AMERICAN BLACK BEAR (*Ursus americanus*) MOVEMENTS AND FOOD-CONDITIONING ALONG THE INTERFACE OF GREAT SMOKY MOUNTAINS NATIONAL PARK AND PRIVATE LAND

A Thesis Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Jessica Leigh-Ann Braunstein
May 2019

ACKNOWLEDGEMENTS

A project of this scope would not have been possible without the assistance, funding, and encouragement of a huge number of individuals, and to these people I am incredibly grateful. Firstly, I owe many thanks to my major professor, Dr. Joe Clark, for providing me with this opportunity to pursue a dream of mine in Great Smoky Mountains National Park. I could not have imagined having a better advisor, project, or study area. I will always be grateful that he kept me on as a student despite asking him what species a skull was on his desk (bear) on my first day of work. I also thank my committee members: Bill Stiver, Dr. John Zobel, and Dr. Lisa Muller. Their wisdom and guidance have been paramount, and I cannot thank them enough. I thank Terry White for all of her administrative assistance. From project budgets to processing endless forms, Terry did it all.

Many thanks are due to the wonderful people at Great Smoky Mountains National Park: Bill Stiver, Ryan Williamson, Rick Varner, Joe Yarkovich, Greg Grieco, Zack Copeland, Nick Melton, Kendra Straub, Tom Colson, and the countless interns and volunteers. It was truly a joy to work with each of these individuals and to learn from them. Special thanks to Ryan Williamson for always being willing to teach others, being open to continuous learning, making every day in the field an adventure, and making me laugh daily with strange Cosby sayings. Few people work as hard as Ryan and with a contagiously positive attitude. I also thank Bill Stiver for all of the tidbits of wisdom and encouragement about both bears and life and for exemplifying what great leadership should look like. I looked forward to going to work in the field every day thanks to the Smokies wildlife crew.

I cannot thank my fellow graduate students enough—Jake Humm, Patrick Helm, Kyle Brasil, Hannah Mullally, and Coy Blair. I have many great stories crawling through rhododendron and daydreaming of Fruit-Loop milkshakes with Coy. Jake and Patrick, thanks for filling the cubicles with laughter and strange sounds and walking through a tough season of life with me. Hannah, thanks for always lending an ear and tackling some tough workouts in the company of a bunch of sweaty, 19-year-old men.

I also thank my wonderful summer technician, Josh Alston, and the many undergraduate volunteers that have come out in the field with me the past few years. I cannot thank Josh enough for his incredible work ethic—many a bear was collared thanks to his hard work and willingness to wake up at the crack of dawn day after day. I also have to acknowledge Josh for single-handedly catching the ugliest bear I've ever laid eyes on for this project.

I also thank my family and friends for their continuous support as I pursue my dreams and stay a perpetual student (I promise I'll get a real job one day). I thank my parents for always encouraging me to work hard in school and to go play in the woods. Thanks to my siblings, Jennifer and James, and their wonderful spouses for listening to my field stories and tagging along when possible. I also wish to thank a recent addition in my life, Jevin Hoeper. Thank you for making the writing stage of this project, and life in general, full of laughter, encouragement, and love. Writing a thesis is tedious, but Jevin made it much more bearable (pun definitely intended).

Finally, I thank the many agencies and groups that provided funding for this project: United States Geological Survey, the National Park Service, Tennessee Wildlife Resources

Agency, and Friends of the Smokies. I will always be grateful for this opportunity to contribute to wildlife research and management in a place near and dear to my heart.

ABSTRACT

The American black bear, *Ursus americanus*, is an iconic symbol of Great Smoky Mountains National Park (GRSM or park), and park officials have speculated that bears developed conflict behavior outside of the park's boundaries. The aim of my study was to better understand black bear space use within GRSM and on surrounding private lands and identify factors resulting in advanced conflict behavior in the park. I used carbon isotopic signatures ($\delta^{13}C$), from black bear hairs to distinguish between food-conditioned (FC) and non-food-conditioned (NFC) bears. I radio-collared FC and NFC bears and estimated annual and seasonal 95% kernel density estimation (KDE) home ranges. I then used conditional logistic regression to estimate a step selection function (SSF) to characterize movement of bears based on landscape characteristics and to determine if bears with higher mean $\delta^{13}C$ used the landscape differently. Based on a logistic regression model with $\delta^{13}C$ as a predictor variable, 24 bear hair samples were classified as FC (16M:8F) and 37 were classified as NFC (14M:23F). Annual 95% KDE home-ranges of female bears differed by year (P = 0.003-0.007) but not mean $\delta^{13}C$ (P = 0.230-0.240). However, the mean proportion of development within female 95% KDE home ranges differed by mean $\delta^{13}C$ ($P < 0.001$). Annual 95% KDE home-range sizes of male bears did not differ based on mean $\delta^{13}C$ (P = 0.132) or year (P = 0.520). The mean proportion of development within male 95% KDE home ranges differed by mean $\delta^{13}C$ (P = 0.022), and the mean proportion of development within home ranges tended to increase as mean $\delta^{13}C$ increased. The top SSF model indicated that bears with higher mean $\delta^{13}C$ had higher selection for low to moderate percent canopy cover and higher selection for slopes >15 degrees. The

SSF model can be used to identify potential landscape modifications that could reduce the probability of bears using particular areas. Modifications could include reducing escape and canopy cover, particularly on moderate slopes. Managers will need to continue to collaborate with the communities surrounding GRSM to minimize the development of conflict behavior.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

Background

The American black bear, *Ursus americanus*, is an iconic symbol of Great Smoky Mountains National Park (GRSM or park), currently the most visited National Park in the United States. Over 11 million visitors visited the park in 2016, many with hopes of catching a glimpse of one of the park's numerous bears (National Park Service [NPS] 2018). The black bear population in Tennessee significantly declined following the arrival of European settlers. The bear population was negatively impacted by factors including extensive habitat loss because of land-clearing, overharvest because of unregulated hunting, and the loss of an important fall food item following the arrival of a blight on American chestnut (*Castanea dentata*, Pelton 2001). The designation of the Smokies as a National Park in 1934 helped to protect bears within its boundaries, and the black bear population increased as a result. In 1973, Coley (1995) estimated 100 bears within GRSM. The population increased to an estimated 118 bears in 1980, 165 bears in 1985, and 458 bears in 1990 (McLean 1991, Coley 1995). The current estimate is about 1,600 bears (F. T. van Manen, University of Tennessee, unpublished data).

Bear management practices within GRSM have evolved over the decades since the park's formation. Specific bear-related management actions were essentially non-existent in the early days of the park when the bear population was low. The intentional feeding of bears was once common, particularly at roadside parking areas, and there were initially no regulations prohibiting this practice. Furthermore, roadside garbage containers were not bear-resistant and were an easily accessible food resource for bears. The park began removing these roadside garbage containers and installing bear-resistant trash cans in human-use areas during the late 1960s through early 1970s. However, the large volume of park visitors, particularly during July and August, resulted in trash accumulation in campgrounds and picnic areas that could not always be accommodated. Visitors would often leave trash beside full trash cans which created an easily accessible food source for bears. During the 1990s, the park began emphasizing sanitation (i.e., trash management) in several new ways. Picnic areas were closed earlier in the evenings, and the park replaced the trash cans with large-capacity bear-resistant dumpsters to accommodate larger volumes of garbage. Some park maintenance staff worked evening schedules to remove any unsecured garbage or other potential attractants from picnic areas after the evening closures. Additionally, the park implemented aversive conditioning techniques to discourage bears from frequenting areas with tourists and scavenging for trash. These changes resulted in a decrease in the number of bear-related human injuries, relocated bears, and euthanized bears each year (W. H. Stiver, NPS, personal communication).

Wildlife managers at GRSM have adopted an aggressive, proactive approach to prevent bears from becoming food-conditioned and visiting picnic areas and campgrounds. Black bears are naturally wary creatures, generally choosing to avoid humans (Powell et al. 1997) but, during spring and early summer when natural foods are sparse, hungry bears or young exploratory individuals may wander into a picnic area or campground during the night when human activity is limited. Park officials monitor campgrounds and picnic areas in the evenings, looking for these night-active bears. When a night-active bear is observed, park officials administer negative conditioning (e.g., on-site capture and release, strike with a paintball gun) to scare the bear away. This aversive conditioning, when administered to early offenders, is often enough to prevent future incidences of this conflict behavior (Clark 1999). Bears that receive no aversive conditioning and repeatedly visit campgrounds and picnic areas are more likely to visit these human-use areas during daylight (Clark et al. 2002, W.H. Stiver, NPS, personal communication). Day-active bears are more likely to be relocated than their night-active counterparts (Clark et al. 2002). Once day-active conflict behavior is established, it is difficult to reverse (Peine 2001).

The park's proactive management approach has been successful at reducing the number of bears annually relocated or euthanized by preventing advanced conflict behavior from becoming established (W.H. Stiver, NPS, personal communication). However, in recent years, park officials have noticed bears displaying more advanced conflict behavior (i.e., frequenting campground and picnic areas during the day) without having been observed during nightly bear monitoring. Although park officials speculate that these bears may have developed conflict behavior outside of the park's boundaries, the origin and cause of this advanced day-activity remains unclear. Cities and communities that border the park likely offer novel anthropogenic food sources such as bird seed, pet food, and garbage. Housing densities in these areas ranged from rural (<1 housing unit per 16.2 ha, Brown et al. 2005) to suburban (1.47–10 housing units per ha, Vukomanovic et al. 2013), with exurban development densities falling between rural and suburban. Exurban landscapes have been shown to facilitate human-bear interactions in Connecticut (Evans et al. 2014), and a similar process may be occurring on private lands surrounding GRSM. Additionally, park campgrounds, picnic areas, backcountry campsites and shelters, roads, and popular hiking trails are also interspersed throughout bear habitat. These areas may bring bears into further contact with humans and their foods. Other potential factors related to advanced conflict behavior include a lack of natural food items (Peine 2001, Baruch-Mordo et al. 2008), life history characteristics such as age and number of cubs (Elfström et al. 2012), season and weather (Baruch-Mordo et al. 2008), and competition among conspecifics (Elfström et al. 2012).

The impact that communities surrounding GRSM have on conflict behavior of bears in GRSM is unclear. Gatlinburg, Tennessee is one of the largest cities adjacent to GRSM and is located on the park's northern border. In 2000, the City of Gatlinburg passed City Ordinance 2188, which required that residents and business owners within the ordinance zone use bear-resistant garbage collective devices or enclosures to prevent bears from accessing garbage. The ordinance also forbade the intentional and unintentional feeding (e.g., leaving out bird feeders or pet food where bears could access them) of bears. The ordinance zone was designed to serve as a trash-free buffer for bears that left park boundaries and entered Gatlinburg. The hope was that these bears would not be able to find anthropogenic foods and return to GRSM. Currently, Gatlinburg is the only city or community adjacent to GRSM with a legal mandate requiring residents to use bear-resistant containers and to make feeding of black bears unlawful. However, the ordinance zone included areas adjacent to the park boundary but did not cover the entirety of Gatlinburg. The implementation of an ordinance zone is one example of how communities can become "BearWise", a designation that black bear managers in the eastern United States have adopted to identify areas that have made efforts to practice peaceful coexistence between bears and humans (BearWise 2018).

Conflict bears in GRSM make up a small proportion of the total bear population, but these bears can cause hundreds to thousands of dollars in property damage annually (W.H. Stiver, NPS, personal communication). Bears that become conditioned to humans may become bolder than normal, spending more time and in closer proximity to human-use areas. This not only puts humans at risk but bears utilizing human developments are three to four times more likely to be killed by humans compared with their wild counterparts (Wilder et al. 2007). Despite the introduction of the city ordinance, Gatlinburg continues to have regular bear conflict issues. To better protect both bears and people, it is critical to understand black bear space use within GRSM and on surrounding private lands and identify factors resulting in advanced conflict behavior in the park. This information could then be used by park staff and state wildlife agencies to improve bear management.

Justification and Scope of Study

GPS Movement Data

In the nearly 50 years of black bear research in GRSM, my study is the first to utilize global positioning system (GPS) radio telemetry to study bear movements. All previous studies solely relied on very high frequency (VHF) radio collars for describing bear movements. An advantage of VHF radio collars is their low cost; however, collecting location data is labor-intensive and time-consuming, particularly if the animal is in a remote area inaccessible by vehicle. To estimate an animal location, researchers using VHF methods record intersecting azimuths at 3 separate locations, a process referred to as triangulation. In theory, the animal will be in the middle of the three intersecting lines. However, these location estimations are subject to error (e.g., false azimuths, recording errors, animal movement between azimuths; Mech and Barber 2002) and may not provide a precise location. Moreover, the time required to collect these triangulation fixes ultimately reduces the number of locations that can be estimated and often results in locations that are disproportionate in space or time due to accessibility limitations. In contrast, GPS radio-collars can automatically collect highly accurate location data many times throughout a 24-hr period. The accuracy of GPS radio collars enables researchers to detect fine-scale movements. If an animal exhibits exploratory behavior or wanders far from its normal home range, GPS radio collars are more likely to capture those movements. Consequently, wildlife tracking with GPS technology has allowed researchers to look at animal movements in more detail than ever before and during time windows that would have rarely been possible with VHF collars (Mech and Barber 2002).

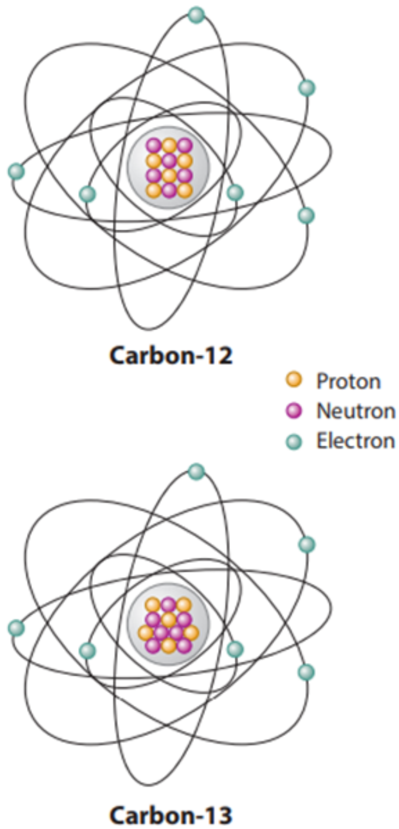
Food-conditioning Determined by Stable Isotope Analysis

All of earth's elements are made up of atoms that consist of protons, neutrons, and electrons. Different elements are distinguished by their unique number of protons, and protons combined with neutrons make up an atom's atomic weight. Isotopes are atoms of the same element but with different numbers of neutrons, and therefore, different atomic weights. An isotope with more neutrons will have a higher atomic weight and is therefore referred to as a "heavy" isotope, and an isotope with fewer neutrons will be referred to as a "light" isotope.

Many elements have multiple isotopes that are commonly found in nature, with one or more typically being more abundant (Figure 1). Two isotopes of the same element are often expressed as a ratio, and this ratio is compared to a common international standard to produce a δ value. The δ value is reported in parts per thousand (‰). Isotopes that do not undergo radioactive decay are referred to as stable isotopes.

When an animal eats, the elemental composition of the consumed foods is incorporated into developing tissues such as hair, blood, and muscle thereby providing a record of diet. Plants can be categorized as C_3, C_4, or CAM plants depending on how they fix carbon during the process of photosynthesis. The C_3 plants produce a three-carbon compound, 3-phosphoglyceric acid, during carbon fixation. The C_4 plants produce an intermediate four-carbon compound, malic acid or aspartic acid, during the carbon fixation process. The CAM plants use the crassulacean acid metabolic pathway to minimize photorespiration during photosynthesis.

Carbon isotopic ratios can be useful measures of relative C_4 plant (i.e., corn, sugarcane) consumption compared with C_3 plant consumption by comparing the ratio of heavy (^{13}C) to light (^{12}C) isotopes. Plants with a C_3 photosynthetic pathway are globally more abundant than plants with a C_4 pathway. In the southern Appalachian region, C_4 plants make up <0.5% of the vegetation (Still et al. 2003). Typical black bear diets are dominated by C_3 plants (Teunissen van Manen 2011, Hopkins et al. 2012, Bentzen et al. 2014). Corn and sugar cane, two widely consumed anthropogenic food products in the United States, are C_4 plants (O'Brien 2015). The $\delta^{13}C$ of C_3 plants is typically a value of -27‰ whereas C_4 plants have values of approximately -12‰ (West et al. 2006). Consequently, bear tissue with enriched ^{13}C is suggestive of a more



Element	Stable isotopes	Abundance (%)*
Hydrogen	^{1}H (H)	99.985
	^{2}H(D)**	0.015
Carbon	^{12}C	98.892
	^{13}C	1.108
Nitrogen	^{14}N	99.635
	^{15}N	0.365
Oxygen	^{16}O	99.759
	^{17}O	0.037
	^{18}O	0.204
Sulfur	^{32}S	95.0
	^{33}S	0.75
	^{34}S	4.21
	^{35}S	0.014

*Abundance does not always sum to 100% because radioisotopes are omitted from this table

**D = deuterium, ^{2}H:^{1}H is often given as D:H

Figure 1. Example of carbon isotopes' atomic structures and other stable isotopes found in nature (from O'Brien 2015).

anthropogenic diet.

Nitrogen isotopic ratios can serve as an indicator of the importance of meat in the diet, with ^{15}N in tissue increasing with each trophic level (Hopkins et al. 2012, Seger et al. 2013). Although black bears will consume meat, they are opportunistic and will utilize what is readily available; Beeman and Pelton (1980) found the bears consumed low amounts of meat in GRSM. Therefore, enriched ^{15}N may also indicate access to anthropogenic food sources that include meat products. Stable isotopic signatures of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) have been successfully used to identify bears utilizing anthropogenic food resources (Mizukami et al. 2005a, Mizukami et al. 2005b, Merkle et al. 2011a, Hopkins et al. 2012, Bentzen et al. 2014).

Drivers of Bear Movements

It is important to understand how food-conditioned and non-food conditioned bears utilize the landscape in moving between GRSM and exurban areas. Step-selection functions are excellent tools for better understanding such stepwise movements. Step-selection function were developed in response to limitations of resource selection functions (RSF, Manly et al. 2002). For example, a RSF assumes that an animal will select for higher quality resources more often than lower quality resources to meet life requirements. A RSF compares used resources to those that are available to draw conclusions about animal resource selection. However, resources may not be uniformly distributed in nature, and availability may vary by individual or may change as a result of an animal moving across the landscape (Arthur et al. 1996, Manly et al. 2002). Step-selection functions break down the movement paths of animals collected by the radio collars into “steps” which are defined as the straight-line segments between successive locations. A step-length and turning angle is calculated for each, and these observed steps are then paired with a user-defined number of random steps, or steps that could have been chosen but were not. These random steps are of varying lengths and turning angles (based either on empirical data or probability distributions) and are unique for each animal and step. The observed and random steps can be compared in models to understand factors contributing to an animal's movements (Fortin et al. 2005). Fortin et al. (2005) used SSF to explore how different environmental factors were affecting the movements of GPS radio-collared elk. Clark et al. (2015) used SSF to examine connectivity among subpopulations of black bears in Louisiana where suitable bear habitat was highly fragmented.

