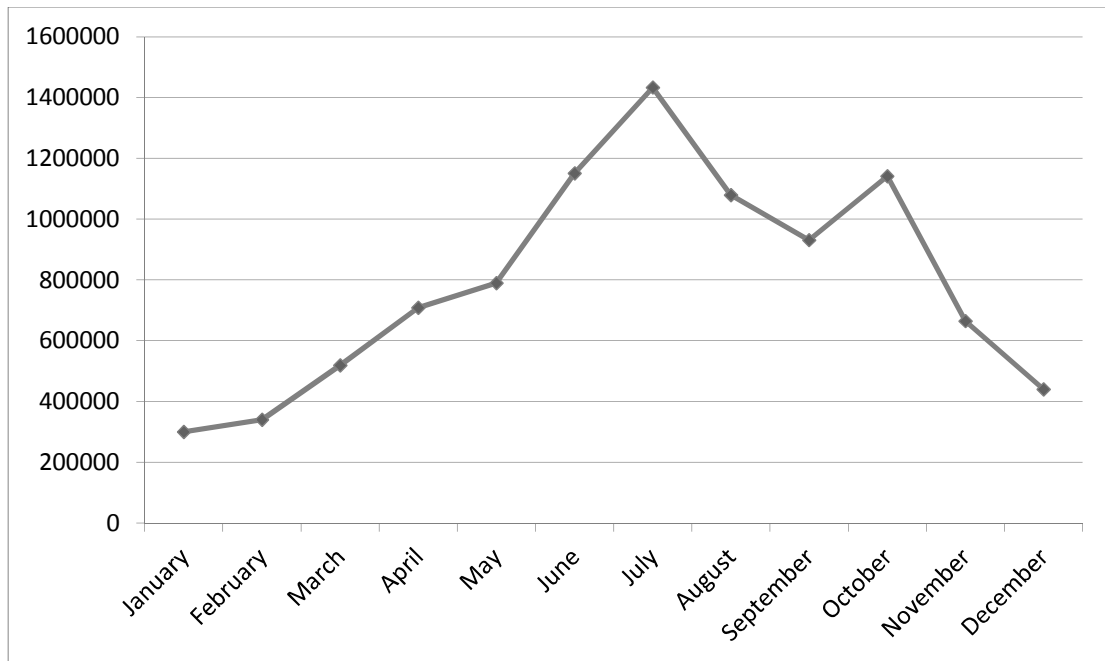


Figure 16. HBI termplots of visitor activity for model M48.f, M38.g and M41.f respectively.

