A SPATIAL ANALYSIS OF MANAGEMENT TECHNIQUES USED ON NUISANCE BLACK BEARS IN GREAT SMOKY MOUNTAINS NATIONAL PARK, USA (1990-2015)

by

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ABSTRACT

Human-bear conflicts have been an important issue for wildlife officials in Great Smoky Mountains National Park since it was first established in 1934. In the Park's early decades, biologists used capture and relocation as the primary method of management for nuisance bears. In 1990, capture and on-site release was introduced and thus provided another way for biologists to manage their individual nuisance bears. Since then, relocation and on-site release have been the two primary techniques used on nuisance bears.

This project gathered the previous 26 years of nuisance bear capture data into a central database and calculated the differences in success rates between nuisance bears that were released on-site and those that were relocated. Bears were separated into two classes: animals that were captured for the first time, and animals that had been previously captured. Their histories were traced to determine if, and when, bears required later management actions.

Results showed significant differences in success rates between the two management techniques. Nuisance bears released on-site following their first capture were successful 61% of the time, while bears that were relocated after their first capture were successful 87% of the time. Median time for recapture of nuisance bears that were initially released on-site and relocated was 65 and 293 days, respectively. Success rates for nuisance bears that had been previously captured and released on-site dropped for their second and third capture to 50% and 0%, respectively. Success rates of experienced nuisance bears that were relocated for their second and third capture were 87% and 67%, respectively. On their second capture, median time before recapture of nuisance bears that were released on-site and relocated dropped to 38 and 41 days, respectively.

Overall, 26% (n=94) of the bears initially captured for management purposes in this thesis were recaptured for later nuisance activity. A general comparison of nuisance bear studies in Great Smoky Mountains National Park indicated that wildlife managers are now doing a better job of managing their nuisance bears than in previous decades. A project that examined the 23 years directly preceding this study’s time period found that 32% (n=108) of all bears captured and relocated for nuisance purposes a first time were recaptured for further nuisance activity. The increase in nuisance bear management success rates could be due, in part, to the introduction and implementation of on-site release as a management technique for nuisance bears.

DEDICATION

"There are some who can live without wild things and some who cannot."
-Aldo Leopold

This project is dedicated to everyone in my life who has taught and encouraged my love of adventure, exploration and conservation. I wouldn't be the person I am today without you all.

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CHAPTER 1

INTRODUCTION

The conflict between humans and bears (*Ursus* spp.) is a longstanding, important topic for wildlife conservation in North America (Can et al. 2014). As humans have expanded development into previously remote regions and eliminated the buffer of wilderness areas, probability for interactions among humans and bears has increased. Black bears are intelligent and highly adaptable animals with opportunistic feeding habits. Therefore, the availability of anthropogenic food sources can lead to behavioral changes and increased interactions between humans and bears (Pelton 2003). These interactions provide ideal conditions for conflict situations between humans and bears. Bear populations that border urban areas or places with easily available human food sources require constant attention and force biologists to make difficult, and often public, management decisions (Don Carlos et al. 2009).

Even in protected areas, some of North America's national parks have regular incidents of human-bear conflicts because of their high bear densities and human visitation rates (Harms 1980, McArthur 1981, Tate and Pelton 1983, Garner and Vaughn 1989, Schirokauer and Boyd 1998). Yellowstone, Glacier, Shenandoah and Great Smoky Mountains National Park all have long histories of human-bear conflicts (Sellars 2009). This project focused specifically on Great Smoky Mountains National Park (GSMNP or Park) and the adjoining areas. GSMNP is the most visited national park in the country hosting more than 10 million people annually (NPS 2015a). The Park also has the highest population density of black bears in North America, with approximately 1,800 resident bears (Laufenberg et al. 2013), creating model conditions for human-bear conflicts. Currently, GSMNP's bear management policies are to manage visitors, employees, concessionaires and bears in a manner that allows wild bears to live naturally while ensuring visitor safety. This policy is implemented using a number of different management strategies by wildlife personnel, "as determined by the District Rangers or Wildlife Biologists, using their best judgment based on education, experience and training…" (NPS 2002, p. 8). A black bear's tendency to exploit available nutrient rich human food sources (Jonkel and Cowen 1971) combined with visitors' failure to follow regulations can result in nuisance activity and human-bear conflicts in the Park. Bears are generally considered a nuisance if they are habitually entering campgrounds, picnic areas or other developed areas and attempting to eat human food or garbage (NPS 2002, W. Stiver, personal communication, 2016). Wildlife personnel have worked to eliminate the availability of human food sources by installing bear-proof dumpsters, trash cans and adding staff to highly-visited sites throughout the frontcountry areas of the Park. Bear-proof food cables have also been installed at major backcountry campsites and shelters, and programs have been designed to help educate visitors about the importance of following regulations regarding wildlife and the consequences of improperly storing food or feeding bears (NPS 2002). Despite these proactive actions, and because of the sheer number of visitors and bears in the Park, human-bear conflicts continue to occur (Clark 1999).

The two most commonly used management techniques for nuisance bears in GSMNP are capture and relocation, and capture and on-site release. Capture and relocation is a reactionary management method that was the primary technique used on nuisance bears in the Park prior to 1990 (Stiver 1991). It involves capturing bears that have been habitually entering campgrounds, damaging property or causing concerns for visitor safety and moving them to another suitable location. Others have identified drawbacks to this management strategy such as the limited size of the Park and black bears' incredible homing abilities (Beeman and Pelton 1976), the substantial resources required to relocate bears (McArthur 1981) and the increased possibility of unnatural mortality caused by moving nuisance bears onto lands where hunting is legal (Clark 1999). In 1990, GSMNP wildlife officials introduced capture and on-site release as an alternative way to manage their nuisance bears. The on-site release management technique attempts to aversely condition nuisance bears and prevent future nuisance activity through the introduction of a negative stimulus, such as capture and handling by humans, as soon as nuisance activity is reported (Clark et al. 2002). Capture and on-site release provides a way for wildlife biologists to be more proactive with the management of their individual nuisance bears. Other management techniques include monitoring nuisance bears and problem sites, posting warning signs, closing areas where nuisance bears are active, aversive conditioning and euthanasia (NPS 2002). The determination of which management technique is most suitable for a given nuisance bear is based largely on the history of the bear and the details of the nuisance activity (Clark et al. 2003).

Scientists from the University of Tennessee have extensively studied bears in GSMNP, and the Park is the home of the longest continuous research project of any bear species in the world (Linzey 2008). In this thesis, we combined the human dimension of wildlife management and Geographic Information Systems to help contribute to the robust body of work on conservation issues within the Park. The objective of this study was to provide wildlife managers with another resource to help in the successful management of nuisance bears in GSMNP.

Specifically, this project aimed to provide Park officials with a comprehensive digital database containing all nuisance bear reports between the years 1990-2015. Secondly, we performed a spatial analysis of captured nuisance bears to quantify the success rates of different bear management techniques and answered the following questions: (1) What percentage of nuisance bears do Park officials release on-site vs. relocate? (2) What percentage of on-site released and relocated bears require later management, and when? (3) What are the demographics of these nuisance bears? (4) What happens to bears that are relocated outside of the Park? Are they seen again, road killed, hunter killed, etc.? (5) What percentage of Park nuisance bears are euthanized?

The analysis of these data and results of this study were interpreted in the context of management applications specifically for the GSMNP bear population.

CHAPTER 2

STUDY AREA

Location

This research was focused in Great Smoky Mountains National Park and its surrounding areas. The Park covers approximately 2,072 km^2 and is located between 35^o 26’ and 35^o 47’ North latitude and 83^o 2’ and 84^o 0’ West longitude (Fig. 2.1). GSMNP straddles the border of eastern Tennessee and western North Carolina and includes parts of Blount, Sevier, Cocke, Haywood and Swain counties. The Park is surrounded by federally-protected land on three sides, including Cherokee National Forest, Nantahala National Forest, Pisgah National Forest and the Cherokee Indian Reservation. These areas combine to provide approximately 17,000 km^2 of contiguous wildlife habitat (USDA 2014), although human infrastructure is scattered within this territory.