Objectives and Hypotheses

Objectives

My study objectives were to:

1) Determine whether isotopic signatures, $\delta^{13}C$ and $\delta^{15}N$, from black bear hairs can be used to distinguish between food-conditioned (FC) and non-food-conditioned (NFC) bears,
2) Determine whether FC bears have different home range sizes and exploit exurban areas to a greater extent than do NFC bears,
3) Evaluate whether bears with conflict histories in GRSM are more likely to have movements that include exurban areas, and
4) Characterize movement behavior of bears based on landscape characteristics and

evaluate whether FC and NFC bears use the landscape differently.

Hypotheses

I hypothesized that:

1) FC bears will exhibit enriched $\delta^{13}C$ and $\delta^{15}N$ signatures, suggesting use of anthropogenic foods, compared with NFC individuals,
2) FC bears will have smaller home ranges and greater overlap with developed areas within and adjacent to the park than do NFC bears,
3) Bears with conflict histories within GRSM will be more likely to exploit developed areas than bears without conflict histories, and
4) FC bears will move on the landscape differently than NFC bears.

CHAPTER 2. STUDY AREA

General

Great Smoky Mountains National Park was established in 1934 and encompasses approximately 2,114 km^2 along the eastern Tennessee and western North Carolina border. The park follows the ridgeline of the Great Smoky Mountains which are part of the Blue Ridge Mountain range. The park is known for its rich and unique biodiversity and received the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) designation as an International Biosphere Reserve in 1976. In 1983, GRSM was designated as a UNESCO World Heritage Site, a designation reserved for areas considered to have special cultural or physical significance.

Both private and public lands surround the park. Several cities and communities border the park including Fontana, Townsend, Wears Valley, Gatlinburg, and Cosby in Tennessee and Maggie Valley, Cherokee, and Bryson City in North Carolina. These cities support a thriving tourist industry, and >11 million of these tourists visit the park each year. The park also shares a border with three National Forests: Cherokee, Pisgah, and Nantahala. Lake Fontana forms the southwest border of the park (Figure 2).

Topography and Geology

Terrain in GRSM is characterized by steep slopes and ridges descending from a high ridgeline traversing the center of the park where the Tennessee and North Carolina borders

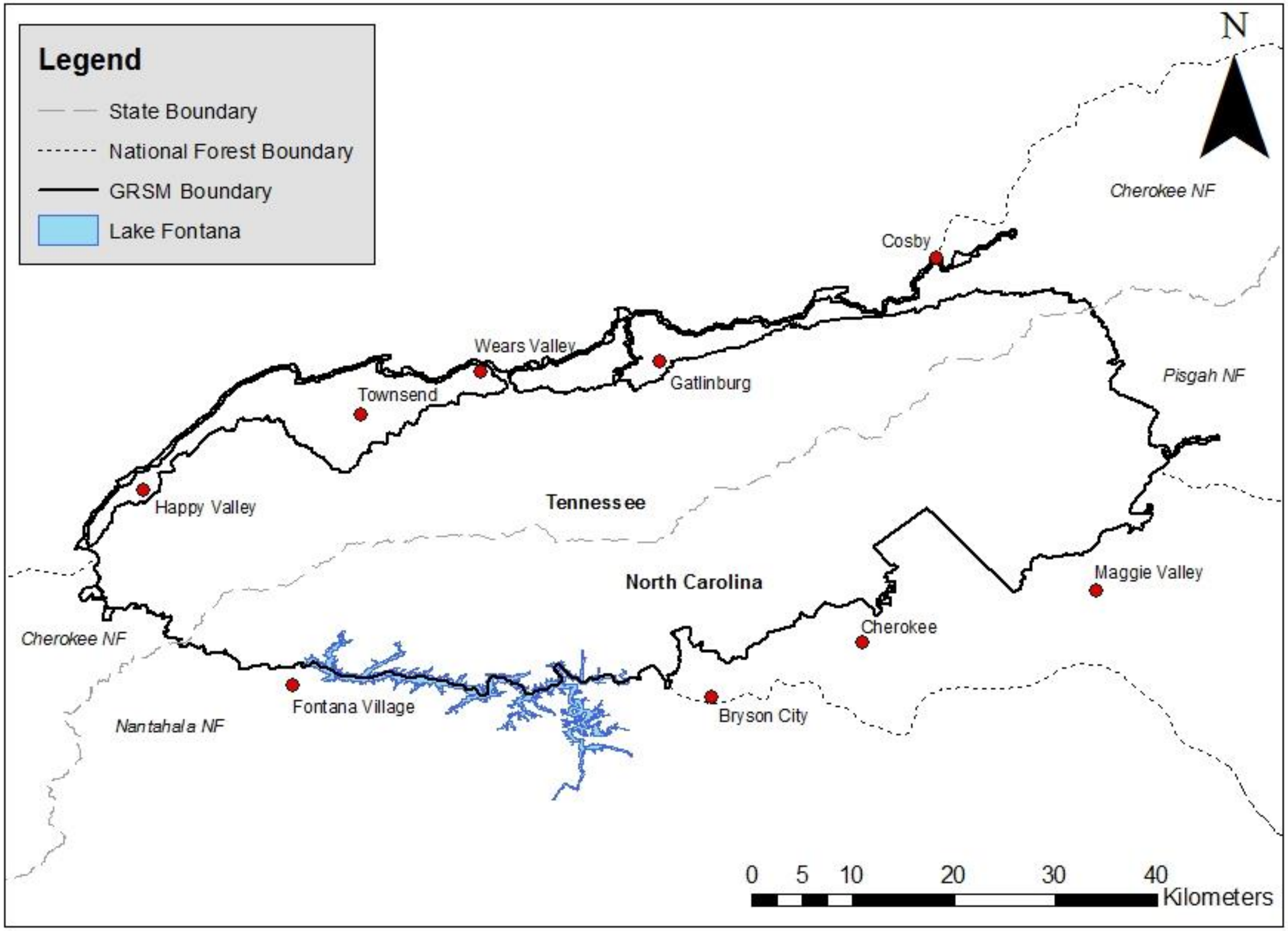


Figure 2. Great Smoky Mountains National Park (GRSM).

meet. Clingmans Dome is the highest point in the park at 2,025 m. Spur ridges descend from the highest points along the states' borders towards the foothills of the Appalachian Valley in Tennessee and the Blue Ridge Mountains in North Carolina. The lowest elevation in the park is 266 m (King et al. 1968, NPS 2018).

Much of the bedrock found in GRSM is sedimentary with pebbly, sandy, and muddy characterization. The rocks that comprise most of the park were thought to have been formed during the late Precambrian period as part of the Ocoee Series. Deformation of the Ocoee Series occurred until late in the Paleozoic period and raised the entire Appalachian region while contributing to the formation of the Great Smoky Mountains range. Since the Paleozoic, the Great Smoky Mountains range has undergone continuous erosion with occasional periods of uplift (King et al. 1968).

Climate

Average rainfall and temperatures in the park varied by elevation. Average annual rainfall at low and high elevations in GRSM were about 140 and 215 cm, respectively. Average high temperatures at Clingmans Dome were 2.1°C, 9.1°C, 17.8°C, and 10.9°C in winter, spring, summer, and fall, respectively. Average low temperatures at Clingmans Dome were -5.2°C, 0.9°C, 10.7°C, and 3.2°C in the winter, spring, summer, and fall, respectively. Average high temperatures in Gatlinburg, which was in a valley, were 11.3°C, 21.3°C, 30.6°C, and 22.4°C in winter, spring, summer, and fall, respectively. Average low temperatures in Gatlinburg were -2.1°C, 5.6°C, 15.0°C, and 6.5°C in winter, spring, summer, and fall, respectively (NPS 2018).

Vegetation

The wide range of temperatures, elevations, and precipitation levels found throughout the park promote rich plant diversity. The park supported >1,600 flowering and 4,000 non-flowering plant species, and >70 unique plant community associations have been identified (NPS 2018). The park was home to 100 native tree species and >100 native shrub species, and Jenkins (2007) identified 8 major forest types in GRSM. About 80% of the park was composed of deciduous forest, and major forest types included montane alluvial, early successional, cove, hemlock, montane oak-hickory, xeric ridge, high-elevation hardwood, and spruce-fir forests (Jenkins 2007, NPS 2018). Whereas much of GRSM was heavily forested, important non-forest community types included grassy balds, heath balds, and pasture/old fields.

Fauna

The variety of habitat types in GRSM supported a diverse range of animals including 65 mammalian species, 200 bird species, 80 reptile and amphibian species, and 50 native fish species. The park has been referred to as the "Salamander Capital of the World", boasting approximately 30 salamander species (Sharkey 2001, NPS 2018). The park also served as a sanctuary for several species that are federally listed as Federally Threatened or Endangered, and GRSM staff have made efforts to save these species from extinction and reintroduce extirpated species. Wildlife viewing within GRSM attracted tourists to several popular viewing areas including Cades Cove, Oconaluftee, and Cataloochee Valley where visitors see large mammal species such as wild turkeys (*Meleagris gallopavo*), white-tailed deer (*Odocoileus* *virginianus*), elk (*Cervus canadensis*), and black bears (NPS 2018). The black bear has become an unofficial symbol of GRSM, and the bear population in GRSM and surrounding areas has experienced significant growth since the park's establishment.

Land Use

The park was surrounded by both private and public land. The park's Tennessee border was adjacent to Blount, Sevier, and Cocke counties which have all experienced population growth in the past several decades (Middleton & Murrary 2009, U.S. Census Bureau 2010). In 1990, estimated human populations in Blount, Sevier, and Cocke counties were 85,962, 51,050, and 29,141 respectively. In 2017, estimated populations in Blount, Sevier, and Cocke counties had grown to 129,929, 97,638, and 35,556 (U.S. Census Bureau 2010). Blount and Sevier Counties were projected to be within the top third of Tennessee counties for projected growth rates, and Sevier County was one of the top ten for projected growth rates (University of Tennessee 2017). The park's North Carolina border was adjacent to Swain and Haywood counties. In 1990, Haywood County had an estimated population of 46,948 individuals and Swain County had an estimated population of 11,268 individuals. In 2017, Haywood and Swain counties had estimated populations of 61,084 and 14,294 people, respectively (U.S. Census Bureau 2010). All five of these counties had varying degrees of development ranging from low-intensity to high-intensity, with Sevier and Blount counties having the highest levels of high-intensity development (National Land Cover Database 2011). The Little River Watershed, which includes portions of Blount and Sevier counties, saw an increase in urban areas from 6.3% to

11.1% from 1984 to 2010 (Zhu and Li 2013).

Much of the conflict bear activity occurred along the park's interface with the city of Gatlinburg, Tennessee and the communities of Wears Valley and Cosby, Tennessee. These communities have also experienced population growth over the preceding several decades. The population of Gatlinburg, a popular mountain resort city, grew by 16.6% from 2000 to 2010, and had a population of about 4,000 in 2010 (U.S. Census Bureau 2010). Wears Valley and Cosby were smaller rural communities located along the park's northern border that supported tourism and agricultural land use. All of these communities offered remote vacation rental homes that were adjacent to park boundaries and oftentimes interspersed within forest cover. The high demand for vacation home site development adjacent to the park has resulted in a lack of vegetational continuity at the park's boundary and has created large amounts of new forest edge (Ambrose and Bratton 1990).

The park was adjacent to Cherokee National Forest in Tennessee and Pisgah and Nantahala national forests in North Carolina. Combined, these forests encompassed 6,700-km^2. Unlike GRSM, the National Forests were managed for multiple uses including timber, recreation, and wildlife (United States Forest Service 2018).

Recreation and Tourism

The park offered numerous recreational opportunities for visitors including horseback riding, fishing, wildlife viewing, backpacking, camping, hiking, photography, and swimming. In addition to 11 picnic areas, GRSM had 10 developed campgrounds, which included restroom facilities, fire grates, and picnic tables. Additionally, the park had >1,200 kilometers of trails used by an estimated 400,000 hikers annually. There were >100 backcountry campsites and shelters spread throughout the park, and GRSM had >600 km of roadway within its boundaries (NPS 2018). While hunting was prohibited within GRSM boundaries, black bear hunting was allowed during the fall and winter in the surrounding national forests, state wildlife management areas, and private lands.

The park was known for high biodiversity, and many visitors came specifically to view and photograph flora and fauna. Spring wildflower viewing drew large crowds each year, and park visitation increased significantly during October as autumn leaves changed color. Many visitors came for wildlife viewing, particularly to see some of the park's larger mammal species including wild turkeys, white-tailed deer, elk, and black bears.

The park served as an economic hub for the region by drawing in tourists and supporting over 10,000 jobs in surrounding cities and communities. Park visitors were estimated to have spent about $734 million in surrounding communities in 2013 (NPS 2018). Popular tourist destinations surrounding GRSM included Gatlinburg, Wears Valley, Townsend, and Fontana in Tennessee and Cherokee and Bryson City in North Carolina.

CHAPTER 3. MATERIALS AND METHODS

Study Area Definition

My study took place in GRSM and on private and public lands bordering the park. I focused trapping efforts primarily within GRSM, specifically on the northern (Tennessee) portion of the park. Historically, the portion of GRSM in Tennessee has received a majority of conflict reports, and these reports were commonly located within close proximity to towns and cities bordering the park. My trapping efforts were centered around the areas of the park bordering Cosby, Wears Valley, and Gatlinburg, TN and around human-use areas within GRSM (Figure 3).

Black Bear Capture and Handling

Trapping Methods

I began trapping bears during the summer of 2015 and continued throughout the summers of 2016 and 2017. Two forms of trapping occurred: conflict and backcountry. Trapping for conflict bears typically was focused on an individual or group of individual bears known to be involved in conflict behavior (e.g., picnic areas, campground, backcountry shelters) inside GRSM (Figure 3). Traps were set in proximity to the conflict incident and traps were removed after the putative offending individual was caught. Trapping for backcountry bears was more temporally and spatially dispersed. I only trapped for bears in backcountry areas of the park, or backcountry bears, during summer 2017, and I used these animals as a control

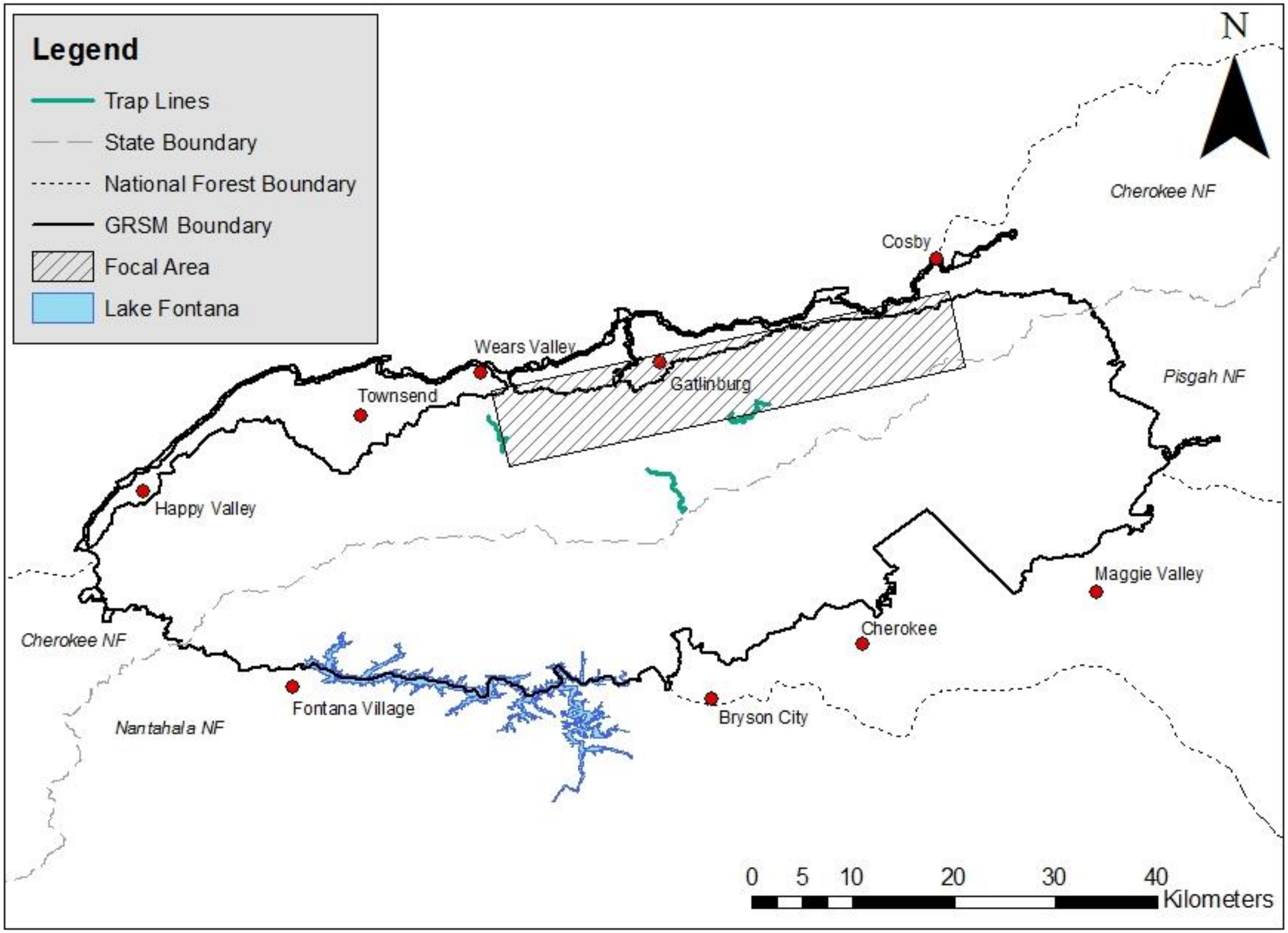


Figure 3. Great Smoky Mountains National Park (GRSM) with study focal area emphasized.

group. Traps were set over a broad backcountry area and were checked for a pre-specified period of time or until a sufficient sample size had been achieved. I set up trap lines on Curry Mountain, Sugarland Mountain, and Brushy Mountain trails (Figure 3). These trails were chosen because they were further away from human-use areas compared with other trails in GRSM. I hypothesized animals captured on these trails were less likely to be food-conditioned or to have developed conflict behaviors. I used a combination of free-range darting and culvert traps near the park's northern boundary to capture conflict bears. I used modified Aldrich foot snares (Johnson & Pelton 1980) to trap backcountry bears and conflict bears when vehicle access was limited.

