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The Reaction-Diffusion of Range Expansion of American Black Bears (Ursus Americanus) In North Carolina, USA

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THE REACTION-DIFFUSION OF RANGE EXPANSION OF AMERICAN BLACK BEARS (*Ursus americanus*) IN NORTH CAROLINA, USA

by

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ABSTRACT

J. E. Folta. The reaction-diffusion of range expansion of the American black bear in North Carolina, USA. 218 pages, 7 tables, 23 figures, 2020. JWM style guide used.

By the early 19th century, many big-game species were extirpated from much of their historic range. Implementation of harvest regulations or restrictions, habitat succession, and changes in land use practices have facilitated the return of many of these species. It is necessary, for proper management, to be able to estimate with precision or certainty, abundance and other demographic parameters as well as range expansion often with personnel and financial limitations. New advancements in analyses allow for greater extraction of information from commonly collected data.

White oak (subgenus *Leucobalanus*) mast production had a strong correlation with non-harvest mortality of American black bears (*Ursus americanus;* $r = 0.89$). Using white oak mast as a surrogate for hunter effort, I used a catch-effort likelihood within statistical population reconstruction (SPR) using an N-mixture multinomial model to estimate the abundance and other demographic parameters of black bears in the Mountain region of North Carolina. Abundance was estimated at 3365 (95% B.C.I. = 3165-3569) for females and 3882 (95% B.C.I. = 3696-4080) for males in 2016, with numbers continuing to increase at a rate of approximately 5% annually. SPR estimates tracked estimates from Downing population reconstruction (DPR until approximately 2008 when DPR indicated population growth to be slowing in contrast to SPR estimates. The probability of harvest ranged from 6.7-15.6% (95% B.C.I. = 6.3-16.3%) for females and 11.6-26.1% (95% B.C.I. = 11.2-26.9%) for males. Additional parameters could be estimated with the inclusion of additional data and likelihoods.

The velocity of range expansion of the Mountain and Coastal black bear populations into the Piedmont was tracked using reliable sightings, frequency and location of bear-vehicle collisions, and demographic parameters in five methods of reaction-diffusion models. The rate of expansion was approximately 4-8 km/year. Each of the five methods yielded similar velocities of range expansion, indicating the simplest method that used commonly-collected data was just as informative as more elaborate methods.

Likelihoods using other food resources availability may be necessary to modify this SPR to fit other species or bear populations in agriculturally-dominated regions, but is easily adaptable. Collecting animal-vehicle mortality locations is an inexpensive way to be estimate range expansion of elusive species.

Key Words: age-at-harvest, bear-vehicle collision, big game, mast index, North Carolina, range expansion, reaction-diffusion, statistical population reconstruction

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PROLOGUE

The end of the 19th century witnessed the near extirpation of a dozen big-game animal species in North America (Schmidt 1978). Indiscriminate persecution, market hunting, and habitat destruction have been implicated as major contributing factors for big game population declines. Adoption of principles that were later described as the *North American Model of Wildlife Conservation* halted the certain demise of most big-game animal populations (Organ et al. 2012), and numbers of most species have gradually increased with better harvest regulations and 100 years of habitat improvement. The principal change agent of improving habitat for big game in the eastern U.S. has been the dramatic increase in the total area of forested land since 1920 (MacCleery 2011). In addition, forest growth has exceeded harvest for decades such that the average standing volume of wood in the eastern U.S. has nearly doubled since 1950 (MacCleery 2011). Consequently, many forest-dwelling species including moose (*Alces alces*) and American black bear (*Ursus americanus*) have been naturally recolonizing their ancestral ranges from nearby established or relic populations, while other species like white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), river otter (*Lontra canadensis*), and wapiti (*Cervus canadensis*) have been assisted through translocation programs (Kennamer et al. 1992, McDonald and Miller 1993, Raesly 2001, O'Gara and Dundas 2002). Some of these very same species have become locally and regionally overabundant with important ecological implications (Garrett et al. 1993, Warren 1997), while others, particularly those in close proximity to urbanized environments, have become symbols of controversy relative to the establishment of traditional consumptive uses (Leong 2009).

American black bears were once numerous and ranged across the United States except for the Great Prairies and the desert southwest. Their range covered all of North Carolina, but habitat conversion, unregulated hunting, and the introduction of chestnut blight (*Cryphonectria parasitica*) in 1925 (Carlock et al. 1983) caused a rapid decline in abundance and reduced bear range to a few remote parts of the mountains and the swamps and pocosins of the coast. Realizing the bear population was in peril, the North Carolina Wildlife Resources Commission (NCWRC) began a formal monitoring program in 1969 (NCWRC 2012). By that time, it was estimated that there were only a few hundred bears left in North Carolina. A Bear Sanctuary System (BSS) was formed (NCWRC 2012) in 1971. By 1972, 28 bear sanctuaries encompassing approximately 3237 km^2 (800,000 ac.) were established (NCWRC 2012). These sanctuaries were to serve as a protected source of breeding females from which offspring would be produced and disperse. Since then, bear abundance has been increasing at a slow, exponential rate throughout their ancestral range. Along with an increase in bear abundance and range expansion has been an increase in bear-human conflicts in the form of bear-vehicle collisions (BVCs).

I was given the challenge of estimating the abundance of black bears in North Carolina using data collected by the North Carolina Wildlife Resources Commission. In addition to locations and dates of BVCs, there were sightings of females with cubs, annual indices of hard and soft mast, and sex- and age-at-harvest of bears killed during the big-game season. Previously, abundance had been calculated using Downing population reconstruction (DPR; Downing 1980, Davis et al. 2007), which under-estimates the true population size by an unknown quantity of bears killed by causes other than hunter harvest. In addition, because DPR is not a statistical method, estimates of precision are unavailable.

A proactive management strategy necessitates knowledge of when bears would recolonize the rest of their historic range in the state. Estimates of the velocity of range expansion is a good first step in that direction. The parallels in contemporary range expansion of a big-game species following near extirpation with typical examples of unwanted species invasions are hard to ignore (Lockwood et al. 2007). Similar to non-native invaders, native species often elicit substantial social, economic, and ecologic impacts (Elton 1958). For example, the impacts of contemporary invasions of native wildlife populations present real and perceived threats to human life or livelihood – it costs billions of dollars to mitigate damage caused by overabundant wildlife species across the United States every year (Conover 2002). Damage to U.S. agriculture was estimated at $944 million (USDA APHIS-WS 2012a), loss of livestock to predation at $138 million (USDA APHIS-WS 2012b), and damage associated with animal-vehicle collisions at $8.4 billion (U.S. Department of Transportation 2008). Other kinds of impacts include damage to homes and other property, diseases transmitted to pets and livestock, zoonotic disease transmission, and ecological degradation of range. However, at the other end of the “wildlife value” spectrum are costs associated with establishing new populations and enhancing existing wildlife populations. Wildlife-related recreation generates nearly $157 billion in revenue for the economy (U.S. Department of the Interior et al. 2016). Management of wildlife species and populations becomes an exercise in balancing the desires of resource enthusiasts with what the range can sustain in the long-term.

Historically, range expansion has been studied by examining putative species records over time (Tingley and Beissinger 2009). Records often included presumed sightings, locations of mortality, sign, or collection sites of museum specimens. The area circumscribing confirmed records were often regressed on time to estimate linear expansion rates based on simple diffusion approximations for heat transfer (Fisher 1937, Skellam 1951). These early models assumed that populations dispersed radially from a point source and equally in all directions throughout the life of the individual. They also assumed a homogeneous, unstructured population and habitat.

However, rather than criticizing simple models on the grounds that the underlying assumptions do not apply, a better tack might be to determine in what sense simple models might still be useful (Andow et al. 1990). For despite their simplicity, they continue to be used and perform remarkably well at predicting linear range expansion of vertebrates at macroscopic spatial scales (Lubina and Levin 1988, Taulman and Robbins 1996, Tinker et al. 2008, White et al. 2012, McDevitt et al. 2014, Fraser et al. 2015) where details of individual behavior and the effects of barriers and corridors on movement are unknown.

Important evolutions of diffusion-type models of range expansion incorporated population structure (e.g., age-structure) and dispersal kernels (van den Bosch et al. 1990, van den Bosch et al. 1992, Hastings 1996, Kot et al. 1996, Turchin 1998, Hastings et al. 2005). The addition of these two features alone allow a much richer investigation of range expansion. Population structure and its interaction with survival and fecundity determine the number of dispersing propagules. Dispersal kernels explicitly incorporate the spatial distribution of propagules relative to their parents. Data elements for estimating velocity of range expansion with a continuous-time version of the Fisher-Skellam reaction-diffusion model (van den Bosch et al. 1992) are few, and in order of model sophistication are: (1) an area of occupation over time, or (2) geo-referenced point locations (i.e., marked spatial point pattern), and (3), age-specific estimates of survival, fecundity, and dispersal distances. Most natural resource agencies have knowledge or data to construct (1). Some have extensive datasets about (2) and (3). Very few have all three.

Although not always the case, increased incidences of human-wildlife conflict are often associated with an increase in abundance of the wildlife species (Conover 2002, Messmer 2009, Margulies and Karanth 2018). However, estimating the population abundance of a species that occurs over broad spatial extents and at often low density is a challenge of the first order. Presently, many states and provincial wildlife agencies use DPR for monitoring black bears across its continental range (Folta 2011). Several crucial problems arise with the use of DPR. Despite its limitations (Davis et al. 2007), few alternatives exist that do not require substantial investment in time and money.

Statistical population reconstruction (SPR) uses the very same age-at-harvest data, but can estimate important population parameters with the addition of certain auxiliary data (Clawson et al. 2017). Harvest data alone are insufficient to estimate all the demographic parameters needed for statistical population reconstruction (Gove et al. 2002), which is why auxiliary data are required to supply the missing information on parameters of interest (i.e., abundance, survival, and harvest rates). More sophisticated SPR models require additional auxiliary datasets to accommodate their increasing complexity (Skalski et al. 2007, Broms et al. 2010, Skalski et al. 2012, Clawson et al. 2013).

Auxiliary data may come from specific studies (e.g., telemetry, mark-recapture, reproductive studies), which are often expensive and conducted over short durations. Data also may come from activities incidental to routine duties (e.g., sightings), which are often the least expensive and least time-consuming to collect. In this dissertation, I attempt to ascertain the utility of these commonly collected data sets, and how they can be used to address broad scale questions like range expansion.

My overarching goal is to illustrate how the principles of invasion ecology can be applied to understanding big game population range expansion for the purpose of setting prospective management policies. An underlying purpose of this dissertation is to demonstrate how commonly collected data can be used to inform management of black bears as they recolonize the North Carolina Piedmont, a region from which they have been absent for nearly 100 years. In Chapter One, I examine the relationships between mortality (i.e., harvest and non-harvest) of black bears in the Mountain region of North Carolina, mast availability, and land cover. I intend to submit Chapter One along with co-authors for peer-reviewed publication to an audience which includes wildlife and forest managers. In Chapter Two, I apply a SPR model that uses hard mast availability as a surrogate for hunter effort. I compared my results to DPR (Downing 1980, Davis et al. 2007), a method commonly used by wildlife biologists and managers. The intended audience is wildlife biologists and managers. I intend to submit Chapter Two with co-authors for peer-reviewed publication in the *Journal of Wildlife Management*. In Chapter Three, I quantify the velocity of range expansion of two distinct and nearly extirpated black bear populations by incorporating multiple data sources and methods. I intend to submit Chapter Three with co-authors for peer-reviewed publication in *Biological Invasions*.

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CHAPTER ONE: RELATIONSHIP OF FOOD AVAILABILITY AND LAND COVER TO FREQUENCY OF MORTALITY OF BLACK BEARS (*Ursus americanus*) IN NORTH CAROLINA, USA

ABSTRACT

I examined the relationships among mast types, and relationships between mast availability, land cover, and mortality of black bears in North Carolina, USA from 1983-2017. The goals were (1) to examine correlations between harvest and non-harvest mortality, and (2) to determine if food availability and land cover can be used to predict non-harvest mortality. Harvest mortality was highly correlated with non-harvest mortality ($r = 0.89$, $P < 0.001$), with bear-vehicle collisions making up 76% of the non-harvest mortalities. Non-harvest mortality was negatively correlated with white oak (*Leucobalanus*) mast abundance ($r = -0.52$, $P = 0.001$). Non-harvest mortality was negatively correlated with pasture/hay fields ($r = -0.32$, $P = 0.06$) and positively correlated with deciduous forest ($r = 0.27$, $P = 0.12$). Linear equations to predict non-harvest mortality were constructed from abundance indices of 12 mast types, and compared using Akaike's Information Criteria adjusted for small sample sizes (AIC_c) to determine the best fit model. White oak mast appeared in all seven of the top predictive models. White oak ($\Delta AIC_c = 0.000$), white oak + hickory (*Carya* spp.; $\Delta AIC_c = 0.267$), white oak + cherry (Prunus spp.; $\Delta AIC_c = 0.746$), and white oak + red oak (*Erythrobalanus*; $\Delta AIC_c = 1.001$) were the top four models. Managers may use this information to predict impacts of mast availability on non-harvest mortality and make comparisons to harvest mortality.

INTRODUCTION

Hard mast is an important food source for many big-game species, including wild turkey (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianus*), wapiti (*Cervus canadensis*), and American black bear (*Ursus americanus*), as well as many small-game and other non-harvested species (Pelton 1989, Wentworth et al. 1992, McShea and Schwede 1993, Wolff 1996, White 2008). Mast abundance not only influences the primary mast consumers, but also their predators, prey, parasites, and diseases (Ostfeld and Keesing 2000, Kelly et al. 2008, Ostfeld 2002), making it a major ecological commodity that structures the wildlife community.

Studies have noted that harvest rates of white-tailed deer (McShea and Schede 1993, Ryan et al. 2004) and wild turkey (Norman and Steffen 2003) increase during years of low hard mast production. Where baiting of deer is legal during hunting season, deer tend to be more attracted to bait piles during years of low acorn production. Nixon et al. (1975) found that increases in hickory (*Carya* spp.) mast increased fecundity, increased survival of juvenile squirrels (*Sciurus carolinensis* and *S. niger*) and decreased emigration of juvenile and sub-adult squirrels. The decrease in emigration decreased non-harvest mortality (e.g., vehicle collision), but harvest rates increased with increases in pre-harvest densities of squirrels (Nixon et al. 1975).

When food resources are scarce, bears tend to travel further in search of food, which predisposes them to mortality sources such as vehicle collisions, harvest, and depredation (Noyce and Garshelis 1997). Black bears have been known to travel to specific locations to feed on white oak (subgenus *Leucobalanus*) acorns (Pelton 1989), indicating the importance of a specific mast type.

The amount of available mast varies annually, and the frequency of high and low mast is not annually consistent. Various hypotheses have been proposed to explain the variability in masting. Hypotheses have included selective adaptations such as seed predator satiation (Silvertown 1980), pollination efficiency (Norton and Kelly 1988, Smith et al. 1990), pollen coupling (Isagi et al. 1997, Satake and Iwasa 2000), resource availability and matching during flower, pollen or seed formation (Norton and Kelly 1988, Sork et al. 1993, Isagi et al. 1997, Fernández-Martínez et al. 2012), and weather cues (Sharp and Sprague 1967, Cecich and Sullivan 1999, Koenig and Knopps 2014, Bogdziewicz et al. 2017, Nussbaumer et al. 2018). Regardless of the reason behind the variability, synchronization of masting events with the natural reproductive cycles of mast consumers, particularly species that do not breed every year such as black bears, can accentuate reproductive successes or failures in these species as well as increase or decrease susceptibility to mortality (Rogers 1976, Elowe and Dodge 1989, Pelton 1989, McLaughlin et al. 1994, Costello et al. 2003).

Because species exhibit affinities to certain land cover types, it seems reasonable to expect some relationship of land cover and mortality. Many studies link land cover type with vehicle collision mortalities (Conard and Gipson 2006, Glista et al 2007, Gunson et al. 2011). Others link land cover type to disease transmission (Flory et al. 2012). For most anthropogenic mortalities, land cover type can influence wildlife mortality simply due to the coincidences of high utilization by wildlife and people. Identifying land cover types that may contribute to mortality of a species can help target mitigation strategies in and around these areas.

Numerous studies have been conducted in North Carolina on bear habitat utilization. Mountain bears used oak, oak-hickory, and cove hardwoods cover types most often (Beeman 1975, Garris 1983, Beringer 1986, Siebert 1989), whereas agricultural fields and pocosins were used most often by Coastal bears (Landers et al. 1979, Lombardo 1993, van Manen 1994, Maddrey 1995, Jones 1996, Allen 1999). Brandenburg (1996) postulated that prime feeding areas separated from bedding areas by high-speed highways contributed to bear-vehicle collisions (BVCs) and that bears crossed primary roads less frequently than secondary roads. However, Reagan (1991) reported that female bears used cover types closer to primary roads and farther from secondary roads than expected.

I examined the relationships between availability of mast types, land cover, and mortality of black bears in the Mountain region of North Carolina, USA. Study objectives were to (1) to explore the relationship between harvest and non-harvest mortality, (2) examine correlations among indices of mast abundance, (3) validate a predictive relationship between hard mast abundance and non-harvest mortality in bears, and (4) surmise land cover affinities of bears by cross-tabulation of the frequency of non-harvest mortality and land cover types.

STUDY AREA

North Carolina is approximately 139,396 km^2 (53,821 mi^2) in size (NetState 2016), with a total landmass of approximately 126,153 km^2 (48,708 mi^2). The state is divided into three main physiographic regions (Mountain, Piedmont, and Coast), each region quite different from the others. For the purpose of this study, regions were designated by work unit boundaries assigned by the North Carolina Wildlife Resources Commission (NCWRC; Fig. 1.1). Topography is diverse across the state, ranging from steep slopes in the west to flat land in the east. Land use patterns, human population abundance, and natural habitats also vary greatly.

The Mountain Region consists of 34 counties in the western one-third of the state. Topography is classified as mountains proper and foothills. Mount Mitchell, the highest elevation east of the Mississippi River, rises to approximate 2037 m (6,684 ft.) above sea level (NCSU, NetState 2016). The high elevation of the mountains absorbs the brunt of storms coming from the midwestern United States, protecting the central Piedmont region from hard storms, and forms the structures necessary for orographic precipitation (NCSU). The result is a different climatic pattern in the Mountain region from that of the rest of the state.

The mean high and low temperatures in Asheville in January are 8.6° C (47.4° F) and –2.9° C (26.7° F), respectively (CantyMedia 2019). The coldest temperature ever recorded in North Carolina was on January 21, 1985, when temperatures dropped to -37° C (-34° F) on Mt. Mitchell (NetState 2016). In July, the mean high and low temperatures are 28.9° C (88° F) and 17.6° C (63.7° F), respectively (CantyMedia 2019). Total annual precipitation in Asheville averages 116 cm (45.6 in.), with snowfall amounts accounting for an average of 25 cm (9.9 in.) (CantyMedia 2019).

Most of the counties in the mountain region are ≥51% forested (Brown and New 2013). Dominant forest types include oak (*Quercus* spp.), southern yellow pine (*Pinus taeda* and *P. palustris*), mixed pine-hardwood, and mixed mesophytic hardwoods (SAMAB 1996, Schafale 2012).

An estimated 2.5 million people reside in the Mountain Region (2019 estimate; U.S. Census Bureau) and the population continues to increase by approximately 23,000 people per year. The NCWRC has estimated that there are >5,000 black bears in this region (Colleen Olfenbuttel, NCWRC Bear and Furbearer Biologist, personal communication.). As populations of bears and people continue to grow, incidences of human-bear conflicts also will increase.

METHODS

Mast Availability

An index of hard mast availability was ascertained every autumn from 1983-2017 by the NCWRC and U.S. Forest Service. Hard mast species included white oak *(Quercus alba, Q. prinus*), red oak (*Q. coccinea, Q. falcata, Q. rubra, Q. velutina*), American beech (*Fagus grandifolia*), and hickory (*Carya glabra, C. laciniosa, C. ovalis, C. ovata, C. tomentosa*). Protocols of Whitehead (1969) and modifications from Wentworth et al. (1992) were used until 2006, then the protocols of Greenberg and Warburton (2007) were used. Transects were established throughout the Mountain region. Each transect was approximately 16-32 km in length. Initially, >1100 trees were surveyed along 10 transects. Over the years, the number of surveys increased until in 2017, surveys were conducted on 12 transects and nearly 1400 trees. At each stop on the transect, approximately five hard mast trees were scanned with binoculars to estimate the number of twigs in the terminal 0.9 m of five branches, the number of twigs producing acorns, the number of acorns per twig, and the percent of crown producing nuts (PCN).

Soft mast data were collected similarly in the summer and autumn from 1993-2017. Beginning in 2005, summer soft mast data were only collected in odd years. Summer species included huckleberry (*Vaccinium* spp. and *Gaylussacia* spp.), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), and pokeberry (*Phytolacca americana*). Autumn mast included cherry (*Prunus* spp.), blackgum (*Nyssa sylvatica*), grape (*Vitis* spp.), and pokeberry. Not all counties had a survey site; therefore, index data were aggregated for the entire region.

Registered Harvest and Sources of Non-harvest Mortality

To monitor harvest levels, harvested bears registered from 1969-2017 were tallied. All harvested bears are required to be registered on-line, by phone, or presented to a check station or NCWRC personnel. Data reported during registration included sex of the bear, county of harvest, and date of harvest. The compliance rate for reporting is not known with certainty, but was assumed to be constant for the years surveyed.

Sources of non-hunting mortality were collected from 1969-2017 and included BVCs, depredation, illegal harvest, other (e.g., natural, euthanasia, etc.), and unknown. Reports of BVCs came from highway commuters, landowners, and NC Department of Transportation personnel. Some BVCs were located by NCWRC staff incidental to other duties. In the earlier years, BVCs locations were recorded using the Quad-Block-Square (QBS) grid system, where each Square is approximately 2.6 km^2 (1 mi^2), each Block is a 5x5 grid of Squares, and each Quad is a 5x5 grid of Blocks. Later, BVCs locations were recorded using latitude-longitude coordinates. Those locations were converted to QBS coordinates. Data for bears reported dying of non-harvest mortality sources included location of mortality to at least the county level, sex of the bear, and mortality factor. Non-harvest mortality was regressed on time to remove a linear trend; residuals of this regression were calculated and used in subsequent analyses. Data used in some correlations with mast and principal component analyses were restricted to 1983-2005 because of the lack of annual soft mast data.

Land Cover

The 2006 USGS National Land Cover Database (NLCD; http://www.mrlc.gov/nlcd06_data.php) raster grid was downloaded. Data from 2006 were selected because it was the most recent data available at the beginning of my analyses. Land cover types consisted of open water, developed-open space, developed-low intensity, developed-medium intensity, developed-high intensity, barren land, deciduous forest, evergreen forest, mixed forest, shrub/scrub, grassland/herbaceous, pasture/hay, cultivated crops, emergent herbaceous wetland, and woody wetland. Patch Analyst 5.1 (Rempel et al. 2012) was used in ArcMap 10.1 (Environmental Systems Research Institute, Redlands, CA) to convert the raster grid to polygons of like cover type. Using the internal tools of ArcMap, the polygons were clipped by county, and the areas of the polygons were summed by cover type, by county, and a percentage of each cover type calculated. Computing time precluded conducting this analysis on more than one set of data. County polygon layers were downloaded from the NC Center for Geographic Information and Analysis (CGIA; http://data.nconemap.gov/geoportal/catalog/main/home.page). It was assumed that land cover did not change significantly between 2004 and 2008.

Data Analyses

All calculations were made using R (R Core Team 2017). Pairwise comparisons were made between harvest mortality and total non-harvest mortality from 1969-2017 using Pearson's correlation coefficient *r*. Pairwise comparisons also were made between non-harvest mortality and mast abundance indices and between hard and soft mast indices from the Mountain region using Pearson's correlation coefficient *r*. Because soft mast data collection was not begun until 1993 and summer soft mast data were collected only in odd years beginning in 2005, any pairwise comparisons involving soft mast were made only for data 1993-2017. Comparisons using only hard mast indices were made from data collected 1983-2017.

To simplify and summarize the correlations between the mast variables, a principal component analysis was done utilizing the R packages “FactoMineR” v. 1.41 (Lê et al. 2008), and “factoextra” v. 1.0.5 (Kassambara and Mundt 2017), and R’s built-in “prcomp()” function. A singular value decomposition of the correlation matrix of non-harvest mortality and mast availability was done to graphically explore the relationships between mast, non-harvest mortality, and year (Greenacre 2012). Data collected during the even years beginning in 2006 were omitted because of the absence of soft mast data collection during those years.

Simple linear regressions were used to adjust for time effects of bear abundance increases, and the residuals (ResMort) were used in further analyses. Linear models of all possible mast combinations sans interactions were constructed and analyzed as predictors of non-harvest mortality using the *dredge* function in R package “MuMIn” (Burtoń 2019). The best model was selected using Akaike Information Criterion corrected for small sample sizes (AIC_c), ΔAIC_c, and Akaike weights (Burnham and Anderson 2010). Models with $\Delta AIC_c < 2.0$ were considered likely candidate models (Burnham and Anderson 2010).

To examine correlations between land cover types and non-harvest mortality, pairwise comparisons were made between percentage of land cover type in each county and non-harvest mortality from 2004-2008. It was assumed that land cover characteristics did not change appreciably within the 5-year period.

RESULTS

The frequency of non-harvest mortality was highly correlated with the frequency of harvest mortality in the Mountain region ($r = 0.89$, $P < 0.001$) (Fig. 1.2), and BVCs accounted for 76% of the frequency of non-harvest mortality.

There were strong negative correlations between white oak (*r* = -0.52, *P* < 0.001), red oak (*r* = -0.35, *P* = 0.04), and cherry (*r* = -0.42, *P* = 0.04) mast abundance indices with ResMort (Table 1.1, Appendix 1.2, Figure 1.3). There were no summer soft mast types significantly correlated with non-harvest mortality.

White oak mast was negatively correlated with beech mast (*r* = -0.42, *P* = 0.01) and positively correlated with grape mast (*r* = 0.50, *P* = 0.01). Cherry mast was positively associated with red oak (*r* = 0.46, *P* = 0.02) and grape (*r* = 0.48, *P* = 0.02) mast. Multidimensional preference analysis of mast abundance indices demonstrated positive correlations among all the hard mast indices except beech mast (Figure 1.4). Summer soft mast was more positively associated with the quantity of beech mast, whereas autumn soft mast was more positively associated with the quantities of white oak, red oak, and hickory mast. Years that fell on the left side of the graph were years in which white oak mast abundance was poor and ResMort was highest.

In analyzing the regressions of various combinations of mast types to predict the frequency of non-harvest mortality in the Mountain region, of the 8192 models tested, seven emerged as potential candidate models ($\Delta AIC_c < 2.0$; Burnham and Anderson 2010; Table 1.2). White Oak appeared in each of the top models. Each of the other hard mast types also appeared in at least one of the top models. The only soft mast to appear in any of the top models was cherry.