Physiography and Geology

The Great Smoky Mountains are part of the Unaka Mountain Range which lies in the Blue Ridge Province of the southern Appalachian Highlands (Fenneman 1938). A single ridge runs in a northeast direction and forms the boundary between Tennessee and North Carolina. More than 90% of the Park, known for its ridges with steep slopes and narrow stream-cut valley bottoms, has a slope greater than 10% (Anonymous 1902). A recently completed stream mapping project found that there are more than 4,667 km of streams in the Park, 1,726 km of which are large enough to hold fish (NPS 2015b). These streams are split across the Park’s ridge and flow into the Oconaluftee and Tuckasegee rivers in North Carolina, and the Little Pigeon and Little Tennessee rivers in Tennessee. Elevations range from 230 m in Abrams Creek to 2,024 m at Clingman's Dome. The Park's bedrock consists of feldspathic sandstone, siltstone and conglomerate from the Ocoee series (King et al. 1968). Soils in this area are highly acidic, have low water storage capacity and include both the Ramsey and Jefferson series (USDA 1945).

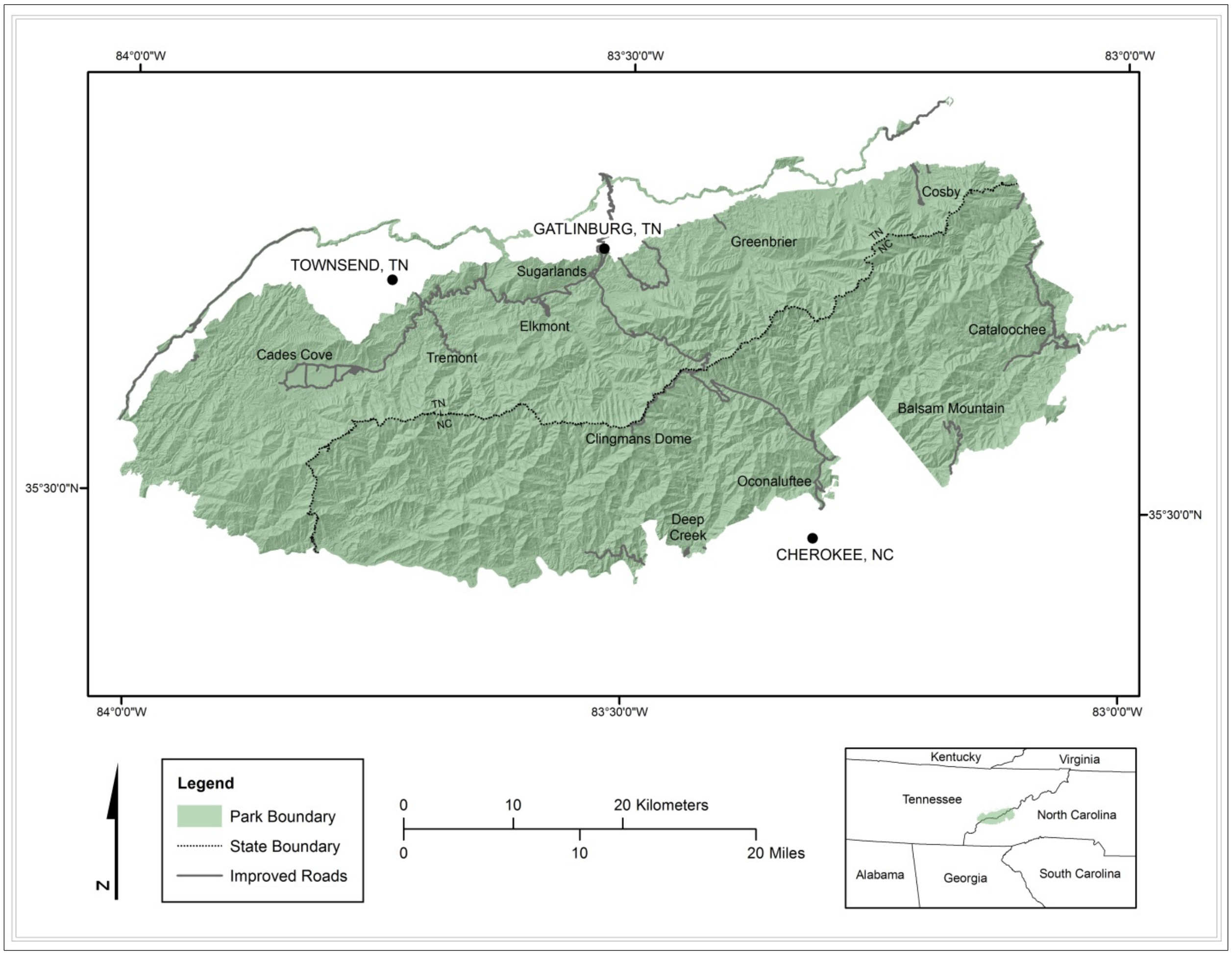

Figure 2.1. Great Smoky Mountains National Park is located on the border of Tennessee and North Carolina.

Climate

Thornthwaite (1948) classified the climate of this area as mesothermal perhumid. This warm-temperate rain forest type climate is characterized by short, mild winters and long, hot summers. Dramatic variation in elevation influences temperatures and creates microclimate conditions within the Park (Shanks 1954a). Average annual temperatures range from 8^{o}C at higher elevations to 14^{o}C at lower elevations, and Shanks (1954a) measured a lapse rate of 4^{o}C per 1,000 m change in elevation. Annual precipitation ranges from 140 cm at lower elevations to 220 cm at higher elevations. The region's highest precipitation usually occurs in July and minimum levels normally occur in September and October (Stephens 1969).

Flora and Fauna

GSMNP's extreme variations in elevation, temperature and precipitation have created one of the most biologically diverse regions in temperate North America. The Park was designated as an International Biosphere Reserve in 1976 and a World Heritage Site in 1983 (Linzey 2008). Altitudinal zonation, most clearly visible through vegetation, is dramatic in the Park. Changes in vegetation from the Park's lowest elevations to the Park's highest elevation mimic changes seen by traveling from Georgia to Maine (King and Stupka 1950). More than 1,300 species of vascular plants (Stupka 1960) and 105 native tree species are present within the Park (Nichols and Langdon 2007). White (1982) reported an additional 288 species of exotic plants. More than 2,000 species of fungi, 230 lichens, 350 mosses and liverworts and 2,400 non-flowering plants have also been identified within GSMNP (Stupka 1960). Over 95% of the Park is forested, with approximately 40,000 ha - 75,000 ha of remaining virgin forest spread among the Deep Creek, Bradley Fork, Raven Fork, Little Pigeon River and Cataloochee watersheds

(NPS 1979, Pyle 1988). The predominant forest types include: spruce-fir, cove hardwoods, hemlock, northern hardwoods, closed oak and open oak (Shanks 1954b).

Pivorun et al. (2009) reported 67 native mammal species in the Park. Of these, four had been previously extirpated. The beaver (*Castor canadensis*) has recolonized, river otter (*Lutra canadensis*) and elk (*Cervus elaphus*) have been successfully reintroduced, and there was a failed attempt at reintroduction of red wolves (*Cervus elsphus*) to GSMNP. The Park is also home to more than 240 species of birds, 83 species of reptiles and amphibians, and 79 species of native fish (King and Stupka 1950). The restoration of brook trout (*Salvelinus fontinalis*), the Park's only native salmonid, has been overwhelmingly successful. Biologists have restored brook trout to more than 18 km across nine streams that were historically occupied exclusively by the fish (NPS 2014).

History and Land Use

Archaeological surveys conducted in the Park show that humans were present in the area at least 8,000 years ago with tools and pottery of every cultural period represented since approximately 6,000 B.C. Bog sediment studies completed on the adjoining Cherokee Indian Reservation show an increase in charcoal from 1450 A.D. - 1600 A.D. This timeframe corresponds to the arrival of the Cherokee Indians in the area (Dickens 1976). The Cherokee occupied approximately 100,000 km^2 of Tennessee, North Carolina, South Carolina, Georgia and Alabama. They lived in villages of large numbers along streams and rivers where they farmed the fertile river bottoms while using the surrounding mountains to hunt game and gather wild plants for food and medicinal purposes. The Cherokee made an impact on the landscape as they cut trees for shelter, canoes and firewood. They also set intentional fires as a way of clearing land for agricultural purposes and managing the forests for wildlife populations (Pierce 2015).