Animal Handling

I chemically immobilized captured bears using a mixture of ketamine (200 mg/ml) and xylazine (100 mg/ml) or a commercial drug combination of butorphanol, azaperone, and medetomidine (BAM, Williamson et al. 2018). When using a mixture of ketamine and xylazine, bears received a dose of 5-8 mg/kg of ketamine and 1-4 mg/kg of xylazine intramuscularly using a jab pole or dart projector. When using BAM, bears were immobilized intramuscularly using an estimated 0.5 mL 23 kg BAM (Williamson et al. 2018). Anesthetized animals were marked with uniquely numbered metal or plastic ear tags, a lip tattoo placed on the inside of the upper lip, and a passive integrated transponder (PIT) tag. I extracted the first upper premolar for age determination and then stored the tooth in a labeled coin envelope. Teeth were sent to Matson's Laboratory in Manhattan, Montana for aging. I recorded standard body measurements and collected full-length guard hairs from the shoulder and back area from each bear. I stored hair samples in a labeled coin envelope at room temperature and away from light. I also collected a 10-ml blood sample from the femoral vein using a no-additive Vacutainer (BD, Franklin Lakes, NJ, USA). I fitted bears with GPS radio collars (Vectronic Aerospace GmbH, GPS PLUS Iridium, Berlin, Germany) for the study. The collars were programmed with a virtual fence, and location fixes were acquired at 2-hour intervals while collared bears were within park boundaries and at 20-minute intervals when bears left the virtual fence area. The virtual fence was adjacent to the park boundary with a buffer of about 400-m inside the boundary. Following animal processing, bears immobilized using a combination of ketamine and xylazine recovered without assistance or were intravenously administered the antagonist drug Yohimbine (20 mg/ml) at a dose of 0.2 mg/kg prior to release at the capture location. Bears that were immobilized with BAM were intramuscularly administered atipamezole (25 mg/ml) at twice the volume of BAM dose and naltrexone (50 mg/ml) at a dose of 0.5 ml per animal (Williamson et al. 2018). Animal handling procedures were approved by the University of Tennessee's Institutional Animal Care and Use Committee (UTK-IACUC #: 2338-0515).

GPS Data Pre-processing

Fix rates and location error of GPS radio collars can vary due to factors such as collar orientation on the animal, canopy cover, topography, and animal activity (D'eon & Delparte 2005, Lewis et al. 2007, Lewis & Rachlow 2011). Therefore, I screened GPS fixes prior to analysis to remove inaccurate or erroneous locations. I first removed obvious location errors (e.g., pre- and post-deployment fixes) and points collected during the denning season which I defined as December 15-April 1 (van Manen 1994). The number and spacing of satellites used to acquire a location fix impacts the accuracy of triangulation. Each GPS data fix was accompanied by a dilution of precision (DOP) value that is a measure of satellite geometry. Lower DOP values are considered more accurate and 3D fixes, which use 4 satellites, are more accurate than 2D fixes, which use 3 satellites. I omitted all 2D fixes and omitted 3D fixes with a PDOP >7 to reduce location errors (Lewis et al. 2007).

Stable Isotope Analysis

I prepared collected hair samples prior to stable isotope analysis following the methods of O'Connell and Hedges (1999) and O'Connell et al. (2001). First, I took a sample of three to seven unbroken guard hairs with roots, placed them in a clean glass vial, and then rinsed the hairs with deionized (DI) water to remove coarse debris. I then placed the samples underneath a fume hood to dry for approximately 24 hours. Once dry, I transferred the hair samples to a small beaker containing a 2:1 chloroform-methanol solution to remove oils. I covered the beakers with aluminum foil and allowed the hairs to soak in the solution for one hour. After one hour, I replaced the 2:1 chloroform solution with fresh solution and allowed to soak for an additional hour. After the second soak in solution, I rinsed the hair samples quickly with DI water and then allowed the hairs to soak in DI water for 20 minutes. I then drained the samples and soaked the hairs in DI water for another 20 minutes before transferring the samples to clean glass vials. Hair samples were left to air dry for 24 hours. Following drying, I placed the hair samples lengthwise into a 5- x 5-cm piece of aluminum foil for cutting. I removed the hair root from the end of each hair using a razor blade and then used forceps to roll 2-3 hairs into a small clump. I loaded 0.6 to 1.0 mg of the hair samples processed in this manner into a 4- x 6-mm pressed tin capsule (Costech Analytical Technologies, Inc., Valencia, California, USA). For each bear hair sample from a unique capture event, I prepared three replicate samples for stable isotope analysis. All prepared tin capsules were placed in a well tray until all samples were ready for further analysis.

I sent all prepared samples to the Washington State University Stable Isotope Core Laboratory in Pullman, Washington, USA for analysis. Prepared hair samples were converted to N_2 and CO_2 with an elemental analyzer (ECS 4010, Costech Analytical, Valencia, California, USA) and analyzed with a continuous flow isotope ratio mass spectrometer (ThermoFinnigan Delta Plus XP, Bremen, Germany; Brenna et al. 1997, Qi et al. 2003). Isotopic reference materials were interspersed with samples for calibration and the contribution of ^{17}O was corrected using the Santrock correction (Santrock et al. 1985). Carbon isotopic results were reported in per thousand (‰) relative to the Vienna Peedee Belemnite (VPDB) standard (Coplen 1994).

I calculated the mean stable isotope values of the three replicate hair samples and used the means for further analyses. I assigned each hair sample a diet year based on the date of collection. Bears molt during the summer months; therefore, hair samples collected before July 1 of each year were assumed to be representative of the foods consumed the previous year, and hair samples collected after July 1 were assumed to be representative of the current year (Hopkins et al. 2012). I treated hair samples collected from the same bear in different years as independent samples. I tested for isotopic differences among years using analysis of variance (ANOVA, $\alpha = 0.05$).

I classified bears as food-conditioned (FC) and non-food-conditioned (NFC) (Greenleaf 2005, Hopkins et al. 2012) based on capture history (conflict or backcountry) and proximity to anthropogenic foods following release based on telemetry data. I classified bears as unknown if I was uncertain if an individual was relying on human food resources. I used a logistic regression model to determine whether prospective FC and NFC bears had $\delta^{13}C$ and $\delta^{15}N$ ratios consistent with food conditioning. I selected the top model based on Akaike's Information Criterion with an adjustment for small sample sizes (AICc, Anderson 2008) and then used this model to predict the status of the unknown bears. I used a receiver operating characteristic (ROC) curve to determine the probability threshold for classifying unknown bears as either FC or NFC and then used this discrimination threshold value to classify all hair samples. Once samples were classified, I used chi-square tests ($P \leq 0.05$) to examine the relationship between classification as FC or NFC and age class and gender.

Home Range and Core Area Estimates

I estimated annual and seasonal home ranges for each bear as 95% utilization distributions using kernel density estimation (KDE; Worton 1989). I also estimated the core area for each bear using the 50% utilization distribution using KDE (Anderson 1982). The KDE method produces a utilization distribution of an animal's home range by creating isopleths of the frequency that locations are used (Hemson et al. 2005). The KDE method does not limit the shape of the home range to a simple polygon or ellipse, therefore accommodating diverse location patterns and potentially providing more accurate home range estimates compared with other common home range estimators such as minimum convex polygon method, bivariate-normal, and harmonic mean methods (Seaman et al. 1999, Gitzen et al. 2006). This method is sensitive to bandwidth values (i.e., smoothing parameters) with large bandwidths tending to over-smooth the utilization distribution which creates an overestimate of the home-range size. Small bandwidths can produce a fragmented distribution resulting in an underestimate of home-range size (Kernohan et al. 2001, Gitzen et al. 2006). I used sex-specific plug-in bandwidths which tend to slightly over-smooth but eliminates exploratory movements and emphasizes concentrated areas of use (Kernohan et al., 2001, Walter et al. 2011). Plug-in bandwidths also perform better with large data sets such as those generated by GPS radio-collars (Gitzen et al. 2006, Walter et al. 2011).

I estimated annual home range size for years 2015, 2016, and 2017. I estimated seasonal home range size for all bears by defining spring as April 1 to June 15, summer as June 16 to September 15, and fall as September 16 to December 15 (van Manen 1994). I estimated the appropriate bandwidth following the methods detailed in Karelus et al. (2016). I used the "adehabitatHR" package (Calenge 2015) in RStudio (RStudio Team 2016) to estimate overall KDE home ranges for each bear using the ad hoc bandwidth as the smoothing parameter. I then estimated separate plug-in bandwidths for males and females by averaging the ad hoc bandwidths for each gender. I then recalculated the 95% KDE home-ranges using the sex-specific bandwidths (males = 1.214 km; females = 0.555 km). I used ANOVAs ($\alpha = 0.05$) to test for differences in home range and core area sizes based on mean $\delta^{13}C$, gender, and season or year. Finally, I performed post-hoc Tukey tests to determine differences in mean annual 95% KDE home-range sizes and 50% KDE core area sizes by year.

I estimated the proportion of human development within bear home ranges and core areas. I used the National Land Cover Database (NLCD) 2011 to create a human development raster. The NLCD is a 30- x 30-m landcover map of North America, with the area classified as one of 16 land cover classification types. All raster creation and analysis were completed using ArcMap® 10.3 (Environmental Systems Research Institute, Redlands, CA). I created the human development raster by combining the 4 development categories (open space, low-intensity, medium-intensity, and high-intensity) and assigning them a value of 1 and assigning the remaining categories a value of zero. I then used the 'Tabulate Area' tool in ArcMap to calculate the proportion of the home range or core area consisting of development. I used ANOVAs ($\alpha = 0.05$) to test for differences in the mean proportions of development within female and male home ranges and core areas by mean $\delta^{13}C$.

Step Selection Functions

I used a variety of data sources to create landscape variables that I thought would affect bear movements. I used the NLCD 2011 to create a human development raster and an escape cover raster. I created a human development raster by combining the 4 development categories (open space, low-intensity, medium-intensity, and high-intensity) and assigning the remaining categories a value of zero. Additionally, I hypothesized that distance to developed areas may impact bear movements, so I created a distance to development layer using the 'Euclidean Distance' tool in ArcMap. I created an escape cover layer which included deciduous forest, evergreen forest, mixed forest, shrub/scrub, and woody wetlands landcover types. I hypothesized that bears may choose to stay in or near areas with adequate escape cover, so I created a distance to cover layer by calculating the Euclidean distance to the nearest forest. I also used the 'Neighborhood Statistics' tool in ArcMap to create a development density raster within a 1500- x 1500-m focal area. Merkle et al. (2011b) found that distance to riparian areas was an important variable in predicting human-black bear interactions in urban areas in Montana, and a study in Connecticut also found that distance to streams was an important predictor of the location of conflict interactions (Evans et al. 2014). I used data from the USA Detailed Streams dataset (ESRI, U.S. Geological Survey in cooperation with U.S Environmental Protection Agency, 2010) to create a distance to water layer. I used digital elevation model (DEM) data produced by USGS (2017) to create an elevation layer and then used the 'Slope' tool in ArcMap to create a percent slope layer. I created a percent canopy layer using the NLCD 2011 percent tree canopy data. I extracted ridgelines features from the DEM using the 'Hydrology Toolset' in ArcMap and then used the 'Euclidean Distance' tool to create a distance to ridge layer. Finally, I used TIGER/Line® roads data (U.S. Census Bureau 2015) and the 'Euclidean Distance' tool to create a distance to roads layer. I used the "amt" package (Signer 2018) in RStudio to calculate step lengths and turning angles for each collected GPS relocation and to generate 9 random steps for each relocation. Attributes of the landscape data at the end of the observed and random steps were used in the analysis.

I estimated step selection functions using conditional logistic regression using the ‘clogit’ function in the ‘survival’ package (Therneau 2018) in R. I began by conducting a correlation analysis and selected one variable to use for further analysis from correlated pairs (i.e., Spearman’s $r > 0.6$). Distance to development was correlated with both percent development and distance to roads. I chose to only use distance to development for further analyses. I scaled slope, distance to water, and distance to development to facilitate model convergence using the scale function from the ‘base’ package in program R (R Studio Team 2016). I followed the model building strategy outlined by Zhang (2015) using the variables mentioned above and to look for interaction effects with sex, age class (i.e., subadult or adult), season, mean $\delta^{13}C$, and time of day (i.e., dawn, day, dusk, or night). I also tested quadratic effects for the distance variables and slope. I used the lowest Akaike’s Information Criterion scores (AIC, Akaike 1974, Burnham and Anderson 1998) to determine the top models. Variables were retained if the AIC scores were reduced by >2. I used the top model to identify significant landscape factors contributing to bears’ movements.

CHAPTER 4. RESULTS

Capture and Handling

I captured 53 bears (29 males: 24 females) from June 2015 through August 2017 (A.1–A.3, Figure 4). Two bears (1 male: 1 female) were removed from further analysis due to limited GPS data. Forty-three bears were captured in response to reports of conflict behavior (24 males: 19 females) and the remaining 10 bears were captured in the backcountry as putative NFC bears (5 males: 5 females). Ages ranged from 1 to 16 years; 31 were classed as adults, 21 were subadults, and the age of 1 bear was unknown. Over 325,000 GPS locations were collected during the study period (Figure 5).

Stable Isotope Analysis to Identify Food-conditioned Bears

I used the mean $\delta^{13}C$ and $\delta^{15}N$ ratios from 61 hair sample replicates for analyses. Samples were representative of 51 individual bears; the additional 10 hair samples were collected during recapture events. Although mean $\delta^{13}C$ ratios did not vary by year (P = 0.207), $\delta^{15}N$ ratios did (P = 0.030), and a post-hoc Tukey test identified a difference between years 2014 and 2016 (P = 0.070).

I classified 32 (12 male, 20 female) of the hair samples as known FC (n = 13) or known NFC (n = 19) a priori based on known histories and post-release location data. The remaining 29 hair samples were considered to have an unknown conflict status (Figure 6, Table B.1). The top logistic regression model included $\delta^{13}C$ as the sole covariate ($\text{logit}(y) = 66.242 + 2.900\delta^{13}C$, Table B.2). I used a ROC curve to calculate a discrimination threshold (> -23.315 $\delta^{13}C$) for

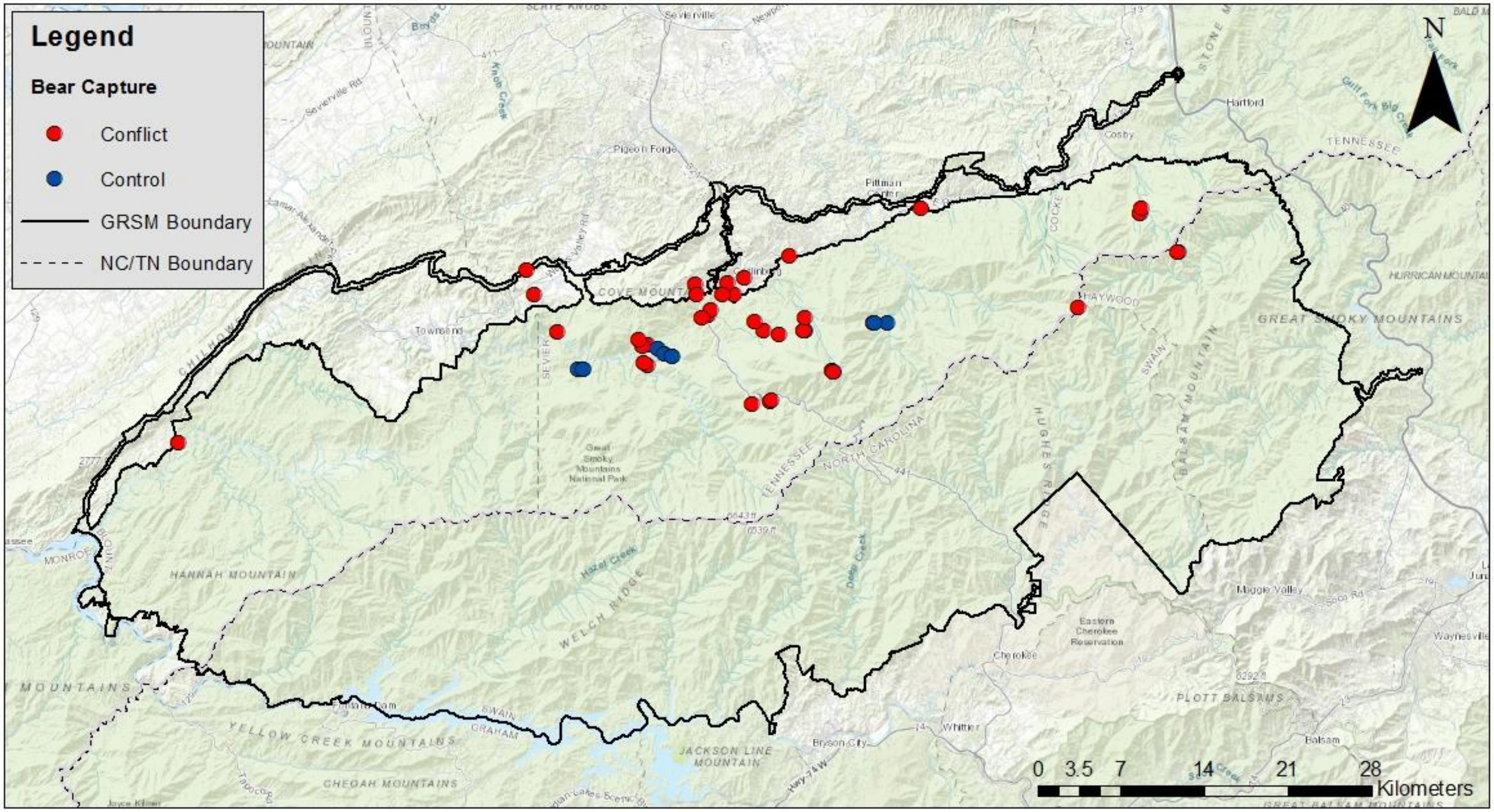


Figure 4. Capture locations for conflict and control bears in Great Smoky Mountains National Park (GRSM) from 2015-2017.