Non-harvest mortality from 2004-2008 was most closely associated with pasture/hay (*r* = -0.32, *P* = 0.06) and deciduous forest (*r* = 0.27, *P* = 0.12) (Table 1.3). Not surprisingly, deciduous forest was negatively correlated with all levels of development.

From 1969-2014, there were 4556 bear mortalities that were aged (Table 1.4). Most mortalities were males. Yearling and sub-adult males made up most of the non-harvest mortality. The dominant age class in the harvest was the 3-5 year age class. Most BVC mortalities occurred in the fall and most depredation mortalities occurred in the summer (Figure 1.5).

DISCUSSION

As has been documented for bears and other big-game species (Danks 2007, Servanty et al. 2010, Sáenz-de-Santa-María and Tellería 2015, Little et al. 2017), I documented a positive correlation between harvest and non-harvest mortality. The positive correlation between harvest and non-harvest mortality is, in part, driven by the availability of high-quality food in the form of mast, which greatly alters bear movements on the landscape (Garshelis and Pelton 1981, Pelton 1989, Schooley et al. 1994, Noyce and Garshelis 1997, Ryan et al. 2004, Obbard et al. 2014). Bears that do not expand their daily movements in search of food may not encounter as many people, roads, or other potential mortality factors. An exception may be the individual bear that becomes food conditioned resulting in “nuisance” behavior.

Pearson’s correlations and the top predictor models of mast types on frequency of non-harvest mortality indicate that white oak mast was the most important mast type. This is consistent with other studies (Beeman and Pelton 1977, Eagle 1979, Landers et al. 1979, Beeman and Pelton 1980, Maddrey 1985, Pelton 1989, Clark et al. 2005). Oaks, in general, are considered important, but white oak acorns have often been credited with being more palatable and more digestible (Short and Epps 1976, Smallwood and Peters 1986) than red oak acorns, even though red oak acorns have a higher fat content (Servello and Kirkpatrick 1989, Chung-MacCoubrey et al. 1997, Wood 2005). Pelton (1989) demonstrated that bears travel great distances in autumn when undergoing hyperphagia to take advantage of white oak mast. This phenomenon has been observed with other species and their respective preferred food type. For example, grizzly bears (*U. arctos horribilis*) in the Greater Yellowstone Ecosystem have been known to travel great distances to take advantage of whitebark pine (*Pinus albicaulis*) seeds, and when seeds are not abundant, grizzlies often take advantage of anthropogenic food sources (Blanchard and Knight 1991).

Bears in North Carolina are mostly harvested with the aid of hounds (Colleen Olfenbuttel, NCWRC Bear and Furbearer Biologist, personal communication). Hunters drive roads until either fresh tracks are found or the strike dog detects a fresh scent, at which point, the dogs are released to pursue the bear. If bears stay in the forest interior due to abundant mast, harvest and non-harvest mortality is lower (Rogers 1976, Pelton 1989, Noyce and Garshelis 1997, Vaughan 2002, Ryan et al. 2007, Obbard et al. 2014). For still hunters, encounter rates with bears may be reduced during years with bumper crops if the hunters are not using anthropogenic food sources as bait (Kane 1989, McDonald et al. 1994, Gore 2003). However, Alt (1980) noted hunter success in Pennsylvania increased when acorns and beechnuts were abundant; however, it is illegal to hunt bears with the use of bait or hounds in Pennsylvania.

The diet of bears varies between seasons (Beeman and Pelton 1977, Eagle 1979, Beeman and Pelton 1980, Maddrey 1995) based on the availability and palatability of alternative foods and bear dietary requirements. High fat and carbohydrate diets in autumn provide the necessary energy and metabolic water during winter dormancy (Eagle 1979, Brody and Pelton 1988, Hellgren et al. 1989). High protein diets during spring and summer replace protein lost while in the den (Eagle 1979, Hellgren et al. 1989). Consequently, more than one food or mast type is required to fulfill the dietary needs of bears throughout the year. Differing phenologies of various mast species assures that some form of food is available for bears every year and for much of the year. Should one type be completely consumed or experience a crop failure, another type often is available. Multidimensional preference analysis showed that if conditions are poor for white oak mast production, other hard mast, especially beech, and soft mast is available.

Five of the seven top models in this study indicated the importance of another mast type in addition to white oak mast. Red oak acorns, hickory nuts, beechnuts, and cherry drupes are important foods for bears. Although those foods were in the top predictive models and may have explained some variability in the prediction of non-harvest mortality, those models were not significantly better ($\Delta AIC_c < 2.0$) than the white oak-only model. The fact that the bear population exhibits higher mortality rates during years with poor white oak mast, demonstrates the value of white oak mast over all other mast types combined.

The study in Virginia by Ryan et al. (2007) overwhelmingly indicated the group “oaks” as an important predictor of non-harvest mortality. However, the models that they tested did not examine the individual contributions of white oak and red oak to the predictive model. And unlike this study, their models that included hickory and cherry did not receive much support.

White oak mast, and to a lesser extent, red oak and hickory mast, were negatively correlated with indices of beech mast indicating different masting phenologies. Oak is more tolerant to drought and heat than beech (Rubio-Cuadrado et al. 2018); therefore, warmer and drier seasons favor oak mast production over beech mast production. Climate parameters such as rain, temperature, and wind conditions during the year of fruiting or ≥ 1 year prior to fruiting can influence whether or not trees produce mast or whether it will be a bumper or lean crop (Sharp and Sprague 1967, Cecich and Sullivan 1999, Koenig and Knopps 2014, Bogdziewicz et al.

2017, Nussbaumer et al. 2018). More importantly, during years of low acorn or hickory nut production, beechnut mast may be vital for bears. Rubio-Cuadrado et al. (2018) posit that climate change will continue to benefit oak forests throughout the 21st century, but they recognize that beech will benefit from the shade produced by the oaks.

Soft mast is an important summer and autumn food (Landers et al. 1979, Maddrey 1995), and may attract bears to highways by growing along road rights-of way (Carr and Pelton 1984, Hellgren 1988, Brody and Pelton 1989). Beringer et al. (1989) observed several scats in the late summer containing pokeberry and that pokeberry and blackberry were abundant along roadways in western North Carolina. The multidimensional preference analysis would support that good production years for blackberry and summer pokeberry would contribute to higher BVCs, but Pearson's correlations (Table 1.2) would suggest otherwise. Only cherry had a strong correlation ($r = -0.42$, $P = 0.04$) with non-harvest mortality. Preference for cherries and large crops in localized areas may reduce bear movements (Garshelis and Pelton 1981). Other soft mast types may be so ubiquitous that their impact as individual mast types on non-harvest mortality is not significant.

Summer soft mast was negatively correlated with oak and hickory mast. However, unlike beechnuts, soft mast could not compensate for oak and hickory crop failure because (1) summer soft mast and beech are available at during different seasons, and (2) soft mast is primarily high in carbohydrates and not fat. Bears need high caloric intake during the fall prior to their winter dormancy period. Peak available calories in the summer are nearly half of what is available in the fall (Inman and Pelton 2002). Inman and Pelton (2002) estimated that soft mast availability peaked at approximately 0.7 billion calories, but only lasted about 7 weeks in the Smoky Mountains. Hard mast availability peaked at approximately 1.3 billion calories and was available ≥13 weeks. They also found that during years of hard mast failure, annual calorie production would decrease from approximately 690,000 cal/ha to 123,000 cal/ha. Even during a good hard mast year, oaks produced 261,000 cal/ha, whereas berries only produced 24,000 cal/ha (Inman and Pelton 2002).

As a population continues to grow, the proportion of juveniles entering the population from reproduction continues to increase (Stephens et al. 1999, Morris 2002). Yearling and sub-adult bears, especially males, made up most harvest and non-harvest mortalities in this study, which is often the trend throughout the range of bears (Bunnell and Tait 1985). Natal dispersal exposes juveniles to disproportionally greater mortality risk than adults, and juvenile males tend to disperse farther than juvenile females, exposing them to disproportionally greater mortality risk. Dispersing juveniles may avoid areas with adult males (Garshelis 1994), thus prolonging their dispersal and potentially forcing them to establish themselves in areas more prone to mortality risks.

Analogous to Holling's (1959) description of functional predation, when bear populations are abundant hunters have a higher probability of encountering and harvesting a bear, and motorists have an increased chance of colliding with a bear on roadways. Additionally, there is an increased likelihood that a bear will encounter some other mortality source (e.g., depredation, disease, fatal injury, etc.). Furthermore, there are other changes in the composition of the harvested and non-harvested population of big game as they increase from low to high abundance.

BVCs, by far, make up most of the non-harvest mortality. Seasonal proximity to food resources, cover, potential mates, and timing and direction of dispersal are all factors contributing to BVCs. Most BVCs occurred in the fall when hard mast was available and when bears are in their hyperphagia state. Another spike occurred in the summer and was consistent with the timing of juvenile dispersal and breeding season. Increased movements of bears are attributed to these events. Conrad and Gibson (2006) observed seasonal changes in animal-vehicle collisions in small and meso-mammals. They attributed high autumn roadkill events to dispersal and low winter roadkills to animal inactivity or reduced movements. This is consistent with patterns observed in black bears in this study and elsewhere.

There are two main factors that influence where BVCs occur: (1) where bear home range or travel corridor overlaps with roads for the potential to encounter a vehicle, and (2) visibility of bears relative to drivers' line of sight. BVCs in the Mountain region were positively correlated with deciduous forests and negatively correlated with hay/pasture. Deciduous forest is the most prevalent land cover-type in this region, and is where bears occur most often (Beeman 1975, Beringer 1986, van Manen 1994).

Many of the roads in this region are winding and have narrow berms. This gives drivers a short reaction time to see and avoid hitting a bear crossing the roadway. The negative correlation of the Hay/Pasture land cover-type and BVCs may be an artifact of more hay fields and pastures occurring on the eastern edge of the Mountain region, and bears being less abundant in the eastern portion.

Landcover is being converted from forest land to developed, grassland, and other land cover types that are not suitable for black bears. From 1973-2000, the southeastern United States has seen a loss of 2.5% of its forests and 1.6% of its agriculture, but a gain of 2.3% in developed areas (U.S. Global Change Research Program 2014). The Piedmont region in North Carolina is projected to lose 8% of its forests and 34% of its agriculture, and increase its developed areas by 44% from 2007-2027 (Ouzts 2007). As land cover is converted from forest and agriculture to developed land cover types, anthropogenic mortality of bears is likely to increase. Although bears are very adaptable to living near people, most people will not tolerate living near bears, which may influence the management to maintain small or even reduce bear populations in the Piedmont.

As the bear population expands in North Carolina into parts of its historic range (See Chapter Three), encounters between bears and people also will increase and contribute to anthropogenic mortality, a pattern not only seen in bears, but also other species (Sparkman et al. 2011, Obbard et al. 2014, Hill et al. 2020). Most mortalities in the Piedmont region were from BVCs. In 2014, the Piedmont region was opened to bear hunting and frequency of harvest mortality is increasing. As more parts of the Piedmont become established bear range, mortality rates from non-harvest mortality as well as harvest are likely to increase. Harvest mortality at low population densities usually exhibits an additive effect, but becomes more compensatory at higher population densities (Bartmann et al. 1992, Sparkman et al. 2011). So, if the goal is to keep bear abundance low and keep the range from expanding throughout the Piedmont, then the additive effect of harvest will have its greatest impact while abundance levels are low in the Piedmont.

MANAGEMENT IMPLICATIONS

This study highlights the importance of mast, especially white oak mast, on overall mortality of black bears in the Mountain region of North Carolina. Indices of white oak mast abundance can be used to predict mortality and influence management decisions; however, caution must be used. Sex and age structure of the population, reproductive potential, and other population parameters, as well as hunting methods and effort need to be considered before opening, closing, or modifying hunting seasons. Mast surveys conducted in autumn may not be conducted and analyzed in time to make regulatory changes before the start of the current harvest season. However, knowledge of mast abundance could be used to stop or extend harvest seasons mid-season. Future research on factors that influence mast abundance may be useful to help form predictions earlier in the year, allowing more time to make regulatory changes. Although climate data may be available far in advance, those data may not be specific enough to make predictions. Spatial and temporal weather parameters such as precipitation, temperature, and their interactions may be more appropriate for projecting masting events.

White oak mast abundance influences both the spatial and temporal movements of bears. Establishing and maintaining suitable corridors between oak forests and other vital habitat can help reduce incidences of human-bear conflicts. Corridors can funnel bears away from roadways and human populated areas. Road crossing structures such as overpasses and underpasses can facilitate movements and reduce or avoid BVCs (van Manen et al. 2001, McCollister and van Manen 2010, Hooker et al. 2016). By directing the path of bears, prime conflict areas can be identified, and along with knowledge of the phenology of mast-producing species, determine the spatial-temporal likelihood of potential conflicts, allowing managers to focus pro-active management methods.

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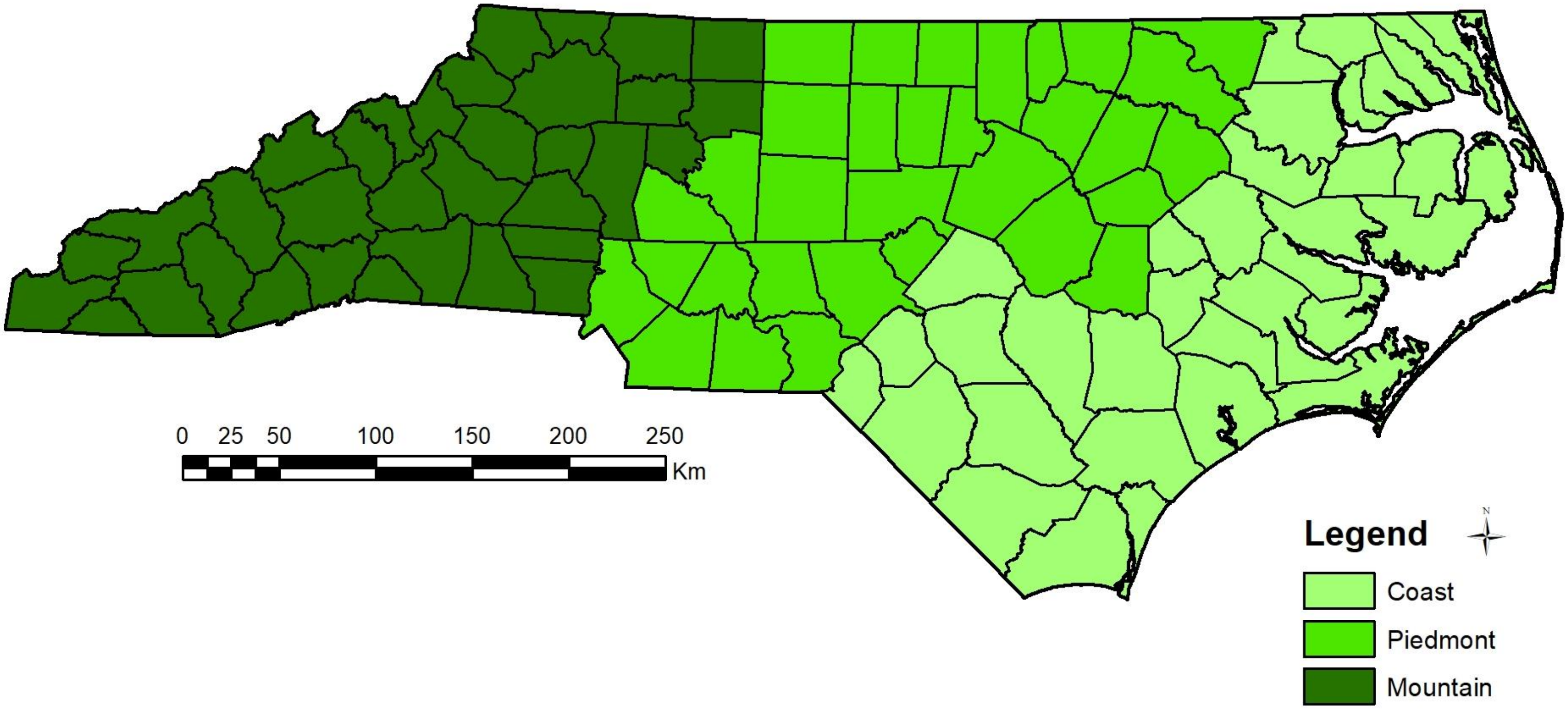

Figure 1.1. Physiographic regions of North Carolina, USA.

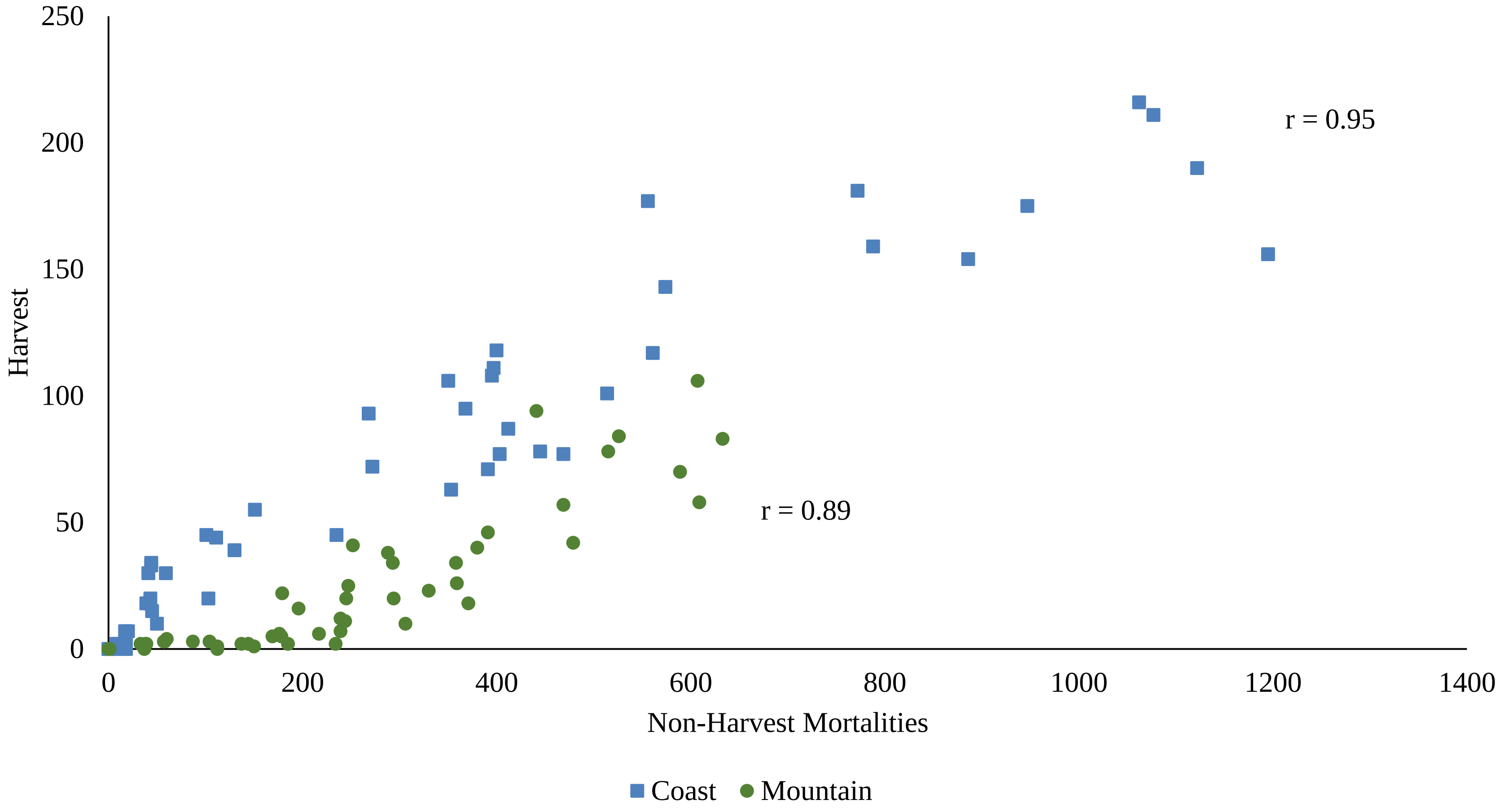

Figure 1.2. Relationship of harvest mortality to non-harvest mortality of black bears in North Carolina, 1969-2017.

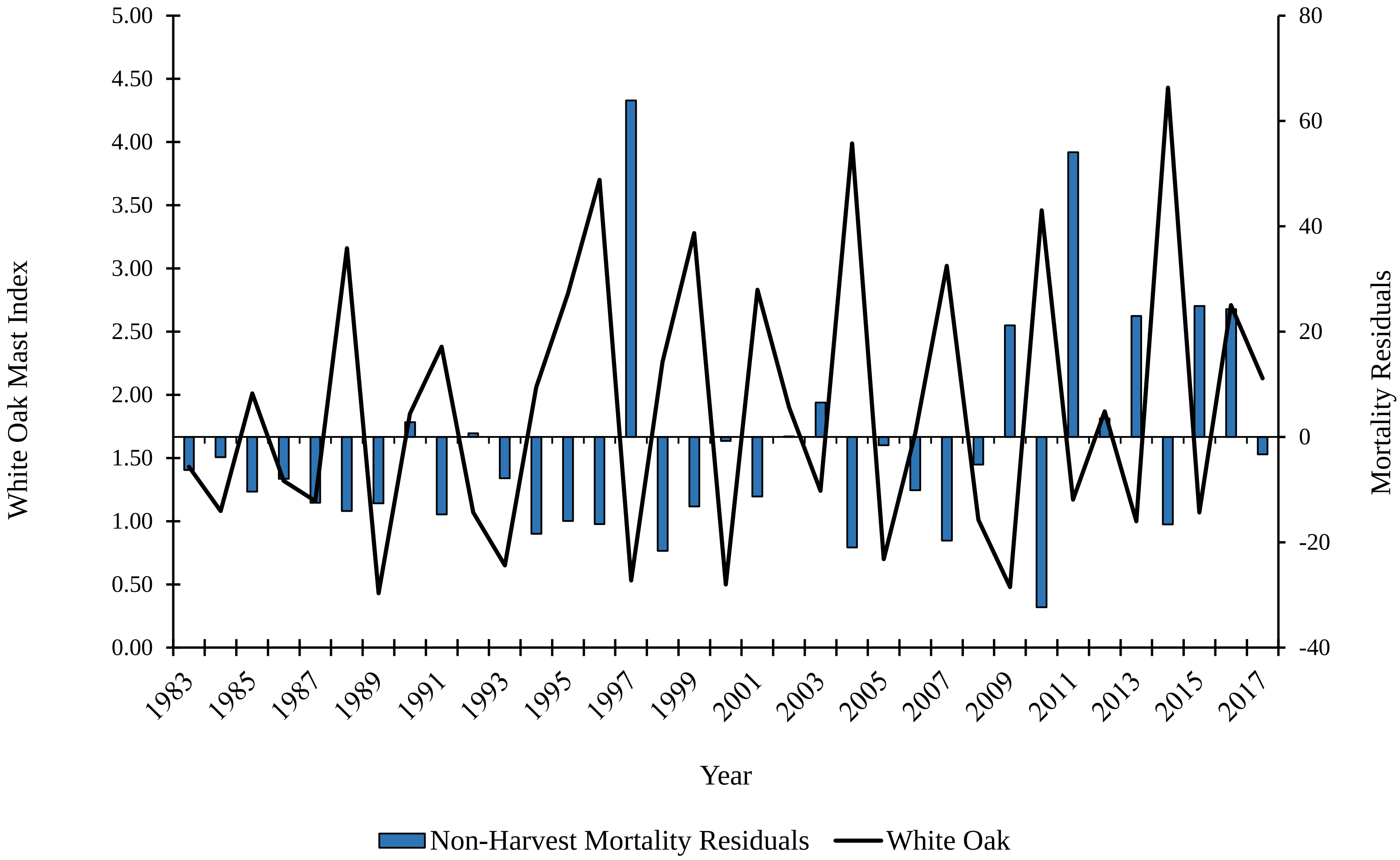

Figure 1.3. Relationship between white oak mast index and Mountain Region residual non-harvest mortality in North Carolina, 1983-2017.

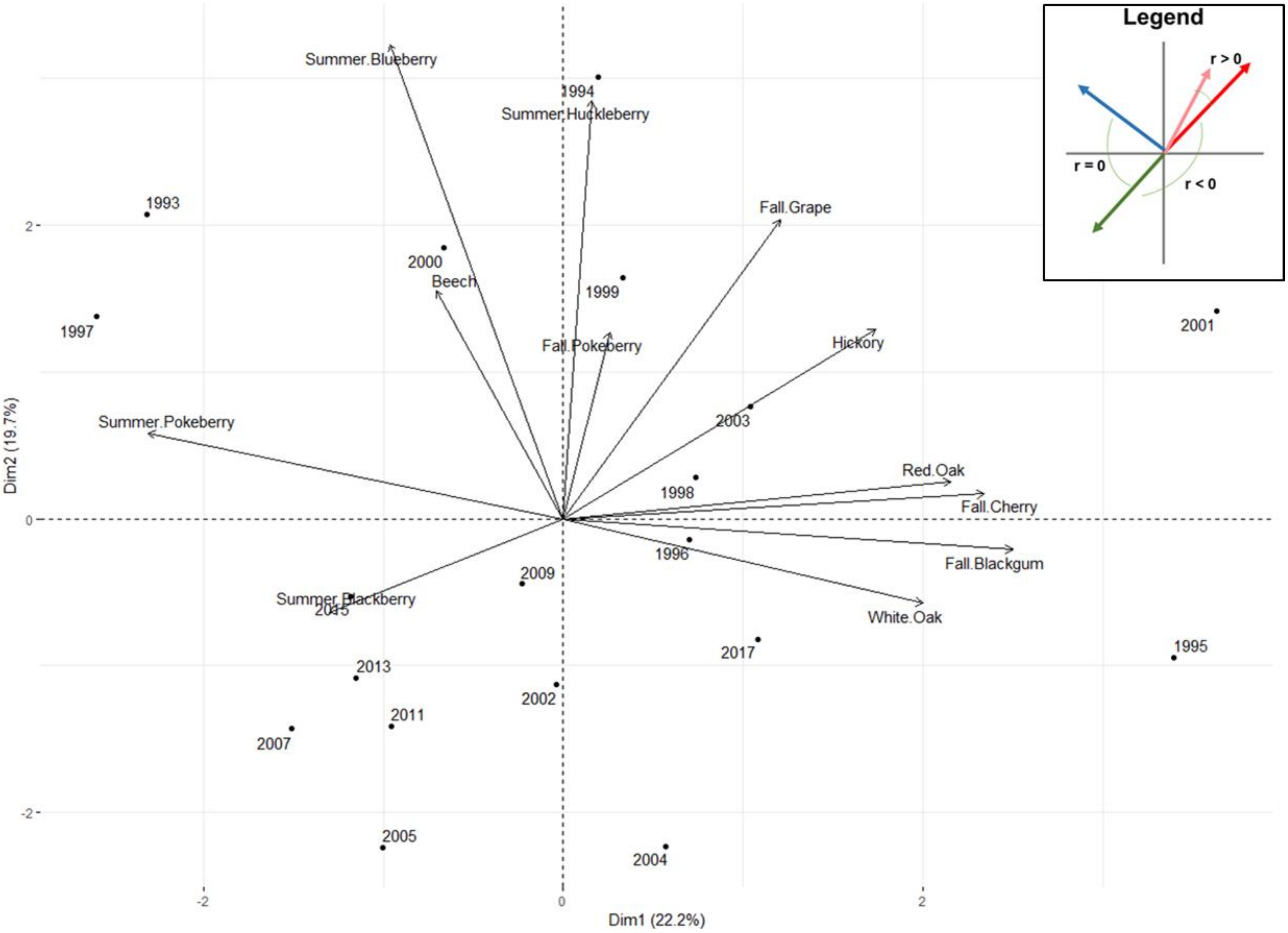

Figure 1.4. Multidimensional preference analysis of the correlation matrix showing the relationships between mast abundance indices in North Carolina, USA 1993-2017.