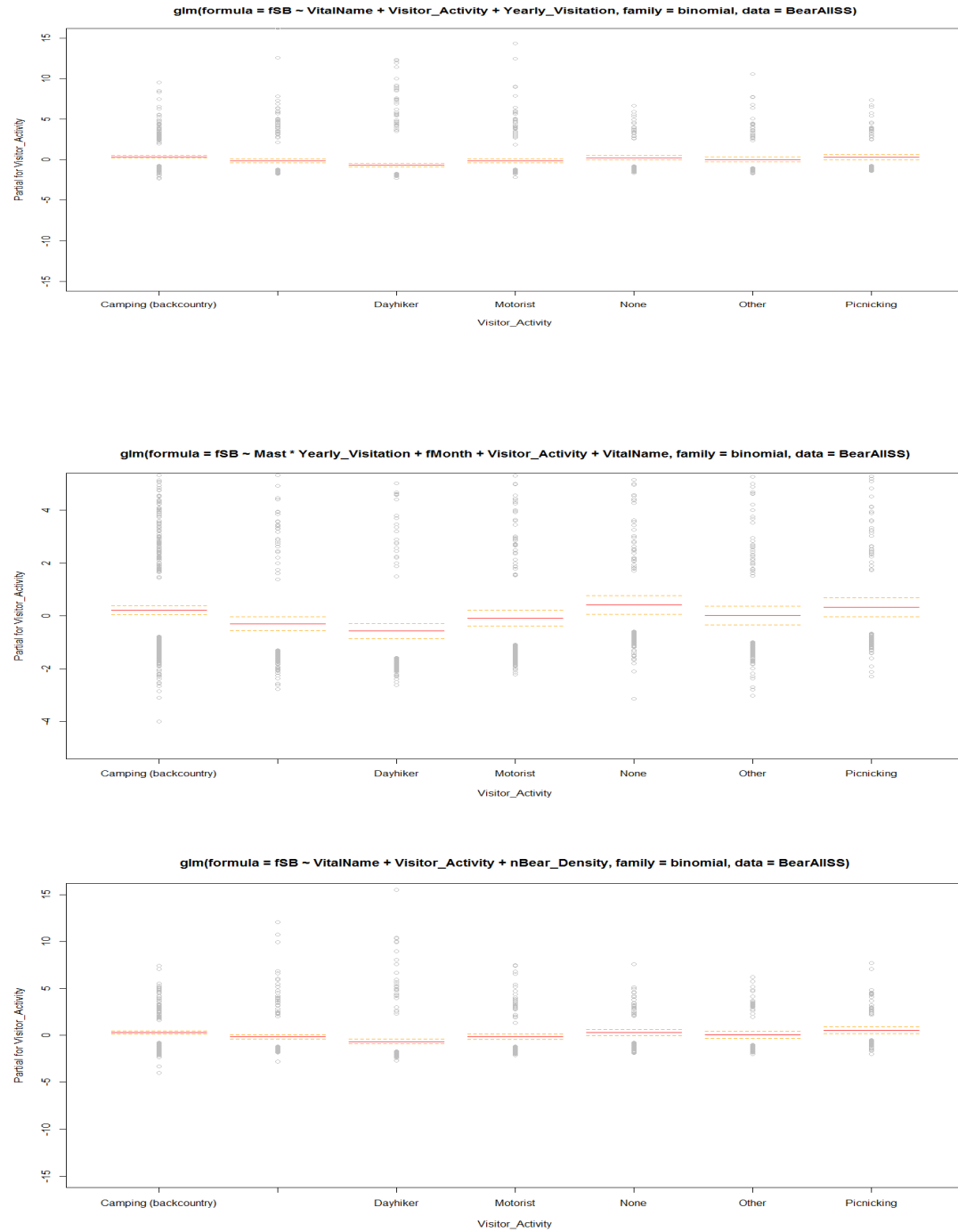


Figure 17. HBI termplots vegetation cover for models M41.f and M48.f respectively.