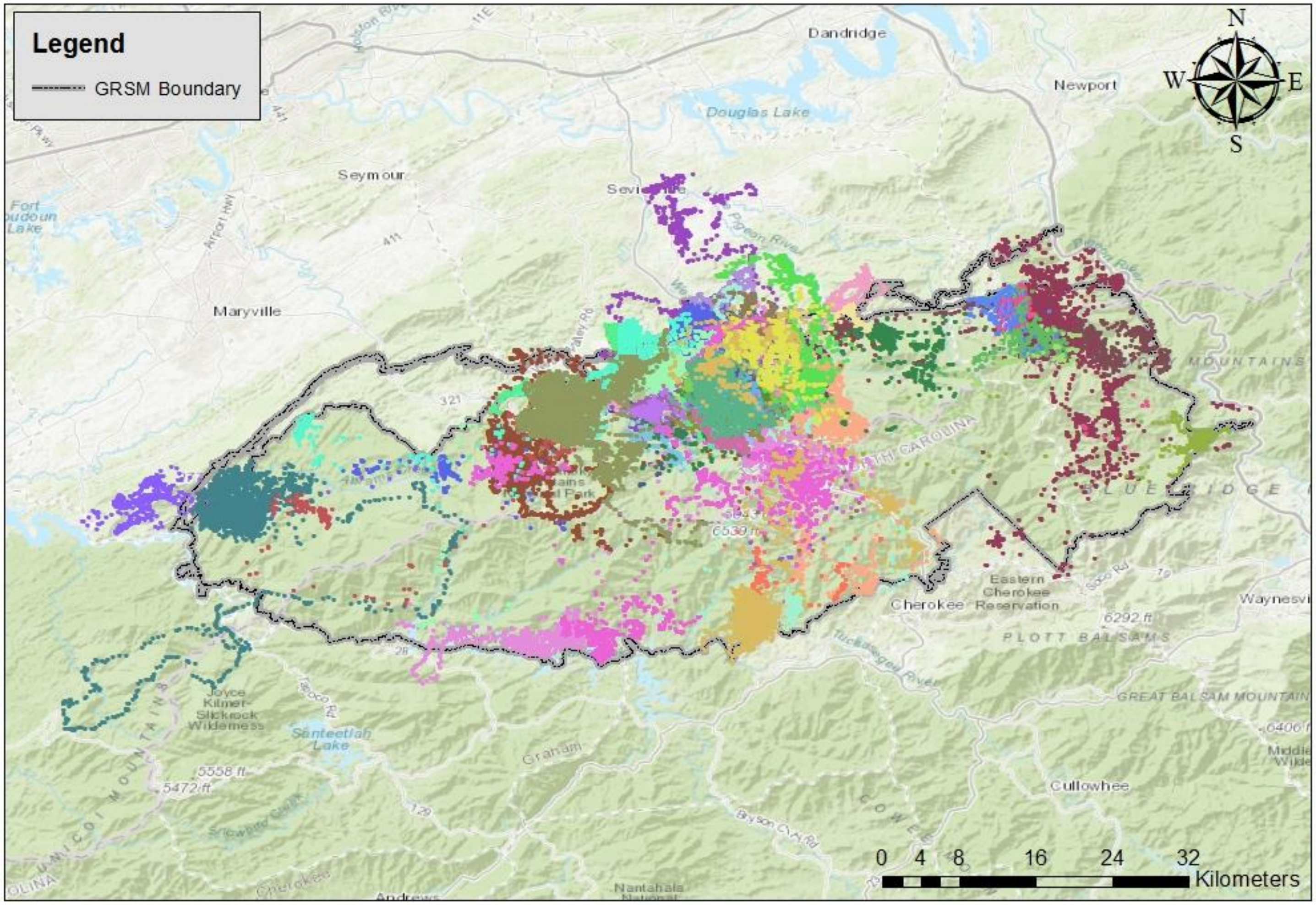


Figure 5. GPS locations for all study bears in Great Smoky Mountains National Park (GRSM) from 2015 to 2017. Individual bears' relocations represented by unique color.

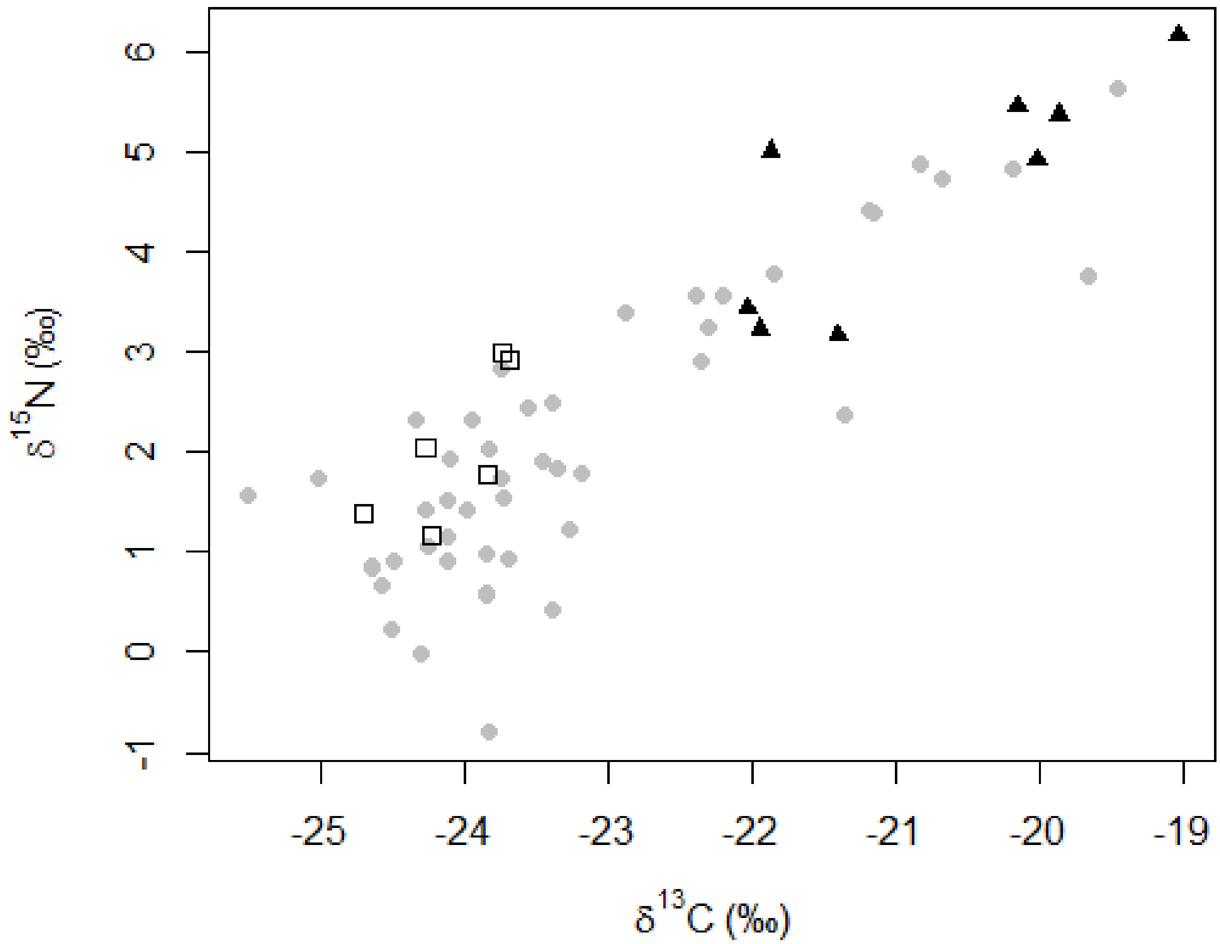


Figure 6. Mean $\delta^{13}C$ and $\delta^{15}N$ of hair samples collected from bears captured in Great Smoky Mountains National Park representing diets from 2014 to 2017. Bears were classified as known food-conditioned (▲), known non-food-conditioned (□), and unknown (●).

classifying bears as FC. The area under the ROC curve was 0.988, indicating the model has a high predictive capacity to correctly classify bears using mean $\delta^{13}C$ as the predictor variable. I used this discrimination threshold value to reclassify all 61 hair samples. Twenty-four bear hair samples were classified as FC and 37 were classified as NFC (Figure 7, Table B.3). One hair sample that was initially classified as being known NFC was reclassified as FC. Of the 24 FC samples (16 males: 8 females), 10 were from adult bears and 14 were from subadult bears. Of the samples classified as NFC (14 males: 23 females), 27 were from adult bears, 9 were from subadults, and one was an unknown age. Forty-three bears were captured in response to reports of conflict behavior as part of this study, but only 24 of those bears were classified as food-conditioned using mean $\delta^{13}C$ as the predictor variable. Conflict status did not differ by sex; however, conflict status differed by age class (χ^2 = 5.432, P = 0.020) and nearly differed by sex (χ^2 = 3.756, P = 0.053). FC bears tended to be subadults and males.

Home-range Estimates

Home-range and Core Area Estimates for Females

Annual 95% KDE home-range sizes of female bears differed by year (*P* = 0.003) but not mean $\delta^{13}C$ (*P* = 0.240). Mean annual 95% KDE home-range sizes for female bears were 55.2 km^2 (SD = 58.4, n = 9), 16.1 km^2 (SD = 9.7, n = 14), and 13.2 km^2 (SD = 4.0, n = 15) in 2015, 2016, and 2017 respectively. (Tables C.1–3). Similarly, annual 50% KDE core areas of female bears differed by year (*P* = 0.007) but not mean $\delta^{13}C$ (*P* = 0.230). Mean annual 50% KDE core areas for female bears were 6.7 km^2 (SD = 5.3, n = 9), 3.6 km^2 (SD = 1.9, n = 14), and 2.8 km^2 (SD = 0.8,

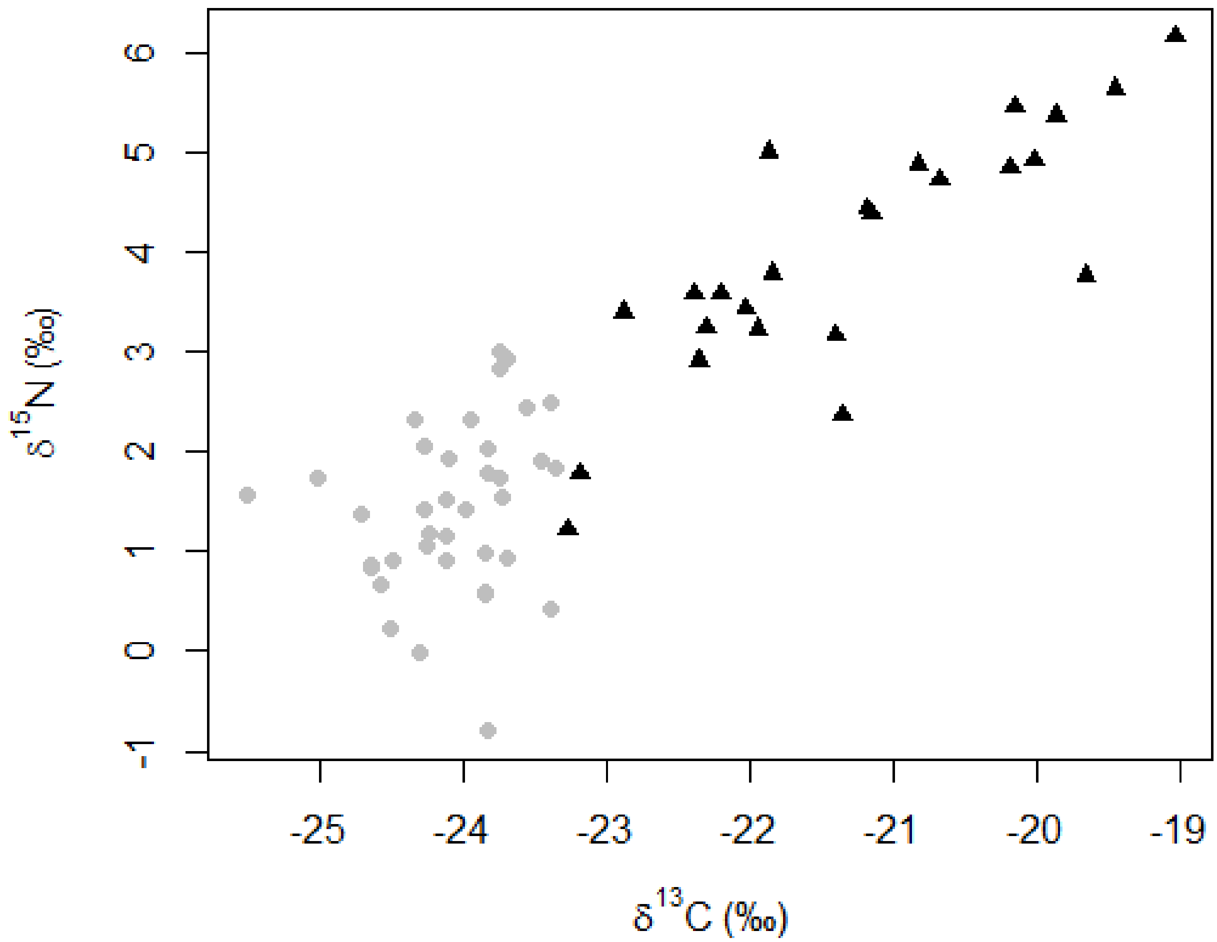


Figure 7. Mean $\delta^{13}C$ and $\delta^{15}N$ of hair samples collected from bears captured in Great Smoky Mountains National Park representing diets from 2014 to 2017. Bears were classified as food-conditioned (▲) or non-food-conditioned (●) using a logistic regression model (logit(y) = 66.242 + 2.900$\delta^{13}C$).

n = 15) in 2015, 2016, and 2017, respectively (Tables C.1-3). The 2015 mean 95% KDE home-range estimates for females were greater than estimates in 2016 (P = 0.008) or 2017 (P = 0.004) but 2016 and 2017 did not differ (P = 0.958). Similarly, the 2015 mean 50% KDE core area estimates were greater than estimates from 2016 (P = 0.036) or 2017 (P = 0.006) but 2016 and 2017 did not differ (P = 0.734).

Because 2015 mean 95% KDE home-range size and 50% KDE core area size differed from the other years, I removed 2015 data and examined the effect of mean $\delta^{13}C$ of female bears for years 2016 and 2017 only. Mean 95% KDE home-range sizes (P = 0.046) and mean 50% KDE core area sizes (P = 0.037) differed by mean $\delta^{13}C$ with home range and core area sizes decreasing with increasing mean $\delta^{13}C$ (Figures 8–9).

Seasonal 95% KDE home-range sizes of female bears differed by season (P = 0.030, Table C.4). Mean spring home-range size were greater than fall (P = 0.049), but there were no significant differences between spring and summer home-range sizes (P = 0.859) and summer and fall home-range sizes (P = 0.076). Mean $\delta^{13}C$ was not related to seasonal home-range sizes (P = 0.318). The mean 95% KDE home-range size in the spring of female bears was 10.1 km^2 (SD = 2.7, n = 13), 12.9 km^2 (SD = 7.9, n = 23) in summer, and 23.2 km^2 (SD = 23.6, n = 21) in the fall. Seasonal 50% KDE core areas of female bears did not differ by season (P = 0.065) or mean $\delta^{13}C$ (P = 0.238).

The mean proportion of development within female 95% KDE home ranges and 50% KDE core areas from 2015–2017 differed by mean $\delta^{13}C$ ($P < 0.001$ and $P < 0.001$, respectively); both tended to increase as mean $\delta^{13}C$ increased (Figures 10–11). A total of 13 of 23 female 95%

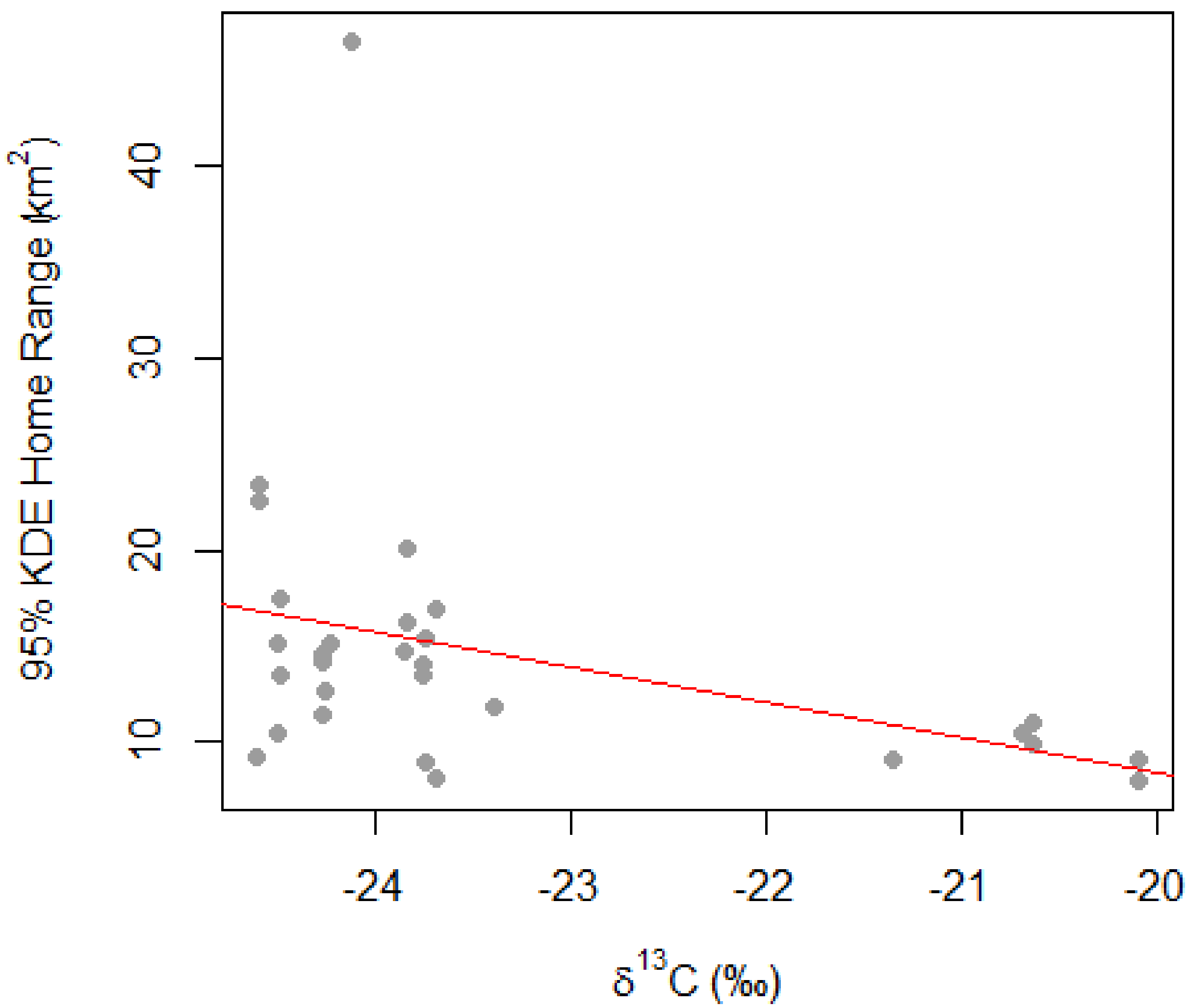


Figure 8. Female 95% kernel density estimation (KDE) home range sizes in relation to mean $\delta^{13}C$ at Great Smoky Mountains National Park, 2016–2017.