Hernando de Soto is believed to have been the first European to see the Great Smoky Mountains when he visited Tallassee in 1540 (Frome 1997). By the mid-1600s, trade with the Europeans was an essential part of Cherokee life, and they increased hunting activities to provide fur for trading. In the following decades, deer populations declined, and bison and elk were extirpated from the area. A series of treaties began in 1761 which allowed the permanent settlement of Europeans in the area. In the late 1790s, the first Europeans settled inside the current boundaries of the Park. In 1819 the Treaty of Calhoun eliminated all Cherokee claim in the Great Smoky Mountains. By the late 1830s, Europeans had settled in nearly all major stream valleys of the Smokies, and the Cherokee Indians were officially removed from their land in 1838. (Pierce 2015).

Commercial logging in the area began in 1880 and consisted of two phases. The first phase, which took place from 1880 to 1900, was characterized by selectively cutting the most valuable timber in easily accessible areas. The second phase of commercial logging began in 1900 and consisted of large-scale clearcuts with the aid of the newly laid railroads (Lambert 1961). By 1938, more than 40% of the Park's forests had been commercially logged (Pyle 1988).

Great Smoky Mountains is the country's twenty-first national park. Campbell (1993) stated that the present-day Park was first suggested by the wife of a Knoxville Iron Company manager, Mrs. Willis Davis, after visiting existing parks in the West. In late 1923, with the goal of organizing efforts in the creation of a national park in the region, the Davis' formed what would become known as the Great Smoky Mountains Conservation Association. Colonel David C. Chapman became the chairman of the group and a champion for the Park's creation. Early supporters lobbied officials and area residents alike in the following years, and on May 22, 1926, the Park was authorized for establishment by Congress (Campbell 1993). But, unlike most national parks which are established on land already owned by the federal government, land for GSMNP had to be acquired by the states. Major fundraising efforts had already begun in both Tennessee and North Carolina and saw modest success. After years of discussion with Park supporters, on Jan. 23, 1928, John D. Rockefeller Jr. matched the amounts put forth by the states and donated $5 million as a tribute to his late mother to complete the purchase of land needed to form the Park (Pierce 2015). By 1931, with the help of the Rockefeller donation, the states had raised enough money to purchase the land for the proposed Park. And, on June 15, 1934, Great Smoky Mountains National Park was officially recognized for full establishment and completion. Because GSMNP was a gift from the people to the federal government, there is no visitor entrance fee. From inception, the Park has been managed in such a manner to conserve the scenery and natural objects in a way to leave them unimpaired for the enjoyment of future generations (Campbell 1993).

CHAPTER 3

LITERATURE REVIEW

Black Bear Ecology

American black bears (*Ursus americanus*) are the most common and widely distributed bear species in North America (Scheick and McCown 2014). They are historically found in the forested, less populated regions of the continent (Pelton 2003), but their omnivorous and opportunistic food habits and the encroachment of civilization on wilderness areas have led to exploitation of anthropogenic food sources in recent decades (Don Carlos et al. 2009).

Adult black bears range from 130 to 190 cm in length and stand 90 cm from ground to shoulder. Adult males weigh 60 to 140 kg on average, but can exceed 300 kg and adult females average 40 to 70 kg (Pelton 2000, Stirling et al. 1993). In a healthy population, average black bear ages range from 3-5 years for males and 5-8 years for females, and some animals can live up to 25 years (Johnson and Pelton 1980). These ages differ in nuisance bears, and McLean and Pelton (1990) found that maximum and average ages of nuisance bears were significantly lower than those of wild bears for both males and females in GSMNP.

According to Jonkel and Cowan (1971), black bears have one of the lowest reproductive rates of any land animal in North America. Average minimum reproductive age for females is 4.6 years in the southern Appalachian Mountains but has been reported as early as 2.5 years (Eiler et al. 1989), and can vary dramatically following years of poor mast availability (Rogers 1976). Jonkel and Cowan (1971) found that, while black bears have constant estrus cycles in the summer months, June and July are peak times for breeding and cubs are born in January or

February in their winter dens. Females will emerge from their dens by early May, and mothers will raise their cubs for approximately 16 months. This period of birth and rearing results in an average two-year cycle of reproduction for female black bears (Beeman 1975). Black bear reproductive age rarely exceeds 15 years, but a Pennsylvania study found that some black bears can successfully reproduce into their mid-twenties (Alt 1989).

Home ranges vary by geographic location, season and available food supply, but Garshelis and Pelton (1981) found that average annual home ranges were 42 km^2 for adult males and 15 km^2 for adult females inside GSMNP. The movements of black bears in the southern Appalachians are affected by habitat, social intolerances, recent weather, human interactions, and most notably, availability of food sources (Garshelis and Pelton 1980, Garshelis and Pelton 1981, Garshelis et al. 1983). Recorded total movements associated with food shortages have exceeded 200 km (Rogers 1987). Bear movements following relocation have been recorded at 507 km (Stratman et al. 2001), and Liley and Walker (2015) recorded a black bear that traveled from New Mexico to Colorado and back for a cumulative distance of 1,482 km in one year.

Black bears are omnivores, but wild bears in the southern Appalachians usually feed on soft and hard mast crops (Pelton 1989). Beeman and Pelton (1980) found the diet of bears in GSMNP changed significantly based on the seasonally abundant food sources to include: grasses and leaves in the spring, berries in the summer, and black cherries, berries and acorns in the fall. Traditionally, black bears are not active predators, but will eat other vertebrates when easily available (Pelton 2003). Jonkel and Cowan (1971) found that bears prefer easily-available human food sources when available. Additionally, McLean and Pelton (1990) found that bears with a high-energy diet consisting of human foods show significant weight gain and enhanced fertility compared to bears with more natural diets.

Black bears are generally most active during twilight hours but breeding, feeding and weather can alter this pattern (Garshelis and Pelton 1981). In GSMNP, bears showed increased activity following rain showers and reduced activities in extreme temperatures (Garshelis and Pelton 1980). Black bears are generally solitary animals except when rearing cubs, during summer breeding periods or when gathered at group feeding sites (Rogers 1987). For social communication, black bears are also known to mark trees by biting or clawing on trees along trails, abandoned roads and ridge tops (Burst and Pelton 1983).

Human-Bear History

America's first national park, Yellowstone, has had a long history of human-bear interactions since its establishment in 1872 (Gunther 1994). Reports as early as 1889, document the gathering and feeding of black bears for public viewing in Yellowstone. This behavior changed the wild bears' foraging habits, and in 1910, reports of black bears begging for human food along roads were recorded (Schullery 1992). On Dec. 8, 1916, Frank Welch was attacked by a grizzly bear named "Old Two Toes" and became the first documented human fatality from a bear in a national park (Whittlesey 2014). Human-bear incident reports increased throughout the years, and in 1931, Yellowstone National Park officials began to keep detailed records of bear-related injuries of humans and damages to their property (Gunther 1994).

Similarly, in the early 1930s, at the Civilian Conservation Corps camps in and around GSMNP feeding bears was reported as routine (Calloway 1955). By 1934, King (1935) reported problems with bears at garbage cans and mess tents in different camps around the Park. These camps were closed and, in the following years, the food conditioned bears began to appear along roads and in Park picnic areas (King 1937). In 1960, the National Park Service implemented a bear management program and began to focus on reducing anthropogenic food sources available to bears in an effort to reduce nuisance bear interactions (NPS 1960). Bear-proof garbage cans were installed in GSMNP in the late 1960s and bear-proof dumpsters were later installed in 1990 (Linzey 2008). Despite the increase in nuisance bear activity, human injuries from black bears are rare. Over the last 26 years, there were only five reported cases of predatory bear attacks in GSMNP, and there has only been one fatal bear attack in the Park's history. On May 21, 2000, a female schoolteacher was killed and partially consumed by an adult female and yearling along the Goshen Prong Trail outside of the Elkmont campground (Stiver 2015).

Bear Management in the Park

The objectives of bear management policies in the Park are to manage visitors, employees, concessionaires and bears in a manner that allows wild bears to live naturally while promoting safe visitor use. This policy is implemented using an array of management techniques by resource personnel, "as determined by the District Rangers or Wildlife Biologists, using their best judgment based on education, experience and training…" (NPS 2002, p.8). This purposefully ambiguous terminology allows wildlife managers to respond to nuisance bears on a case-by-case basis in an effort to manage the population the best way possible (W. Stiver, personal communication, 2015).