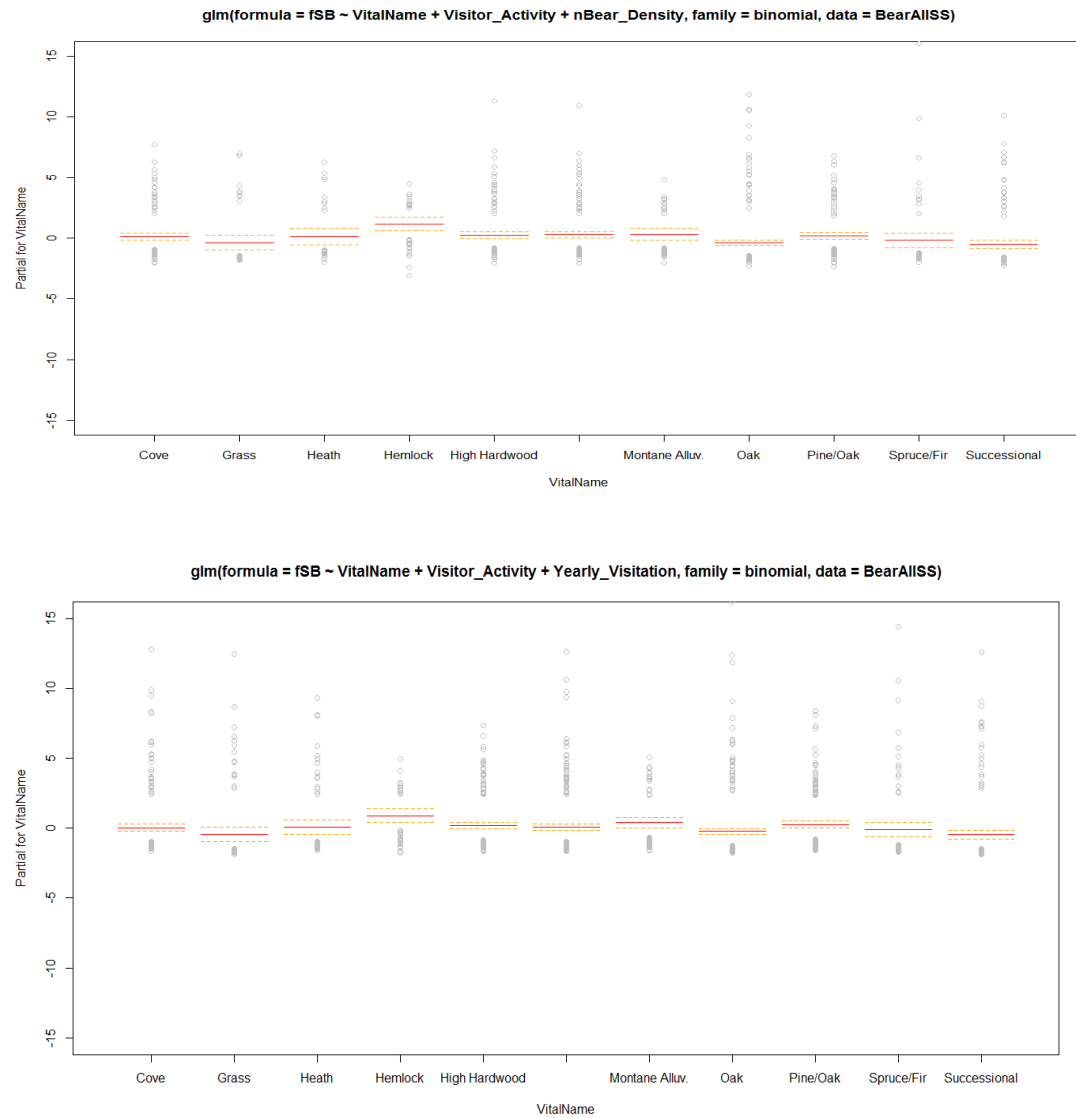


Figure 18. HBI termplots of vegetation cover for models M38.g and M45.fs.B respectively.