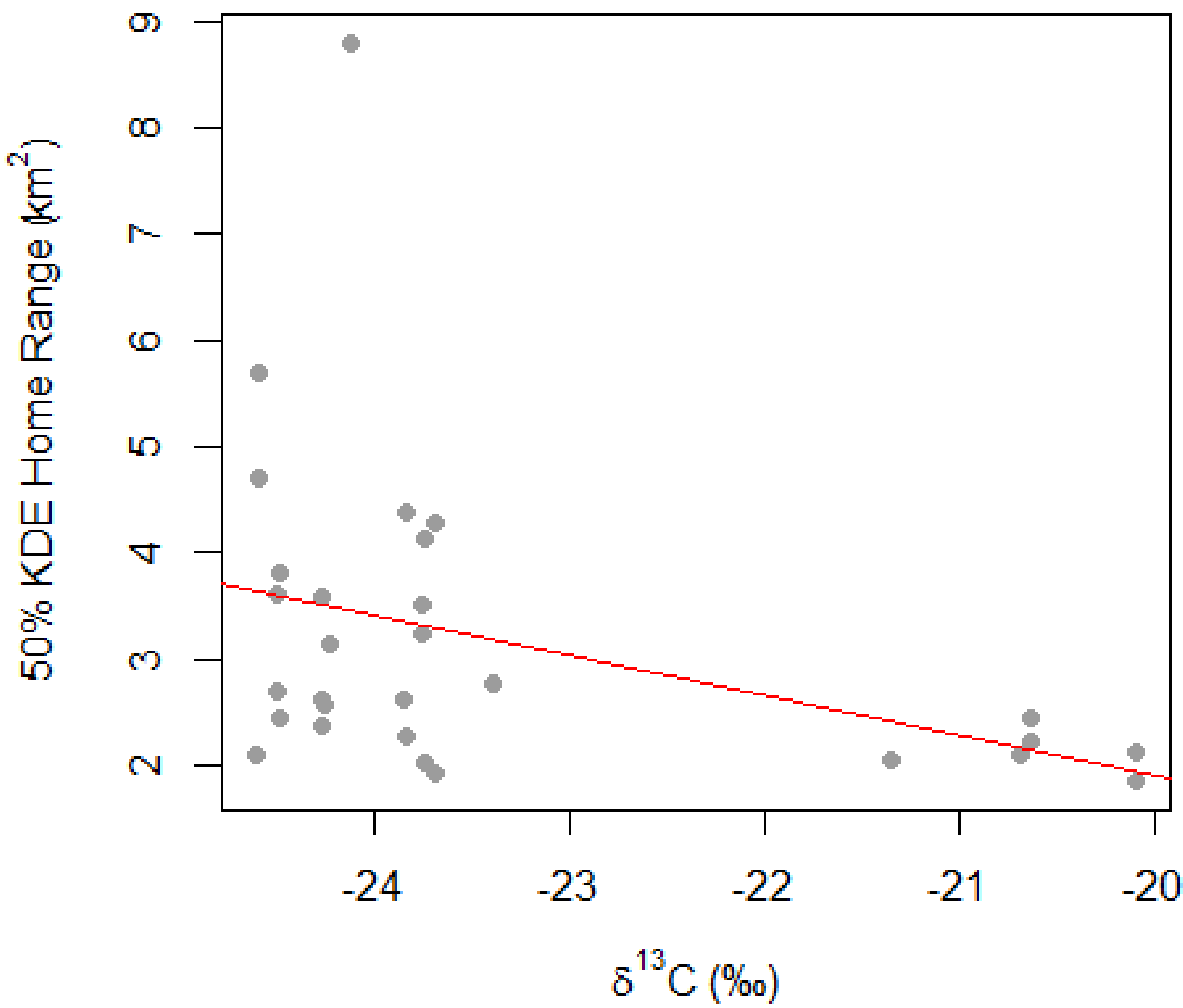


Figure 9. Female 50% kernel density estimation (KDE) core area sizes in relation to mean $\delta^{13}C$ at Great Smoky Mountains National Park, 2016–2017.

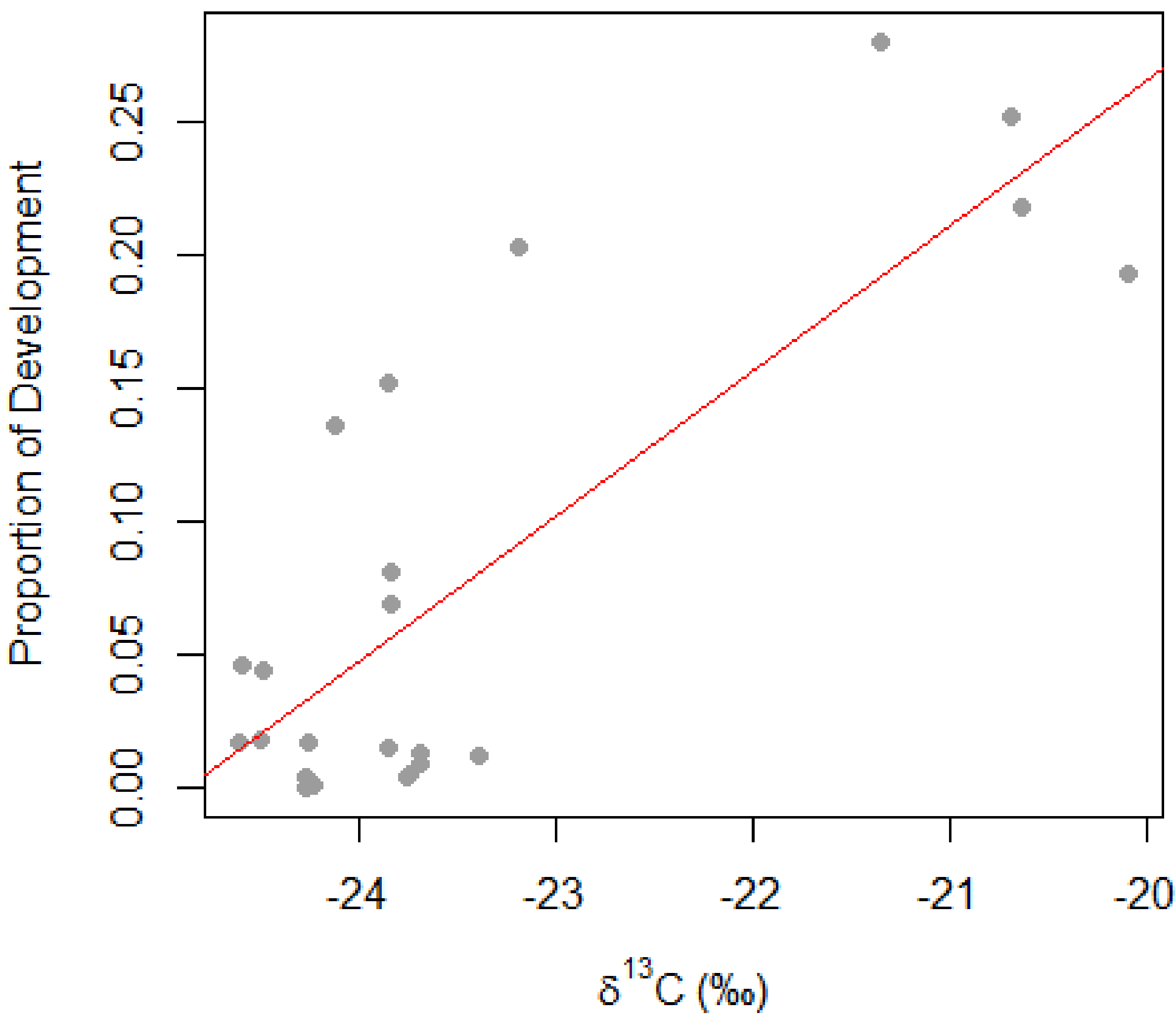


Figure 10. Proportion of development within female 95% kernel density estimation home ranges in relation to mean $\delta^{13}C$ at Great Smoky Mountains National Park, 2015–2017.

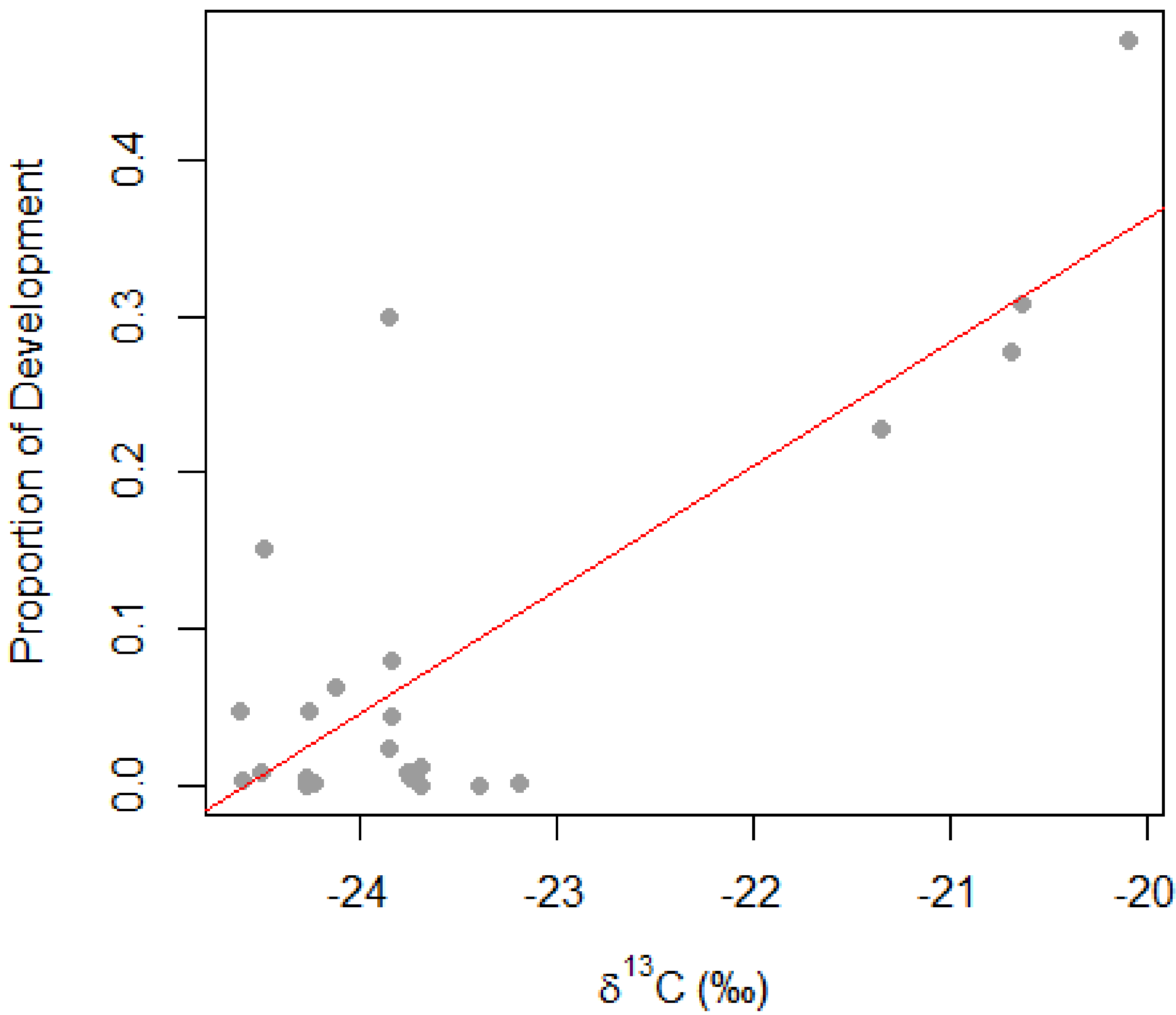


Figure 11. Proportion of development within female 50% kernel density estimation core area sizes in relation to mean $\delta^{13}C$ at Great Smoky Mountains National Park, 2015–2017.

KDE home ranges encompassed areas outside the GRSM boundary (5FC:8NFC). Ten out of 23 female bears had 50% KDE core areas that encompassed private land outside of the park boundary (5FC:5NFC).

Home-range and Core Area Estimates for Males

Annual 95% KDE home-range size and 50% KDE core area sizes were greater for males than females ($P \leq 0.001$, Tables C.1–3). Annual 95% KDE home-range sizes of male bears did not differ based on mean $\delta^{13}C$ ($P = 0.132$) or year ($P = 0.520$). Similarly, annual 50% KDE core areas of male bears did not differ based on mean $\delta^{13}C$ ($P = 0.270$) or year ($P = 0.803$). Mean annual 95% KDE home-range size of male bears was 124.9 km^2 (SD = 65.3, n = 39). Mean 50% KDE core area size of male bears was 20.5 km^2 (SD = 7.5, n = 39, Tables C.1–3).

Seasonal 95% KDE home-range sizes of male bears differed by season ($P = 0.010$, Table C.5). Mean spring home-range size differed from summer ($P = 0.014$) and fall ($P = 0.030$) home-range sizes, but there was no significant difference between summer and fall home-range sizes ($P = 0.975$). Mean $\delta^{13}C$ was not related to seasonal home-range sizes ($P = 0.160$). The mean 95% KDE home-range size for male bears was 67.2 km^2 (SD = 25.0, n = 19) in spring, 110.5 km^2 (SD = 57.8, n = 26) in summer, and 107.5 km^2 (SD = 55.0, n = 23) in the fall. Seasonal 50% KDE core areas of male bears did not differ by season ($P = 0.191$) or mean $\delta^{13}C$ ($P = 0.507$).

The mean proportion of development was related to mean $\delta^{13}C$ for male 95% KDE home ranges ($P = 0.022$) but not 50% KDE core areas ($P = 0.057$), though the latter *P*-value neared the alpha level of 0.05. The mean proportion of development within male home ranges and core areas tended areas tended to increase as mean an $\delta^{13}C$ increased (Figures 12–13). A total of 26

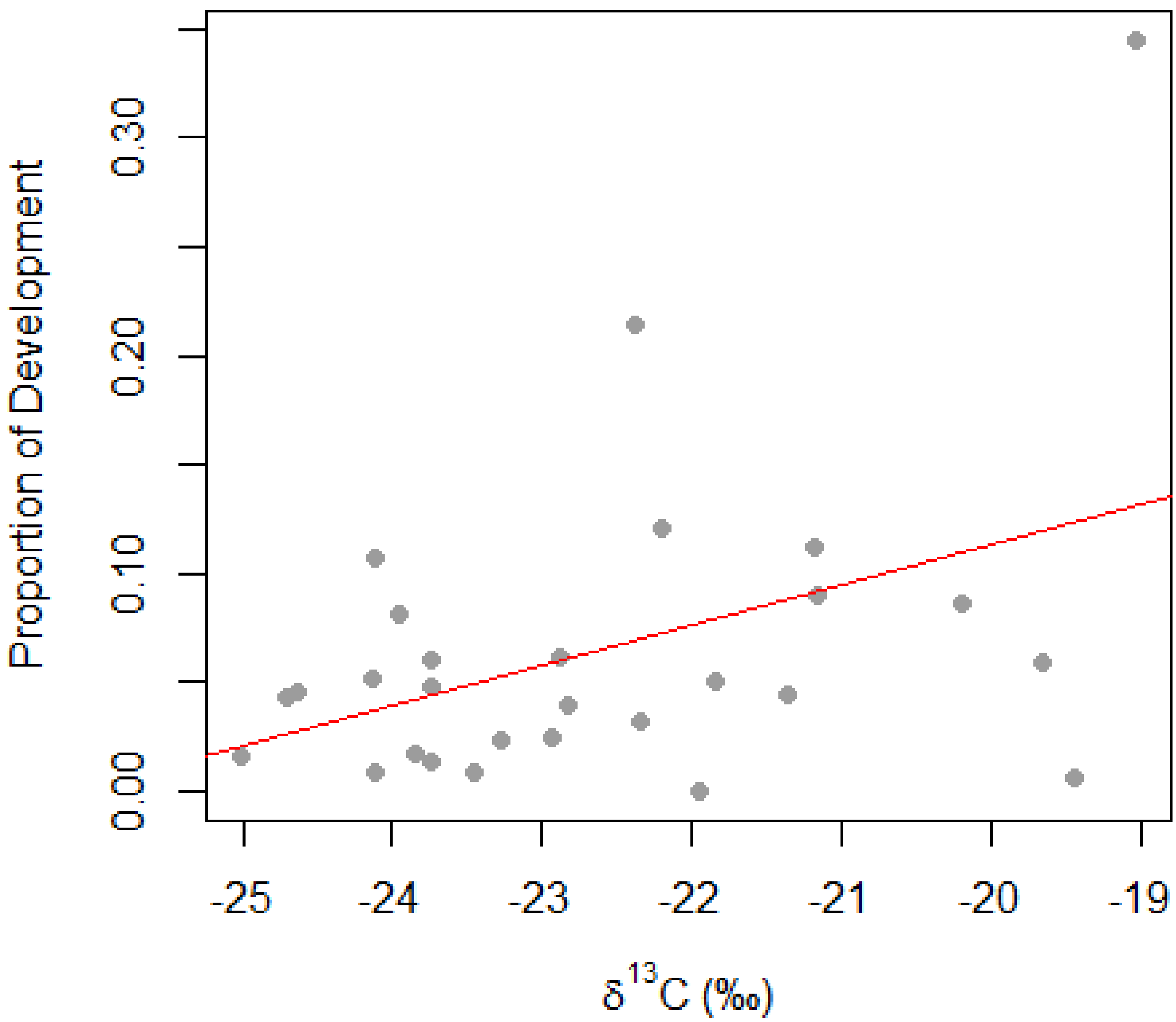


Figure 12. Proportion of development within male 95% kernel density estimation home ranges in relation to mean $\delta^{13}C$ at Great Smoky Mountains National Park, 2015–2017.