Prior to 1990, capture and relocation was the primary management method used on nuisance bears in GSMNP (Stiver 1991). Previous studies have evaluated the efficacy of relocation on nuisance black bears and found varying results (Beeman and Pelton 1976, Singer and Bratton 1980, McArthur 1981, Fies et al. 1987, Rogers 1986, Stiver 1991, Landriault et al. 2009). Black bears are known for their remarkable homing ability (Beeman and Pelton 1976), and Rogers (1986) found that 81% of nuisance bears relocated less than 64 km returned to their original site. In a study observing 23 years of nuisance bear data in GSMNP, Stiver (1991) found that 32% (n=108) of bears relocated for nuisance purposes were recaptured for further nuisance behavior. Of the bears that were recaptured, 82% (n=93; 28% of all nuisance bears) were captured within 9 km of their original capture site. In one exceptional case, between June 1988 – July 1990 GSMNP bear #75, originally moved from Cades Cove, travelled in excess of 2,500 air kilometers between 11 relocations in an effort to return home (unpublished records).

Great Smoky Mountains National Park measures approximately 32 km by 82 km (Fig. 2.1). Depending on capture site, this limited area prevents nuisance bears from being relocated adequate distances, or requires movement to federal lands adjacent to the Park. Furthermore, capture and removal of adult bears may affect the social structure of an area's bear population and cause an increase in nuisance activity (Rogers 1987). Tate and Pelton (1983) saw that the removal of one dominant adult bear from an area often resulted in the arrival of two or three sub-adults to that site. Finally, the substantial amount of resources required to relocate nuisance bears, and a decrease in willingness of neighboring state agencies to receive relocated nuisance bears led Park biologists to consider alternative solutions (Clark et al. 2003).

In 1990, wildlife managers in the Park began to use on-site release as an alternative for the management of nuisance black bears. This technique, involves capturing and immobilizing bears that frequent developed areas, collecting their biological information — a work up — and releasing the bears back at the original capture site. This process works to reinforce a bear's natural fear of humans without harming the animal (Clark et al. 2002). Previous studies have evaluated the success of on-site release of nuisance bears with varying results using small sample sizes and fine temporal scales (Brady and Maehr 1982, Clark 1999, Leigh and Chamberlain

2008). In Sequoia National Park, Mazur (2010) found that aversive conditioning was most successful on wild bears that had not yet been conditioned to human food sources. In a study similar to this thesis, Clark (1999) tested success rates of nuisance bears released on-site in GSMNP from 1990-1998 and found an overall success rate of 74%.

CHAPTER 4

METHODS

Data Collection and Database Creation

Data used for this project were gathered from the Resource Management Services (RMS) division of Great Smoky Mountains National Park's records on black bears. The RMS office has paper copies of bear management reports dating back to 1959. Additional data containing harvest and road kill records were compiled from wildlife agencies in Georgia, North Carolina and Tennessee. These data include 982 captures of 759 bears recorded from Feb. 2, 1990 to Nov. 9, 2015.

The bears in this study were captured using Aldrich spring-activated snares, culvert traps, hav-a-hart traps or free range immobilization. Trap or snare captured bears were injected using jab poles. Free ranging bears were immobilized using darts fired from CO_2 rifles or pistols. Bears were injected with a combination of Ketamine and Xylazine for chemical immobilization. Captured bears were measured and weighed, and general condition and demographics, such as age and sex were recorded. Most bears were marked with ear tags and tattoos. Premolars were extracted and sent for cementum-annuli counts for aging (Willey 1974). In some cases, external parasites, hair and blood samples were collected for research purposes. After work-ups were completed, bears were released on-site or relocated. Relocated bears were transported to remote regions of the Park when appropriate or donated to North Carolina or Tennessee wildlife agencies and released in state or national forests.

I worked with the GSMNP data manager, GIS manager and wildlife officials to compile this information into a database that contains capture and release locations of nuisance black bears in a Geographic Information System using the previously collected reports. The biological information pertaining to each capture and release location was entered into a Microsoft SQL Server database. These two database formats were linked to provide Park wildlife managers a comprehensive digital database for all nuisance bear reports from 1990 to 2015. This database can be updated in perpetuity and used for future analysis and management decisions.

Definitions

This study focused only on bears that were captured for management purposes. These include habituated or food conditioned bears that entered campgrounds, picnic areas, parking lots and other developed areas in search of human food and garbage. Some bear captures in this data set were excluded from analysis including: orphaned cubs (n=78), road kill bears (n=145), bears captured solely for research purposes (n=4), bears found dead (n=38) and injured bears (n=18). Cub and yearling bears that were captured with an adult female for nuisance purposes were treated and labeled as management bears.

Unlike previous nuisance bear studies, where releases were considered successful if the bear was not recaptured within a year (McArthur 1981, Clark 1999), we defined success as a bear that was never recaptured. Bears that were legally harvested after a nuisance capture were also considered successful. Nuisance bears released on-site were considered experienced if they had been previously captured for management purposes. Bears that had been previously captured and released on-site and were later relocated were included in the analysis of experienced relocated bears. These bears were not considered experienced until after their first relocation.

Data Analysis

ESRI's ArcGIS (ESRI ArcGIS Desktop 10.2) was used in the creation of the aforementioned database to plot the capture and release locations of GSMNP bears. Definition queries were performed in the geodatabase to select relevant capture and release points, to separate experienced and unexperienced bears and to export data to Microsoft Excel (Microsoft Office 2013).

In Microsoft Excel, bears captured for the first time were isolated and separated into animals that were released on-site and animals that were relocated. Some bears did not have a clearly defined capture history and were removed from the analysis. Subsequent capture history of the remaining bears was tracked to determine recapture and success rates. Statistical data analyses were performed using SPSS (IBM SPSS Statistics 22) and a significance value of 0.05 was used for all statistical tests. T-test procedures were used to test for significant differences in success rates between nuisance bears that were released on-site after their first capture and those that were relocated after their first capture. Mean age at time of initial capture and sex ratios were calculated for on-site released bears. T-tests were used to test for significant differences of mean ages of successful and unsuccessful captures. Chi-square Goodness of Fit Test was used to test for even sex ratios.

Capture history of nuisance bears that had been relocated was also tracked and success rates were calculated for each subsequent capture. Bears that had been previously captured and released on-site, but were relocated in later captures (n=46), were included in the calculation of success for relocated bears. These bears were not considered to be experienced until after their first relocation.

To determine major areas of conflict, nuisance bear captures were aggregated into groups using ArcGIS to represent each relative location. The size of each location and the decision of which captures to include in the aggregated groups were based on the size of the location's feature. For example, the group of captures labeled Cade's Cove consisted of all nuisance bear captures in Cade's Cove campground, picnic area, ranger station, visitor center and everything around the loop, while bears captured in Chimney's Picnic Area were grouped into a much smaller location that surrounded the Chimney's Picnic parking area and picnic loop.

Bears relocated outside Park boundaries were selected in ArcGIS and their histories were tracked to determine recapture rates. Harvest records and road kill reports from state agencies were compiled for GSMNP bears. These reports were combined with the aforementioned Park bear database to determine the subsequent history of nuisance bears relocated outside the Park.

CHAPTER 5

RESULTS

Nuisance Captures

After removing 64 captures without a bear number or marking, the remaining 403 nuisance bears were captured 635 times from May 11, 1990 to Oct. 27, 2015 (Fig. 5.1). The year with most nuisance bear captures was 1992 (n=77), and 1991 had the lowest number of nuisance bear captures (n=6).