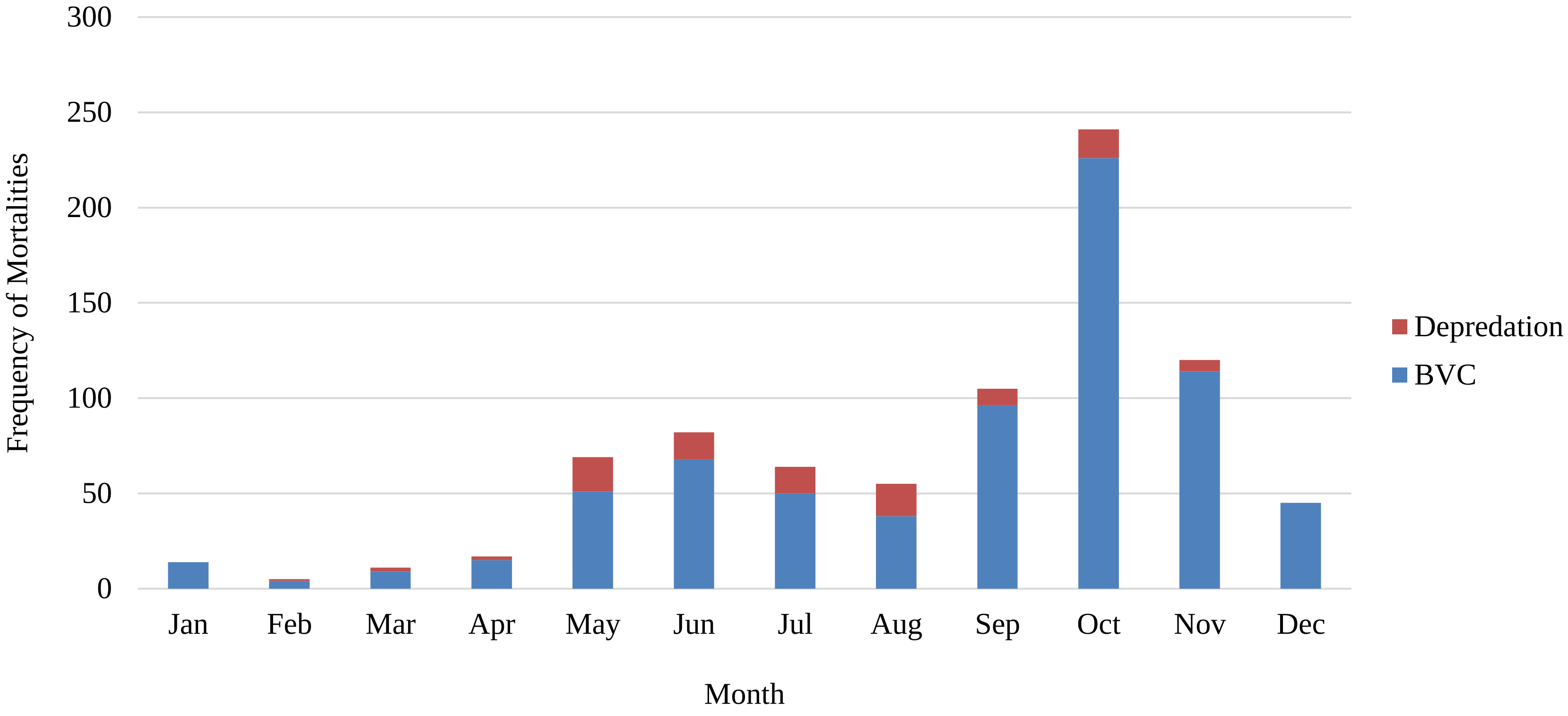

Figure 1.5. Frequency of bear-vehicle collisions and depredation mortalities in the Mountain region of North Carolina, USA, 1969-2014.

Table 1.1. Pearson product moment correlations between hard mast (1983-2017), soft mast (1993-2017), and residual non-harvest mortality of black bears in the Mountain region of North Carolina.

	WO	RO	HI	BE	FP	FC	FG	FBG	SB	SH	SBK	SP	ResMort
WO	1.00												
RO	0.32	1.00											
HI	0.02	0.02	1.00										
BE	-0.42*	-0.24	0.43*	1.00									
FP	-0.02	0.18	0.29	-0.04	1.00								
FC	0.33	0.46*	0.53**	-0.47*	0.04	1.00							
FG	0.50*	0.17	0.34	-0.29	0.23	0.48*	1.00						
FBG	0.17	0.08	0.49*	0.00	0.21	0.36	0.32	1.00					
SB	-0.22	-0.09	0.06	0.30	0.18	-0.04	0.42	-0.30	1.00				
SH	-0.16	0.09	0.09	0.06	0.07	0.22	0.38	-0.02	0.84***	1.00			
SBK	-0.18	-0.07	-0.18	-0.18	-0.05	-0.06	-0.26	-0.06	-0.03	0.01	1.00		
SP	-0.21	-0.14	-0.07	0.07	0.26	-0.20	-0.18	-0.60**	0.33	-0.07	0.38	1.00	
ResMort	-0.52**	-0.35*	-0.31	0.09	0.06	-0.42*	-0.38	-0.14	-0.02	-0.04	0.20	0.10	1.00

WO = White Oak, RO = Red Oak, HI = Hickory, BE = Beech, FP = Autumn Pokeberry, FC = Cherry, FG = Grape, FBG = Blackgum, SB = Blueberry, SH = Huckleberry, SBK = Blackberry, SP = Summer Pokeberry

*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$ (p-values are given in Appendix 1.1)

Table 1.2. Models ranked in order of support relating mast indices to non-harvest mortality of black bears in the Mountain region of North Carolina, 1993-2017, where K = number of parameters, AIC_c = AIC corrected for small sample size, $\Delta AIC_c = AIC_c - AIC_c$ minimum.

Model	K	AIC_c	ΔAIC_c	Akaike Weight	Adjusted R^2
Non-Harvest Mortality ~ White Oak	3	171.813	0.000	0.045	0.398
Non-Harvest Mortality ~ White Oak + Hickory	4	172.079	0.267	0.039	0.454
Non-Harvest Mortality ~ White Oak + Cherry	4	172.558	0.746	0.031	0.440
Non-Harvest Mortality ~ White Oak + Red Oak	4	172.814	1.001	0.027	0.432
Non-Harvest Mortality ~ White Oak + Year	4	172.921	1.108	0.026	0.429
Non-Harvest Mortality ~ White Oak + Beech + Cherry	5	173.353	1.540	0.021	0.489
Non-Harvest Mortality ~ White Oak + Hickory + Year	5	173.679	1.867	0.018	0.480

Table 1.3. Pearson's pairwise comparisons (r) of land cover and non-harvest mortality (NHM) in the Mountain region of North Carolina, 2004-2008.

Cover Type[a]	D-OS	D-LI	D-MI	D-HI	BL	DF	EF	MF	SS	GH	PH	CC	WW	EHW	NHM 2004-2008
D-OS	1.00														
D-LI	0.79****	1.00													
D-MI	0.90****	0.93****	1.00												
D-HI	0.90****	0.93****	0.99****	1.00											
BL	0.07	-0.04	-0.05	-0.00	1.00										
DF	-0.57***	-0.71***	-0.60***	-0.62****	-0.12	1.00									
EF	0.18	0.21	0.11	0.18	0.47**	-0.50**	1.00								
MF	-0.27	-0.22	-0.21	-0.25	-0.17	0.17	0.06	1.00							
SS	-0.10	-0.02	-0.09	-0.09	-0.02	-0.38*	0.40*	0.28	1.00						
GH	0.30	0.39*	0.29	0.36*	0.59***	-0.75***	0.71***	-0.18	0.39*	1.00					
PH	0.19	0.40*	0.24	0.26	-0.06	-0.86***	0.23	-0.19	0.40*	0.55***	1.00				
CC	0.32	0.11	0.14	0.09	-0.17	-0.24	-0.06	0.15	-0.11	0.01	0.21	1.00			
WW	0.47	0.51**	0.42*	0.50	0.43*	-0.67***	0.60***	-0.33	0.07	0.76***	0.42*	0.08	1.00		
EHW	0.05	0.31	0.25	0.24	-0.06	-0.34*	0.10	-0.18	0.07	0.29	0.35*	0.02	0.41*	1.00	
NHM 2004-2008	0.09	-0.14	-0.03	-0.09	0.01	0.27	-0.19	0.06	-0.22	-0.24	-0.32	0.04	-0.22	-0.14	1.00

[a] D-OS = Developed-Open Space, D-LI = Developed-Low Intensity, D-MI = Developed-Medium Intensity, D-HI = Developed-High Intensity, BL = Barren Land, DF = Deciduous Forest, EF = Evergreen Forest, MF = Mixed Forest, SS = Shrub/Scrub, GH = Grassland/Herbaceous, PH= Pasture/Hay, CC = Cultivated Crops, WW = Woody Wetlands, EHW = Emergent Herbaceous Wetlands

*** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$ (p-values are given in Appendix 1.2)

Table 1.4. Frequency of mortalities by type, region, and age class of black bears in North Carolina, 1969-2014.

Mortality Type	Age Class	Coast		Mountain		Piedmont	
		Male	Female	Male	Female	Male	Female
Non-Harvest Mortalities	Cub	27	16	4	2	0	1
	Yearling	85	37	30	5	5	1
	Subadult	88	35	34	4	9	1
	3-5 yrs. old	66	45	18	14	5	0
	6-10 yrs. old	34	26	7	4	1	1
	11-15 yrs. old	11	9	0	0	0	0
	>15 yrs. old	1	2	0	0	0	1
	Unknown	41	30	10	6	5	1
Harvest Mortalities	Cub	22	13	14	6	0	0
	Yearling	303	126	328	98	0	1
	Subadult	343	147	264	117	2	1
	3-5 yrs. old	465	233	315	227	1	1
	6-10 yrs. old	304	155	95	143	0	0
	11-15 yrs. old	70	63	9	34	0	0
	>15 yrs. old	8	13	1	5	0	0
	Unknown	56	33	19	12	0	0

Appendix 1.1. P-values from Pearson product moment correlations between hard mast (1983-2017), soft mast (1993-2017), and residual non-harvest mortality of black bears in the Mountain region of North Carolina.

	WO	RO	HI	BE	FP	FC	FG	FBG	SB	SH	SBK	SP
WO												
RO	0.07											
HI	0.91	0.89										
BE	**0.01**	0.16	**0.01**									
FP	0.92	0.39	0.15	0.84								
FC	0.11	**0.02**	**0.01**	**0.02**	0.86							
FG	**0.01**	0.41	0.10	0.16	0.27	**0.02**						
FBG	0.42	0.69	**0.01**	1.00	0.32	0.08	0.12					
SB	0.36	0.73	0.80	0.21	0.46	0.88	0.07	0.21				
SH	0.52	0.71	0.72	0.82	0.77	0.37	0.11	0.94	0.00			
SBK	0.46	0.76	0.47	0.45	0.82	0.81	0.28	0.81	0.90	0.96		
SP	0.38	0.57	0.77	0.78	0.28	0.42	0.47	**0.01**	0.17	0.79	0.11	
ResMort	**0.00**	**0.04**	0.07	0.60	0.76	**0.04**	0.06	0.51	0.94	0.86	0.41	0.69

WO = White Oak, RO = Red Oak, HI = Hickory, BE = Beech, FP = Autumn Pokeberry, FC = Cherry, FG = Grape, BG = Blackgum, SB = Blueberry, SH = Huckleberry, SBK = Blackberry, SP = Summer Pokeberry

Appendix 1.2. P-values from Pearson product moment correlations between cover types and non-harvest mortality (NHM) in the Mountain region of North Carolina, 2004-2008.

Cover Type[a]	D_OS	D_LI	D_MI	D_HI	BL	DF	EF	MF	SS	GH	PH	CC	WW	EHW
D_OS														
D_LI	**0.00**													
D_MI	**0.00**	**0.00**												
D_HI	**0.00**	**0.00**	**0.00**											
BL	0.71	0.82	0.77	0.99										
DF	**0.00**	**0.00**	**0.00**	**0.00**	0.51									
EF	0.31	0.23	0.53	0.31	**0.01**	**0.00**								
MF	0.13	0.21	0.23	0.16	0.35	0.35	0.73							
SS	0.57	0.92	0.60	0.60	0.93	**0.03**	**0.02**	0.11						
GH	**0.09**	**0.02**	**0.10**	**0.04**	**0.00**	**0.00**	**0.00**	0.30	**0.02**					
PH	0.29	**0.02**	0.17	0.14	0.74	**0.00**	0.19	0.28	**0.02**	**0.00**				
CC	**0.07**	0.54	0.43	0.60	0.34	0.17	0.75	0.41	0.55	0.98	0.23			
WW	**0.01**	**0.00**	**0.01**	**0.00**	**0.01**	**0.00**	**0.00**	**0.06**	0.69	**0.00**	**0.01**	0.64		
EHW	0.76	**0.07**	0.16	0.17	0.73	**0.05**	0.56	0.31	0.71	**0.10**	**0.04**	0.91	**0.01**	
NHM	0.62	0.42	0.85	0.61	0.95	0.12	0.28	0.73	0.21	0.18	**0.06**	0.81	0.21	0.42

[a] D-OS = Developed-Open Space, D-LI = Developed-Low Intensity, D-MI = Developed-Medium Intensity, D-HI = Developed-High Intensity, BL = Barren Land, DF = Deciduous Forest, EF = Evergreen Forest, MF = Mixed Forest, SS = Shrub/Scrub, GH = Grassland/Herbaceous, PH= Pasture/Hay, CC = Cultivated Crops, WW = Woody Wetlands, EHW = Emergent Herbaceous Wetlands

CHAPTER TWO: HARD MAST AS A SURROGATE FOR HUNTER EFFORT IN STATISTICAL POPULATION RECONSTRUCTION OF BIG-GAME SPECIES

ABSTRACT

Downing population reconstruction (DPR) is a commonly used method for monitoring abundance of big-game species. However, DPR underestimates the true population abundance by an unknown degree and because it is not statistical, it produces no estimates of precision. Variability in food availability has been implicated in influencing movements of black bears (*Ursus americanus*), which impact their survival. A multinomial *N*-mixture model was used to perform a statistical population reconstruction (SPR) of a black bear population in the Mountain region of North Carolina. An age-at-harvest likelihood was constructed using data collected from voluntary hunter check stations from 1983-2017. Surveys of hard mast were completed from 1983-2017, and age-at-harvest likelihood was combined with a catch-effort likelihood in which the availability of mast from the white oak subgenus *Leucobalanus* was used as a surrogate for hunter effort. Downing population reconstruction (DPR) was also performed on the same age-at-harvest data for comparison. The SPR estimate of the 2016 black bear population was 7380 bears: 3400 females (95% Bayesian Credible Interval (B.C.I.) = 3198-3603) and 3980 males (95% B.C.I. = 3789-4185). The estimated rate of increase was 5.2% annually. Initially, SPR estimates were similar to those of DPR albeit slightly higher. Reconstructions diverged rapidly beginning in 2008. For any given year, the probability of harvest for males ranged from 4.4-10.7% higher ($t = -28.608$, d.f. = 34, $P < 0.001$) than that for females. Mast availability appears to be a suitable surrogate for catch-effort statistics and its inclusion performs better than reconstruction methods that rely exclusively on age-at-harvest data.

INTRODUCTION

Estimation of total abundance, natural survival, recruitment, and harvest rates of big-game populations is essential for proper management (Williams et al. 2002). Knowledge of these parameters is necessary for setting hunting regulations (e.g., season lengths, bag limits, permits to be issued, etc.), for evaluating the effects of population and habitat manipulation, and for modeling population dynamics. For many wildlife resource agencies, tight budgets constrain the number and nature of studies necessary to fulfill these critical information needs. Most agencies collect information on the sex and age of harvested animals, however, and have done so annually for decades. While the utility of sex and age of harvested animals for estimating population size and demographic rates has been extensively critiqued (Millspaugh et al. 2009), interest remains on the use of age frequencies from expired cohorts for making inferences about big-game population dynamics (Skalski et al. 2005), as these data are easy and relatively inexpensive to collect.

For the past 40 years, arithmetic population reconstruction has been used for assessing population size and recruitment of big-game populations, despite a number of serious methodological limitations (Downing 1980, Davis et al. 2007). Primary among them, arithmetic population reconstruction (i.e., Downing Population Reconstruction; DPR) assumes that all mortality is from legal harvest, which for big-game species, may only apply under limited situations (Rosenberry and Woolf 1991). Natural survival rates less than unity lead to underestimation of population size because animals dying from natural causes are not included in the reconstruction (Davis et al. 2007). Furthermore, mortality from anthropogenic sources other than harvest are not included in the reconstruction. Secondly, DPR assumes that all animals harvested are also reported. Underreporting is a common feature of big-game harvest (Strickland et al. 1994, Rupp et al. 2000, Rosenberry et al. 2004), and leads to underestimation of total population size. Third, the presence of incomplete cohorts in the reconstruction also leads to underestimation of total population size, especially in later years (Skalski et al. 2005). Finally, because DPR is a backward summation of expired cohorts, there are no estimates of uncertainty associated with the minimum calculated population size.

Over the past two decades, statistical population reconstruction (SPR) has been advanced as an alternative to DPR (Gove et al. 2002). As the name implies, SPR is a type of integrated population model (Schaub and Abadi 2011) that combines multiple sources of data (e.g., age-at-harvest, radio-telemetry, hunter effort, abundance, reporting, mark-recapture) in a statistical framework to estimate certain population parameters and their uncertainty (Skalski et al. 2007, Clawson et al. 2013). Using modern likelihood methods, multiple sources of data commonly collected by wildlife management agencies are combined via probability statements to estimate harvest rate, natural survival rate, as well as population size. The availability of other relevant data allows for a more complex formulation and reconstruction. In fact, age-at-harvest data alone are insufficient for statistical population reconstruction. At least one additional data source and likelihood is required (Gove et al. 2002).

In most applications, the additional likelihood for minimal sufficiency is some form of catch-per-unit-effort derived from the number of hunters or other measure of cumulative effort (Skalski et al. 2007, Clawson et al. 2017). Technically speaking, any additional likelihood will work; however, the catch-effort likelihood is most commonly used for estimating probability of harvest (Gilbert et al. 2007, Skalski et al. 2007, Clawson et al. 2013). Currently, program PopRecon 2.0 is the only freely available software for performing SPR (Clawson et al. 2017), and requires data to parameterize the catch-effort likelihood before reconstruction can be performed. The challenge for wildlife managers is that data for modeling catch-effort relationships in big-game harvests are often non-existent, especially over large spatial extents like management units or regions.

In this Chapter, I demonstrate a way to parameterize the catch-effort likelihood for SPR by using an oak mast index as a proxy for hunter effort. The impact of mast availability on big-game harvests throughout much of the oak-dominated forests in the eastern U.S. is well-documented (McShea and Schede 1993, Norman and Steffen 2003, Ryan et al. 2004, Ryan et al. 2007, this study). A dearth of mast increases movements of big game, which leads to higher encounters with hunters and increased harvest (Gilbert et al. 1978, Alt 1980, McDonald et al. 1994, Noyce and Garshelis 1997, Obbard et al. 2014). This phenomenon is so pervasive and impactful, that many wildlife management agencies monitor the availability of mast over large geographical areas (e.g., >36,000 km^2). Legacy datasets span four decades or more. The combination of age-at-harvest data and annual mast surveys puts the potential of statistical population reconstruction for improved big-game management within reach for most natural resources agencies.

The overarching goal of this chapter is to demonstrate the value of SPR, and the validity of this particular application, to big-game management relative to current adherence to simple arithmetic reconstruction. The purpose is to estimate the observed rate of increase of a regional black bear (*Ursus americanus*) population expanding its range a century after habitat destruction and unregulated harvest in the Mountain Region of North Carolina. My specific objectives are to: (1) use SPR to reconstruct the black bear population of the Mountain Region of North Carolina; (2) plot the trend and estimate the observed rate of increase of the population from

1983-2017, and (3) relate estimated demographic rates to contemporary range expansion of bears into other physiographic regions of the state.

STUDY AREA

The Mountain region consists of 34 counties in the western one-third of the state (Fig. 3.1). Topography is classified as mountains proper and foothills. Mount Mitchell, the highest elevation east of the Mississippi River, rises to approximate 2037 m (6,684 ft.) above sea level (NCSU, NetState 2016). The high elevation of the mountains absorbs the brunt of storms coming from the midwestern United States, protecting the central Piedmont region from hard storms, and forms the structures necessary for orographic precipitation (NCSU). The result is a different climatic pattern in the Mountain region from that of the rest of the state.

The mean high and low temperatures in Asheville in January are 8.6^{o} C (47.4^{o} F) and –2.9^{o} C (26.7^{o} F), respectively (CantyMedia 2019). The coldest temperature ever recorded in North Carolina was on January 21, 1985, when temperatures dropped to -37^{o} C (-34^{o} F) on Mt. Mitchell (NetState 2016). In July, the mean high and low temperatures are 28.9^{o} C (88^{o} F) and 17.6^{o} C (63.7^{o} F), respectively (CantyMedia 2019). Total annual precipitation in Asheville averages 116 cm (45.6 in.), with snowfall amounts accounting for an average of 25 cm (9.9 in.) (CantyMedia 2019).

Nearly all counties in the mountain region are ≥50% forested (Brown and New 2013). Dominant forest types include oak (*Quercus* spp.), southern yellow pine (*Pinus taeda* and *P. palustris*), mixed pine-hardwood, and mixed mesophytic hardwoods (SAMAB 1996, Schafale 2012). It was assumed that there is a stable to slightly increasing population of >5,000 black bears in this region (C. Olfenbuttel, North Carolina Wildlife Resources Commission (NCWRC), personal communication). As populations of bears and people continue to grow, incidences of human-bear conflicts are anticipated to increase.

METHODS

Mast Surveys

An index of availability of hard mast was collected every autumn from 1983-2017 by the NCWRC and U.S. Forest Service. Hard mast species included white oak *(Quercus alba, Q. prinus*), red oak (*Q. coccinea, Q. falcata, Q. rubra, Q. velutina*), American beech (*Fagus grandifolia*), and hickory (*Carya glabra, C. laciniosa, C. ovalis, C. ovata, C. tomentosa*). Linear models using hard mast to predict the frequency of mortality (see Chapter One) indicated that white oak (*Leucobalanus*) mast availability best predicts the frequency of harvest and non-harvest mortality. Therefore, this chapter will focus on the use of white oak mast abundance only.

For a complete description of the methodology for mast data collection, see Greenberg and Warburton (2007). Transects were established throughout the Mountain region. Each transect was approximately 16-32 km in length. Initially, >1100 trees were surveyed along 10 transects. Over the years, the number of surveys increased until in 2017, surveys were conducted on 12 transects and nearly 1400 trees. Survey stops were spaced at $\bar{x} = 23.2 \pm 6.3$ stops/transect at elevation intervals of approximately 30.5 m (Greenberg and Warburton 2007). At each stop on the transect, approximately five hard mast trees were scanned with binoculars for two minutes to estimate the percent crown producing nuts (PCN). Next, the terminal 0.9 m of five limbs were scanned to estimate the number of twigs, the number of twigs producing mast, and the number of acorns per twig. Protocols of Whitehead (1969) and modifications from

Wentworth et al. (1992) were used until 2006, then the protocols of Greenberg and Warburton (2007) were adopted.

Mast index values were converted back to PCN following Greenberg and Warburton (2007) using the linear function

$$\%\ crown\ with\ nuts\ (PCN) = \frac{\left[\frac{(Mast\ \mathit{Index} - 0.485)}{0.067}\right]}{100}.$$

Conversion to PCN was necessary. Greenberg and Warburton (2007) used reduced major axis regression (Sokal and Rohlf 1981) rather than ordinary least-squares regression to convert the proportion of trees bearing acorns (PBA) to hard mast index (HMI) because the dependent variable (i.e., PBA) was subject to sampling error; whereas, ordinary least-squares regression assumes no error in the independent variable. Using PCN rather than HMI allows for a more intuitive interpretation of the amount of mast produced. By converting from HMI to PCN, I assume that total crop abundance is positively correlated with PCN. Because mortality is inversely related to mast availability (Chapter One), I use the compliment of PCN hereafter.

Arithmetic Population Reconstruction

Population reconstruction has a long history in wildlife and fisheries management (Skalski et al. 2005). These methods were originally designed for stock assessment in fisheries because the traditional methods used to estimate populations were very difficult to implement. However, more than just estimates of population abundance are needed for proper management. Newer methods of population reconstruction now allow researchers and managers to estimate other key parameters, such as demographic and harvest parameters as well as the reconstructed population size.

DPR was derived from Virtual Population Analysis (Fry 1949) and Cohort Analysis (Pope 1972), where expired cohorts are summed over time, but makes assumptions of survival and harvest rates to reconstruct incomplete cohorts. DPR calculations were made following Davis et al. (2007) using age-at-harvest (AAH) data from 1976-2017. This method requires an estimate of the total number of animals harvested by year (H_t) and a subsample of animals harvested by age and year ($S_{a,t}$), from which the percent sampled (A_t) is calculated. Population estimates are made using the following steps (Davis et al. 2007).

1) AAH is corrected to account for those animals not subsampled.

$$H_{a,t} = S_{a,t}/A_t$$

2) Age classes then can be conflated to the desired age class (x) by summing the AAH for age classes $\geq x$.