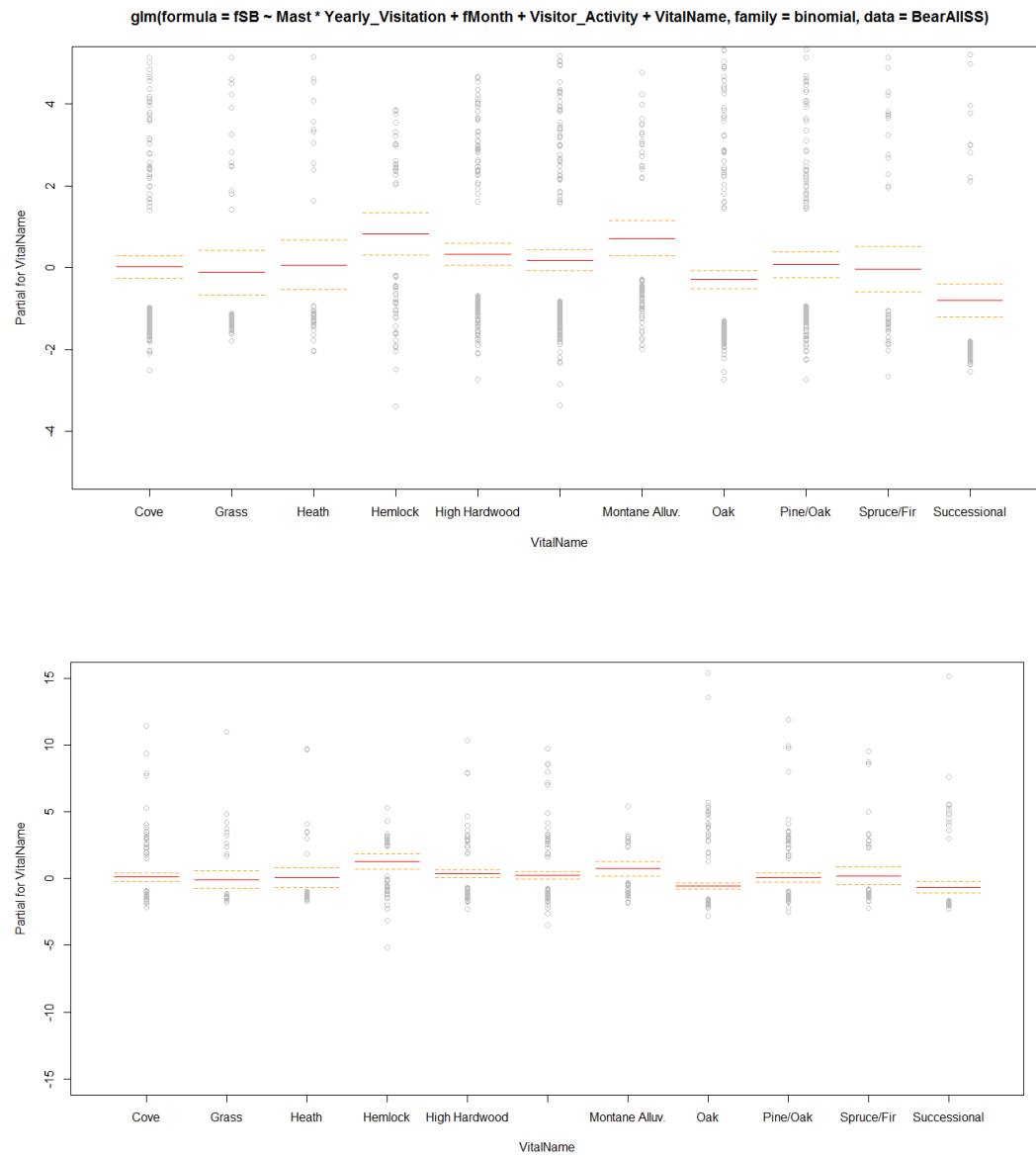


Figure 19. HBI termplots of relative bear abundance for models M41.f and M45.fs.B respectively.

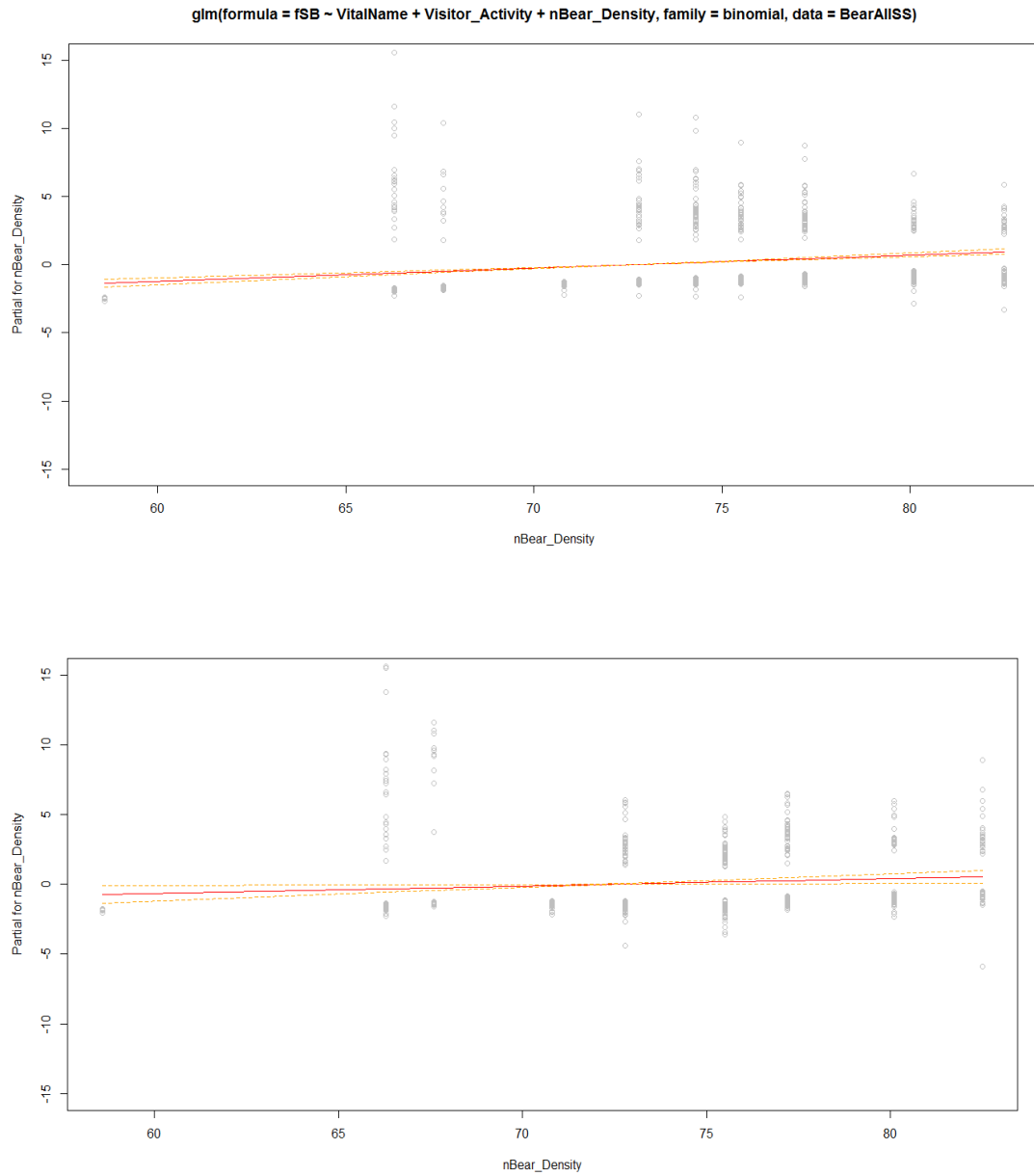
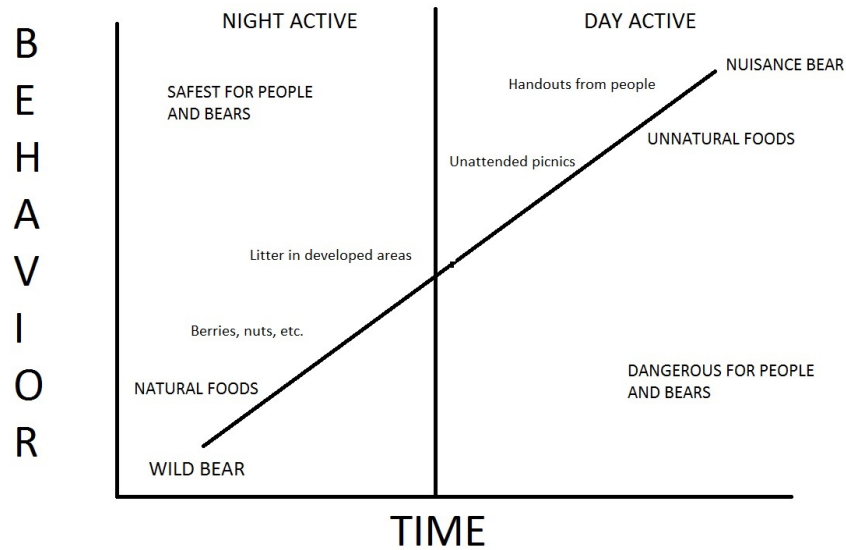