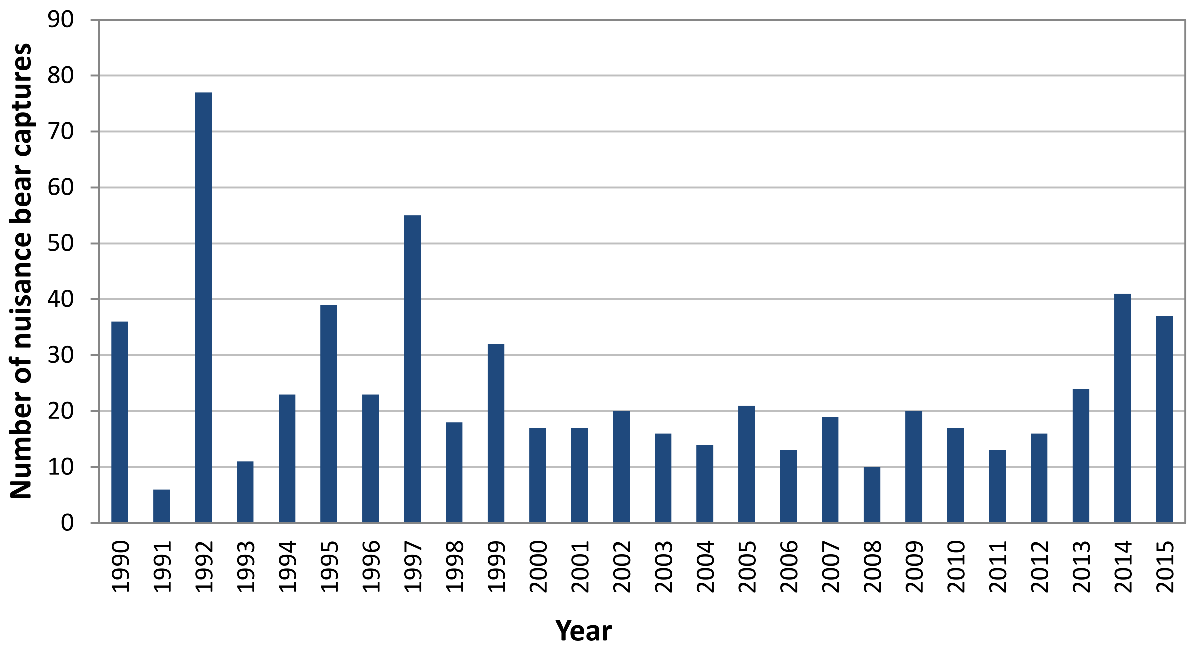

Figure 5.1. Nuisance bear captures in Great Smoky Mountains National Park (1990-2015).

Techniques, Success Rates and Demographics

Of the 403 nuisance bears captured in this study, only 367 bears had a definite traceable history following their first capture. A total of 26% (n=94) of these bears captured for nuisance purposes required later management actions.

A total of 47% (n=300) of the management bear captures in this study were released on-site. The year with the highest percentage of captures released on-site was 2008 (90%, n=9), and 1990 had the lowest percentage of nuisance bear captures that were released on-site (8%, n=3) (Fig. 5.2).

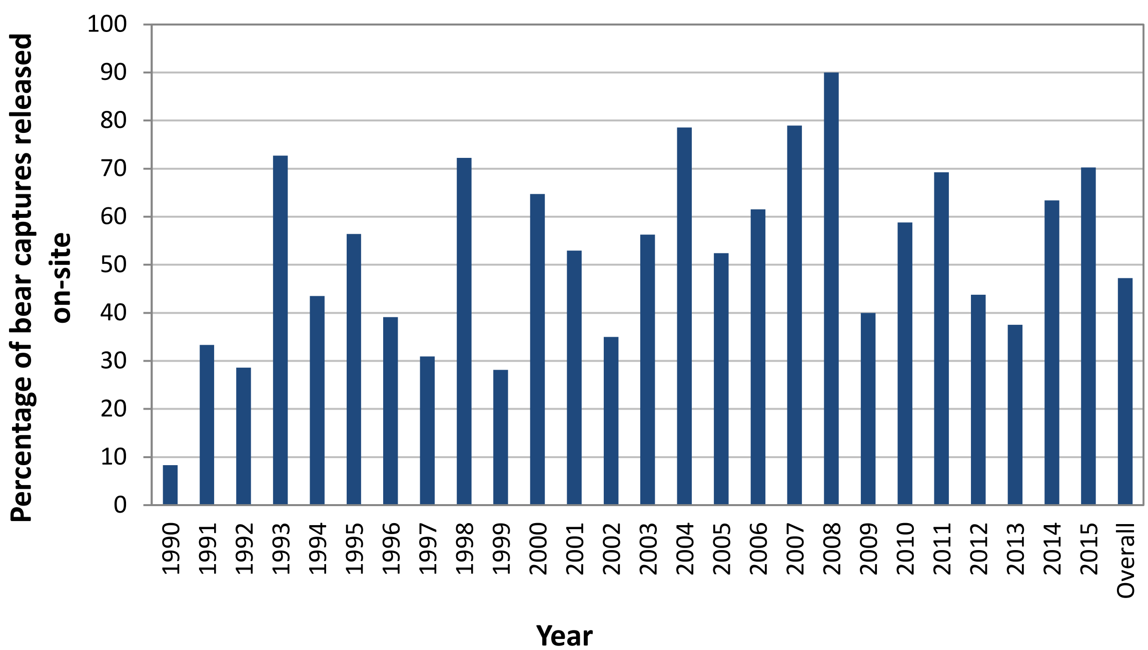

Figure 5.2. Percentage of total nuisance bear captures that were released on-site (1990-2015).

Nuisance bears captured for the first time were relocated 2% more often than they were released on-site (Table 5.1). These trends have reversed in recent years, however, and during the last five years, 65% (n=53) of nuisance bears captured for the first time were released on-site.

Table 5.1. Techniques used for nuisance bears captured for the first time in Great Smoky Mountains National Park (1990-2015).

	First-Time Captures	
Year	**On-site Release**	**Relocated**
1990	5% (n=1)	95% (n=19)
1991	50% (n=2)	50% (n=2)
1992	30% (n=17)	70% (n=40)
1993	78% (n=7)	22% (n=2)
1994	38% (n=5)	62% (n=8)
1995	47% (n=9)	53% (n=10)
1996	38% (n=8)	62% (n=13)
1997	37% (n=11)	63% (n=19)
1998	92% (n=12)	8% (n=1)
1999	25% (n=5)	75% (n=15)
2000	50% (n=4)	50% (n=4)
2001	42% (n=5)	58% (n=7)
2002	36% (n=4)	64% (n=7)
2003	50% (n=6)	50% (n=6)
2004	100% (n=7)	0% (n=0)
2005	46% (n=6)	54% (n=7)
2006	67% (n=6)	33% (n=3)
2007	90% (n=9)	10% (n=1)
2008	100% (n=7)	0% (n=0)
2009	43% (n=6)	57% (n=8)
2010	58% (n=7)	42% (n=5)
2011	86% (n=6)	14% (n=1)
2012	45% (n=5)	55% (n=6)
2013	38% (n=5)	62% (n=8)
2014	71% (n=22)	29% (n=9)
2015	75% (n=15)	25% (n=5)
Total	**49%** (n=197)	**51%** (n=206)

Of the 403 bears initially captured for management purposes, 197 were released on-site following their first nuisance capture. Nineteen bears were missing adequate information to determine a definite history and were removed from this analysis. Of the 178 bears remaining in this dataset, 39% (n=70) of the bears that were initially captured and released on-site were recaptured for management purposes (Table 5.2). Mean time elapsed until second capture was 356 days (*SD* = 528, *Median* = 65).

Table 5.2. Recapture rates of nuisance bears that were initially released on-site (1990-2015).

Year	Released On-Site	Captured Again	Percent Captured Again
1990	1	0	0%
1991	2	1	50%
1992	16	12	75%
1993	6	5	83%
1994	4	1	25%
1995	9	3	33%
1996	8	2	25%
1997	11	5	46%
1998	12	5	42%
1999	5	3	60%
2000	4	0	0%
2001	5	4	80%
2002	4	3	75%
2003	5	1	20%
2004	7	2	27%
2005	5	1	20%
2006	5	1	20%
2007	9	3	33%
2008	7	3	43%
2009	6	3	50%
2010	7	0	0%
2011	6	2	33%
2012	5	1	20%
2013	1	1	100%
2014	13	6	46%
2015	15	2	13%
Total	**178**	**70**	**39%**

Of the 403 bears initially captured for management purposes, 206 were relocated following their first nuisance capture. Seventeen bears were missing adequate information to determine a definite history and were removed from this analysis. Of the 189 bears remaining in this dataset, 13% (n=24) of the bears that were initially captured and relocated were recaptured for management purposes (Table 5.3). Mean time elapsed until second capture was 253 days (*SD* = 241, *Median* = 293).

Table 5.3. Recapture rates of nuisance bears that were initially relocated (1990-2015).

Year	Relocated	Captured Again	Percent Captured Again
1990	16	4	25%
1991	2	0	0%
1992	36	3	8%
1993	2	0	0%
1994	7	1	14%
1995	10	1	10%
1996	12	0	0%
1997	19	2	11%
1998	1	1	100%
1999	12	1	8%
2000	4	0	0%
2001	7	0	0%
2002	7	0	0%
2003	6	1	17%
2004	0	0	0%
2005	5	0	0%
2006	3	1	33%
2007	1	0	0%
2008	0	0	0%
2009	7	0	0%
2010	5	1	20%
2011	1	0	0%
2012	6	2	33%
2013	8	1	13%
2014	8	4	50%
2015	4	1	25%
Total	**189**	**24**	**13%**

An equal variances t-test revealed percentages of nuisance bears that required additional attention after initial capture was significantly higher for on-site released bears than it was for relocated bears, $t(50) = 3.69$, $p = 0.001$.