3) For the three most recent years ($t = y, y\text{-}1, y\text{-}2$), the mean corrected harvests (C_a) of two oldest age classes ($a = x, x\text{-}1$) are calculated.

$$C_x = (H_{x,y} + H_{x,y-1} + H_{x,y-2})/3$$

$$C_{x-1} = (H_{x-1,y} + H_{x-1,y-1} + H_{x-1,y-2})/3$$

4) The mortality rate (M) for the two oldest age classes is estimated as:

$$M = C_{x-1}/(C_x + C_{x-1})$$

5) The total number in the oldest age class (Z_x) is

$$Z_x = C_x/M$$

6) Reconstruction begins at the most recent year (y). The population estimate for the oldest age class is:

$$N_{x,y} = H_{x,y}/[1 - Z_x/(Z_x + H_{x-1,y} + H_{x,y})]$$

and the estimate for the next youngest age class is:

$$N_{x-1,y} = H_{x-1,y}/[1 - Z_x/(Z_x + H_{x-1,y} + H_{x,y})]$$

7) For the other years, the estimates for the two oldest age classes are:

$$N_{x,t} = H_{x,t}/[1 - N_{x,t+1}/(N_{x,t+1} + H_{x-1,t} + H_{x,t})]$$

and

$$N_{x-1,t} = H_{x-1,t}/[1 - N_{x,t+1}/(N_{x,t+1} + H_{x-1,t} + H_{x,t})]$$

8) The younger age classes are estimated as

$$N_{a,t} = N_{a+1,t+1} + H_{a,t}.$$

DPR assumes:

1. Age classification is accurate.
2. Harvest numbers are reported accurately.
3. Harvest mortality is the primary source of mortality.
4. Natural mortality rates are low and constant over time.
5. If incomplete cohorts are used and one extrapolates from complete to incomplete cohorts, then harvest mortality must be constant.
6. The mortality rates of the two oldest cohorts are equal.
7. Subsamples of the ages of harvested animals are representative of the population.

Statistical Population Reconstruction

Unlike the arithmetic operations of DPR, SPR is statistical. SPR uses one or more auxiliary data sets to extract the maximum amount of information from the AAH matrix, which in addition to total abundance, may include the estimation of survival rates, harvest and reporting rates, and recruitment rates in a single comprehensive framework (Gove et al. 2002). By itself, the AAH matrix is insufficient for population reconstruction (Pope 1972, Gove et al. 2002). A joint likelihood using the AAH matrix and at least one additional data source is analyzed to extract parameter estimates (Kéry and Shaub 2012). In calculating a joint likelihood, SPR allows for the estimation of as many parameters, and their uncertainties, as the data can support (Gove et al. 2002).

With colleagues, I developed a multinomial N-mixture model (Kéry and Royle 2016) to perform SPR (*manuscript in prep.*), which I adapted to reconstruct the Mountain region black bear population in this study. We used the Poisson formulation of the multinomial mixture model because the marginal likelihood can be computed analytically (Kéry and Royle 2016). The goal was to predict the initial cohort strength from the diagonal elements of the AAH matrix by multiplying the multinomial cell probabilities by the Poisson intensity. The cell probabilities are products of harvest, natural survival and reporting/aging rates typical of SPR models (Gove et al. 2002). Initial numbers of the recruitment and the pseudo-recruitment (i.e., animals already in the population at the start of the first harvest) cohorts are estimated by the model and total population size is calculated as a derived quantity (i.e., it is reconstructed). Uncertainties associated with all predicted and estimated quantities are propagated through to the posterior distribution of total population size. Estimates were charted over time along with 95% Bayesian credible intervals (B.C.I.). Population reconstruction was implemented in the JAGS programming language (Plummer 2003) in R version 3.5 (R Core Team 2017). Three main likelihoods were used: AAH, catch effort, and ageing. A Bayesian implementation made construction of a solution of the product likelihood more approachable for non-mathematicians (Kéry and Shaub 2012).

Assessment of model fit

Currently, there is no omnibus goodness-of-fit test for these kinds of hierarchical models (Royle and Dorazio 2008, Royle et al. 2011). A Bayesian posterior predictive check on predicted recruitment was incorporated as a goodness-of-fit criterion (Gelman et al. 1996). The posterior predictive check uses a discrepancy measure between the observed data and their expected values. To evaluate the recruitment component of the model, observed and expected recruitment in the Freeman-Tukey discrepancy statistic were used to compute the Bayesian p-value; values near 0 or 1 indicate a general lack-of-fit. Because this model predicts recruitment in two components (i.e., those animals born into the population during the period of harvest and those already in the population at the time harvest is initiated), discrepancies for both were computed and combined into a single metric.

Early analyses indicated a high frequency of over-dispersion in bear population reconstructions. Simulation studies (unpublished data) revealed high variation in annual harvest probability leads to over-dispersion and lack-of-fit. Consequently, a two-staged approach was developed for analyzing AAH data. The first stage uses a normal random effect on harvest probability in addition to the Poisson catch, and models the Poisson intensity on the logarithmic scale. This stage accomplishes two objectives. First, it converges on a reconstruction when initial values of recruitment are lacking, a common situation in most contexts. Second, the normal random effect on harvest probability solves the over-dispersion problem albeit at a cost to precision. Consequently, the original model was retained as a second stage to produce a more precise reconstruction which uses estimated, first-stage recruitment as initial values.

Model convergence was improved by increasing the adaptive phase of the Markov Chain Monte Carlo (MCMC). The default adaptive phase is 100 iterations (Plummer 2003). Meredith

(2016) recommended using a larger number of adapt iterations and few, if any, burn-in iterations. By trial-and-error, simulations of 100,000 iterations, using three chains, an adaption phase of 20,000, burn-in of zero, and a thinning rate of two were used for phase one. Phase two ran for 12,000 iterations, using three chains, an adaption phase of 2,000, burn-in of zero, and a thinning rate of two. The Gelman-Rubin statistic, $\hat{R}$, was used to monitor convergence and examined trace and kernel density plots to ensure adequate mixing of the Markov chains for each parameter of interest. Values of $\hat{R} \leq 1.1$ indicated convergence (Gelman et al. 2004).

The catch-effort likelihood declares the probability of harvest (p_i) as a function of hunter effort (H_i) and a constant vulnerability coefficient (c; Seber 1982, Skalski et al. 1983, Skalski et al. 2005)

$$p_i = f(c, H_i).$$

However, no data were available on hunter effort for bear hunters in North Carolina. Until recently, a bear tag was issued with every big-game license regardless of whether the hunter was going to hunt bears or not. Beginning in 2014 any resident wishing to hunt bears had to purchase a bear tag separate from the other big-game species. Those hunters that purchased a lifetime license prior to 2014, had to request a free electronic bear tag. Because the tag was free, some hunters were requesting the bear tag in the event that there was an unplanned opportunity to harvest a bear during the overlap of the deer and bear seasons; otherwise, the hunter was not going to specifically hunt bears.

In North Carolina, most bears are harvested with the aid of hounds (NCWRC 2016). After a bear is harvested with the aid of a pack of hounds, the same pack may be used again in an attempt to harvest another for a different hunter. Therefore, effort may not change appreciably. Essentially, hunter effort is a measure of the chance that a hunter will encounter a bear. If hunter effort does not change appreciably and yet harvest is variable annually, then other factors must be considered. Rather than measure effort the hunter put forth to encounter a bear, this chapter focuses on measuring “effort” the bear unwittingly puts forth “avoiding” a hunter. This effort is measured by mast availability and a bear’s propensity to travel more during years of poor mast production in search of food (Beeman and Pelton 1980, Pelton 1989), which makes it more vulnerable to harvest.

In conventional situations, vulnerability is often related to harvest probability through the Poisson catch (Seber 1982):

$$p_i = 1 - e^{-cH_i}.$$

However, other plausible models exist (Chao and Chang 1999). Although the choice of catch function can affect estimates of population abundance, the Poisson and the multiplicative models are approximately equal when $c*H_i$ is small (Mao 2007).

The inverse of mast abundance (i.e., 1-PCN) was scaled using R’s *scale* function without centering in order to facilitate Markov Chain Monte Carlo (MCMC) convergence and those values were submitted as hunter effort (H_i). Vague priors were specified for all unknowns in the reconstruction to perform essentially a maximum-likelihood estimation of parameters. SPR requires an AAH matrix and at least one auxiliary data set (Gove et al. 2002). To determine year-specific or age-specific survival rates or vulnerability coefficients, additional auxiliary data sets must be used. Survival rate (S) and vulnerability coefficient (c) were drawn from binomial and uniform distributions, respectively, and assumed constant over time to narrow the parameter space due to minimal auxiliary information in this study. Furthermore, the SPR model only used AAH data from 1983-2017 due to an absence of mast or other auxiliary data prior to 1983. Both sexes were analyzed separately.

The current implementation of this SPR model uses only "complete" age-structures rather than conflated age classes. Maximum age of bears was 22 years for males and 26 years for females. This study only used data for 18 age classes (i.e., age 0.75-17.75). Data were truncated because: (1) reliability of ages of bears decreases with age, (2) when the AAH matrix has many zero entries, finding solutions using MCMC can be problematic, and (3) age classes >17.75 years made up <1% of the harvest.

Finally, I compared the finite rate of population increase (λ) derived from the regression of the natural logarithm of reconstructed population size on time (realized λ) to that derived from the Euler-Lotka equation (projected λ; Lotka 1956, Euler 1970),

$$1 = \sum_{x=1}^{A} \lambda^{-a} l(x) m(x),$$

where, *l(x)* is the age-specific survival rate, and *m(x)* is age-specific fertility rate. Projected λ is the expected population growth if the conditions of the model are not stochastic (Cooch and White 2019).

RESULTS

White oak mast indices ranged from 0.48-4.43, or 0-59% PCN (Table 2.1). By using mast availability as an index of effort, SPR tracked closely with DPR for females until approximately 1996, then diverged rapidly beginning at approximately 2008 (Fig. 2.2). SPR tracked DPR for males until approximately 2008 (Fig. 2.3). Female and male abundance in 2008 calculated by DPR was 2351 and 2596, respectively. Estimates for females and males from SPR were 2609 (95% B.C.I. = 2452-2773) and 2641 (95% B.C.I. = 2511-2777), respectively. By 2016, DPR calculated female and male abundance as 1916 and 2091, respectively. SPR estimates in 2016 were 3365 (95% B.C.I. = 3165-3569) for females and 3882 (95% B.C.I. = 3696-4080) for males. Estimates for 2017 declined by approximately 400 for both females and males.

Recruitment increased over time from 187 to 1484 bears per year (Fig. 2.4), but was highly variable. The observed finite rate of increase (λ) calculated from the geometric mean of the annual population estimates was 1.048, 1.050, and 1.049 for females, males, and both sexes combined, respectively, resulting in the total population increasing from 1278-7379 from 1983 to 2016 (Fig. 2.5). Projected lambda for females derived from the Euler-Lotka equation was 1.21.

Estimated vulnerability coefficients were 0.137 (95% B.C.I. = 0.128-0.144) for females and 0.245 (95% B.C.I. = 0.235-0.254) for males. The annual probability of harvest was 6.7-15.6% for females, and 11.6-26.1% for males. For any given year, the probability of harvest for males was 4.5-10.5% higher than that of females (Fig. 2.6), and males were more greatly impacted (Fig. 2.7) in years of poor mast availability than females.

DISCUSSION

Using the two-stage approach, I was able to create a precise (coefficient of variation, *cv* = 2-5%) reconstruction of the Mountain region black bear population over a 35-year period. The DPR and SPR models tracked well together in the earlier years (1983-1995) with differences of only 5-106 animals for each sex. DPR estimates fell outside the B.C.I.s of the SPR estimates beginning around 2008. By 2016, estimates from SPR of the total population were nearly 3250 greater than DPR.

DPR estimates are biased low because it calculates a “best guess” of the minimum number of animals in the population. It assumes that all members of the population are accounted for in the AAH matrix (i.e., either 100% aged or 100% reported). Because the frequency of non-harvest mortality is increasing (See Chapter One), this may be the reason DPR and SPR were very different beginning around 2008. The population may have reached a threshold in the proportion of non-harvest mortality that DPR fails to account for.

SPR is a type of integrated population model. As such, datasets draw strength from one another when estimating parameters (Schaub and Abadi 2011). The sampling and processing uncertainties are included in and propagated through the model (Schaub and Abadi 2011). SPR may better account for those animals not included in the AAH matrix by drawing strength from the catch-effort likelihood (Schaub and Abadi 2011). The ability of SPR to capture the bias that DPR cannot, could have large impacts on harvest management, especially for species where the objective is to control over-population.

An index of white-oak mast abundance as a surrogate for hunter effort was successful in providing information on harvest rates for both female and male black bears. Variability of annual harvest probability in a system where hunter effort remains constant can be explained by changes in vulnerability of the target species and/or changes in population abundance. For black bears, their vulnerability to mortality increases when the availability of high-quality food sources decreases (Beeman and Pelton 1980, Pelton 1989, Noyce and Garshelis 1997, Ryan et al. 2004, Ryan et al. 2007). In North Carolina, white oak mast availability had the highest correlation with bear mortality (See Chapter One), and with the probability of harvest.

Mast production in the Southern Appalachian Mountains can be quite variable (Greenberg and Parresol 2000). Weather and other environmental conditions (Sharp and Sprague 1967, Sharp and Chisman 1961, Sork et al 1993, Cecich and Sullivan 1999, Koenig and Knops 2014), as well as past reproductive history (Sork et al. 1993) affect the quantity and quality of the crop. This variability provided the changes in the catch-effort needed to explain annual changes in harvest probabilities. This study assumed that vulnerability was constant thus giving the illusion that effort was changing. When annual hunting effort does not change significantly, the observed change in harvest is due to the bears' "effort in avoiding harvest" by limiting their movements in years with bumper mast crops. Annual vulnerability may not have been constant, but to be able to decipher annual variation, additional data need to be collected and additional likelihoods created.

The black bear population in the Mountain region increased at an exponential rate consistent with that predicted from variants of the Euler-Lotka equation. The Euler-Lotka equation estimated the maximum potential of lambda (λ) to be 1.21 for females. Observed lambda calculated from SPR population estimates and $\lambda = \frac{N_{t+1}}{N_t}$ was 1.05. Therefore, the bear population is not increasing at its full potential, but increasing, nonetheless.

The velocity of range expansion (C) is proportional to rate of increase by the equation $C = \sqrt{rs}$, where s is a diffusion constant (van den Bosch et al. 1992; See Chapter Three). Viewed from a fixed position on the ground, an observer would not be able to see the velocity of the range expansion (van den Bosch et al. 1992). As the front of the expanding range passes by a fixed position, even if the velocity of range expansion is constant, the perception at that position is that the population is exhibiting exponential growth because of increasing population density (van den Bosch et al. 1992). If, however, there is a change in s and the corresponding change in C, the appearance from that fixed position would be that there is a change in r. That could have large impacts on drafting management decisions, especially harvest regulations where input from the public is considered.

Harvest rates for black bears in NC predicted from the mast catch-effort likelihood were reasonable based on comparisons with radio-telemetry studies, SPRs, capture, and other studies

(Bunnell and Tait 1985, Harris and Metzgar 1987, Noyce and Garshelis 1997, Diefenbach et al 2004, Dobey et al. 2005). Dieffenbach et al. (2004) estimated harvest rates for adults of 9.7-22%, and as high as 48.3% for 1-year-olds. Annual probability of harvest for males was as much as 10.5% higher than females, which is realistic considering males have larger home ranges than females (Hamilton 1978, Alt et al. 1980, Garris 1983, Clevenger 1986, Brody and Pelton 1989, Lombardo 1993), thus having a higher likelihood of encountering more hunters. The probability of harvest for females also is reduced because of denning during late hunting seasons (Erikson, 1964, Alt 1977, Lindzey 1981), which should be considered when drafting harvest regulations.

MANAGEMENT IMPLICATIONS

The SPR approach I adopted demonstrated that commonly collected field data are sufficient to estimate parameters that cannot be estimated otherwise. While additional data might improve the reconstruction, relatively inexpensive data such as mast surveys, can be used initially. As information needs grow, more expensive surveys (e.g., radio telemetry, catch-release, mark-recapture) can be targeted to fill knowledge gaps. One of the benefits of integrated models is that additional likelihoods can be added as data become available.

This study focused on the Mountain region population. Although mast is available in the Coastal region, bears rely extensively on agricultural crops (Maddrey 1995, Jones 1996, Allen 1999). Therefore, mast index is not suitable for use in the catch-effort likelihood for this population. Other likelihoods need to be developed for this population.

Data collected for the AAH matrix is through voluntary submission to check stations. Smaller and younger bears are often not submitted to check stations, therefore not included in the AAH matrix. Although registration of a successful harvest is mandatory, the true reporting rate is unknown. Adding additional auxiliary likelihoods could allow for estimating annual reporting rates. Required check stations would increase sample sizes, perhaps allowing to obtain estimates at a smaller landscape scale. By tracking reporting rates over smaller areas, law enforcement would be able to better focus their efforts.

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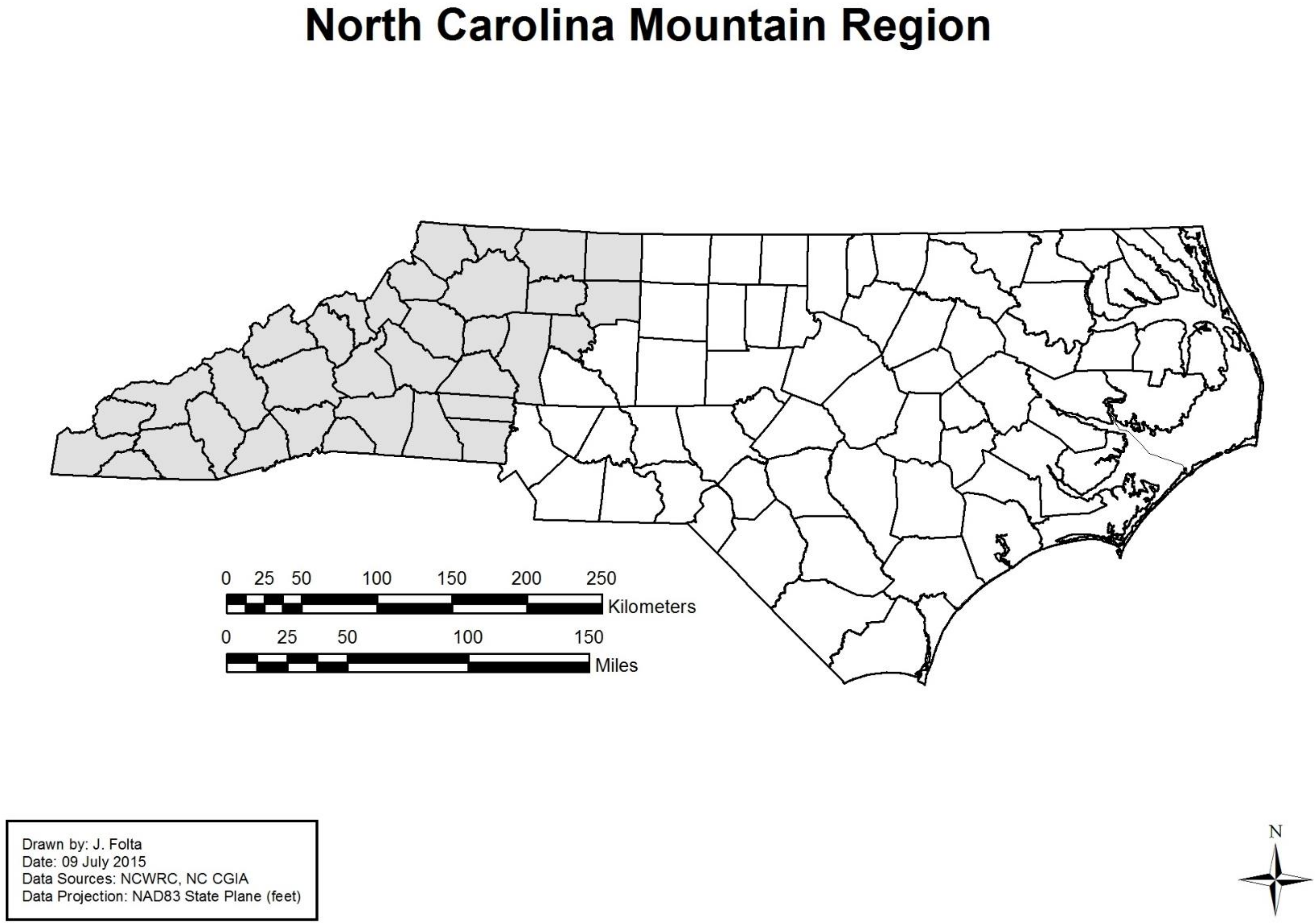


Figure 2.1. Mountain region of North Carolina, USA.

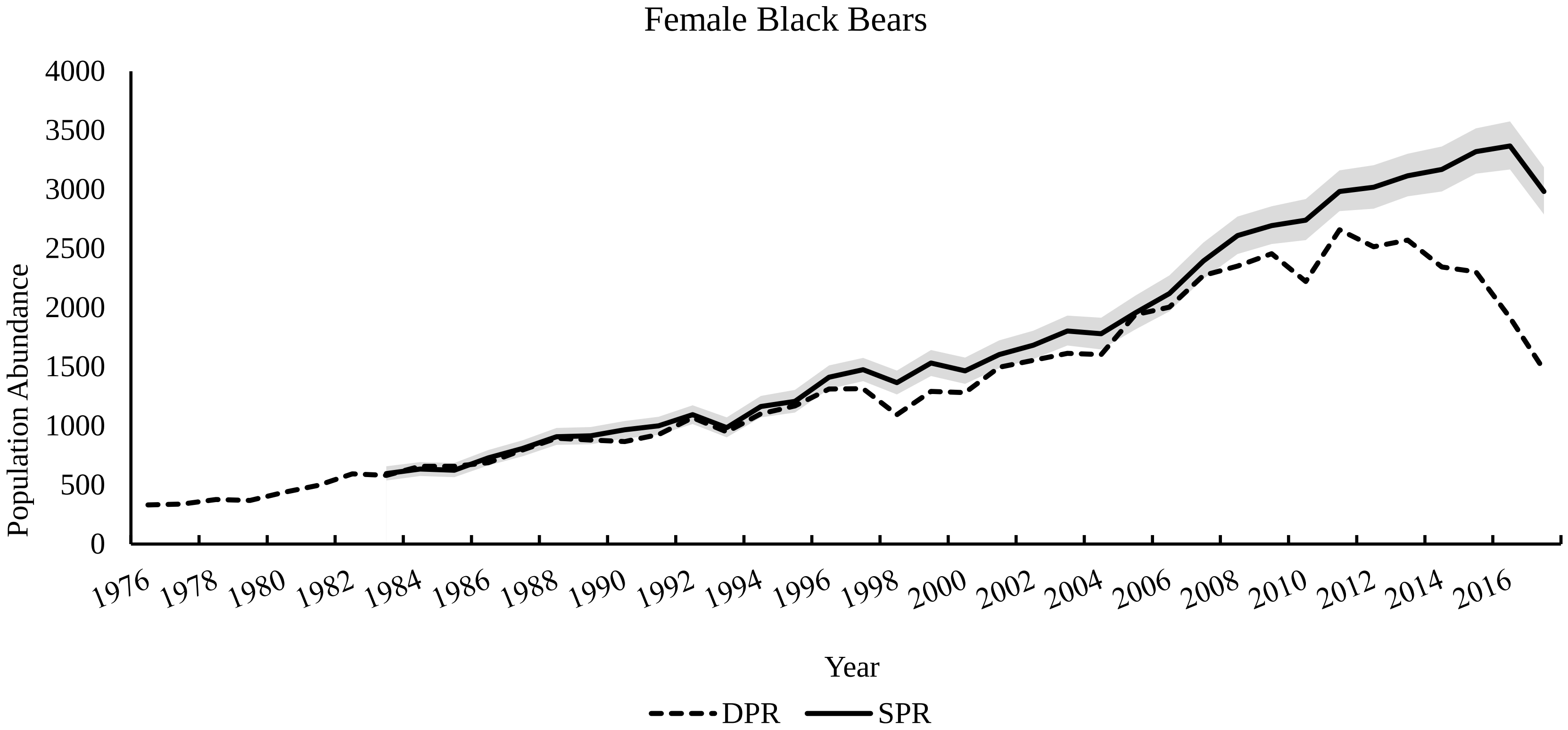


Figure 2.2. Downing population reconstruction (DPR) and statistical population reconstruction (SPR; ± 95% B.C.I.) of female black bears from the Mountain region of North Carolina, USA, 1976-2017.

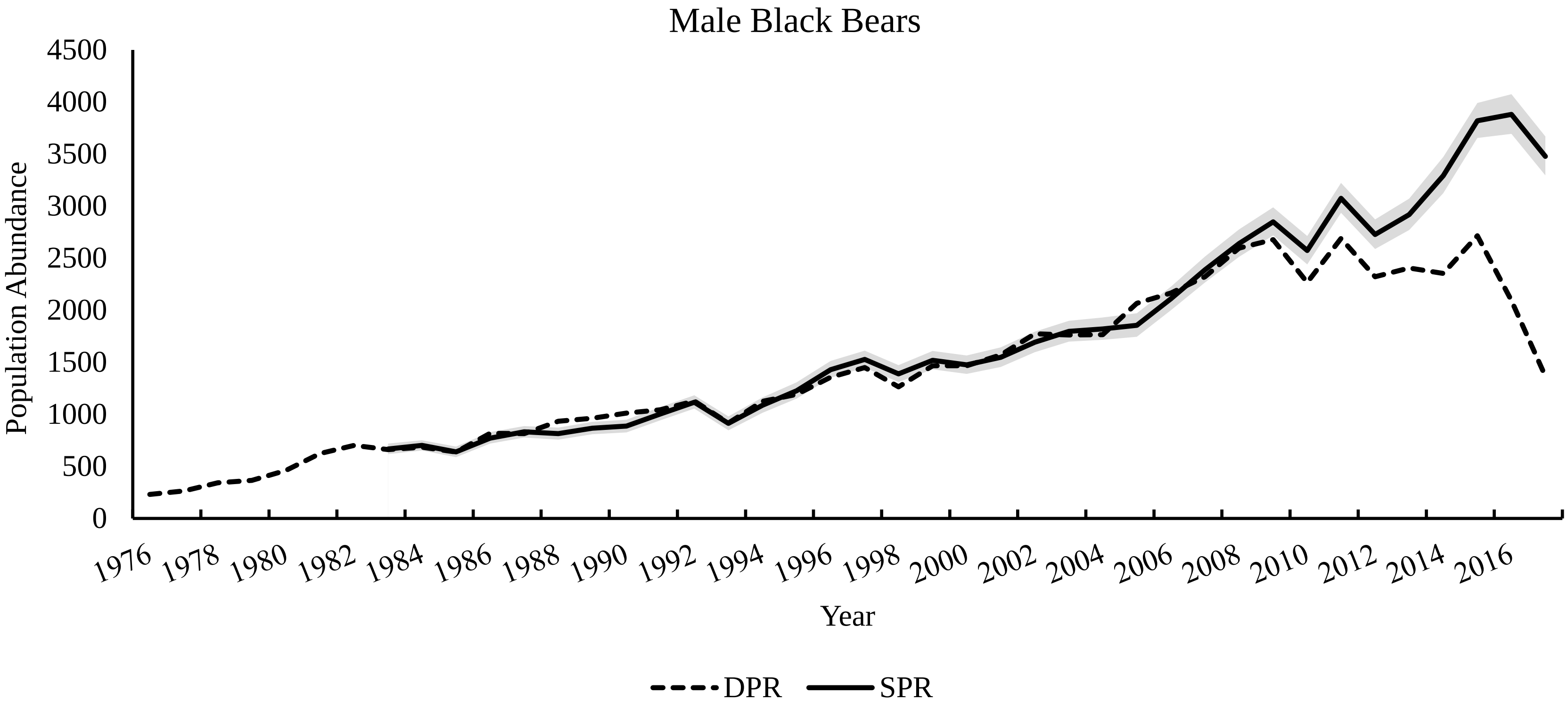


Figure 2.3. Downing population reconstruction (DPR) and statistical population reconstruction (SPR; ± 95% B.C.I.) of male black bears from the Mountain region of North Carolina, USA, 1976-2017.