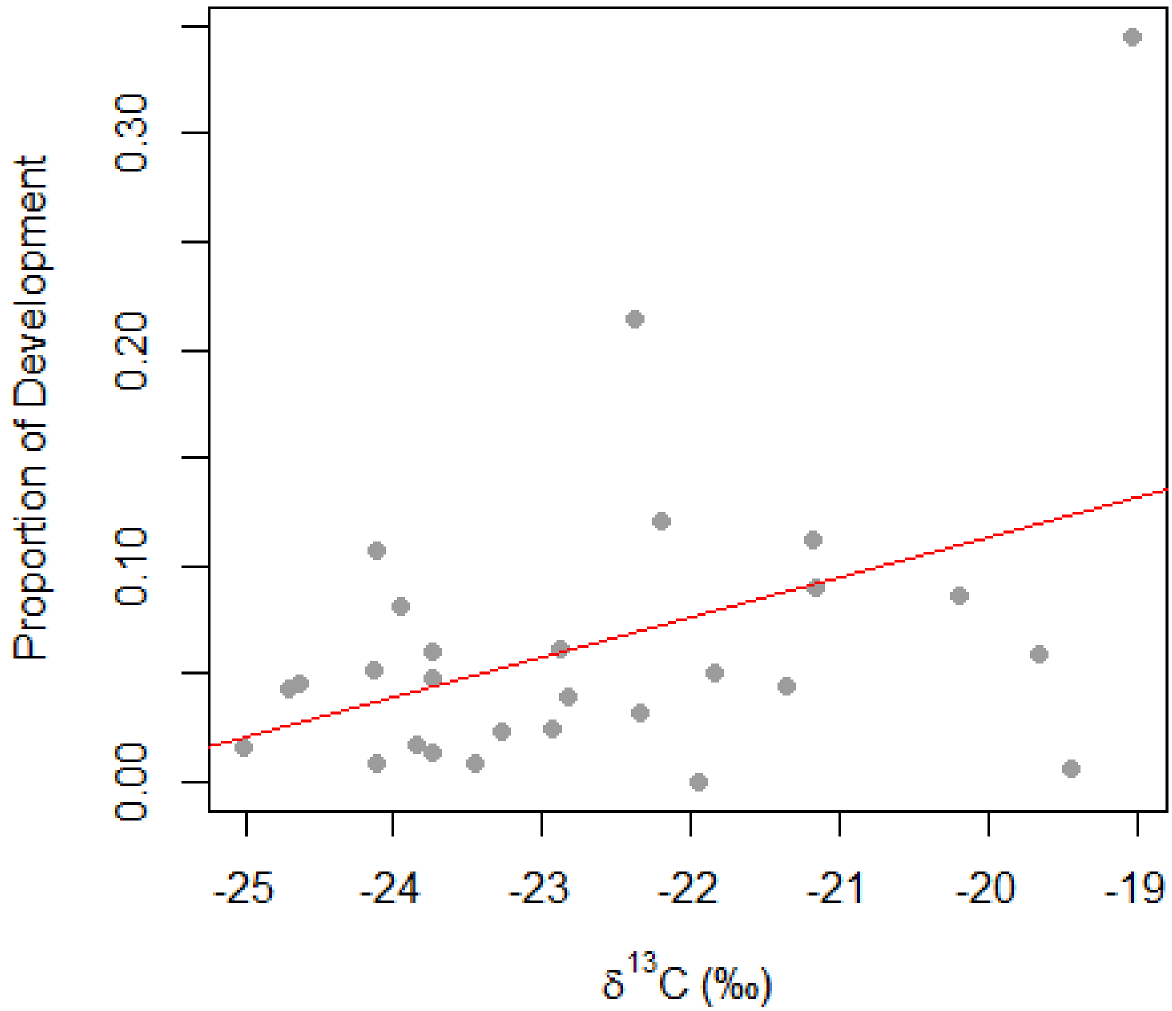


Figure 13. Proportion of development within male 50% kernel density estimation core area sizes in relation to mean $\delta^{13}C$ in Great Smoky Mountains National Park, 2015–2017.

out of 28 male 95% KDE home ranges encompassed an area outside of the GRSM boundary (13FC:13NFC). Twenty-one out of 28 male bears had 50% KDE core areas that encompassed private land outside of the park boundary (13FC:8NFC).

Step Selection Functions

I evaluated a number of different model formulations examining effects of mean $\delta^{13}C$ for 50 of the bears that I radio collared (Table D.1). Three of the 53 study bears did not have sufficient GPS relocation data for SSF analysis. The top model included the log of percent canopy and quadratic effects for distance to nearest ridge, distance to cover, distance to development, and slope. The probability of a step being selected increased as percent canopy increased. Selection was highest for low to intermediate values of slope (0–45 degrees) and distance to ridge. Selection was high at short distances from cover, lower at intermediate distances, and highest at long distances from cover. Selection was highest at shorter distances to development. The probability of selection was also influenced by interactions between sex and distance to cover, slope, and distance to development. Selection was relatively high at lower distances to cover but decreased for female bears at intermediate distances and then increased at higher distances. Male bears selected for distance to cover similarly to females, but selection was higher overall. The probability of a step decreased as slope increased for males, but selection increased slightly as slope increased for female bears and stabilized at about 60 degrees. Female step selection in relation to distance to development was weaker than male selection. Male bear selection decreased slightly as distance to development increased, and female selection decreased more rapidly than male selection as distance to development increased. The top model also included interactions between season and slope and distance to nearest ridge. The probability of a step decreased as slope increased beyond 15 degrees during the summer and fall. During the spring, selection was highest between 15 and 45 degrees. The probability of a step decreased as distance to ridge increased during the summer and fall but was highest at intermediate distances to nearest ridges during the spring. The top model also included an interaction between the distance to ridge and time of day. Probability of a step was highest between 50 to 150 m from the nearest ridge, but selection was highest at dawn and lowest at dusk. Also, the top model included interactions between age class and slope and age class and distance to ridge. Probability of a step was highest between 50 to 150 m from the nearest ridge, and subadult bears preferred shorter distances to ridges compared to adult bears. Probability of a step also decreased as slope increased for adult bears, but probability increased for subadult bears. Finally, the top model included interaction effects between mean $\delta^{13}C$ and percent canopy and slope. Bears with higher mean $\delta^{13}C$ had higher selection for low to moderate percent canopy cover compared with bears with lower mean $\delta^{13}C$. Bears with lower mean $\delta^{13}C$ had higher selection for slopes ranging from 0 to 15 degrees, whereas bears with higher mean $\delta^{13}C$ had higher selection for slopes >15 degrees.

CHAPTER 5. DISCUSSION

Hopkins et al. (2012) used mean $\delta^{15}N$ to predict the conflict status of bears in Yosemite National Park and noted a strong positive correlation between carbon and nitrogen isotopic ratios. They suggested that bears with high isotopic values of carbon and nitrogen that were strongly correlated consumed anthropogenic foods at a higher proportion than bears that consumed more of a plant-based diet, likely because of the indirect consumption of products containing sugar cane and corn while feeding on meat products. Furthermore, many domestic animals used for meat are fed corn. Although there appears to be a similar correlation between the two isotopic ratios at higher $\delta^{13}C$ in my study (Figure 6), mean $\delta^{15}N$ was not supported in my logistic regression model for predicting conflict status. A potential reason for this difference may be the consumption of wild boar (*Sus scrofa*) meat by bears in GRSM, regardless of level of human food conditioning. The park has an active hog management program aimed at reducing the hog population. Hog carcasses are left for GRSM's native species to consume, and bears have been observed feeding on these carcasses (R. Williamson, NPS, personal communication). In addition, hair samples of subadult bears may have had enriched ^{15}N from nursing (Jenkins et al. 2001) and higher protein consumption to promote growth and development (Teunissen van Manen et al. 2014). Average $\delta^{15}N$ varied by year with 2014 being lower than years 2015, 2016, and 2017. The reason for this annual variation is unclear, though it may be attributed to a small sample size (n = 4) in 2014 or a hard mast failure in 2015 (Olfenbuttel 2015). Teunissen van Manen (2011) reported enriched $\delta^{15}N$ in black bear hair samples representing years when white oak mast production was low and depleted $\delta^{15}N$ in years with abundant white oak mast.

Forty-three bears were captured in response to reports of conflict behavior as part of this study, but only 24 of those bears were classified as food-conditioned using mean $\delta^{13}C$ as the predictor variable. Food-conditioned bears tended to be males and subadults which is consistent with previous research conducted on “panhandler” bears in GRSM (McLean 1991). Younger bears, particularly dispersing males, may be more likely to explore human-use areas as they are excluded from high-quality habitat by older, more dominant bears (Mattson et al. 1990). Anthropogenic food sources may be an important resource for these younger bears, resulting in enriched isotopic ratios. Male bears also had larger home ranges than females, increasing their chances of encountering developed areas and human foods. Twenty-six of 28 (93%) of male study bears had home ranges that included areas outside the GRSM boundary compared with 13 of 23 (57%) of female bears. Twenty-one of 28 (75%) of male study bears had core areas that extended beyond park boundaries compared with 10 of 23 (44%) of female bears.

The threshold isotope values that I used to classify bears did not produce a clear separation between the two groups (Figure 7.) Consequently, I used the mean $\delta^{13}C$ as a covariate for comparing home range sizes and predicting resource selection because those values represent a continuum rather than a categorical classification as either food conditioned or not. If a categorical classification is the goal, it may be helpful to manually inspect bears with mean $\delta^{13}C$ that fall within a certain range of values based on the threshold value and then classify these animals individually.

Regardless, the threshold isotope values that I used to classify bears may not have been sensitive enough to detect all food-conditioned bears. It is also probable that some conflict bears were habituated to human presence but not food-conditioned. Stable isotopes are a useful indicator of diet, but not necessarily representative of behavioral patterns such as food-conditioning. Conflict behavior is often assumed to be comprised of both food-conditioning and habituation to human presence. However, the two processes are a result of distinctly different learning pathways (Hopkins et al. 2010) and can occur independently. Habituation is a result of repeated exposure to humans with a lack of negative consequences while food-conditioning is a result of receiving positive food rewards (Herrero et al. 2005). Park biologists and researchers have reported an increase in grizzly bear habituation in both Yellowstone National Park and Grand Teton National Park, likely linked to the increases in park visitation (Gunther et al. 2015). A similar process is likely occurring in GRSM in which the high bear density coupled with a large number of visitors likely influences bears becoming tolerant of humans though not necessarily food-conditioned. Several of the female bears that I captured were in response to repeated reports of conflict behavior, yet they did not exhibit stable isotope ratios that would indicate they were food-conditioned. It is likely that these female bears, due to high bear density and volume of tourists, have grown tolerant of people while still relying mostly on natural foods. Younger bears and females may be more susceptible to habituation as they are forced by older males to use less desirable habitat such as areas in close proximity to roads or developments (Mattson 1990).

Annual female home-range and core area sizes differed by year whereas male home-range and core area sizes did not. This could be attributed to a regional hard mast failure in 2015 (Olfenbuttel 2015) that may have put more nutritional stress on females, particularly those with cubs. Several female study bears traveled relatively large distances outside their normal home-ranges during fall 2015 but not in the other years (Figure 14). When analyzing just years 2016 and 2017, female home ranges and core areas varied by mean $\delta^{13}C$ with home range and core area sizes decreasing with increasing mean $\delta^{13}C$. This is consistent with other studies in which bears feeding on crops (Ditmer et al. 2015), at artificial feeding sites (Massé et al. 2014), or in urban areas (Baruch-Mordo et al. 2014), where food resources tended to be concentrated, had smaller home range sizes.

Annual male home ranges and core areas were not related to mean $\delta^{13}C$. Males that relied on anthropogenic food sources within park boundaries may have had comparable home range sizes as backcountry bears due to distance between human-use areas in the park. Campgrounds, picnic areas, and backcountry campsites are not concentrated in one area, and males with enriched ^{13}C may have exploited multiple human-use areas in the park as well as human food sources outside GRSM boundaries. Whereas GRSM is a relatively large park, male home ranges are also large and encompass areas outside of park boundaries. Ninety-three percent of male study bears had 95% KDE home ranges that extended beyond the GRSM boundary.

Both male and female seasonal home ranges and core areas did not differ by mean $\delta^{13}C$, though there was variation in home range size by season. Females had larger 95% home ranges in the fall than in the other seasons, and males had smaller 95% home ranges in the

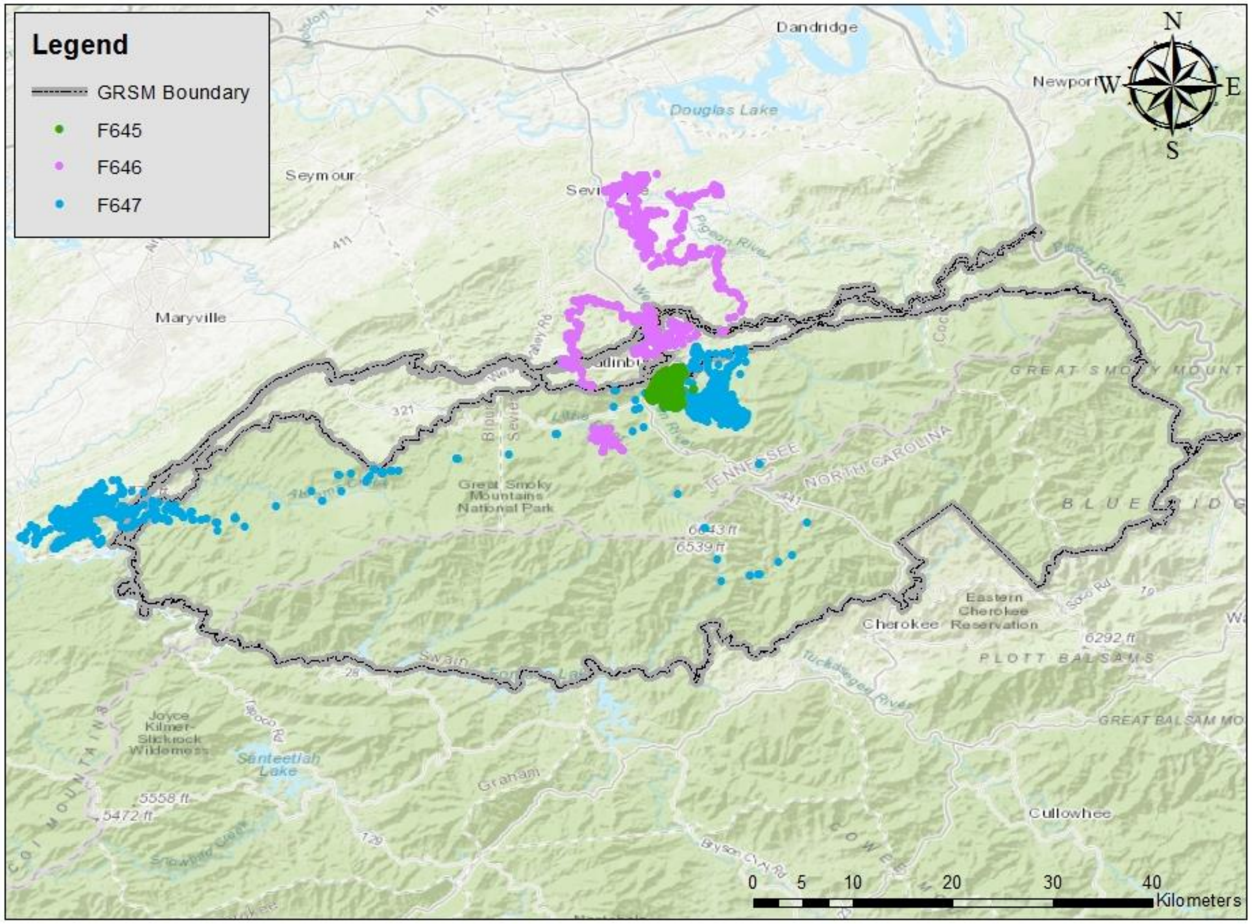


Figure 14. GPS data for several female bears with long-distance movements in fall 2015 (F646 and F647), Great Smoky Mountains National Park. Bear F645's data is representative of the relatively small home range sizes of female bears without any long-distance movements.

spring than in summer and fall. The larger female fall home ranges is consistent with previous research in which female bears were observed to have larger fall home ranges with space use increasing during years with hard mast failures (Moyer et al. 2007). Male home ranges are likely larger in the summer due to breeding behavior and fall ranges may be larger as they undergo hyperphagia in preparation for winter denning.

The proportion of development within home ranges and core areas of female bears varied by mean $\delta^{13}C$. Female bears with enriched ^{13}C had home ranges and core areas with significantly higher proportions of development compared to females with lower mean $\delta^{13}C$, and all the female bears classified as FC had home ranges and core areas that extended beyond GRSM boundaries. This suggests that access to anthropogenic food sources outside GRSM boundaries is likely resulting in food-conditioning of female bears. The proportion of development within male bear home ranges and core areas also differed in relation to mean $\delta^{13}C$, and the mean proportion of development within male home ranges and core areas tended to increase as mean $\delta^{13}C$ increased.

The SSF indicated that female bears preferred to be closer to development than male bears; however, this finding may be a consequence of our targeted trapping of conflict bears in developed areas. Smaller female home ranges may have resulted in female bears selecting steps closer to development more frequently than male bears that tended to have larger home ranges. My SSF model indicated that bears with enriched ^{13}C have are more prone to select for areas with less canopy cover, likely due to developed areas tending to have less tree cover. Bears had increasing selection for slopes >15 degrees as ^{13}C enrichment increased. Food-conditioned bears in and around GRSM may be selecting for steeper slopes while navigating developed areas to minimize human interaction. Previous research has shown that bears may use steeper slopes to avoid human disturbance or interaction (Amstrup and Beecham 1976, Powell and Mitchell 1998).

CHAPTER 6. MANAGEMENT AND RESEARCH IMPLICATIONS

The bear population in Tennessee continues to grow, and GRSM supports a high density of bears. With an increasing bear population and a concomitant increase in the number of visitors to GRSM and the resident human population surrounding the park, it is unlikely that human-bear interactions will decrease in the near future. Prevention is the best remedy for lessening issues with conflict bears, and it will be of increasing importance to prevent bears from becoming food-conditioned. My SSF model can be used by wildlife managers in communities surrounding the park to predict where human-bear interactions are likely to occur and, if the objective is to reduce human-bear interactions, where landscape modifications might be made to reduce the probability of bears using particular areas. Modifications could include reducing escape and canopy cover, particularly on moderate to steep slopes.

Food conditioning aside, tackling habituation to human presence may be worth examining further. While the park supports visitor viewing of wildlife in a safe manner, many bears are becoming habituated to the extent that public safety may become an issue. Signage throughout GRSM reminds visitors that is a federal offense to approach wildlife or to disrupt their natural behavior. However, visitors are regularly observed approaching wildlife in the park, and this could lead to habituation. In the past, GRSM has emphasized sanitation and educating the public about the importance of securing food and garbage. It is likely that the issue of habituation needs to be emphasized in conjunction with food-conditioning because the two are linked but not synonymous. I found bears in my study that were clearly food-conditioned but not habituated, those that were habituated but not food-conditioned, those that were both, and those that were neither. Both types of conflict behaviors are unwanted by humans and detrimental to the bears, and both need to be addressed by managers in tandem. For example, female bear 604 (F604) was regularly reported to be walking along a popular road and in a busy trailhead parking lot in GRSM, and F604's behavior around park visitors and vehicles was consistent with that of a habituated bear. However, this bear was not classified as FC using stable isotopes, and she was not observed panhandling or frequenting dumpsters in the park during the study. The park's emphasis on sanitation may have reduced food-conditioning in bears but has not been effective in preventing habituation.