Nuisance bears that had been previously captured and released on-site were recaptured more frequently than those released on-site for the first time. Recapture rates for on-site released nuisance bears captured a second, third and fourth time were 50% (n=17), 100% (n=5) and 80% (n=4), respectively (Table 5.4). Median time passed between capture 1, capture 2, capture 3 and capture 4 was 65 days, 38 days, 386 days and 83 days, respectively.

Table 5.4. Recapture rates of experienced nuisance bears that were released on-site in Great Smoky Mountains National Park (1990-2015).

	Capture 1	**Capture 2**	**Capture 3**	**Capture 4**
Nuisance Captures	367[a]	70	17	5
Released On-Site	178	34	5	5
Recaptured	70	17	5	4
% Recaptured	39%	50%	100%	80%
% Released on-site (male)	55%	50%	20%	20%
% Released on-site (female)	44%	47%	80%	80%
% Recaptured (male)	50%	41%	20%	0%
% Recaptured (female)	49%	59%	80%	100%
Days later (median)	65	38	386	83

[a]Includes all nuisance bears with a traceable capture history.

Nuisance bears that had been previously captured and relocated were also recaptured more frequently than those relocated for the first time. Recapture rates for relocated nuisance bears captured a second and third time were 13% (n=3) and 33% (n=1), respectively (Table 5.5). Median time passed between capture 1, capture 2 and capture 3 was 207 days, 41 days and 52 days, respectively.

Table 5.5. Recapture rates of experienced nuisance bears that were relocated in Great Smoky Mountains National Park (1990-2015).

	Capture 1	Capture 2	Capture 3	Capture 4
Nuisance Captures	367[a]	28	3	1
Relocated	252[b]	23	3	-
Recaptured	28	3	1	-
% Recaptured	11%	13%	33%	-
% Released on site (male)	51%	35%	33%	-
% Released on site (female)	47%	65%	67%	-
% Recaptured (male)	39%	33%	100%	-
% Recaptured (female)	61%	67%	0%	-
Days later (median)	207	41	52	-

[a]Includes all nuisance bears with a traceable capture history.
[b]Includes bears that had been previously captured and released on-site.

Of the 252 bears that were relocated for the first time, 35 had been captured and released on-site once before they were relocated. These bears had an 11% (n=4) recapture rate. None of the bears that had been captured and released on-site twice before relocation (n=11) were recaptured for nuisance purposes.

An equal variances t-test also revealed percentages of experienced nuisance bears that required additional attention after second capture was significantly higher for on-site released bears than it was for relocated bears, $t(50) = 3.06$, $p = 0.004$.

Mean age of males was significantly lower than females at the time of initial capture for nuisance bears that were released on-site, $t(131) = 7.06$, $p < 0.001$ (Table 5.6). Mean age of male nuisance bears released on-site and recaptured was not significantly different than those that were not recaptured, $t(65) = 1.95$, $p = 0.055$. Mean age of female nuisance bears released on-site and recaptured was significantly lower than those that were not recaptured, $t(51) = 2.45$, $p = 0.018$.

Table 5.6. Mean age at the time of initial capture for nuisance bears that were released on-site.

	Male	Female
Overall	3.5	6.3
Recaptured	3	5.4
Not recaptured	3.8	7.2

Mean age of males at the time of initial capture was also significantly lower than mean age of females for nuisance bears that were relocated, $t(104) = 5.24$, $p < 0.001$ (Table 5.7). Mean age of male nuisance bears relocated that were recaptured was not significantly different than those that were not recaptured, $t(46) = 0.82$, $p = 0.417$. Mean age of female nuisance bears that had been relocated and were recaptured was not significantly different than those that were not recaptured, $t(50) = 1.28$, $p = 0.208$.

Table 5.7. Mean age at the time of initial capture for nuisance bears that were relocated.

	Male	Female
Overall	3.0	5.3
Recaptured	3.4	4.3
Not recaptured	2.9	5.5

When testing for an even sex ratio between all nuisance bears captured in this study, six bears without a recorded sex were removed from analysis. Males made up 54% (n=213) of the nuisance bears captured for the first time, but there was not a significant deviation from the expected 1:1 sex ratio, $x^2(1) = 2.12$, $p = 0.146$. A total of 25% (n=94) of these bears were recaptured for nuisance purposes. Males made up 46% (n=43) of nuisance bears captured a second time, but there was not a significant deviation from the expected 1:1 sex ratio, $x^2(1) = 0.53$, $p = 0.468$.

Capture and Release Locations

Most bears captured for management purposes in this study were captured in frontcountry areas within the Park, and 53% (n=374) of all nuisance bear captures occurred at one of six locations. The most problematic areas for nuisance bear activity were: Cades Cove (20%, n=145), Chimney's Picnic Area (18%, n=126), Cosby Campground (5%, n=40), Balsam Mountain Campground (3%, n=27), Metcalf Bottoms Picnic Area (2%, n=18) and Elkmont Campground (2%, n=18) (Fig. 5.3).

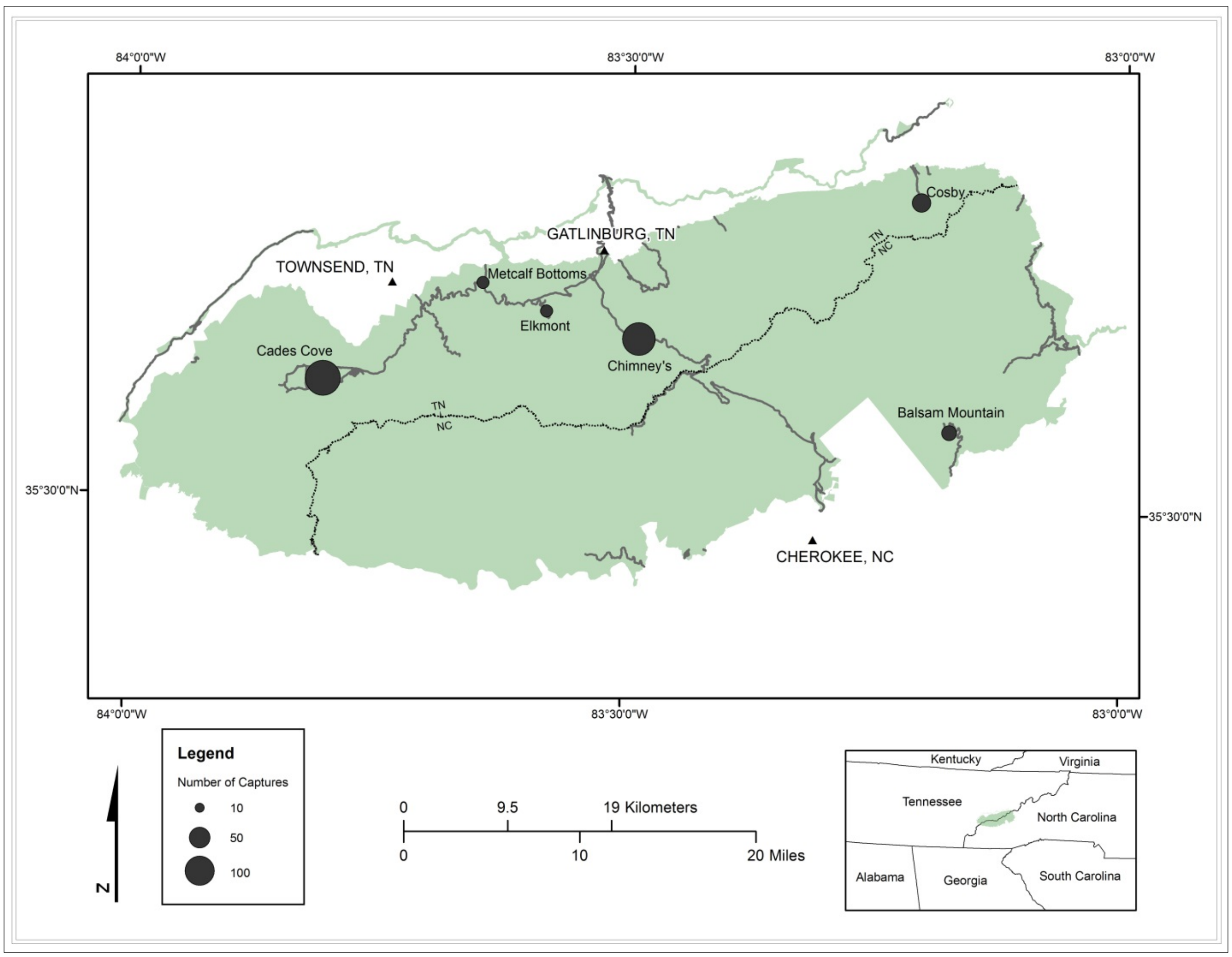

Figure 5.3. Major areas of conflict for nuisance bear captures within Great Smoky Mountains National Park (1990-2015).