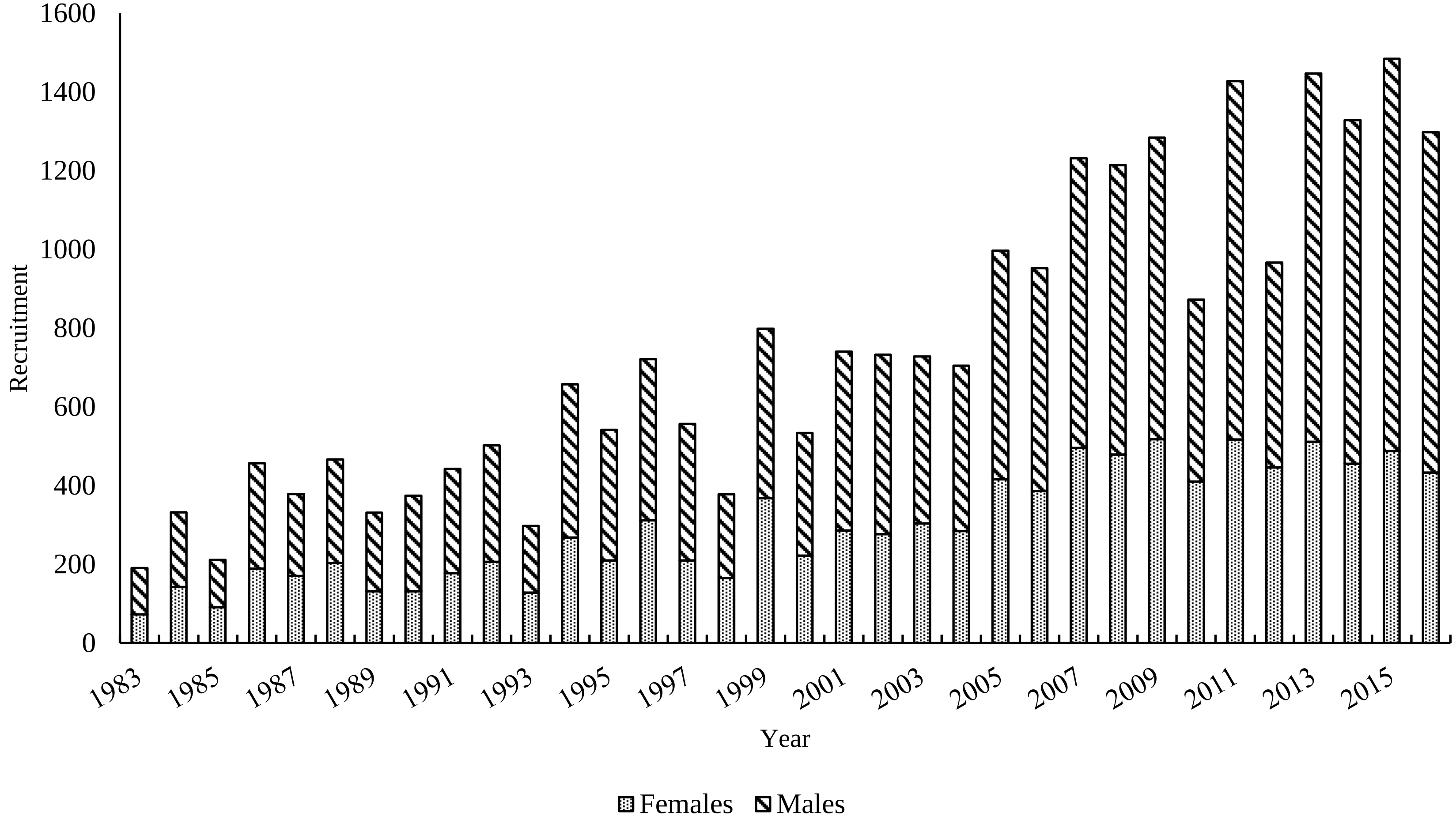


Figure 2.4. Estimated annual recruitment of black bears in the Mountain region of North Carolina, USA, 1983-2016.

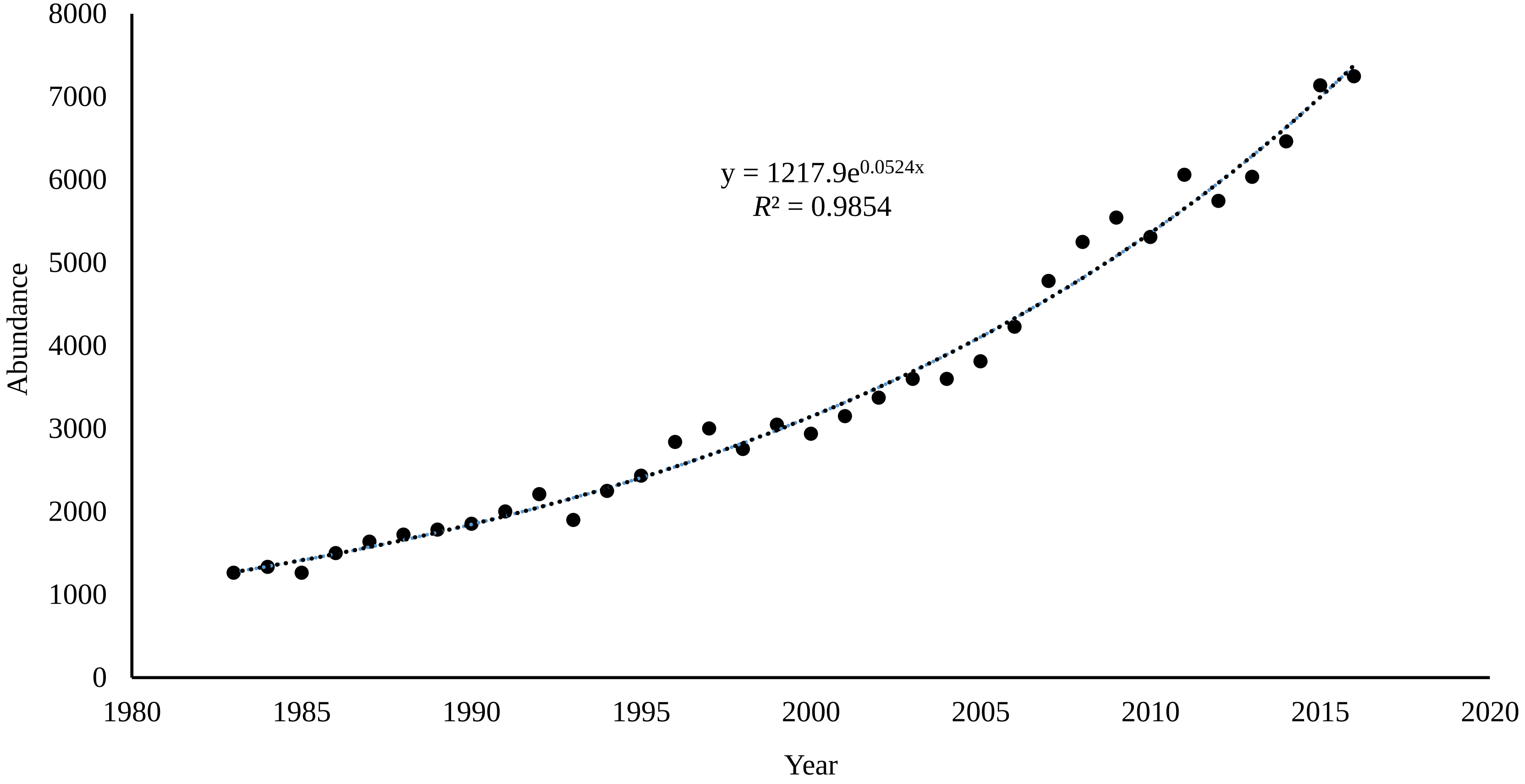


Figure 2.5. Exponential rate of increase for black bears in the Mountain region of North Carolina, USA, 1983-2016.

Figure 2.6. Annual probability of harvest of black bears in the Mountain region of North Carolina, USA, 1983-2017.

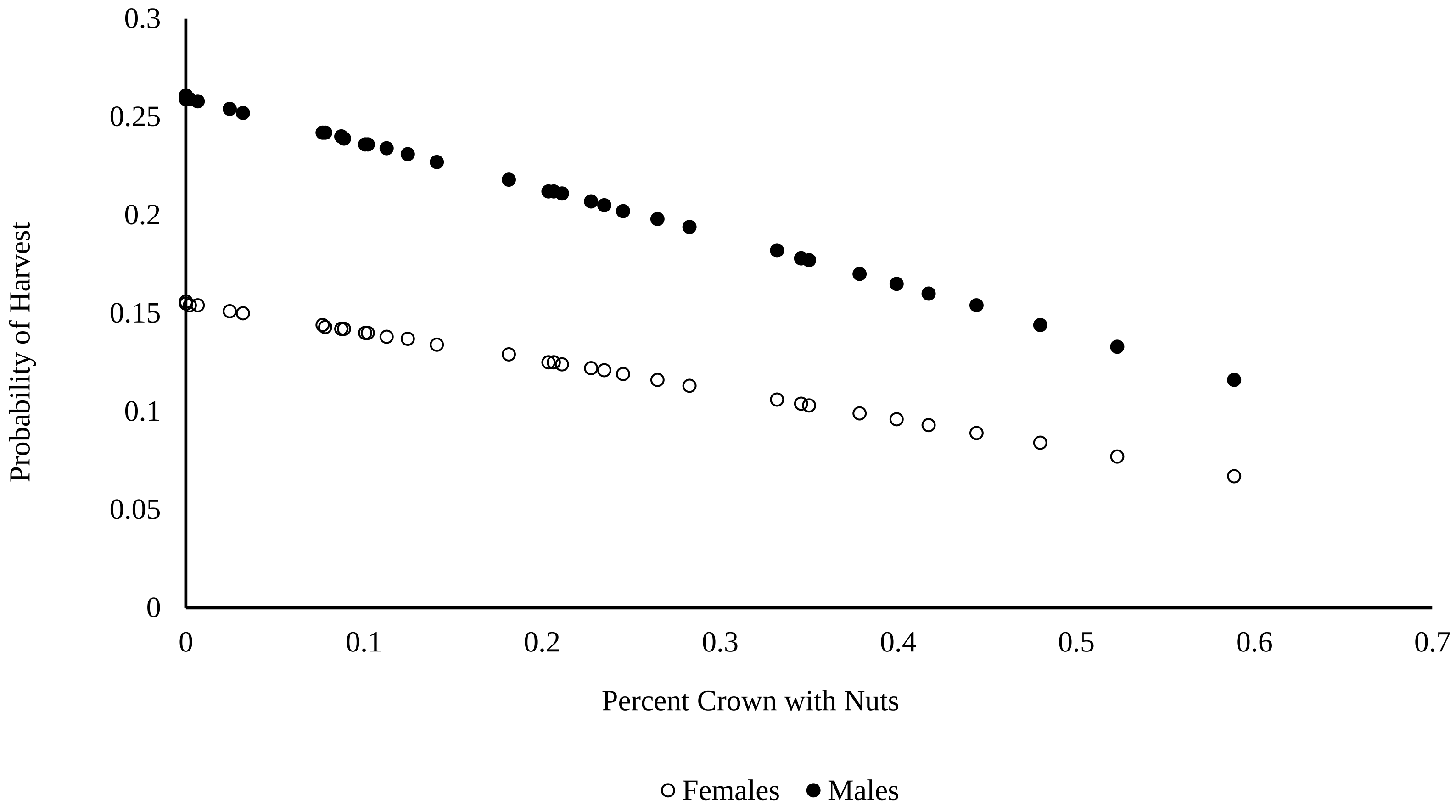
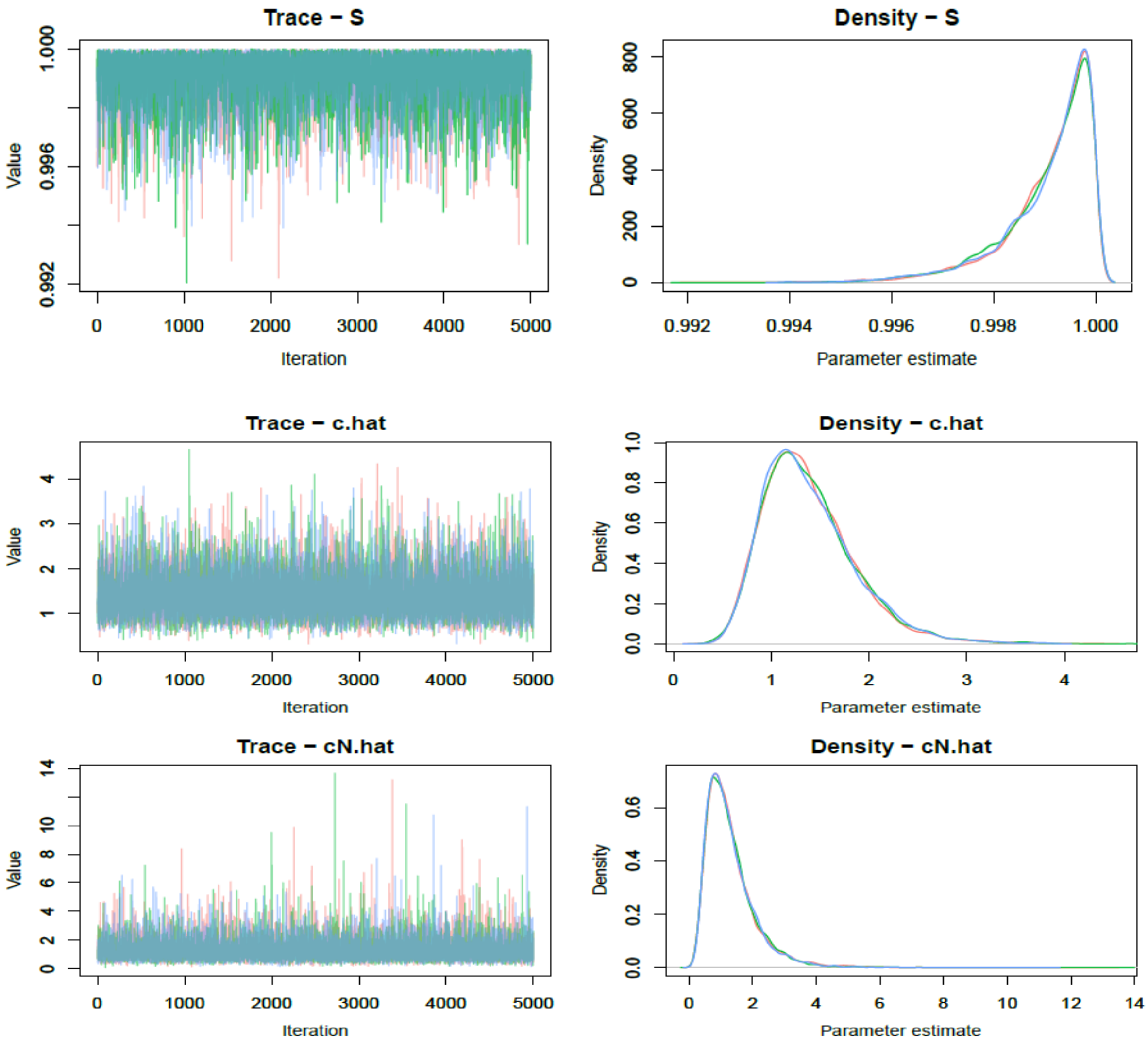


Figure 2.7. Probability of harvest in relation to white oak acorn availability in the Mountain region of North Carolina, USA, 1983-2017.

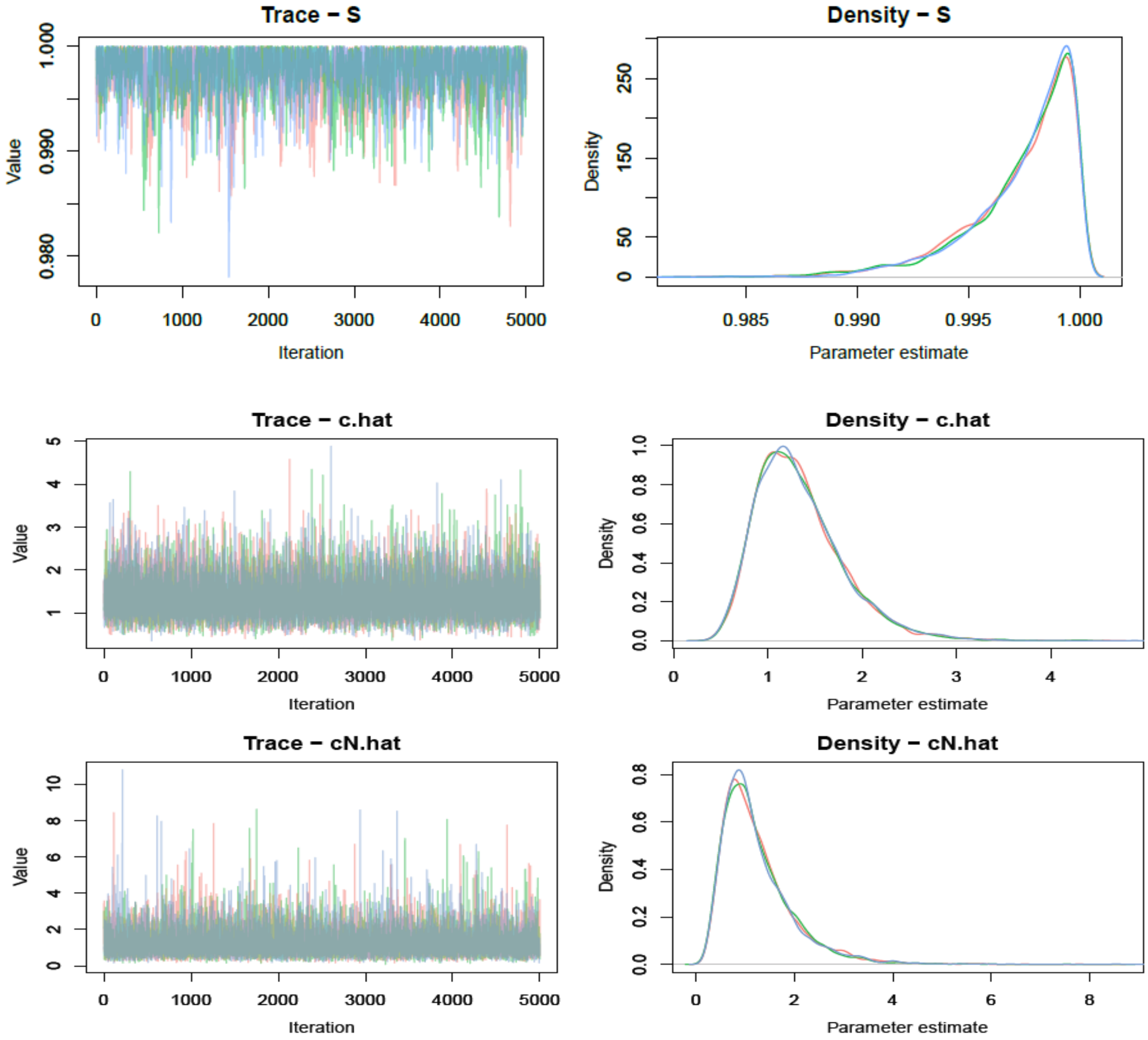
Table 2.1. White oak mast production in the Mountain region of North Carolina, USA, 1983-2017.

Year	White Oak Index	PCN	1 – PCN
1983	1.43	0.141	0.859
1984	1.08	0.089	0.911
1985	2.01	0.228	0.772
1986	1.32	0.125	0.875
1987	1.16	0.101	0.899
1988	3.16	0.399	0.601
1989	0.43	-0.008	1.008
1990	1.85	0.204	0.796
1991	2.38	0.283	0.717
1992	1.07	0.087	0.913
1993	0.65	0.025	0.975
1994	2.06	0.235	0.765
1995	2.80	0.346	0.654
1996	3.70	0.480	0.520
1997	0.53	0.007	0.993
1998	2.26	0.265	0.735
1999	3.28	0.417	0.583
2000	0.50	0.002	0.998
2001	2.83	0.350	0.650
2002	1.90	0.211	0.789
2003	1.24	0.113	0.887
2004	3.99	0.523	0.477
2005	0.70	0.032	0.968
2006	1.70	0.181	0.819
2007	3.02	0.378	0.622
2008	1.01	0.078	0.922
2009	0.48	-0.001	1.000
2010	3.46	0.444	0.556
2011	1.17	0.102	0.898
2012	1.87	0.207	0.793
2013	1.00	0.077	0.923
2014	4.43	0.589	0.411
2015	1.07	0.087	0.913
2016	2.71	0.332	0.668
2017	2.13	0.246	0.754

Appendix 2.1. Trace and density plots of selected parameters of female black bears, North Carolina.



Appendix 2.2. Trace and density plots of selected parameters of male black bears, North Carolina.



CHAPTER THREE: VELOCITY OF RANGE EXPANSION OF TWO BLACK BEAR POPULATIONS IN NORTH CAROLINA, USA

ABSTRACT

By the end of the 19th century, several North American big-game species were nearly extirpated from their former ranges. By the early 20th century, American black bears (*Ursus americanus*) were nearly extinct in North Carolina. Only a few populations remained in the Mountain and Coastal regions. The establishment of black bear sanctuaries in 1971 and stricter harvest regulations allowed the bear population to increase and expand from the sanctuaries throughout the Coastal and Mountain regions and into the Piedmont region where most people live in the state. Five methods were used to calculate the velocity of range expansion of bears across the state — simple reaction diffusion of bear observations, convex hull analysis of bear-vehicle collision (BVCs) locations, Delaunay triangulation of BVC locations, proximity analysis of BVC locations to black bear sanctuaries, and a parameterized Fisher-Skellam reaction-diffusion model. Each method resulted in a statewide velocity of spread of 4-8 km/year, but the Coastal population appeared to be expanding at a faster rate than the Mountain region. The velocity of range expansion was 0.2-2.4 km/yr for the Mountain region, and 3.2-4.1 km/yr for the Coastal region. The simple Fisher-Skellam reaction-diffusion model using observations from agency personnel and reliable public sightings performed just as well as more elaborate methods. This study emphasizes the importance of easily-collected, long-term data sets in answering broad-scale spatial questions.

INTRODUCTION

By the end of the 19th century a dozen big-game animal species were nearly extirpated in North America (Schmidt 1978). Indiscriminate persecution, market hunting, unregulated harvest, and habitat destruction have been implicated as major contributing factors for big-game population declines. Adoption of practices that would become the *North American Model of Wildlife Conservation* halted the certain demise of most big-game animal populations (Organ et al. 2012), and most species have increased in abundance with the implementation of better harvest regulations and 100 years of habitat improvement. The principal change agent of improving habitat for big-game species in the eastern U.S. has been the dramatic increase in the total area of forested land since 1920 (MacCleery 2011). From the mid-1800s until approximately 1920, forests were being converted to agriculture at a rate of about 35 km^2 per day (MacCleery 2011). Since then, forest growth has exceeded harvest for decades such that the average standing volume of wood in the eastern U.S. has nearly doubled since 1950 (MacCleery 2011). Consequently, many forest-dwelling species including moose (*Alces alces*) and American black bear (*Ursus americanus*) have been naturally recolonizing their ancestral ranges from nearby established or relic populations, while other species like white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*), northern river otter (*Lontra canadensis*), and wapiti (*Cervus canadensis*) have been assisted through translocation programs (Kennamer et al. 1992, McDonald and Miller 1993, Raesly 2001, O'Gara and Dundas 2002). Some of these very same species have become locally and regionally overabundant with important ecological (Garrett et al. 1993, Warren 1997), while others, particularly those near urbanized environments, have become symbols of controversy relative to the establishment of traditional consumptive uses (Leong 2009).

In the case of black bears, they were once distributed across all of North Carolina. Poor harvest management and land conversion largely impacted bear populations, but the introduction of chestnut blight (*Cryphonectria parasitica*) in 1925 (Carlock et al. 1983) may have had the greatest impact. By 1969, it was estimated that there were only a few hundred bears left in North Carolina. Those that remained were relegated to remote parts of the mountains in the west and the swamps and pocosins in the east.

In order to conserve the bear population, a Bear Sanctuary System (BSS) was created in 1971, which created 28 bear sanctuaries encompassing approximately 3237 km^2 (800,000 ac.) (NCWRC 2012; Fig. 3.1). These sanctuaries were to serve as a protected source of breeding females from which offspring would disperse and repopulate the range. Since the establishment of the sanctuary system, bear abundance has increased, and their range expanded greatly.

Historically, the study of range expansion was driven by economics and derived from theories of invasion ecology (Elton 1958). The number of studies of the spread of invasive species has sharply increased over the last 30 years (Lockwood et al. 2007). As invasive species expand beyond their native range or are introduced into novel locations, they often have severe economic and ecological impacts. Understanding the spread of species can be used to establish threatened and endangered species, and other species of positive economic importance (e.g., game species). But even species of positive economic importance can have negative economic impacts (e.g., forestry and agricultural damage, animal-vehicle collisions, damage to personal property, disease vectors, etc.).

The study of the velocity of range expansion began with theories rooted in physics with simple reaction-diffusion models (Fisher 1937, Skellam 1951). Later methods incorporated life history traits (van den Bosch et al. 1990, van den Bosch et al. 1992), heterogeneous habitat effects (Fraser et al 2015), and interactions between individuals (Durrett and Levin 1994). But even the simplest methods proved to be very accurate over broad spatial and temporal scales (Hastings 1996). Temporal and spatial observations of individuals and museum specimens are often used to calculate areas of occupancy during specific time intervals, and the changes in area represents the velocity of range expansion (Fisher 1937, Skellam 1951, van den Bosch et al. 1992, Hastings 1996, White et al. 2012). However, scant reports of elusive species can make estimates of occupancy and changes in range size difficult.

Studies have successfully used animal-vehicle collisions to monitor population abundance (Mallick et al. 1998, Baker et al. 2004, George et al. 2011). But Jahn (1959), indicated that for species that have different probabilities of encounter with roads due to sex or age, using sightings and roadkill incidences to monitor populations can be problematic. However, even given their limitation, in locations where credible sightings are limited, bear-vehicle collisions (BVCs) may have some value.