Figure 20. Hypothetical diagram of the progression of a wild night active bear to a nuisance day active bear through anthropogenic rewards (GSMNP Resource Management, unpubl data).



APPENDIX A

BEAR MANAGEMENT REPORT USED IN GSMNP

REVISED 04/11

BEAR MANAGEMENT REPORT

GREAT SMOKY MOUNTAINS NATIONAL PARK

1 INCIDENT DATE _____ 2 INCIDENT TIME _____

3 LOCATION _____ 5 NAME _____

6 TELEPHONE# _____ 7 E-MAIL _____

8 VISITOR ACTIVITY

- a. None
- b. Camping (Frontcountry)
- c. Camping (Backcountry)
- d. Picnicking
- e. Day hiker
- f. Motorist/Overlook/Road side
- g. Other _____

9 PERSONAL INJURY

Yes _____ No _____

10 PROPERTY DAMAGE

Yes _____ No _____
(Describe in #25)

11 VALUE OF DAMAGED

PROPERTY\$ _____

13 DID BEAR GET FOOD OR GARBAGE

Yes _____ No _____

14 DID BEAR GET A PACK

Yes _____ No _____

15 DID BEAR TEAR INTO A CAR

Yes _____ No _____

16 DID BEAR TEAR INTO A TENT

Yes _____ No _____

17 DID BEAR GET INTO A STRUCTURE/BUILDING

Yes _____ No _____

18 DID BEAR VOCALIZE and/or SWAT GROUND

Yes _____ No _____

19 HOW CLOSE DID THE BEAR APPROACH (Yards) (COMPLETE ALL THAT APPLY)

- a. People: _____
- b. Shelter/Tent: _____
- c. Vehicle/Camper: _____
- d. Picnic Table: _____
- e. Building: _____
- f. Other: _____

20 WAS BEAR SPRAY DEPLOYED

Yes _____ No _____

21 AGE OF BEAR

- a. Unknown
- b. Cub
- c. Yearling
- d. Adult

22 SEX OF BEAR

- a. Unknown
- b. Male
- c. Female

23 SIZE OF BEAR

- a. Small
- b. Medium
- c. Large
- d. Est. Weight _____

24 ASSOCIATED BEARS

- a. None
- b. Cubs: # _____
- c. Yearlings: # _____
- d. Other Bears: # _____

25 DESCRIBE DETAILS OF INCIDENT (INJURY, DAMAGED PROPERTY, ETC: CONTINUE ON BACK IF NEEDED)

26 HAS COMMUNICATIONS BEEN NOTIFIED Yes _____ No _____

Date _____ Time _____ Initials _____

27 FAXED TO RESOURCE MANAGEMENT Yes _____ No _____

RM Fax # (865-430-0341) Date _____

28 REPORTED BY: _____

TO BE COMPLETED BY PARK WILDLIFE MANAGEMENT PERSONNEL: 29 MANAGEMENT ACTIONS TAKEN:

- None
- Bear Jam (Break up)
- Capture
- Attempted Capture

- Monitoring
- Area Closure
- Area Opening
- Aversive Conditioning

- Post Warnings
- Remove Warnings
- Other: _____

APPENDIX B

BEAR WARNING SIGN

4

National Park Service
U.S. Department of the Interior

DANGER!
BEARS
ARE ACTIVE IN THIS
AREA
DO NOT APPROACH THEM!
ATTACKS ON HUMANS HAVE
OCCURRED INFLICTING
SERIOUS INJURIES AND
DEATH

Unlawful Removal of This Sign May Result in Injury to Others.



APPENDIX C

FOOD CABLE SYSTEM FOR BACKCOUNTRY CAMPSITES IN GSMNP

FOOD STORAGE CABLE

Share cables - maximum two backpacks per pulley.
Do not throw ropes over cable.

To suspend food sack/ backpack:

1. Unsnap brass clip from eyebolt in bottom of tree.
2. Use black rubber handles to lower the upper "S" Hooks.
3. Attach food sack/ backpack to upper "S" hook.
4. Use black rubber handles to pull up food sack/backpack.
5. Reattach brass clip to eyebolt in bottom of tree to suspend food sack/ backpack.

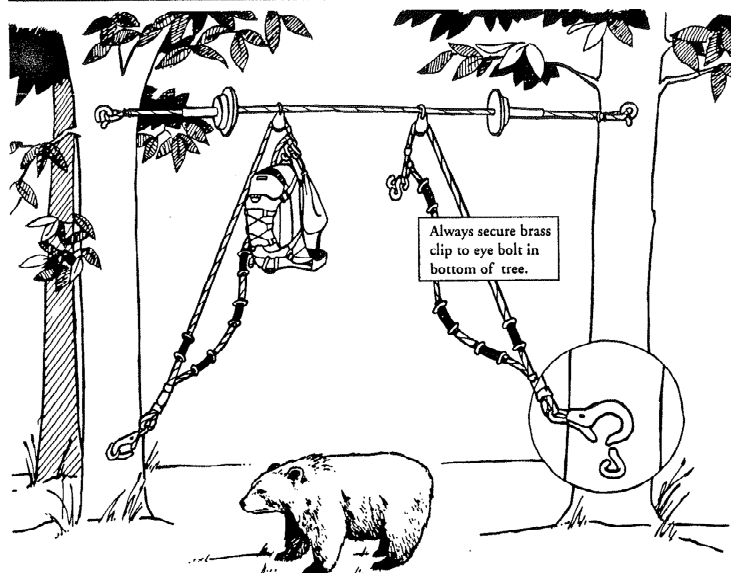
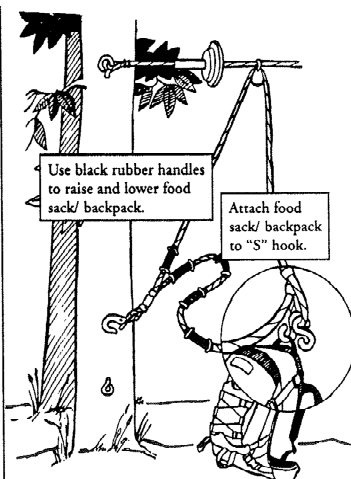
To retrieve food sack/ backpack:

1. Unsnap brass clip from eyebolt in the bottom of tree.
2. Use black rubber handles to slowly lower food sack/ backpack.
3. Reattach brass clip to eyebolt in bottom of tree for the next visitor.

WARNING:

Improper use could cause serious injury

1. Do not handle cables during lightning.
2. Do not stand under any suspended items.
3. Do not swing or hang on cables.
4. Always use black rubber handles to raise and lower food sack/ backpack.
5. Always secure brass clip to eyebolt on tree.



GARBAGE KILLS BEARS

- Secure all food, toothpaste, soap and trash at night or when not in use.
- Do not cook or store food in or near your tent.
- Pack out All your trash, don't bury or burn anything!
- If a bear approaches you, frighten it by yelling, banging pans together, or throwing rocks.



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