A total of 235 nuisance bears were relocated outside Park boundaries 249 times (Fig. 5.4). Twenty-two of these relocated bears were not tagged with ear tags, tattoos or other markings and were removed from this analysis. Of the remaining 213 bears, only 8% (n=17) were captured again for management purposes. Of these 17 recaptures, 12 were relocated again, two were released on-site and three were euthanized. Three of the 12 relocated bears were captured again; one was euthanized and two were again relocated outside the Park and euthanized on subsequent captures (Table 5.8).

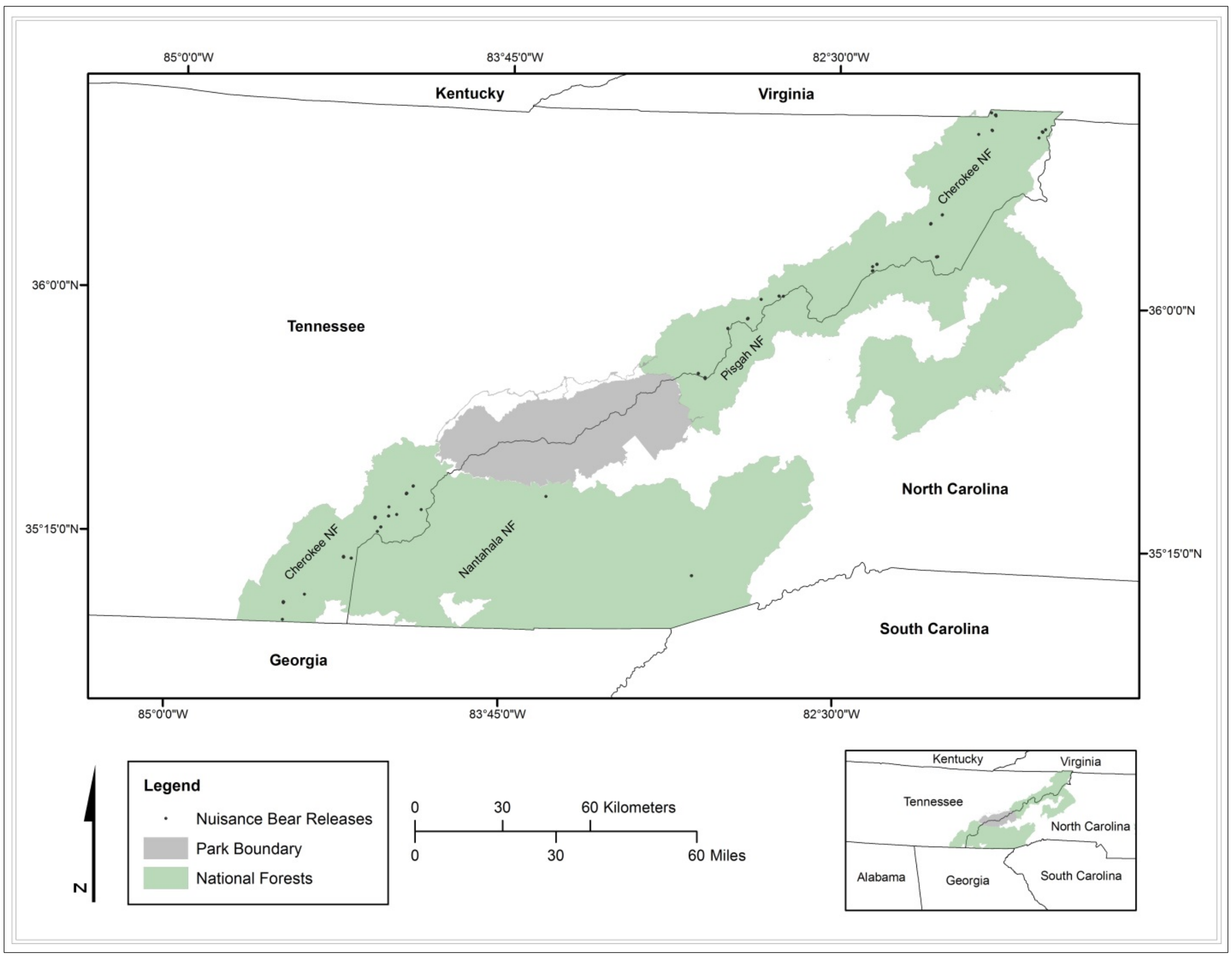

Figure 5.4. Nuisance bears that were relocated outside Great Smoky Mountain National Park boundaries (1990-2015).

Table 5.8. Final fate of nuisance bears that were relocated outside Great Smoky Mountains National Park boundaries (1990-2015).

Final Fate of Bear	Number	Percent
Unknown (includes some recaptured bears)	174	82%
Euthanized	6	3%
Road kill	8	4%
Legal harvest	25	12%
Total	**213**	**100%**

Euthanized Bears

Of the 479 nuisance bears captured in this survey, 12% (n=56) were euthanized (Fig. 5.5). In order to include all instances of euthanized bears, bears that had no tags, tattoos or other markings, and were excluded from other analysis, were included in these results. Eighteen (32%) of the 56 nuisance bears that were euthanized had been previously captured. Experienced bears that were euthanized had been captured an average of 1.5 times previously.

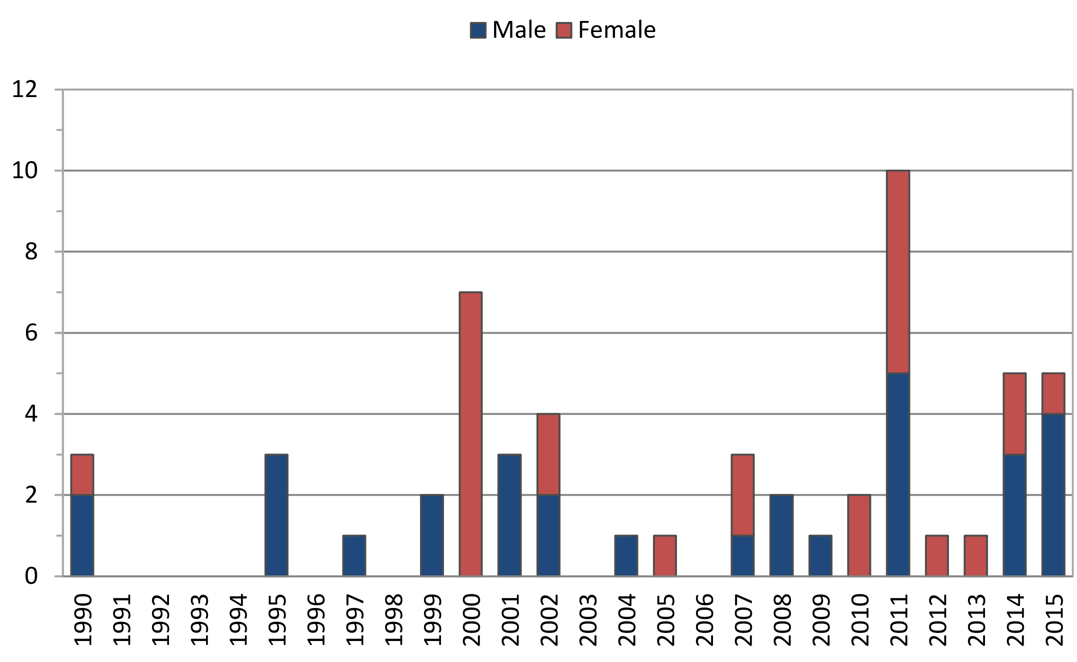

Figure 5.5. Nuisance bears that were euthanized in Great Smoky Mountains National Park (1990-2015).