The purpose of this study was to determine the spatial and temporal spread of bears into and throughout the major physiographic regions of North Carolina using principles of invasion ecology and commonly collected data sets. I attempt to glean inferences from commonly collected data (e.g., sightings), and compare them against more specialized models. Specific research objectives include:

(1) calculating the regional velocity of range expansion of black bears in North Carolina,
(2) examining differences in velocity of range expansion calculated using different methods, and
(3) examining regional differences in velocity of range expansion.

STUDY AREA

North Carolina is approximately 139,396 km^2 (53,821 mi^2) in size (NetState 2016), with a total landmass of approximately 126,153 km^2 (48,708 mi^2). The state is divided into three main physiographic regions (Mountain, Piedmont, and Coast), each region quite different from the others (Fig. 3.2). For the purpose of this study, regions were delineated using the jurisdictional boundaries set by the NCWRC. Topography is diverse across the state, ranging from steep slopes in the west to flat land in the east. Land use patterns, human population abundance, and natural habitats also vary greatly. According to the 2010 United States Census, the human population was 9.5 million (United States Census Bureau), and there were 3.5 million registered motor vehicles in 2016 (Wagner 2018).

Mountain Region

The Mountain Region consists of 34 counties in the western one-third of the state. Topography is classified as mountains proper and foothills. Mount Mitchell, the highest elevation east of the Mississippi River, rises to approximate 2037 m (6,684 ft.) above sea level (NCSU, NetState 2016). Nearly all counties in the mountain region are ≥50% forested (Brown and New 2013). Dominant forest types include oak (*Quercus* spp.), southern yellow pine (*Pinus taeda* and *P. palustris*), mixed pine-hardwood, and mixed mesophytic hardwoods (SAMAB 1996, Schafale 2012). It was assumed that there is a stable to slightly increasing population of >5,000 black bears in this region (C. Olfenbuttel, NCWRC bear and furbearer biologist, personal communication).

Coastal Region

The Coastal region consists of 34 counties in the eastern part of the state. This area is dominated by agriculture (e.g., tobacco, cotton, soybeans, peanuts, corn, sorghum, melons, wheat and other small grains). This area also is known for its production of timber and timber products, especially loblolly pine (*P. taeda*) and longleaf pine (*P. palustris*). Several large river drainages, Carolina bays, pocosins, and other bottomland hardwood forests provide cover adjacent to agriculture fields. These bottomland forests also provide soft mast in the form of blackgum (*Nyssa* spp.) and gallberry (*Ilex* spp.) and some hard mast. It was assumed that there are approximately 10,000 bears in this region (C. Olfenbuttel, NCWRC bear and furbearer biologist, personal communication).

Piedmont Region

The Piedmont contains the remaining 32 counties in the middle of the state. This region is the most urbanized of the three regions. It contains urban centers known as the Triad (i.e., Greensboro, High Point, and Winston-Salem) and the Triangle (i.e., Raleigh, Durham, and Chapel Hill), and contains the largest city in the state, Charlotte. Natural habitats and those components that support bears are a mix of those found in the Mountain and Coastal regions. In the rural areas, agriculture and forestry industries dominate. Because natural areas still abound in the Piedmont, there are many areas capable of supporting bears. The interspersion and juxtaposition of the natural and developed areas increases the likelihood of human-bear conflicts as bears expand their range from the west and east. There are no estimates of the current bear population of the Piedmont region.

METHODS

The velocity of range expansion (*C*) is a constant that is measured by changes in the square root of the area of occupancy (Fisher 1937, Skellam 1951, van den Bosch et al. 1992, Hastings 1996, White et al. 2012). For many of the methods I described, areas of occupancy were delineated using ArcMap 10.1 (Environmental Systems Research Institute, Redlands, CA). The square roots of calculated areas were regressed on time, returning the slope of the regression line, which is the velocity of range expansion (Fisher 1937, Skellam 1951, van den Bosch et al. 1992, Hastings 1996, White et al. 2012). Maps were drawn by creating buffers to depict projected occupancy as ranges expanded spatially and temporally.

Simple Fisher-Skellam Model

Approximately every 10 years beginning in 1970, the NCWRC District Wildlife Biologists created and edited a range map (Fig. 3.3) based on reliable reports of observations of live or dead female bears and/or cubs-of-the-year. Range boundaries using those sightings were drawn at the discretion of the biologists with the only caveat being the range did not stop abruptly at geopolitical boundaries or landscape features, unless a landform (e.g., wide river) or structure (e.g., multi-lane superhighway) might limit expansion. The area of occupancy for each time period and the velocity of range expansion were calculated as described above. For purposes of this study, this method will be referred to as the observed range expansion.

Convex Hull Method

In earlier years, locations of BVCs were recorded using a Quad-Block-Square (QBS) coordinate system developed by the North Carolina Forest Service. Each Square is ~2.6 km^2 (1 mi^2); a Block is five Squares by five Squares, and a Quad is five Blocks by five Blocks. Later, BVCs were recorded using hand-held GPS units in latitude-longitude and converted to QBS coordinates. If available, BVCs were plotted using the original GPS coordinates; if not, the centroid of the QBS coordinate was plotted. Multiple bears killed at the same location and time were considered non-independent and recorded as a single event. Whenever possible, a multiple-BVC event was recorded in favor of adult females. However, sexes had to be combined for analysis due to small sample sizes. Convex hulls (White et al. 2012) were created around BVC locations in the Mountain and Coastal regions for each year from 1999-2011 using the Convex Hull tool in XTools Pro 16.0 (XTools, LLC) and ArcMap 10.1. Areas of convex hulls and the velocity of range expansion were calculated as described above.

Delaunay Triangulation Method

Delaunay triangulation was used to calculate the alpha hull areas (Downs and Horner 2007, Downs and Horner 2009, Dale and Fortin 2014) of the BVCs. ArcMap 10.1 was used to create a triangular irregular network (TIN) using the BVC locations from 1999-2011 (Fig. 3.5). The TIN worked by connecting BVC locations by vectors such that no points fall within a triangle and no vectors crossed. There is no methodologically objective way to select an alpha threshold (Downs and Horner 2007, Downs and Horner 2009). Consequently, six times the median distance from the nearest sanctuary was selected as the alpha threshold through trial-and-error. Black bears have been known to disperse >260 km (Moore et al. 2014), although most disperse over considerably shorter distances (Lee and Vaughan 2003, Costello 2010, Moore et al. 2014, Vreeland 2015). Six times the median distance to a bear sanctuary should account for most dispersals. Vectors exceeding the alpha level were removed from the TIN and the areas of the remaining hulls were calculated.

Proximity Analysis Method

The distance from each BVC location from 1999-2011 to the nearest bear sanctuary was computed using the Near tool in XTools Pro 16.0 and ArcMap 10.1. The distribution of the BVC locations in relation to the nearest bear sanctuary for each year was analyzed. The maximum distances of the distributions define the limits of range expansion for each time period and were regressed on time to calculate the maximum invasion rate. These maximum invasion rates are the maximum dispersal rates, or the rate of expansion due to exploratory dispersals.

Parameterized Life History Model

The parameterized Fisher-Skellam model (van den Bosch et al. 1992, White et al. 2012), which uses a frequency of distribution of dispersal distances and life history traits (van den Bosch et al. 1992) was used to estimate the velocity of range expansion. Life history traits were gleaned from the literature, particularly from those studies in and around North Carolina to construct a life table according to Eberhardt (1985). Juvenile survival rate of 0.86 (Hellgren 1988, Coley 1995), and adult survival rate of 0.95 (Carney 1985, Folta 1998, Martorello 1998), and a modal age of senescence of 20 years (Pelton 1982, Kolenosky and Strathearn 1987) were used to construct a schedule of idealized survival. Reproductive rates ranged from 0.55 cubs/female in 3-year-olds to 0.72 cubs/female in adults (Warburton and Osborne, unpublished data). The frequency distribution of dispersal distances was derived from Vreeland's (2015) study of black bear dispersal in Pennsylvania to calculate the dispersal kernel (Appendix 2.1). All data were combined for statewide analysis.

A life table (Appendix 2.2; Eberhardt 1985) was constructed using Siler's (1979) 5-parameter competing risk model where the total risk is $r(t) = a_1 exp^{-b_1 t} + a_2 + a_3 exp^{b_3 t}$, and

a_1 = *ln(survivorship to maturity)* + a_2 + *age at maturity,*

a_2 = *ln(adult survival rate),*

a_3 = *exp(-*b_3 ** age of senescence),*

b_1 = *1/age of maturity,*

b_3 = *1/standard deviation of age of senescence,*

L_x = *age-specific survivorship,*

m_x = *age-specific fecundity,* and

l_x = *age at mid-class.*

The competing risk model assumes each life stage within the population experiences different competing, but noninteracting, risks to their survival (Siler 1979).

Velocity of range expansion was calculated following van den Bosch et al. (1992):

$$C = \frac{\sigma}{\mu}\sqrt{2\ln R_0}\left\{1 + \left[\left(\frac{\nu}{\mu}\right)^2 - \beta + \frac{1}{12}\gamma\right] lnR_0\right\}$$

where,

the net reproductive rate (R_0) was calculated by:

$$R_0 = \sum L_x m_x,$$

the mean age at first reproduction (μ) by,

$$\mu = \frac{1}{R_0}\sum l_x L_x m_x,$$

and its variance (v^2) by,

$$\nu^2 = \frac{1}{R_0} \sum l_x^2 L_x m_x - \mu^2.$$

These were combined with age-specific dispersal distances (d_x) from Vreeland (2015), from which the dispersal variance (σ^2) was calculated as,

$$\sigma^2 = \frac{\sum (d_x)^2}{2n},$$

and its kurtosis (γ) of the marginal spatial distribution of recovered bears as,

$$\gamma = \frac{1}{\sigma^4} \frac{3}{8} \frac{1}{n} \sum (d_x)^4 - 3.$$

For species that settle after an initial juvenile dispersal, the interaction between dispersal and reproduction (β) is zero.

RESULTS

Maps drawn from reliable sightings of live and dead female bears and/or cubs-of-the-year resulted in velocities of range expansion of 3.2 km/yr for the Coastal region and 2.4 km/yr for the Mountain region (Fig. 3.6). Statewide range expansion was estimated to be 4.0 km/yr (Table 3.1).

Drawing a convex hull around locations of BVCs resulted in range expansions of 3.2 km/yr in the Coastal region, 1.6 km/yr in the Mountain region, and 8.6 km/yr in the Piedmont region (Fig. 3.7). When regional data were combined, statewide range expansion was 5.4 km/yr Based on Delaunay triangulation, black bear range expanded at a rate of 0.2 km/yr in the Mountain region and 4.1 km/yr in the Coastal region (Fig. 3.8), and 3.7 km/yr statewide. The areas of occupancy in the Mountain region were larger 10 years out of 13 years from 1999-2011 using the convex hull method versus the Delaunay triangulation method (Table 3.1). In the Coastal region, only four of the 13 years were larger using the convex hull method.

The data points for 1999 and 2000 appeared to by outliers and were removed from the regression. After excluding points for 1999 and 2000, the maximum velocity of range expansion was estimated to be 8.0 km/yr (Fig. 3.9). The parameterized Fisher-Skellam model estimated the velocity of range expansion as 5.9 km/yr (Table 3.2).

Projected range expansion maps for 4 km/yr (Fig. 3.10) and 8 km/yr (Fig. 3.11) indicate that by 1995 reports of bears could be probable in any part of the Piedmont. By 2010, isolated areas with suitable habitat in the Piedmont may contain small, resident populations of bears.

DISCUSSION

Statewide estimates of the velocity of range expansion for black bears in North Carolina were similar regardless of the method used, indicating the simplest model, using the simplest data, performed as well as more sophisticated models and data. When data could be parsed to regionwide, the velocity of range expansion was highest for the Piedmont, followed by the Coast, then the Mountains.

The high velocity of range expansion in the Piedmont region can be attributed mainly to exploratory movements associated with dispersal of juveniles. Juvenile dispersal in bears has been attributed to avoidance of male kin such that inclusive fitness is increased (Rogers 1987). After juveniles have dispersed far enough to reduce breeding competition with male kin, unfavorable habitat and anthropogenic conditions may further increase distances from natal home ranges.

Rates of expansion in the Coast being higher than the Mountains could have several explanations. The Mountain and Coastal populations may be at different points in the timeline of the reaction-diffusion process. The Coastal population may be further into the diffusion phase, whereas the Mountain population may not have reached the threshold in the reaction phase to trigger the amount of diffusion being exhibited by the Coastal population.

Although Mountain bears show higher age-specific incidences of corpora lutea and placental scars (Warburton and Osborne, unpublished data), the relative consistency of agricultural crops in the Coastal region versus the variability of hard mast in the Mountain region, may lead to more consistent recruitment in the Coastal region. Higher density of bears in the Coastal region could force bears to disperse farther than their Mountain counterparts, thus contributing more bears to the Piedmont.

The simple reaction-diffusion of bear sightings could be considered the “observed” range expansion against which the theoretical methods were compared. Unlike the results of this study, one might expect differences of at least an order of magnitude between methods used and between theoretical and observed rates of spread. Andow et al. (1990) found that theoretical rates generally underestimated observed rates of spread. Habitat and environmental conditions, physical barriers, competition, etc. can alter the speed and direction of spread, thus slowing invasion rates (White et al. 2012). For this reason, the simple reaction-diffusion model using reliable sightings may be better for predicting bear occupancy than the other models. The convex hull and Delaunay triangulation models using BVC locations each create vertices outlining areas that may not encompass bear range, and the parameterized Fisher-Skellam model produced a radial expansion rate that may be inaccurate due to land cover types that are unusable by bears. White et al. (2012) recognized that radial expansion in all directions was not possible in their study because the Atlantic Ocean created a barrier. The Atlantic Ocean, large cities, and other barriers would have caused the same problems with this study.

In contrast to Andow et al. (1990), Reid's Paradox (Clark et al. 1988) results in observed rates exceeding that of theoretical rates due to external forces translocating propagules as might be observed from translocations. Although it is possible that bears were illegally translocated by private individuals, as has been done with coyotes (*Canis latrans*), feral hogs (*Sus scrofa*), and other species, the results of this study did not indicate long range translocations were made. The longest distance (179 km) between BVC location and black bear sanctuary is consistent with juvenile dispersals (Lee and Vaughan 2003, Vreeland 2015), which may have been exploratory movements prior to establishment of what would have been a permanent home range.

One of the obstacles that wildlife agencies face is how to acquire or allocate funding for data collection. Data from capture-recapture and telemetry studies are expensive to collect (Thomas et al. 2011). Therefore, agencies often are faced with trying to answer management questions with little to no specialized data, relying only on professional opinion of field staff. In this study, data not only came from wildlife professionals, but also relied on the public for observations. Although, some research has shown that citizen science data can be as accurate as data collected by professionals (Kosmala et al. 2016), several problems exist with using public-reported data (Snäll et al. 2011). False positives can happen especially when data are collected or reported by untrained personnel. For example, some reports of BVCs were found to be dogs. False positives can result in large biases (MacKenzie et al. 2006). Sightings had to be evaluated by wildlife professionals before being considered valid observations. In the case of BVCs, biological data were collected from the bears whenever possible or data were reported by Department of Transportation personnel when collecting the carcass for disposal. This reduced the number of false positive BVC reports to zero. Regardless, Snow et al. (2015) showed that biases because of underreporting of wildlife-vehicle collisions were not significant unless very high (≥70%).

State-space related variation in the regressions can be seen. As populations grow (reaction) they eventually will exceed some threshold or biological carrying capacity, triggering range expansion (diffusion) and larger exploratory movements. Fluctuations in the abundance of bears (Rogers 1976, Elowe and Dodge 1989, Noyce and Garshelis 1997, Costello et al. 2003) and their behaviors are influenced by the abundance of food resources (Garshelis and Pelton 1981). Higher nutritional availability increases reproductive rates and survival rates, contributing to the reaction phase and ultimately to the diffusion phase. Conversely, in years of poor nutritional availability, bears may not reproduce or may not survive harsh winters, slowing the reaction phase and decreasing rate of diffusion.

The type of road was not considered in the analysis; however, road class and other roadway characteristics (e.g., fences, guard rails, etc.), average daily traffic volume, and mean traffic speed influence the number of animal-vehicle collisions (Gunson et al. 2011). Although interstates and primary roads are wide, have high traffic volumes, and high-speed traffic which could increase the frequency of BVCs, bears may avoid such roads (Beringer et al. 1990, Brandenburg 1996). Secondary and tertiary roads may not be avoided, but many may be winding, limiting the site distances of drivers, thus increasing the frequency of BVCs. Brody and Pelton (1989) found that bears that used areas near roads were more vulnerable to harvest mortality (i.e., more easily detected) than those that avoided roads because of the use of strike dogs as a method of hunting. Despite not factoring the effects of road types, the results from the methods using BVC locations were similar to that of the parameterized Fisher-Skellam model that did not use BVC locations.

LIMITATIONS AND MANAGEMENT IMPLICATIONS

Presence-only data have been used to examine range expansion, but not without controversy (Ward et al. 2009, Elith et al. 2010, Gromley et al. 2011, Royle et al. 2012, Hastie and Fithian 2013). For species that are elusive, have large home ranges, or travel long distances before settling at the end of a dispersal stage, the use of presence-only data can be problematic. Bears have all these characteristics. But being a charismatic species, when they are seen, especially in areas where they may be uncommon, they are often reported. Even when using animal-vehicle collision data, animals that are struck by vehicles and leave the roadway before dying may go unreported (i.e., undetected). However, it must be emphasized that the lack of observations does not indicate absence, but rather is an artifact of detection. For species that are ubiquitous or uncharismatic, this type of data may not work and should be further researched.

When the probability of detection is <1, estimates using presence-only will be conservative (MacKenzie et al. 2006, Royle et al. 2012). In this study, velocity of expansion using sightings was conservative, but only by about 1-2 km/year as compared to the parameterized Fisher-Skellam model. Therefore, rather than collecting data on reproductive capacity, survival, and dispersal distances, opportunistic, reliable sightings of live animals and BVCs by the public, personnel from the wildlife agency, emergency services, and department of transportation can be a valuable and cost-effective resource for monitoring range expansion. However, for species that may be less charismatic, people may need to be encouraged to report sightings.

Uniform sampling is not possible at the statewide scale when using opportunistic data reported by the public or when using animal-vehicle collisions. People and the target species are not uniformly distributed across the landscape. Road density, speed limits, and traffic volume are variable resulting in variable animal-vehicle collisions and reporting. Despite the lack of uniform sampling, the presence-only sighting method and the methods using BVC locations performed just as well as the parameterized Fisher-Skellam method. This highlights the importance of commonly collected data and the information that can be extracted from them. For black bears in North Carolina, reported sightings and BVC data prove valuable for quantifying velocity of range expansion. It would be worthwhile to repeat these methods using a different species to see if similar results can be obtained.

This study highlights the usefulness of extensive, long-term datasets, and emphasizes the importance of opportunistic data that are easy and relatively inexpensive to collect (e.g., sightings, BVC data) in answering broad-scale questions. The results of this study can help predict how quickly bears may show up in areas across the state so that various agencies and organizations can be proactive in their management to reduce bear-human conflicts, and provide a baseline for the velocity of range expansion to determine if management actions are effective. However, fine-scale temporal and spatial analyses should be done to determine barriers that may slow or shift the direction of range expansion.

This study also demonstrates the resilience of black bears to respond when provided some protection. The BSS provided 3237 km^2 of protected land in which the population could reproduce (reaction) and from which bears could disperse (diffusion). Now their range is estimated to be in excess of 77,000 km^2.

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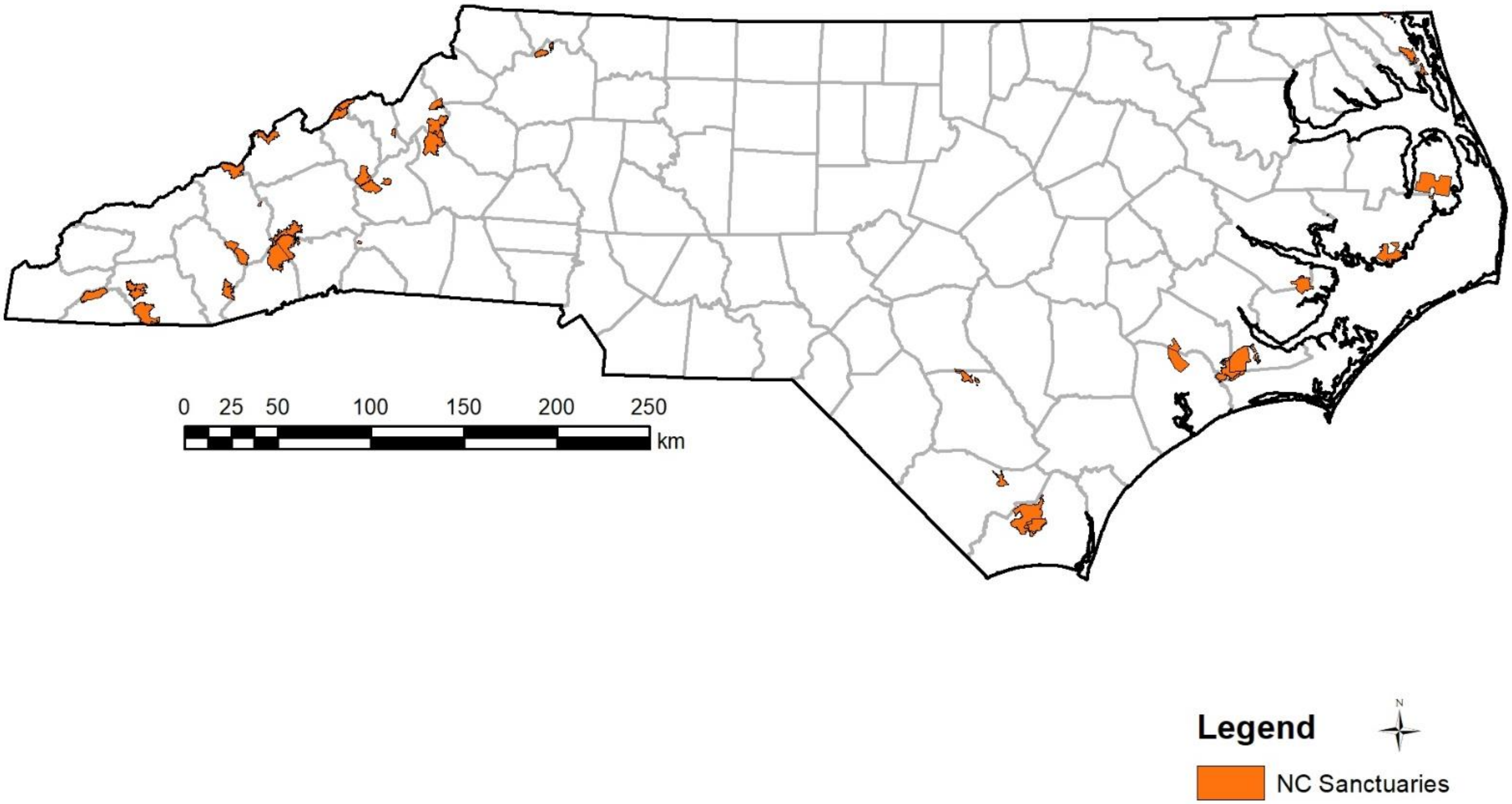

Figure 3.1. Distribution of black bear sanctuaries in North Carolina, USA.

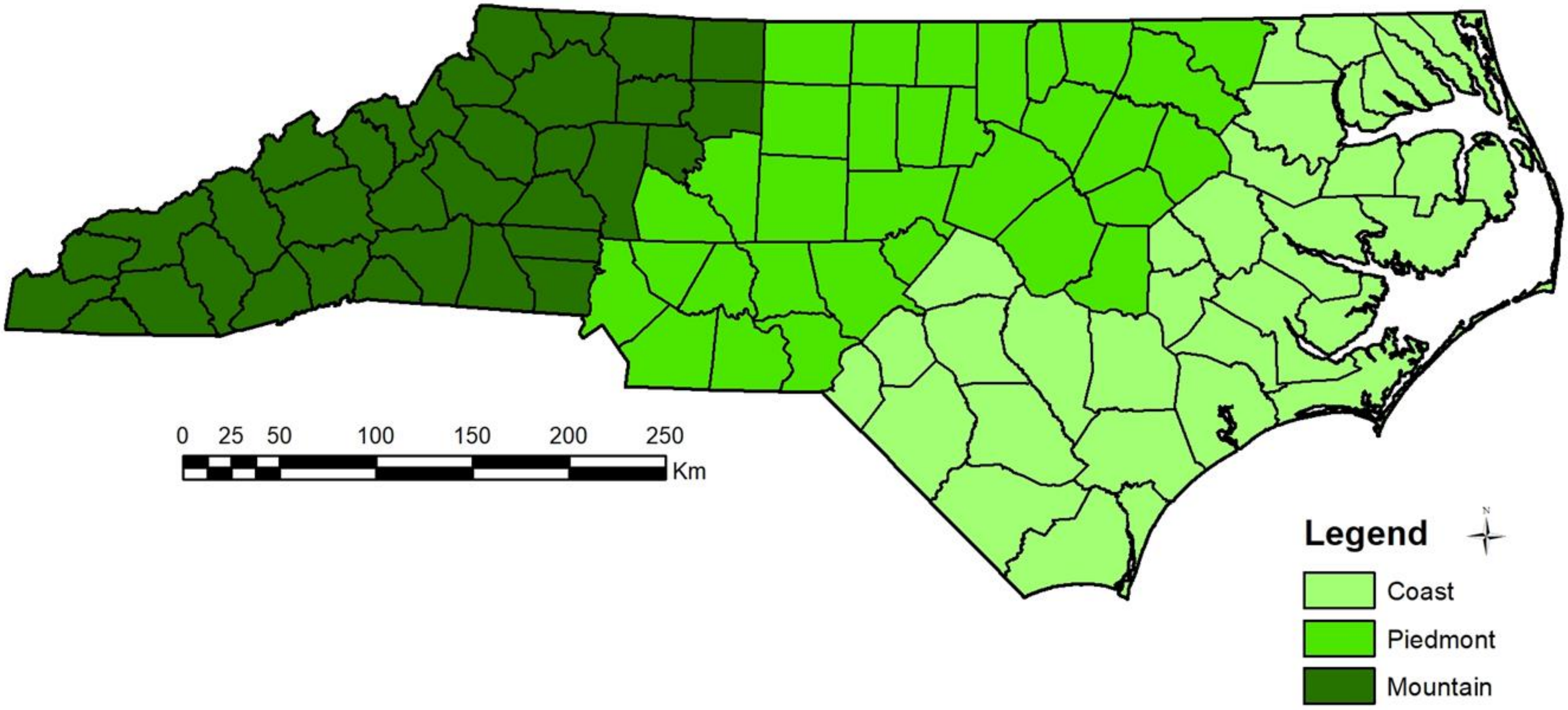

Figure 3.2. Physiographic regions of North Carolina, USA.