Female bears exhibited smaller home-range sizes than males, and aversive conditioning may not be as effective if managers want female conflict bears to leave human-use areas. The high bear density in the park may force some female bears to remain in or near human-use areas simply due to a lack of available natural habitat, and they may be more likely to tolerate human presence compared with male bears. This proximity to human-use areas may increase a female bear's chances of becoming habituated and food-conditioned, and these female bears are likely to become persistent problems. Male bears have larger home-ranges and aversive conditioning may be more effective at driving these individuals out of a particular area. However, if male bears are food-conditioned or habituated, they may remain in the area or create conflict issues elsewhere.

Despite the introduction of the city ordinance in 2000, Gatlinburg has a reputation for conflict bear problems that may stem from the challenges of educating the millions of visitors passing through the park, maintaining bear resistant trash containers, and consistent law enforcement (Brandenburg 2005). My GPS data indicate that bears travel throughout the city of Gatlinburg and well beyond the city boundary (Figure 15). The ordinance zone covers roughly 8 km^2 within Gatlinburg, which comprises only a small proportion of the mean male home range of approximately 125 km^2. Furthermore, my results suggest that bears that access human food sources in cities or communities outside GRSM likely return to the park and can engage in conflict behavior there. Bears are likely to encounter anthropogenic food sources in communities besides Gatlinburg, and managers should consider expanding the current ordinance zone in addition to encouraging other surrounding communities to adopt regulations that prevent food-conditioning in bears. The park will need to continue to collaborate with the communities surrounding GRSM to effectively minimize the development of conflict behavior.

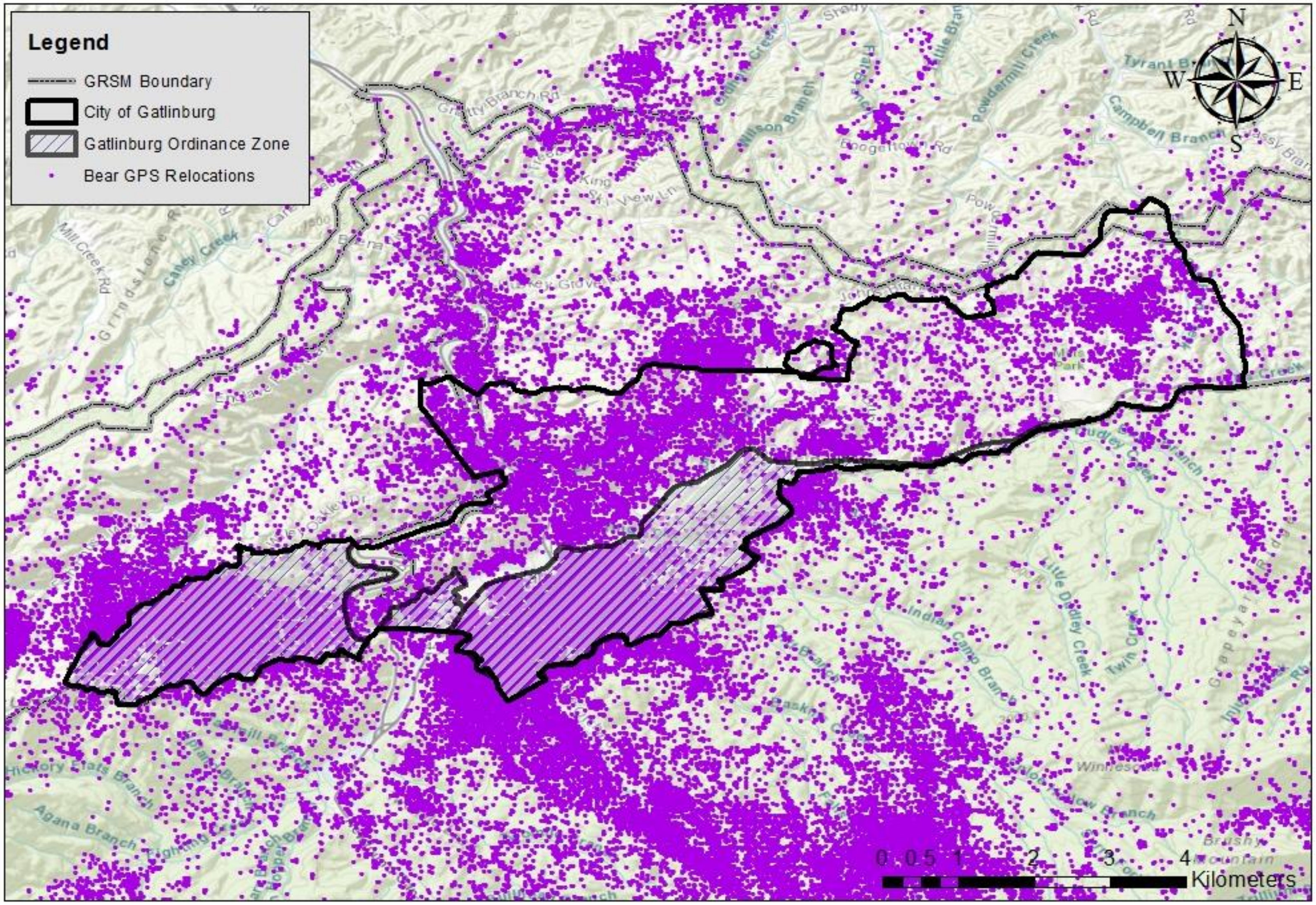


Figure 15. City of Gatlinburg, Tennessee and city Ordinance Zone with bear GPS relocations.

LITERATURE CITED

Akaike, H. 1974. A new look at statistical model identification. Institute of Electrical and Electronics Engineers Transactions on Automatic Control 19:716–723.

Ambrose, J. P., and S. P. Bratton. 1990. Trends in landscape heterogeneity along the borders of Great Smoky Mountains National Park. Conservation Biology 4(2):135–143.

Amstrup, S. C., and J. Beecham. 1976. Activity patterns of radio-collared black bears in Idaho. Journal of Wildlife Management 40:240–348.

Anderson, D. 1982. The home range: a new nonparametric estimation technique. Ecology 63:102–112.

Anderson, D. R. 2008. Model based inference in the life sciences: a primer on evidence. Springer Science and Business Media, LLC, New York, New York, USA.

Arthur, S. M., B. F. J. Manly, L. L. McDonald, and G. W. Garner. 1996. Assessing habitat selection when availability changes. Ecology 77: 215–227.

Baruch-Mordo, S., S. W. Breck, K .R. Wilson, and D. M. Theobald. 2008. Spatiotemporal distribution of black bear-human conflicts in Colorado, USA. Journal of Wildlife Management 72:1853–1862.

Baruch-Mordo, S., K. R. Wilson, D. L. Lewis, J. Broderick, J. S. Mao, and S. W. Breck. 2014. Stochasticity in natural forage production affects us of urban areas by black bears: implications to management of human-bear conflicts. PLoS ONE 9:e85122.

BearWise. 2018. BearWise communities. <https://bearwise.org/bearwise-communities/>. Accessed 10 November 2018.

Beeman, L. E., and M. R. Pelton. 1980. Seasonal foods and feeding ecology of black bears in the Smoky Mountains. International Conference on Bear Research and Management 3:141–147.

Bentzen, T. W., R. T. Shideler, and T. M. O'Hara. 2014. Use of stable isotope analysis to identify food-conditioned grizzly bears on Alaska's North Slope. Ursus 25:14–23.

Brandenburg, D. M. 2005. Tennessee black bear status report. 18th Eastern Black Bear Workshop 2005 18:156–162.

Brenna, J. T., T. N. Corso, H. J. Tobias, R. J. Caimi. 1997. High-precision continuous-flow isotope ratio mass spectrometry. Mass Spectrometry Reviews 16:227–258.

Brown, D. G., K. M. Johnson, T. R. Loveland, and D. M. Theobald. 2005. Rural land-use trends in the conterminous United States, 1950-2000. Ecological Applications 15:1851–1863.

Burnham, K., and D. Anderson. 1998. Model selection and inference: an information-theoretic approach. Spring-Verlag, New York, New York, USA.

Calenge, C. 2015. adehabitatHR: home range estimation. R package version 0.4.15. < https://cran.r-project.org/web/packages/adehabitatHR/index.html>. Accessed 2 February 2018.

Clark, J. E. 1999. Capture and on-site release of nuisance black bears and survival of orphaned black bears released in the Great Smoky Mountains. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Clark, J. E., F. T. van Manen, and M. R. Pelton. 2002. Correlates of success for on-site releases of nuisance black bears in Great Smoky Mountains National Park. Wildlife Society Bulletin 30:104–111.

Clark, J. D., J. S. Laufenberg, M. Davidson, and J. L. Murrow. 2015. Connectivity among subpopulations of Louisiana black bears as estimated by a step selection function. Journal of Wildlife Management 79:1347–1360.

Coley, A. B. 1995. Population dynamics of black bears in Great Smoky Mountains National Park. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Coplen, T. B. 1994. Reporting of stable hydrogen, carbon, and oxygen isotopic abundances. Pure and Applied Chemistry 66:273–276.

Ditmer, M. A., D. L. Garshelis, K. V. Noyce, A. W. Haveles, and J. R. Fieberg. 2015. Are American black bears in an agricultural landscape being sustained by crops? Journal of Mammalogy 97:54–67.

D'eon, R. G., and D. Delparte. 2005. Effects of radio-collar position and orientation on GPS radio-collar performance, and the implications of PDOP in data screening. Journal of Applied Ecology 42:383–388.

Elfström, M., A. Zedrosser, O. Støen, and J. E. Swenson. 2012. Ultimate and proximate mechanisms underlying the occurrence of bears close to human settlements: review and management implications. Mammal Review 44:5–18.

Evans, M. J., J. E. Hawley, P. W. Rego, and T. A. G. Rittenhouse. 2014. Exurban land use facilitates human-black bear conflicts. Journal of Wildlife Management 78:1477–1485.

Fortin, D., H. L. Beyer, M. S. Boyce, D. W. Smith, T. Duchesne, and J. S. Mao. 2005. Wolves influence elk movements: behavior shapes a trophic cascade in Yellowstone National Park. Ecology 86:1320–1330.

Gitzen, R. A., J. J. Millspaugh, and B. J. Kernohan. 2006. Bandwidth selection for fixed-kernel analysis of animal utilization distributions. Journal of Wildlife Management 70:1334–1344.

Greenleaf, S. S. 2005. Foraging behavior of black bears in a human-dominated environment, Yosemite Valley, Yosemite National Park, California 2001-2003. Thesis, University of Idaho, Moscow, USA.

Gunther, K. A., K. R. Wilmot, S. L. Cain, T. Wyman, E. G. Reinertson, and A. M. Bramblett. 2015. Habituated grizzly bears: a natural response to increasing visitation in Yellowstone and Grand Teton National Parks. Yellowstone Science 23:33–39.

Hemson, G., P. Johnson, A. South, R. Kenwards, R. Ripley, and D. Macdonald. 2005. Are kernels the mustard? Data from global positioning system (GPS) collars suggests problems for kernel home-range analyses with least-squares cross-validation. Journal of Animal Ecology 74:455–463.

Herrero, S., T. Smith, T. D. DeBruyn, K. A. Gunther, and C. A. Matt. 2005. Brown bear habituation to people: safety risks and benefits. Wildlife Society Bulletin 33:362–373.

Hopkins, J. B., S. Herrero, R. T. Shideler, K. A. Gunther, C. C. Schwartz, and S. T. Kalinowski. 2010. A proposed lexicon of terms and concepts for human-bear management in North American. Ursus 21:154–168.

Hopkins, J. B., P. L. Koch, C. C. Schwartz, J. M. Ferguson, S. S. Greenleaf, and S. T. Kalinowski. 2012. Stable isotopes to detect food-conditioned bears and to evaluate human-bear management. Journal of Wildlife Management 76:703–713.

Jenkins, S. G., S. T. Partridge, T. R. Stephenson, S. D. Farley, and C. T. Robbins. 2001. Nitrogen and carbon isotope fractionation between mothers, neonates, and nursing offspring. Oecologia 129:336–341.

Jenkins, M. A. 2007. Vegetation communities of Great Smoky Mountains National Park. Southeastern Naturalist 6:35–56.

Johnson, K. G., and M. R. Pelton. 1980. Prebaiting and snaring techniques for black bears. Wildlife Society Bulletin 8:46–54.

Karelus, D. L., J. W. McCown, B. K. Scheick, M. van de Kerk, and M. K. Oli. 2016. Home ranges and habitat selection by black bears in a newly colonized population in Florida. Southeastern Naturalist 15:346–364.

Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 126–166 *in* J. J. Millspaugh and J. M. Marzluff, editors. Radiotracking and animal populations. Academic Press, San Diego, California, USA.

King, P. B., R. B. Neuman, and J. B Hadley. 1968. Geology of the Great Smoky Mountains National Park, Tennessee and North Carolina. U. S. Geological Survey Professional Paper 587.

Lewis, J. S., J. L Rachlow, E. O. Garton, and L. A. Vierling. 2007. Effects of habitat on GPS collar performance: using data screening to reduce location error. Journal of Applied Ecology 44:663–671.

Lewis, J. S., and J. L. Rachlow. 2011. Activity patterns of black bears in relation to sex, season, and daily movement rates. Western North American Naturalist 71:388–395.

Manly, B. F. J., L. L. McDonald, D. A. Thomas, T. L. McDonald, and W. E. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic, Dordrecht, Netherlands.

Massé, S., C. Dussault, C. Dussault, and J. Ibarzabal. 2014. How artificial feeding for tourism-watching modifies black bear space use and habitat selection. The Journal of Wildlife Management 78:1228–1238.

Mattson, D. J. 1990. Human impacts on bear habitat use. Bears: Their Biology and Management 8: 33–56.

McLean, P. K. 1991. The demographic and morphological characteristics of black bears in the Smoky Mountains. Dissertation, University of Tennessee, Knoxville, Tennessee, USA.

Mech, L. D., and S. M. Barber. 2002. A critique of wildlife radio-tracking and its use in National Parks. U. S. Geological Survey report, Northern Prairie Wildlife Research Center, Jamestown, North Dakota, USA.

Merkle, J. A., J. J. Derbridge, and P. R. Krausman. 2011a. Using stable isotope analysis to quantify anthropogenic foraging in black bears. Human-Wildlife Interactions 5:159–167.

Merkle, J. A., P. R. Krausman, N. J. Decesare, and J. J. Jonkel. 2011b. Predicting spatial distribution of human-black bear interactions in urban areas. Journal of Wildlife Management 75:1121–1127.

Middleton, E. J., and M. N. Murray. 2009. Population projections for the state of Tennessee, 2010-2030. Tennessee Advisory Commission on Intergovernmental Relations and the University of Tennessee Center for Business and Economic Research, Knoxville, Tennessee, USA. 59 p. Available: <http://www.state.tn.us/tacir/PDF_FILES/Other_Issues/Population2010.pdf. Accessed 23 April 2015>.

[a]Mizukami, R. N., M. Goto, S. Izumiyama, H. Hayashi, and M. Yoh. 2005a. Estimation of feeding history by measuring carbon and nitrogen stable isotope ratios in hair of Asiatic black bears. Ursus 16:93–101.

[b]Mizukami, R. N., M. Goto, S. Izumiyama, M. Yoh, N. Ogura, and H. Hayashi. 2005b. Temporal diet changes recorded by stable isotopes in Asiatic black bear (*Ursus thibetanus*) hair. Isotopes in Environmental and Health Studies 41:87–94.

Moyer, M. A., J. W. McCown, and M. K. Oli. 2007. Factors influencing home range size of female Florida black bears. Journal of Mammalogy 88:468–476.

National Park Service [NPS]. 2018. NPS homepage. <https://www.nps.gov/index.htm>. Accessed 10 Oct 2018.

Olfenbuttel, C. 2015. Western North Carolina hard and soft mast survey report, 33rd year: fall 2015. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA.

O'Brien, D. M. 2015. Stable isotope ratios as biomarkers of diet for health research. The Annual Review of Nutrition 35:565–594.

O'Connell, T. C., and R. M. Hedges. 1999. Investigations into the effect of diet on modern human hair isotopic values. American Journal of Physical Anthropology 108:409–425.

O'Connell, T. C., R. M. Hedges, M. A. Healey, and A. H. R. W. Simpson. 2001. Isotopic comparison of hair, nail, and bone: modern analyses. Journal of Archaeological Science 28:1247–1255.

Peine, J. D. 2001. Nuisance bears in communities: strategies to reduce conflict. Human Dimensions of Wildlife 6:223–237.

Pelton, M. R. 2001. American black bear. Pages 224–233 *in* J. G. Dickson, editor. Wildlife of southern forests: habitat and management. Hancock House Publishers, Blaine, USA.

Powell, R. A., and M. S. Mitchell. 1998. Topographical constraints and home range quality. Ecography 21:337–341.

Qi, P., O. Vermesh, M. Grecu, A. Javey, Q. Wang, and H. Dai. 2003. Toward large arrays of multiplex functionalized carbon nanotube sensors for highly sensitive and selective molecular detection. Nano Letters 3:347–351.

RStudio Team. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA.

Santrock J., S. A. Studley, and J. M. Hayes. 1985. Isotopic analyses based on the mass spectrum of carbon dioxide. Analytical Chemistry 57: 1444–1448.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739–747.

Seger, R. L., F. A. Servello, R. A. Cross, and D. H. Keisler. 2013. Body mass and mast abundance influence foraging ecology of the American black bears (*Ursus americanus*) in Maine. Canadian Journal of Zoology 91:512–522.

Sharkey, M. J. 2001. The all taxa biological inventory of the Great Smoky Mountains National Park. The Florida Entomologist 84:556–564.

Signer, J. 2018. amt: animal movement tools. R package version 0.0.5.0. <https://cran.r-

project.org/web/packages/amt/index.html>. Accessed 9 November 2018.

Still, C. J., J. A. Berry, G. J. Collatz, and R. S. DeFries. 2003. Global distribution of C_3 and C_4 vegetation: carbon cycle implications. Global Biogeochemical Cycles 17:1006.

Teunissen van Manen, J. L. 2011. Using stable isotopes to assess longitudinal diet patterns of black bears (*Ursus americanus*) in Great Smoky Mountains National Park. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Teunissen van Manen, J. L., L. I. Muller, Z. Li, A. M. Saxton, and M. R. Pelton. 2014. Using stable isotopes to assess dietary changes of American black bears from 1980 to 2001. Isotopes in Environmental and Health Studies 50:382–398.

Therneau, T. M. 2018. Survival: survival analysis. < https://cran.r-project.org/web/packages/survival/index.html>. Accessed 1 December 2018.

University of Tennessee, Boyd Center for Business and Economic Research. 2017. Annual Tennessee country population projection totals. <http://tndata.utk.edu/sdcpopulationprojections.htm>

U. S. Census Bureau, Population Division. 2017. Annual estimates of the resident population: April 1, 2010 to July 1, 2017. <https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk>. Accessed 7 April 2018.

U. S. Census Bureau, 2010 Census. 2010. Population, housing units, area, and density: 2010 – United States – County by state; and for Puerto Rico. <https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk>. Accessed 9 April 2018.