CHAPTER 6

DISCUSSION

Total nuisance bear captures in this study ranged from a low of 6 (1991) to a high of 77 (1992) (Fig. 5.1). Previous studies have linked poor mast production to increases in distances bears have traveled in search of food (Beeman 1975, Garshelis and Pelton 1981, Rogers 1987, Clark 2004). The increase in distances traveled could heighten the likelihood a bear will encounter human food sources and become a nuisance. We did not compare mast production to nuisance bear captures, but Stiver (1991) suggested a correlation between poor hard mast crop yields and an increase in nuisance bear reports.

Throughout the last 26 years, 47% (n=300) of all bear captures made for management purposes in the Park were released on-site (Fig. 5.2). Bears captured for the first time were relocated 2% more than they were released on-site (Table 5.1). The decision to release a nuisance bear on-site, rather than relocate it, is based mainly on the history of that bear, the timing of the event and the nature of the nuisance activity (W. Stiver, personal communication, 2015). A bear that is fearful of people and has not yet been conditioned to human food, will be more receptive to on-site release than those that are no longer afraid of people and have already been food-conditioned (Clark 1999, Mazur 2010).

Bears that were released on-site following their first nuisance capture were successful 61% of the time (Table 5.2). This was significantly lower than the 87% success rate of nuisance bears that were relocated for their first management action (Table 5.3). Despite this difference, the resources saved by not relocating a nuisance bear may be worth the higher rate of recapture for Park officials. Mean time elapsed for on-site released bears that required additional management actions was 356 days after their first capture (*SD* = 528, *Median* = 65). Mean time elapsed for nuisance bears that were relocated after initial capture and required additional management actions was 253 days later (*SD* = 241, *Median* = 293). The high standard deviation of on-site released (*SD*=528) and relocated (*SD*=241) bears could suggest that the median time of 65 and 293 days would be a more accurate measurement for the central tendency of days delayed, however.

Experienced nuisance bears that were relocated had significantly higher success rates than experienced bears that were released on-site. Nuisance bears that were captured and released on-site a second time were only successful 50% of the time (Table 5.4), while nuisance bears that had been relocated once before were successful 87% of the time (Table 5.5). Mean time until additional captures decreased to 229 days (S*D*=655, M*edian*=38) for experienced bears released on-site and 110 days (*SD*=185, *Median*=41) for experienced nuisance bears that were relocated a second time.

Males made up 54% (n=213) of the nuisance bears that were captured for the first time, but tests revealed there was not a significant deviation from the 1:1 expected sex ratio. Mean age of nuisance bears at the time of initial capture for males was 3.3 years and 5.7 years for females. Previous studies have documented similar results and suggested that the majority of young-male nuisance bears is probably caused by dispersing movements and the long distances males travel before establishing a home range (Jonkel and Cowan 1971, Rogers 1976, Rogers 1987, Stiver 1991). Older, more established adult males may already occupy the premium habitats in a given area and force young males to increase their movements while looking to establish their own home range (Rogers 1987, Garshelis and Pelton 1981). These dispersing movements could increase the chances of human-bear interactions and the need for management attention. Stiver (1991) suggested that the older age structure of female nuisance bears may be linked to nutritional needs of mother bears. He found that 54% (n=22) of nuisance female bears 3.5 years or older had cubs or were lactating at the time of capture. Only 30% (n=29) of the female bears 3.5 years or older in this study had cubs or were lactating at the time of capture. The most captured nuisance bear in this project was GSMNP bear #236. This female bear was captured and released on-site nine times over the course of the study. Cementum annuli tests revealed she was 19 years old at the time of her last capture on Aug. 1, 2008.

It is not surprising that most nuisance captures occurred at a few frontcountry areas (Fig. 5.3). Stiver (1991) and Clark (1999) saw similar results, and these frontcountry areas are where the majority of the Park's 10 million annual visitors spend their time. Park officials have installed bear-proof dumpsters and trash cans at these locations, and most frontcountry sites staff seasonal employees to ensure that visitors follow Park regulations. Despite these actions, it is impossible to guarantee total compliance of GSMNP regulations, and some sample of the visitor population will inevitably disobey regulations and encourage nuisance bear behavior. The relatively low number of nuisance bears captured in backcountry areas could be explained by the corresponding low number of visitors that use those areas. Also, wildlife officials patrol backcountry areas less often than frontcountry areas, and it is possible that some nuisance activities in backcountry areas go unreported or do not receive management attention.

Only 8% (n=17) of the nuisance bears moved outside the Park boundary were recaptured for management purposes. These results come from GSMNP bear records and include any correspondence between state agencies and Park officials regarding the activity of tagged bears. It is possible that other GSMNP bears could have required later handling and were not reported to the Park. Area hunters legally harvested only 12% (n=25) of the nuisance bears that had been relocated outside the Park (Table 5.8). Harvest records show a total of 44 Park bears were legally killed by hunters throughout the last 26 years. Rogers (1986) suggested that relocated nuisance bears that remained near their release area could negatively affect the social structure of that area's bear population by increasing competition for food and suitable habitat, but Stiver (1991) found little evidence that relocated bears remained in their release areas. Park managers can use these results to show state agencies that nuisance bears relocated on to their adjacent lands do not usually require later attention or capture for management purposes.

Twelve percent (n=56) of all nuisance bears in this study were euthanized (Fig 5.5). Only 18 (32%) of the 56 euthanized bears had been previously captured. Experienced bears that were euthanized had been captured an average of 1.5 time before euthanasia. Information regarding nature of euthanized nuisance bear activity was not available at the time this thesis was completed. Generally, euthanasia is used only when an animal shows aggressive behavior that poses a threat to visitor safety (W. Stiver, personal communication, 2016).

Like all spatial analysis, we were faced with the Modifiable Aerial Unit Problem described by Openshaw and Taylor (1979). Our study area is a heavily forested park surrounded by similar forested lands on three sides. Furthermore, there are no fences or barriers to keep bears from moving in and out of the Park. As so, these results do not necessisarly describe the population of the bears that surround the Park. And, the results of this study might have been different if the study was replicated in a different study area, or zone, adjacent to the Park (Jelinski and Wu 1996).

There were some limitations in these data. While hunting is illegal in the Park, there is an open hunting season for black bears in both Tennessee and North Carolina that begins in late-fall. Nuisance bears that were captured and released within 45 days of the start of bear season were not chemically immobilized in case of human consumption. These bears were not marked with ear tags or tattoos and were not included in this analysis. There were also instances where bears that had been previously captured and marked lost their tags or had illegible tattoos. These bears were sometimes given a new tag number. When possible, notes in the capture reports were used to identify and track these bears for calculating success rates. When this wasn’t possible, the bears were removed from analysis.

CHAPTER 7

CONCLUSION

This study found results that may be helpful for Great Smoky Mountains National Park wildlife officials in the management of their nuisance bears. Our research has shown that success rates for bears captured and released on-site are significantly lower than success rates of bears captured and relocated, for both experienced and unexperienced bears. Despite the lower success rates, the resources saved from not having to move a bear and the time saved until future management actions were required could make on-site release a worthwhile management action, especially when a nuisance bear is captured for the first time.

Releasing a nuisance bear on-site is also beneficial to the overall bear population as a resource, as it causes less stress to each bear and does not move them onto lands where hunting is legal. Additionally, we found that 19% (n=39) of all bears moved outside Park boundaries for nuisance purposes were eventually killed from unnatural causes. The goal of biologists in regards to bear management in the Park is to allow bears to live as wild and naturally as possible, while ensuring visitor safety by minimizing human-bear conflicts. Therefore, even though releasing a nuisance bear on-site might result in a higher rate of return, this action could ultimately prevent more bears from having unnatural deaths than if they were relocated.

A general look at nuisance bear studies in GSMNP reveal that biologists are now doing a better job of managing nuisance bears than in previous decades. Stiver’s (1991) study examined nuisance bear success rates from 1967-1989 and found that 32% (n=108) of all bears captured and relocated for nuisance purposes a first time were recaptured for later nuisance activity. Since then, our study examined the years 1990-2015 and, revealed that only 26% (n=94) of the nuisance bears originally captured for management purposes were recaptured for later nuisance activity. This increase in success rates could be due, in part, to the introduction and implementation of on-site release as a management technique for nuisance bears.

Ultimately, with its high visitor rates and black bear population density, human-bear conflicts in GSMNP are inevitable. We remain optimistic, however, in the fact that wildlife managers seem to be using the available resources to minimize nuisance bear conflicts whenever possible, and these results that show a general increase in success rates of nuisance bear management in Great Smoky Mountains National Park.

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