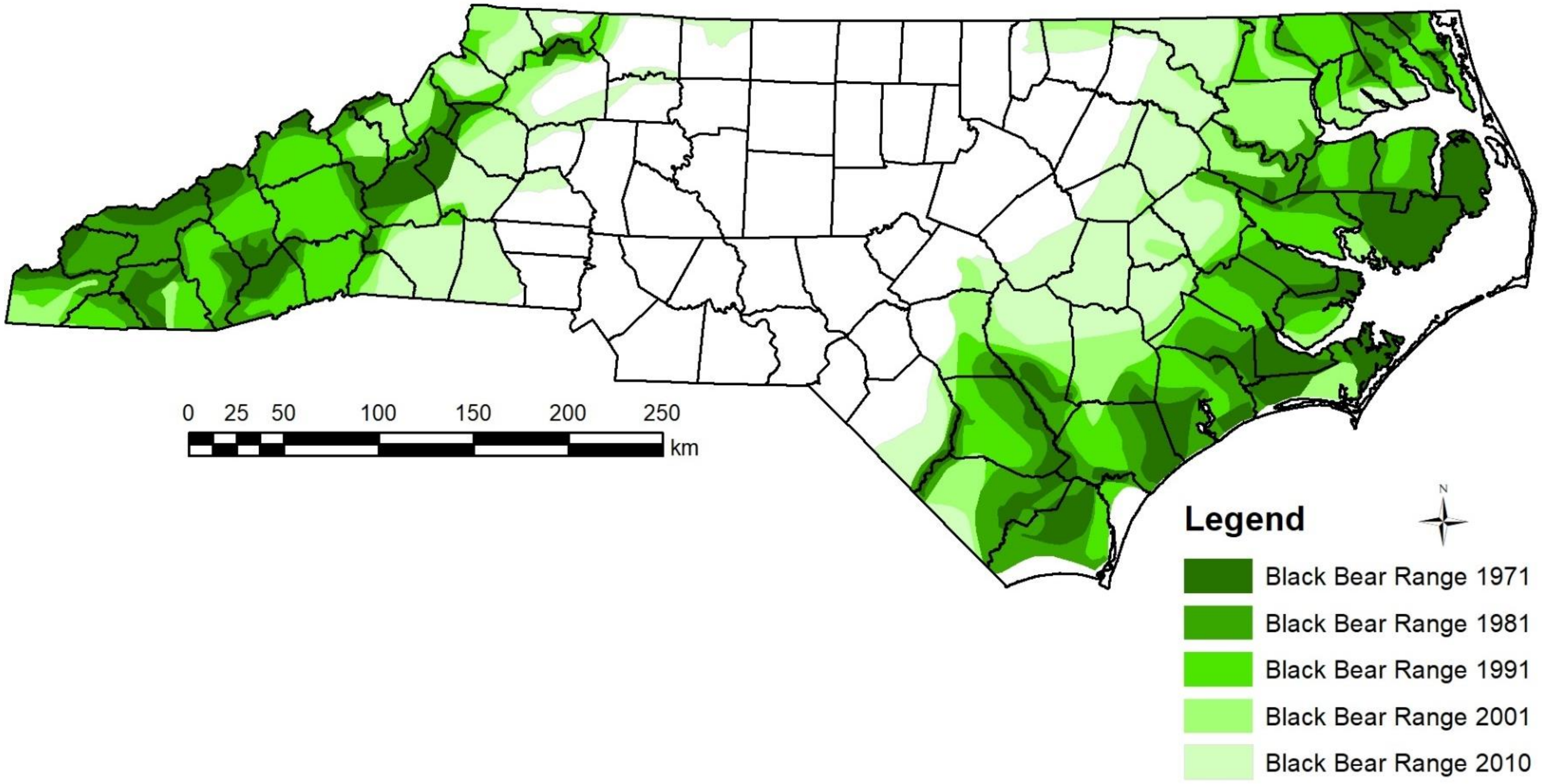

Figure 3.3. Estimated occupied range based on reliable sightings of female black bears or cubs-of-the year in North Carolina 1971-2010.

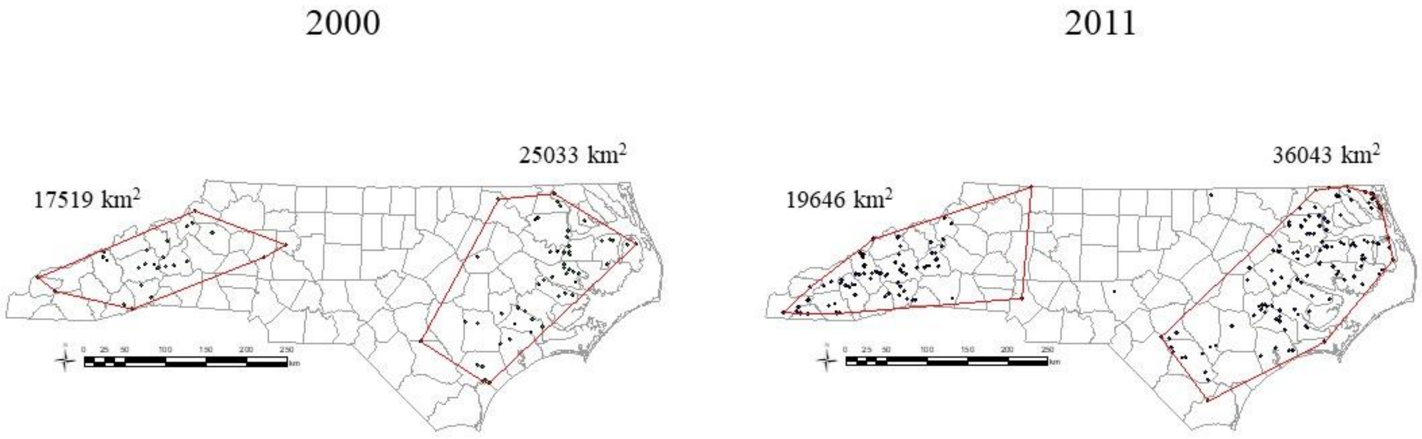

Figure 3.4. Minimum convex polygons drawn around bear-vehicle collisions (BVCs) in North Carolina during 2000 and 2011.

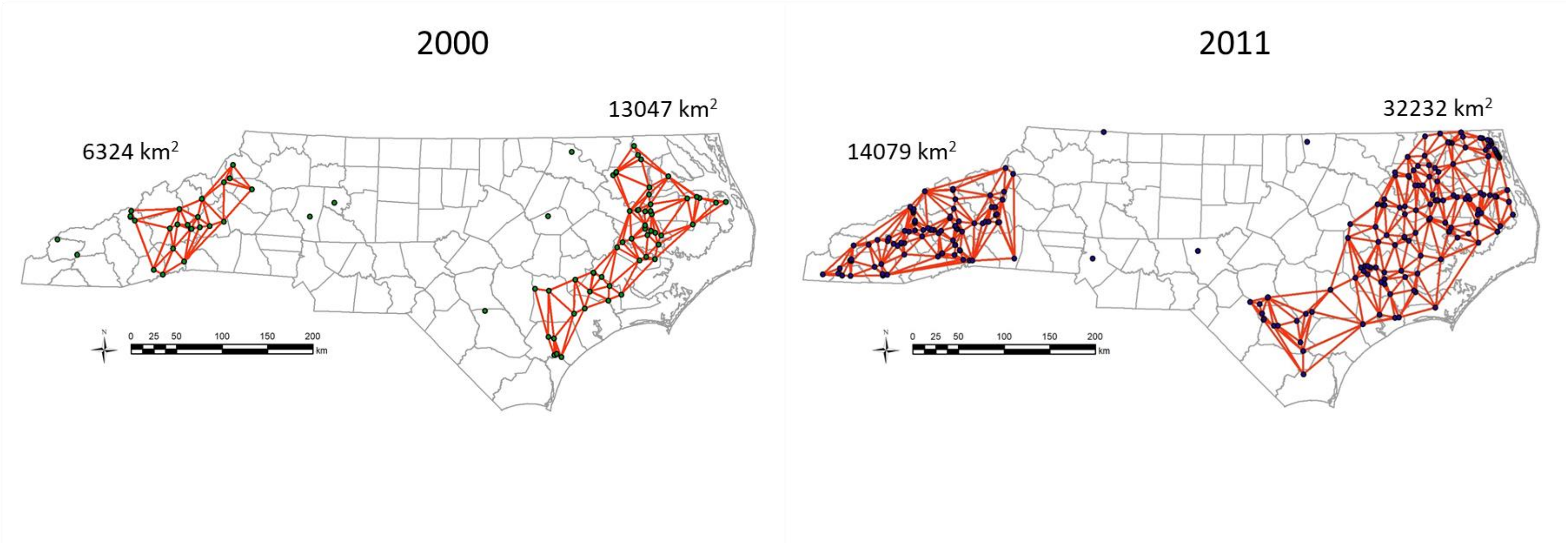

Figure 3.5. Delaunay triangulation of bear-vehicle collisions (BVCs) in North Carolina during 2000 and 2011.

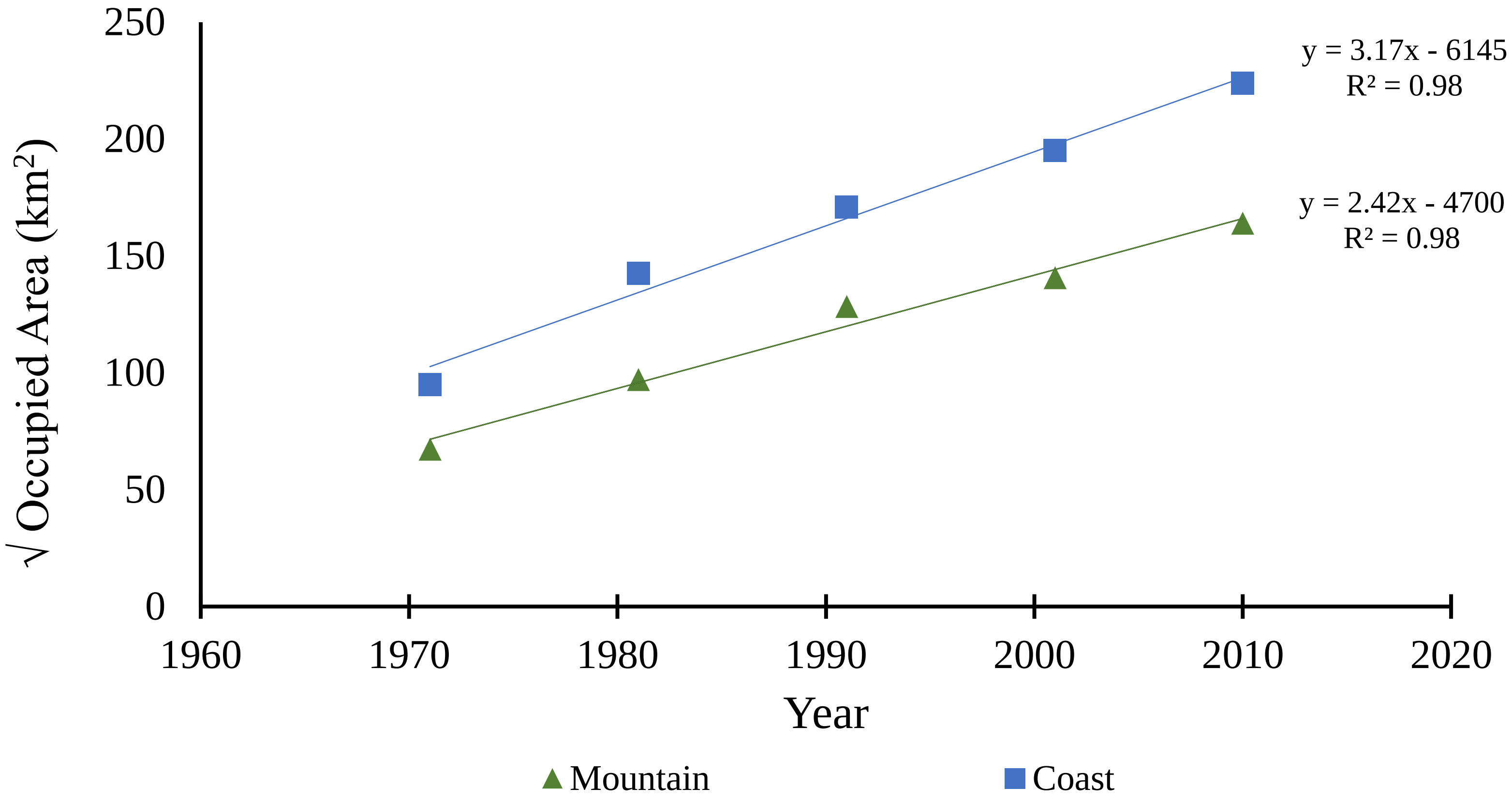

Figure 3.6. Linear range expansion of black bears in North Carolina calculated from the Experts' opinion map, 1970-2010.

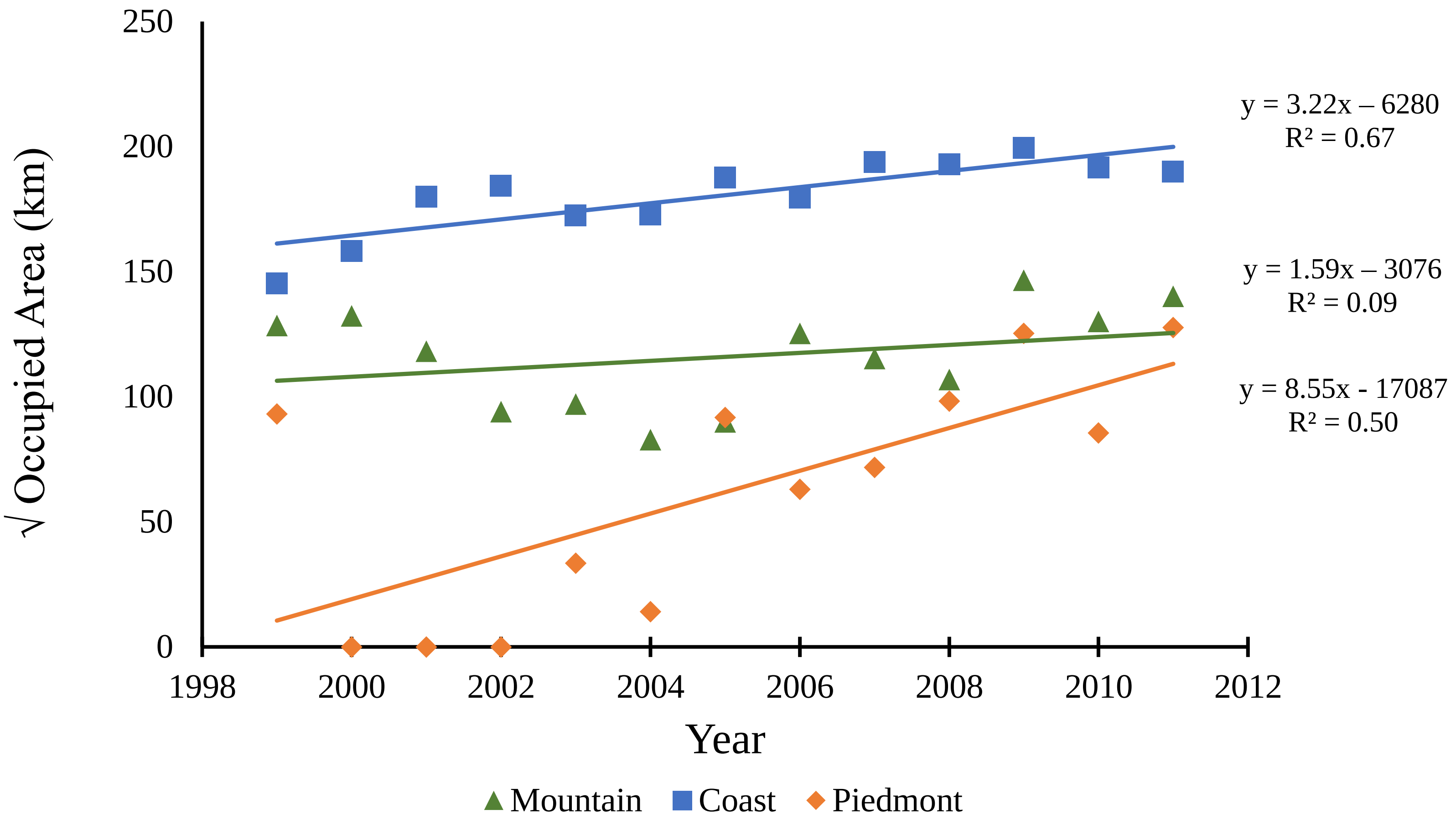

Figure 3.7. Linear range expansion of black bears in North Carolina calculated from minimum convex hull polygons drawn around BVCs, 1999-2011.

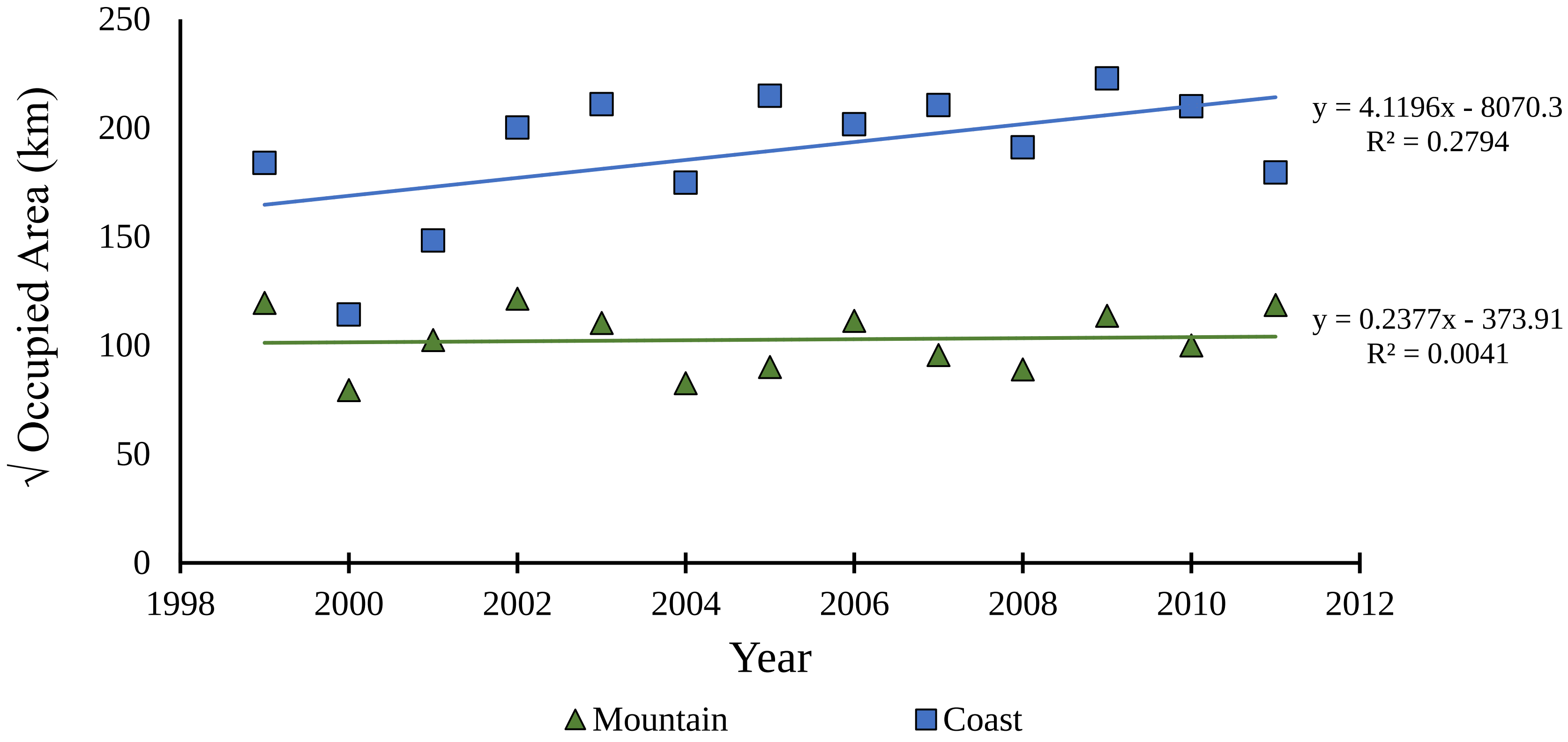

Figure 3.8. Linear range expansion of black bears in North Carolina calculated from alpha hull drawn by Delaunay triangulation around BVCs, 1999-2011.

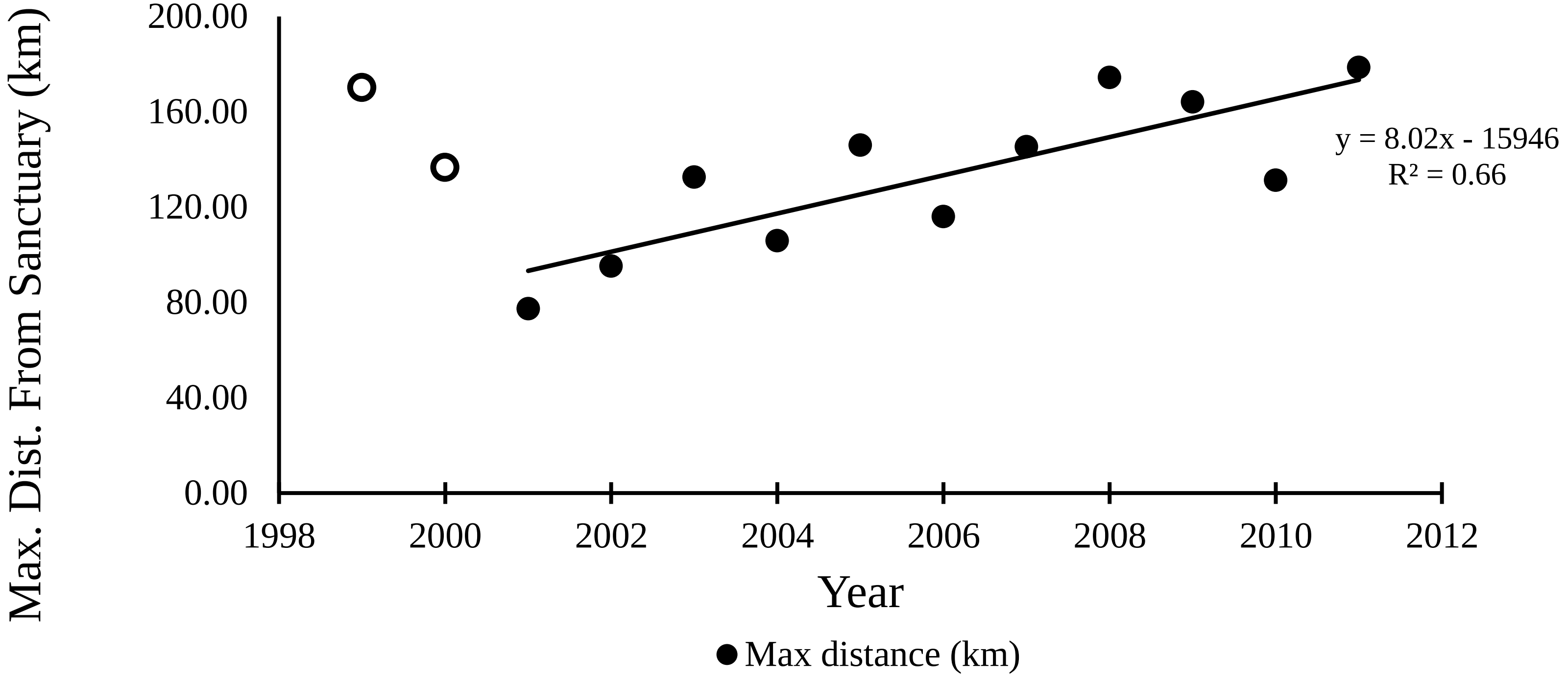

Figure 3.9. Maximum linear range expansion of black bears in North Carolina calculated from the distribution of the maximum distances of BVCs to the nearest bear sanctuary 2001-2011. Data Outliers are indicated with open dots.

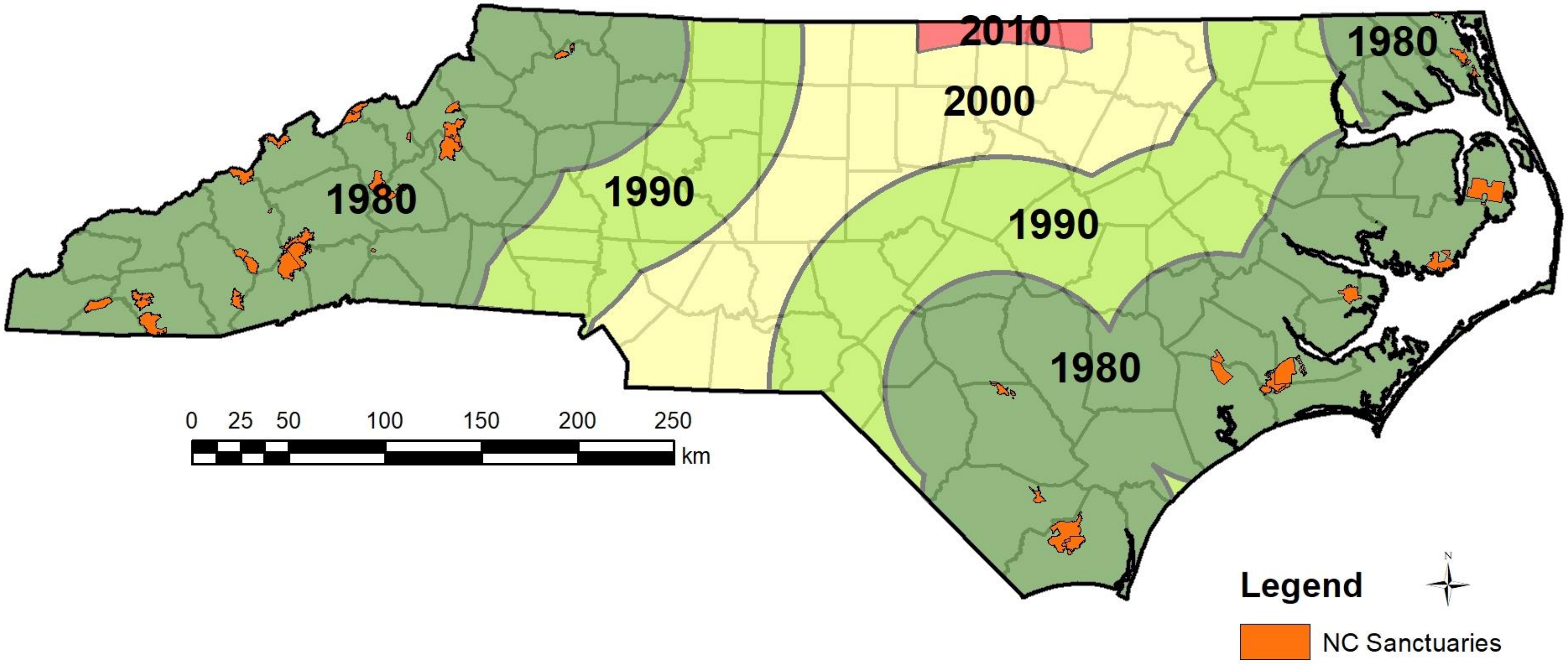

Figure 3.10. Estimated changes in bear occupancy in North Carolina based on expansion rates of 4 km/year.