U. S. Forest Service [USFS]. 2018. USFS homepage. https://www.fs.fed.us. Accessed 10 Oct 2018.

van Manen, F. T. 1994. Black bear habitat use in Great Smoky Mountains National Park. Dissertation, University of Tennessee, Knoxville, Tennessee, USA.

Vukomanovic, J., S. L. Doumas, W. R. Osterkamp, and B. J. Orr. 2013. Housing density and ecosystem function: comparing the impacts of rural, exurban, and suburban densities on fire hazard, water availability, and house and road distance effects. Land 2:656–677.

Walter, W. D., J. W. Fischer, S. Baruch-Mordo, and K. C. VerCauteren. 2011. What is the proper method to delineate home range of an animal using today's advanced GPS telemetry systems: the initial step. USDA National Wildlife Research Center Staff Publications. Paper 1375.

West, J. B., G. J. Bowen, T. E. Cerling, and J. R. Ehleringer. 2006. Stable isotopes as one of nature's ecological recorders. Trends in Ecology and Evolution 21:408–414.

White, R. D., K. D. Patterson, A. Weakley, C. J. Ulrey, and J. Drake. 2003. Vegetation classification of Great Smoky Mountains National Park. Report

Wilder, J. M., T. D. DeBruyn, T. S. Smith, and A. Southwould. 2007. Systematic collection of bear-human interaction information for Alaska's national parks. Ursus 18:209–216.

Williamson, R. H., L. L. Muller, and C. Blair. 2018. The use of ketamine-xylazine or butorphanol-azaperone-medetomidine to immobilize American black bears (*Ursus americanus*). Journal of Wildlife Diseases 54:1–8.

Zhang, Z. 2016. Model building strategy for logistic regression: purposeful selection. Annals of Translational Medicine 4(6):111.

Zhu, C. and Y. Li. 2013. High temporal resolution land use/land cover change from 1984 to 2010 of the Little River watershed, Tennessee, investigated using Landsat and Google Earth images. Southeastern Geographer 53(3):250–266.

APPENDICES

Appendix A. GRSM Black Bear Capture Data

Table A.1. Great Smoky Mountains National Park bear capture data, 2015.

Bear ID	Sex	Age	Capture Date	Capture Reason
601	Female	6	9/11/2015	Conflict
604	Female	4	9/8/2015	Conflict
618	Male	4	6/7/2015	Conflict
627	Male	2	6/9/2015	Conflict
628	Male	4	6/15/2015	Conflict
629	Female	16	7/8/2015	Conflict
642	Female	5	7/30/2015	Conflict
644	Female	9	9/17/2015	Conflict
645	Female	5	8/14/2015	Conflict
646	Female	8	8/31/2015	Conflict
647	Female	7	8/25/2015	Conflict
648	Male	5	8/27/2015	Conflict
649	Female	11	8/28/2015	Conflict
650	Male	1	9/8/2015	Conflict

Table A.2. Great Smoky Mountains National Park bear capture data, 2016.

Bear ID	Sex	Age	Capture Date	Capture Reason
436	Female	14	3/23/2016	Conflict
637	Male	6	5/21/2016	Conflict
657	Female	7	7/11/2016	Conflict
1004	Male	4	5/23/2016	Conflict
1005	Female	2	5/23/2016	Conflict
1008	Male	3	5/29/2016	Conflict
1010	Male	2	6/2/2016	Conflict
1012	Female	5	5/30/2016	Conflict
1013	Male	8	6/10/2016	Conflict
1014	Male	2	6/7/2016	Conflict
1015	Male	2	6/10/2016	Conflict
1017	Male	3	6/11/2016	Conflict
1020	Male	5	7/1/2016	Conflict
1022	Female	6	7/16/2016	Conflict
1023	Female	2	7/29/2016	Conflict
1025	Female	2	8/7/2016	Conflict
1028	Male	5	7/16/2016	Conflict
1030	Female	8	8/11/2016	Conflict
1031	Male	6	8/29/2016	Conflict
1032	Male	3	10/27/2016	Conflict
1039	Male	1	11/7/2016	Conflict

Table A.3. Great Smoky Mountains National Park bear capture data, 2017.

Bear ID	Sex	Age	Capture Date	Capture Reason
959	Male	2	2/2/2017	Conflict
1033	Male	n/a	4/18/2017	Conflict
1034	Female	6	5/28/2017	Conflict
1035	Female	2	6/3/2017	Conflict
1040	Male	2	1/19/2017	Conflict
1041	Male	4	4/20/2017	Conflict
1042	Male	2	5/21/2017	Conflict
1043	Male	2	5/18/2017	Conflict
1047	Male	2	6/9/2017	Control
1048	Male	3	6/10/2017	Control
1049	Female	4	6/10/2017	Control
1051	Male	4	6/15/2017	Control
1052	Male	3	6/17/2017	Control
1053	Female	3	6/17/2017	Control
1056	Female	8	6/6/2017	Control
1062	Female	12	8/9/2017	Control
1063	Female	9	8/12/2017	Control
1070	Male	5	8/15/2017	Control

Appendix B. Stable Isotope Analysis of GRSM Bear Hair Samples

Table B.1. Mean stable isotope ratios for bears classified as known food-conditioned (FC) or known non-food-conditioned (NFC) based on GPS relocation data and personal observations, Great Smoky Mountains National Park, 2014–2017. Known FC and NFC stable isotope ratios were used to develop a logistic regression model.

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
618	M	Adult	2014	-23.737	1.537	NFC
629	F	Adult	2014	-24.123	0.917	NFC
644	F	Adult	2015	-24.503	0.233	NFC
646	F	Adult	2015	-23.193	1.783	FC
648	M	Adult	2015	-23.273	1.217	FC
649	F	Adult	2015	-23.843	0.567	NFC
650	M	Subadult	2015	-23.740	2.827	NFC
657	F	Adult	2016	-24.276	1.433	NFC
959	M	Subadult	2016	-23.740	3.000	NFC
1005	F	Subadult	2015	-23.693	2.923	NFC
1012	F	Adult	2015	-23.697	0.927	NFC
1014	M	Subadult	2015	-21.943	3.227	FC
1015	M	Subadult	2016	-23.357	1.840	NFC
1020	M	Adult	2016	-19.040	6.150	FC
1022	F	Adult	2016	-23.743	1.743	NFC

Table B.1. continued.

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
1023	F	Subadult	2016	-20.023	4.920	FC
1023	F	Subadult	2017	-20.160	5.447	FC
1025	F	Subadult	2016	-20.683	4.723	FC
1028	M	Adult	2016	-19.657	3.763	FC
1030	F	Adult	2016	-23.837	2.033	NFC
1031	M	Adult	2016	-21.843	3.780	FC
1035	F	Subadult	2016	-21.873	5.000	FC
1035	F	Subadult	2017	-20.827	4.883	FC
1041	M	Adult	2016	-20.193	4.837	FC
1043	M	Subadult	2016	-22.387	3.573	FC
1047	M	Subadult	2016	-22.203	3.570	NFC
1049	F	Adult	2016	-23.853	0.983	NFC
1053	F	Subadult	2016	-23.387	0.413	NFC
1056	F	Adult	2016	-24.260	1.060	NFC
1062	F	Adult	2017	-24.273	2.047	NFC
1063	F	Adult	2017	-24.233	1.167	NFC
1070	M	Adult	2017	-24.710	1.380	NFC

Table B.2. Logistic regression model selection results for classifying bears as food-conditioned or non-food-conditioned based on $\delta^{13}C$ and $\delta^{15}N$ ratios, Great Smoky Mountains National Park, 2014–2017.

Model	Number of parameters	Log likelihood	AICc	ΔAICc	Model weight
Classification ~ $\delta^{13}C$	2	-6.352	17.118	0.000	0.614
Classification ~ $\delta^{13}C + \delta^{15}N$	3	-5.887	18.632	1.514	0.288
Classification ~ $\delta^{13}C * \delta^{15}N$	4	-5.728	20.937	2.305	0.091
Classification ~ $\delta^{15}N$	2	-10.914	26.241	5.304	0.006

Table B.3. Mean stable isotope ratios for bears classified as food-conditioned (FC) or non-food-conditioned (NFC) using a logistic regression model (log it(y) = 66.242 + 2.900$\delta^{13}C$), Great Smoky Mountains National Park, 2014–2017.

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
436	F	Adult	2015	-24.487	0.913	NFC
601	F	Adult	2015	-23.857	0.603	NFC
604	F	Adult	2015	-24.337	2.320	NFC
604	F	Adult	2016	-23.390	2.487	NFC
604	F	Adult	2017	-23.557	2.443	NFC
618	M	Adult	2014	-23.737	1.537	NFC
627	M	Subadult	2014	-23.453	1.900	NFC
628	M	Adult	2014	-23.833	-0.797	NFC
628	M	Adult	2016	-22.030	3.427	FC
629	F	Adult	2014	-24.123	0.917	NFC
637	M	Adult	2015	-23.947	2.310	NFC
642	F	Adult	2015	-24.650	0.873	NFC
642	F	Adult	2016	-24.577	0.660	NFC
644	F	Adult	2015	-24.503	0.233	NFC
645	F	Adult	2015	-21.403	3.160	FC
645	F	Adult	2016	-19.867	5.363	FC

Table B.3. continued

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
646	F	Adult	2015	-23.193	1.783	FC
647	F	Adult	2015	-24.313	-0.017	NFC
647	F	Adult	2016	-23.977	1.433	NFC
647	F	Adult	2017	-25.513	1.560	NFC
648	M	Adult	2015	-23.273	1.217	FC
649	F	Adult	2015	-23.843	0.567	NFC
650	M	Subadult	2015	-23.740	2.827	NFC
657	F	Adult	2016	-24.277	1.433	NFC
959	M	Subadult	2016	-23.740	3.000	NFC
1004	M	Adult	2015	-19.453	5.637	FC
1005	F	Subadult	2015	-23.693	2.923	NFC
1008	M	Subadult	2015	-24.640	0.827	NFC
1010	M	Subadult	2015	-21.357	2.367	FC
1012	F	Adult	2015	-23.697	0.927	NFC
1013	M	Adult	2015	-25.013	1.740	NFC
1014	M	Subadult	2015	-21.943	3.227	FC
1015	M	Subadult	2016	-23.357	1.840	NFC
1015	M	Subadult	2015	-22.303	3.237	FC

Table B.3. continued

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
1017	M	Subadult	2015	-22.353	2.903	FC
1020	M	Adult	2016	-19.040	6.150	FC
1022	F	Adult	2016	-23.743	1.743	NFC
1023	F	Subadult	2016	-20.023	4.920	FC
1023	F	Subadult	2017	-20.160	5.447	FC
1025	F	Subadult	2016	-20.683	4.723	FC
1028	M	Adult	2016	-19.657	3.763	FC
1030	F	Adult	2016	-23.837	2.033	NFC
1031	M	Adult	2016	-21.843	3.780	FC
1032	M	Subadult	2016	-22.880	3.390	FC
1033	M	n/a	2016	-24.110	1.927	NFC
1035	F	Subadult	2016	-21.873	5.000	FC
1035	F	Subadult	2017	-20.827	4.883	FC
1040	M	Subadult	2016	-21.183	4.423	FC
1041	M	Adult	2016	-20.193	4.837	FC
1042	M	Subadult	2016	-21.160	4.380	FC
1043	M	Subadult	2016	-22.387	3.573	FC
1047	M	Subadult	2016	-22.203	3.570	FC

Table B.3. continued

Bear ID	Sex	Age	Year	$\delta^{13}C$	$\delta^{15}N$	Classification
1048	M	Subadult	2016	-23.840	1.780	NFC
1049	F	Adult	2016	-23.853	0.983	NFC
1051	M	Adult	2016	-24.127	1.513	NFC
1052	M	Subadult	2016	-24.120	1.163	NFC
1053	F	Subadult	2016	-23.387	0.413	NFC
1056	F	Adult	2016	-24.260	1.060	NFC
1062	F	Adult	2017	-24.273	2.047	NFC
1063	F	Adult	2017	-24.233	1.167	NFC
1070	M	Adult	2017	-24.710	1.380	NFC

Appendix C. Annual and Seasonal Home Ranges of GRSM Black Bears

Table C.1. Estimates of kernel density estimation home range sizes (km^2) of food-conditioned (FC) or non-food-conditioned (NFC) black bears in Great Smoky Mountains National Park, 2015.

		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
NFC	95	52.9	59.8	7	10.0-182.1	154.8	49.8	3	98.3-192.2
	50	5.6	2.8	7	2.1-8.5	21.1	6.0	3	14.1-24.6

		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
FC	95	62.9	75.3	2	9.7-116.2	142.0	13.5	2	132.5-151.6
	50	10.5	11.8	2	2.2-18.9	23.4	12.4	2	14.7-32.2

Table C.2. Estimates of kernel density estimation home range sizes (km^2) of food-conditioned (FC) or non-food-conditioned (NFC) black bears in Great Smoky Mountains National Park, 2016.

		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
NFC	95	17.8	10.3	11	8.2-46.5	130.0	73.5	5	65.4-230.3
	50	4.0	1.9	11	1.9-8.8	22.3	7.6	5	11.7-31.0
		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
FC	95	9.8	0.7	3	9.0-10.4	103.2	47.7	10	43.0-191.4
	50	2.2	0.1	3	2.1-2.2	20.2	7.8	10	10.3-35.4

Table C.3. Estimates of kernel density estimation home range sizes (km^2) of food-conditioned (FC) or non-food-conditioned (NFC) black bears in Great Smoky Mountains National Park, 2017.

		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
NFC	95	14.1	3.8	12	8.9-22.5	146.8	66.8	9	48.4-289.9
	50	3.0	0.8	12	2.0-4.7	20.5	8.6	9	8.4-37.7
		Females				Males			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
FC	95	9.4	1.5	3	8.0-11.0	112.0	84.9	10	39.8-290.2
	50	2.1	0.3	3	1.9-2.4	19.0	7.5	10	8.7-34.0

Table C.4. Seasonal mean kernel density estimation home range sizes (km^2) of food-conditioned (FC) or non-food-conditioned (NFC) female black bears in Great Smoky Mountains National Park.

		Spring				Summer				Fall			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
FC	95	8.7	2.1	3	7.4-11.2	10.2	1.3	5	8.7-11.6	29.6	45.6	5	8.6-111.2
	50	2.0	0.5	3	1.7-2.5	2.2	0.2	5	2.0-2.5	5.3	7.1	5	1.9-18.1

		Spring				Summer				Fall			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
NFC	95	10.5	2.8	10	7.3-14.3	13.7	8.9	18	7.6-46.2	21.1	13.0	16	7.6-52.1
	50	2.4	0.7	10	1.7-3.7	3.1	1.8	18	1.8-9.5	3.9	1.9	16	1.7-8.2

Table C.5. Seasonal mean kernel density estimation home range sizes (km^2) of food-conditioned (FC) or non-food-conditioned (NFC) male black bears in Great Smoky Mountains National Park.

		Spring				Summer				Fall			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
FC	95	68.8	26.0	12	35.6-121.3	92.5	39.8	14	48.4-191.8	106.2	64.8	12	43.0-248.3
	50	15.2	6.6	12	8.1-27.3	18.0	8.5	14	9.5-37.0	17.6	11.4	12	10.3-47.9

		Spring				Summer				Fall			
	%	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range	$\bar{x}$	SD	*n*	range
NFC	95	64.3	24.9	7	39.6-101.5	131.6	69.5	12	45.8-290.0	108.9	45.0	11	44.1-188.7
	50	13.0	4.2	7	9.6-21.4	19.6	7.5	12	8.5-29.4	16.7	5.3	11	9.3-28.3

Appendix D. Step Selection Function Model

Table D.1. Top conditional logistic regression models to create a step selection function for black bears in GRSM. Case represents whether a step was used or random; pc represents the log of percent canopy; dc represents the scaled distance to cover; s represents slope; dd represent the scaled distance to development; dr represents the scaled distance to nearest ridge; log_sl represents the log of step length; SEX represents male or female; SEAS represents season; tod represent time of day; age represents the age class; and CARB represents mean $\delta^{13}C$.

Model	Number of parameters	Log likelihood	AIC	ΔAIC	Model weight
Case ~ pc + dc + dc2 + s + s2 + dd + dd2 + dr + dr2 + log_sl + SEX + SEX*dc + SEX*s + SEX*dd + SEAS + SEAS*s + SEAS*dr + tod* dr + age + age*s + age*dr + CARB + CARB*pc + CARB*s + CARB*dr	30	-416782.3	833624.6	0.000	0.441
Case ~ pc + dc + dc2 + s + s2 + dd + dd2 + dr + dr2 + log_sl + SEX + SEX*dc + SEX*s + SEX*dd + SEAS + SEAS*s + SEAS*dr + tod* dr + age + age*s + age*dr + CARB + CARB*pc + CARB*s	29	-416783.4	833624.8	0.254	0.388
Case ~ pc + dc + dc2 + s + s2 + dd + dd2 + dr + dr2 + log_sl + SEX + SEX*dc + SEX*s + SEX*dd + SEAS + SEAS*s + SEAS*dr + tod* dr + age + age*s + age*dr + CARB + CARB*pc + CARB*s + CARB*dd	30	-416783.2	833626.5	1.895	0.171
Case ~ pc + dc + dc2 + s + s2 + dd + dd2 + dr + dr2 + log_sl + SEX + SEX*dc + SEX*s + SEX*dd + SEAS + SEAS*s + SEAS*dr + tod* dr + age + age*s + age*dr + CARB + CARB*pc	28	-416799.1	833654.1	29.572	0.000

VITA

Jessica Braunstein, daughter of Robert and Sunny Braunstein, was born in Daegu, South Korea on October 22, 1990. Her family moved to Maryville, Tennessee in 1992 where she grew up and attended Maryville High School. In 2009, she began her Bachelor of Science in Biological Sciences at Lee University in Cleveland, Tennessee. During her undergraduate studies, she assisted with several research projects including studies on the eastern hellbender in Tennessee and blue crabs in the Chesapeake Bay. After completion of her bachelor's degree in May of 2013, she moved to Shaver Lake, California to work as a wildlife intern for the United States Forest Service's King's River Fisher Project for six months. The following year, she completed an Appalachian Trail thru-hike before applying for graduate school. In April 2015, she returned to Tennessee to begin her Master of Science in Wildlife Science at the University of Tennessee in Knoxville. Her graduate degree research focused on food-conditioning and movements of American black bears in Great Smoky Mountains National Park. During the last summer of her graduate studies, she worked as a seasonal Biological Science Technician for the National Park Service in Great Smoky Mountains National Park and assisted with black bear, bat, and wild hog management. Beginning in 2019, Jessica will continue her career in wildlife research and management at the University of Tennessee by pursing a PhD in Natural Resources. Her doctoral research will focus on estimating the elk population in western North Carolina.