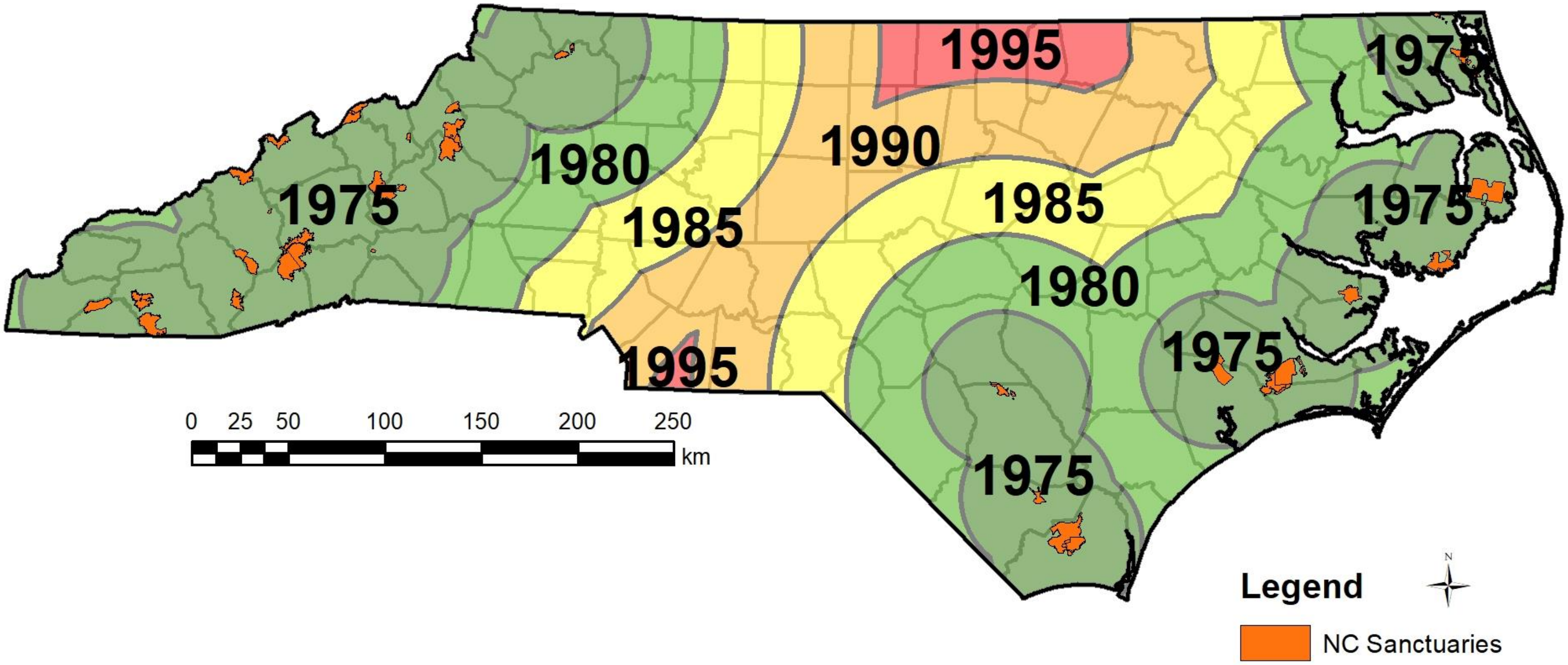

Figure 3.11. Estimated changes in bear occupancy in North Carolina based on expansion rates of 8 km/year.

Table 3.1. Velocity of range expansion of black bears of both sexes combined in North Carolina computed from various methods.

Method	**Estimate (km/year)**	**SE**	**Pr > |t|**
Simple Fisher-Skellam	4.0	0.28	0.0007
Convex Hull Method	5.4	1.15	0.0007
Delaunay Triangulation	3.7	2.02	0.0940
Proximity Analysis	8.0	1.90	0.0022
Parameterized Fisher-Skellam	5.9	NA	NA

Table 3.2. Calculation of the parameterized Fisher-Skellam model.

Parameter	Calculation	Result
Variance of Marginal Dispersal Density (σ^2)	$\sigma^2 = \frac{\sum(d_x)^2}{2n}$	175.0
Kertosis of Marginal Dispersal Density (γ)	$\gamma = \frac{1}{\sigma^4}\frac{3}{8}\frac{1}{n}\sum(d_x)^4 - 3$	8.7
Net Reproductive Rate (R_0)	$R_0 = \sum L_x m_x$	4.9
Mean age of First Reproduction (μ)	$\mu = \frac{1}{R_0}\sum l_x L_x m_x$	10.1
Standard Deviation of First Reproduction (ν^2)	$\nu^2 = \frac{1}{R_0}\sum l_x^2 L_x m_x - \mu^2$	23.5
Velocity of Range Expansion (C)	$C = \frac{\sigma}{\mu}\sqrt{2\ln R_0}\left\{1 + \left[\left(\frac{\nu}{\mu}\right)^2 - \beta + \frac{1}{12}\gamma\right] lnR_0\right\}$	5.9

Appendix 3.1. Dispersal frequencies of black bears in Pennsylvania (Vreeland 2015).

Class Bound (km)	Class Midpoint (d)	Freq (f)	$(Dx)^2 = f*d^2$	$(Dx)^4 = f*d^4$
0	0.0	69	0	0
13-20	16.5	11	2915.8	793825.9
21-25	23.0	5	2597.4	1374019.3
26-30	28.0	6	4547.2	3565004.8
31-35	33.0	3	2918.5	3178268.3
36-40	38.0	0	649.8	938311.2
41-45	43.0	2	3309.7	6119653.8
46-50	48.0	0	1036.8	2388787.2
51-55	53.0	1	3764.1	10573244.5
56-60	58.0	0	1513.8	5092423.2
61-65	63.0	0	0	0
66-70	68.0	1	4115.4	19029424.6
71-75	73.0	1	4742.8	25274434.5
76-80	78.0	0	2737.8	16656775.2
81-85	83.0	0	0	0
86-90	88.0	0	0	0
91-95	93.0	0	0	0
96-100	98.0	0	0	0

Appendix 3.2. Life table using optimum parameter values gleaned from the literature on black bears.

Age (yr)	l	l_x	m_x	l_xm_x	ll_xm_x	$l^2l_xm_x$	l_xm_x*exp($-r$*l)
0	0.5	1	0	0.000000	0.000000	0.000000	0.000000
1	1.5	0.8710	0	0.000000	0.000000	0.000000	0.000000
2	2.5	0.7772	0	0.000000	0.000000	0.000000	0.000000
3	3.5	0.7056	0.55	0.384874	1.347061	4.714713	0.195980
4	4.5	0.6485	0.62	0.399987	1.799942	8.099739	0.167956
5	5.5	0.6010	0.72	0.432753	2.380143	13.090784	0.149846
6	6.5	0.5603	0.72	0.403386	2.622011	17.043073	0.115181
7	7.5	0.5241	0.72	0.377357	2.830178	21.226336	0.088852
8	8.5	0.4912	0.72	0.353658	3.006095	25.551804	0.068668
9	9.5	0.4605	0.72	0.331554	3.149761	29.922732	0.053086
10	10.5	0.4312	0.72	0.310469	3.259925	34.229209	0.040992
11	11.5	0.4027	0.72	0.289918	3.334051	38.341591	0.031565
12	12.5	0.3742	0.72	0.269454	3.368179	42.102239	0.024192
13	13.5	0.3453	0.72	0.248647	3.356738	45.315956	0.018409
14	14.5	0.3154	0.72	0.227067	3.292471	47.740829	0.013863
15	15.5	0.2838	0.72	0.204302	3.166680	49.083547	0.010286
16	16.5	0.2500	0.72	0.180008	2.970135	49.007228	0.007473
17	17.5	0.2139	0.72	0.154009	2.695154	47.165193	0.005272
18	18.5	0.1756	0.72	0.126454	2.339402	43.278939	0.003570
19	19.5	0.1362	0.72	0.098029	1.911556	37.275341	0.002282
20	20.5	0.0974	0.72	0.070129	1.437654	29.471905	0.001346
21	21.5	0.0623	0.72	0.044850	0.964279	20.731990	0.000710
22	22.5	0.0341	0.72	0.024528	0.551890	12.417528	0.000320
23	23.5	0.0150	0.72	0.010783	0.253392	5.954705	0.000116
24	24.5	0.0049	0.72	0.003495	0.085617	2.097628	0.000031
25	25.5	0.0010	0.72	0.000740	0.018873	0.481270	0.000005

Where r is the intrinsic rate of growth

EPILOGUE

The overarching goals of this project were to (1) develop a statistical population reconstruction model for black bears in the Mountain region of North Carolina, and (2) apply the theories of invasion biology to the populations in the Mountain and Coastal regions to quantify the rate at which bear range is spreading into the Piedmont region. Suitable estimates of abundance are necessary for sound management of any species. Additionally, knowledge of both abundance and rate of spread of bears into areas unoccupied for over 100 years will help managers be proactive in making management policies.

A lack of region-wide data on North Carolina's black bear population produced some interesting challenges. There were no region-wide mark-recapture or telemetry studies, no large-scale censuses, nor any other techniques traditionally used to estimate abundance. What was available was an extensive age-at-harvest (AAH) matrix. These data are relatively inexpensive to collect and are the exclusive data source in Downing population reconstruction (DPR; Downing 1980, Davis et al. 2007). However, DPR under-estimates true abundance by an unknown and variable degree and estimates of precision cannot be produced. Statistical population reconstruction (SPR) overcomes the deficiencies of DPR by combining likelihoods of several processes into one joint likelihood thereby extracting maximum information from each dataset and allowing for the construction of precision intervals around the estimates (Gove et al 2002, Skalski et al. 2007, Skalski et al. 2012a, Skalski et al 2012b, Clawson et al. 2013, Clawson et al. 2017). The problem facing this study was what data were available to be used in the likelihoods.

Wildlife managers have observed that when hard mast production is low, black bear reproduction rates are low and mortality rates are high (Rogers 1976, Beeman and Pelton 1980, Elowe and Dodge 1989, Pelton 1989, Schooley et al. 1994, Kasbohm et al. 1996, Noyce and

Garshelis 1997, Ryan et al. 2004, Clark et al. 2005, Ryan et al. 2007, Obbard et al. 2014). Black bear mortality could be from starvation, but more often it is from depredation or from travelling longer distances in search of food (Pelton 1989), perhaps in unfamiliar areas, exposing them to above-average vehicle or hunting mortality. In Chapter One, I found a positive correlation between harvest and non-harvest mortality ($r = 0.89$, $P < 0.001$) and a negative correlation between white oak (*Leucobalanus*) mast availability and non-harvest mortality ($r = -0.52$, $P = 0.001$). Other mast types did not show the strength of this relationship, indicating the importance of this subgenus.

White oak acorns are very palatable and digestible (Short and Epps 1976, Smallwood and Peters 1986), and although a preferred food source, are not the only mast species eaten by bears. The variability in white oak mast production correlates well with mortality, but a complete failure does not result in massive starvations. Principal component analysis (PCA; Fig. 1.4) suggested that during years of low white oak mast production, production other mast types, especially beech and summer soft mast, was moderate to high. However, those other mast types combined still cannot match the importance of white oak.

Climate parameters such as rain, temperature, and wind conditions during the year of fruiting or ≥ 1 year prior to fruiting can influence whether or not trees produce mast or whether it will be a bumper or lean crop (Sharp and Sprague 1967, Cecich and Sullivan 1999, Koenig and Knopps 2014, Bogdziewicz et al. 2017, Nussbaumer et al. 2018). Climate change may cause future changes in the phenology of mast trees. Kueppers et al. (2005) modeled climate change impacts on California endemic oaks and found that their range could be reduced by over 50%. Weather conditions that may reduce white oak mast production may benefit beechnut production. This could result in changes in population dynamics, but it also could result in a shift in diet composition. This has been observed already with the loss of the American chestnut (*Castanea dentata*). American chestnut was once the dominant species in the Appalachian region, and has since been replaced by oak (Quercus spp.)-hickory (Carya spp.) forests (Dickson 2004). American chestnut used to be a primary food source for many forest-dwelling species, but they have since switched to oaks and other mast to fill the void.

I also examined the relationship between land cover type and non-harvest mortality from 2004-2008. The strongest correlation found was a negative correlation (r = -0.32, P = 0.06) between pasture/hay type and non-harvest mortality, which is not surprising because bears are not found very often in that cover type. The hay and pastures are primarily fescue, which is not a preferred bear food. Additionally, most of the non-harvest mortality was from BVCs. Pasture/hay cover type allows motorists more time to see and react to a bear crossing a roadway, thus reducing the chance of collision. The strongest positive correlation between non-harvest mortality and cover type was deciduous forest (r = 0.27, P = 0.12). Mountain bears were found most often in oak, oak-hickory, and cove hardwoods (Beeman 1975, Garris 1983, Beringer 1986, Siebert 1989). Simply stated, where the bears are most often is where they are most likely to die.

In Chapters Two and Three, I examined the reaction-diffusion processes (Fisher 1937, Skellam 1952, van den Bosch et al. 1990, van den Bosch et al. 1992) undergone by spreading organisms. The reaction portion can be found in Chapter Three. I developed a statistical population reconstruction model in which I used an index of white oak mast abundance in place of hunter effort in a catch-effort likelihood. Traditional hunter-effort data were not available. Given the probability of harvest $p_i = 1 - e^{-cH_i}$, where c is the harvest vulnerability and H_i is hunter effort (Seber 1982), it stands to reason that effort on the part of the hunter harvesting a target animal and the animal's effort to avoid being harvested have equal bearing on p_i. I compared my estimates of abundance to results from DPR (Downing 1980, Davis et al. 2007). SPR estimates from 1983-2008 were at most 400 bears greater than that given by DPR calculations. After 2008, the differences became more pronounced. By 2016, SPR estimated 3365 (95% B.C.I. = 3165-3569) females and 3882 (95% C.I. = 3696-4080) males, and a total of nearly 3241 more bears than DPR calculations. The difference between that of SPR and DPR is that DPR is unable to account for animals still alive in the population and data are only from those animals that are harvested. SPR can adjust for that by sharing information between likelihoods that use different data sources (Gove et al 2002, Skalski et al. 2007, Skalski et al. 2012a, Skalski et al 2012b, Clawson et al. 2013, Clawson et al. 2017).

A major benefit of likelihoods borrowing strength from one another and sharing information in a SPR is that latent parameters within the data can be extracted (Gove et al 2002, Skalski et al. 2007, Skalski et al. 2012a, Skalski et al 2012b, Clawson et al. 2013, Clawson et al. 2017). From the AAH matrix, I was able to ascertain that the annual probability of harvest for females was 6.7-15.6% and for males was 11.6-26.1%. Not surprisingly, males were more greatly affected than females when mast availability was poor by 4.9-10.5% (Fig. 3.7). The geometric mean of annual finite rates of increase was 1.05 (Fig 3.5), which was less than calculated from reproductive data and the Euler-Lotka equation ($\lambda = 1.21$). This may be a result of overemphasis of the reproductive capacity of older females and underestimating those of younger females (Fijiwara and Diaz-Lopez 2017), but the Euler-Lotka estimate is constructed from data under ideal circumstances.

The diffusion portion of the reaction-diffusion process was the focus of Chapter Two. I used bear sighting data, locations of BVCs, life history parameters, and five methods to calculate the velocity of range expansion of bears as their range spreads into the Piedmont region. All models tested resulted in a velocity of range expansion of 3.7-8.0 km/year (Table 2.1). The simple Fisher-Skellam reaction-diffusion model (Fisher 1937, Skellam 1952) using reliable sighting data performed just as well as all the other models, supporting the importance of easily obtained and commonly collected data. Proximity analysis used the annual maximum distance of BVC to the nearest sanctuary. The result from that analysis was the highest at 8.0 km/year. The results would be consistent with exploratory movements by juvenile males skewing the distribution of distances toward longer distances from the nearest black bear sanctuary. In Pennsylvania, dispersal distances of a few bears exceeded 50 km (Vreeland 2015). The highly urbanized Triangle and Triad in the Piedmont could force dispersing bears to travel further distances in search of a suitable home range while avoiding the problems associated with urbanization. Bears may travel quickly through those areas, only to get to the other side before being struck by a vehicle.

The simple Fisher-Skellam model using reliable sightings may have been better than using the alpha hull (White et al. 2012) and Delaunay triangulation (Downs and Horner 2007, Downs and Horner 2009, Dale and Fortin 2014) methods. Both the alpha hull and Delaunay triangulation likely encompass areas that are not occupied by bears. Thus, areas of occupancy could be biased high. When comparing areas of occupancy between years, it is unknown if the ratios of occupied to unoccupied areas are consistent. If not, velocity of range expansion could be biased.

The results of this study showed that black bear abundance and range are increasing, and will likely continue to increase. The incidences of bear-human conflicts, including BVCs, are likely to increase as well. Proactive as well as reactive education should be a high priority to reduce potential conflicts. BearWise (BearWise.org) and other programs are already used in

North Carolina, but the vast majority of citizens are unaware of such programs. Other media distribution platforms or channels should be explored.

Potential impacts on mast production or land cover from climate change and land use change will have an impact on bear abundance and occupied range. From 1973-2000, forest cover in the southeastern U.S. decreased by 2.51%, agriculture by 1.62%, and wetlands by 0.69%, and developed land increased by 2.28% (Melillo et al. 2014). Reductions in suitable bear cover types and increases in urban and developed cover types will put more bears in contact with people. Bear food resources will decrease. Suitable cover will diminish. Bear-human conflict will increase.

This study emphasized the benefits of commonly collected data such as sightings and BVC locations. But SPR could benefit from additional specialized regional or statewide data collection. Only a few years of other auxiliary data are needed. Additional likelihoods in the SPR model would increase precision of parameter estimates, as well as allow for extracting age- or year-specific parameters. More data could allow for smaller scale estimates to be calculated. Currently, the state is divided into three bear management units (BMUs; NCWRC), each BMU could have one to several bear hunting seasons based only on anecdotal data. If parameters could be estimated at a scale of several counties, hunting season could be set based on scientific data.

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APPENDIX

Appendix A. Mortalities of black bears from the Coastal and Mountain regions of North Carolina, 1969-2017.

	Coast							Mountain						
Year	Auto	Depred-ation	Hunt	Illegal	Other	Unknown	Total Non-Harvest	Auto	Depred-ation	Hunt	Illegal	Other	Unknown	Total Non-Harvest
1969	0	0	18	0	0	0	0	0	0	37	0	0	0	0
1970	2	0	15	0	0	0	2	0	3	57	0	0	0	3
1971	2	0	8	0	0	0	2	1	1	33	0	0	0	2
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	10	0	0	0	0	0	0	38	2	0	0	2
1974	3	1	18	1	0	0	5	1	0	39	1	0	0	2
1975	0	0	1	0	0	0	0	0	0	1	0	0	0	0
1976	7	0	20	0	0	0	7	3	0	58	0	0	0	3
1977	6	0	17	1	0	0	7	3	0	60	1	0	0	4
1978	18	0	43	2	0	0	20	1	0	112	0	0	0	1
1979	9	0	45	5	0	1	15	0	0	87	2	1	0	3
1980	16	0	39	1	0	1	18	3	0	104	0	0	0	3
1981	9	0	50	1	0	0	10	0	0	112	0	0	0	0
1982	17	0	42	1	0	0	18	2	0	137	0	0	0	2
1983	25	4	44	4	0	0	33	1	0	185	1	0	0	2
1984	24	6	59	0	0	0	30	4	0	217	1	0	1	6
1985	31	1	44	1	0	1	34	0	1	150	0	0	0	1
1986	26	3	41	0	1	0	30	4	0	178	0	1	0	5
1987	14	2	103	3	0	1	20	2	0	234	0	0	0	2
1988	35	1	111	5	2	1	44	1	1	144	0	0	0	2
1989	43	1	101	0	1	0	45	3	0	169	0	1	1	5
1990	47	4	151	3	1	0	55	18	2	179	1	1	0	22
1991	30	3	130	6	0	0	39	5	0	176	1	0	0	6
1992	34	4	235	5	1	1	45	13	3	330	5	2	0	23

Appendix A. Mortalities of black bears from the Coastal and Mountain regions of North Carolina, 1969-2017. (continued)

	Coast							Mountain						
Year	Auto	Depred-ation	Hunt	Illegal	Other	Unknown	Total Non-Harvest	Auto	Depred-ation	Hunt	Illegal	Other	Unknown	Total Non-Harvest
1993	62	2	272	4	3	1	72	6	0	196	6	3	1	16
1994	79	5	268	6	0	3	93	6	0	239	1	0	0	7
1995	74	12	368	7	1	1	95	2	2	244	5	2	0	11
1996	50	8	353	3	0	2	63	8	2	239	1	1	0	12
1997	91	8	350	3	1	3	106	72	6	441	12	1	3	94
1998	93	4	397	9	2	3	111	9	0	306	1	0	0	10
1999	71	1	403	3	0	2	77	11	1	294	6	2	0	20
2000	60	3	391	3	3	2	71	22	5	293	2	3	2	34
2001	66	2	469	4	3	2	77	17	3	247	0	4	1	25
2002	79	0	412	5	1	2	87	28	3	288	2	4	1	38
2003	93	1	514	3	3	1	101	37	3	391	4	1	1	46
2004	72	0	445	2	1	3	78	16	2	245	0	1	1	20
2005	101	2	395	2	2	1	108	33	1	252	3	1	3	41
2006	113	1	400	3	1	0	118	27	4	358	2	0	1	34
2007	133	3	574	3	2	2	143	21	2	359	1	2	0	26
2008	170	1	556	3	2	1	177	28	7	479	2	2	3	42
2009	107	1	561	6	1	2	117	48	11	589	5	0	6	70
2010	144	4	788	5	3	3	159	16	1	371	0	0	1	18
2011	168	0	772	5	6	2	181	100	0	607	2	2	2	106
2012	140	3	886	4	3	4	154	46	7	469	1	2	1	57
2013	160	8	947	3	1	3	175	53	16	515	3	2	4	78
2014	160	21	1122	2	1	6	190	30	6	380	2	1	1	40
2015	188	16	1077	4	2	1	211	64	7	633	6	3	3	83
2016	200	11	1062	0	4	1	216	70	4	526	1	5	4	84
2017	150	4	1195	0	0	2	156	50	2	609	1	0	5	58

Appendix B. Soft and hard mast indices from the Mountain region of North Carolina, 1983-2017.

	Soft Mast								Hard Mast			
	Summer				Fall							
Year	Blueberry	Huckleberry	Blackberry	Pokeberry	Pokeberry	Cherry	Grape	Blackgum	White Oak	Red Oak	Hickory	Beech
1983	NA	NA	NA	NA	NA	NA	NA	NA	1.43	2.59	1.99	5.51
1984	NA	NA	NA	NA	NA	NA	NA	NA	1.08	2.73	3.05	4.28
1985	NA	NA	NA	NA	NA	NA	NA	NA	2.01	3.66	0.80	3.06
1986	NA	NA	NA	NA	NA	NA	NA	NA	1.32	1.98	2.25	5.22
1987	NA	NA	NA	NA	NA	NA	NA	NA	1.16	0.56	3.57	5.75
1988	NA	NA	NA	NA	NA	NA	NA	NA	3.16	4.07	2.04	4.25
1989	NA	NA	NA	NA	NA	NA	NA	NA	0.43	4.89	2.78	6.44
1990	NA	NA	NA	NA	NA	NA	NA	NA	1.85	2.62	1.20	1.89
1991	NA	NA	NA	NA	NA	NA	NA	NA	2.38	1.93	3.75	6.89
1992	NA	NA	NA	NA	NA	NA	NA	NA	1.07	2.45	0.72	1.17
1993	3.20	3.60	3.80	2.40	2.00	2.70	2.10	0.40	0.65	3.58	2.43	4.77
1994	3.20	3.50	3.50	1.40	3.10	2.00	3.80	1.70	2.06	3.48	2.02	6.20
1995	1.90	2.50	3.10	1.20	2.70	5.00	2.20	1.80	2.80	5.60	2.48	0.36
1996	2.00	2.00	3.40	1.50	2.40	1.60	3.30	1.80	3.70	1.99	2.81	4.31
1997	2.80	3.00	3.80	2.00	4.20	1.30	3.10	0.80	0.53	1.79	1.17	2.35
1998	1.90	1.20	3.30	2.33	4.63	2.67	2.80	1.50	2.26	4.68	3.27	4.70
1999	2.72	2.45	2.90	1.78	2.40	2.70	3.25	1.10	3.28	2.76	2.80	6.22
2000	2.70	2.72	2.99	1.64	2.20	2.70	3.30	1.00	0.50	2.11	2.73	5.71
2001	2.27	2.73	2.87	0.87	2.80	3.30	4.18	2.33	2.83	4.92	2.88	3.97
2002	1.87	2.22	3.55	1.32	1.10	2.45	2.73	1.27	1.90	3.01	1.75	3.44

Appendix B. Soft and hard mast indices from the Mountain region of North Carolina, 1983-2017. (continued)

Year	Soft Mast								Hard Mast			
	Summer				Fall							
	Blueberry	Huckleberry	Blackberry	Pokeberry	Pokeberry	Cherry	Grape	Blackgum	White Oak	Red Oak	Hickory	Beech
2005	1.57	1.41	4.07	1.48	2.45	2.09	1.36	1.55	0.70	3.11	1.86	4.30
2006	NA	NA	NA	NA	3.73	2.00	3.17	2.50	1.70	1.40	3.20	4.10
2007	2.11	1.23	2.48	1.84	2.08	1.58	2.73	0.67	3.02	1.19	0.73	2.71
2008	NA	NA	NA	NA	2.91	4.64	4.08	2.58	1.01	2.40	3.82	4.34
2009	2.08	2.06	2.78	1.09	1.92	1.82	2.33	1.83	0.48	2.47	1.72	5.58
2010	NA	NA	NA	NA	2.90	5.80	4.80	1.40	3.46	3.97	3.50	0.87
2011	1.69	1.53	3.28	1.37	2.50	1.67	2.33	1.42	1.17	2.22	1.30	4.96
2012	NA	NA	NA	NA	2.50	1.08	2.92	1.00	1.87	2.68	2.01	3.14
2013	1.87	1.07	3.73	1.89	2.00	2.75	2.75	1.08	1.00	1.43	2.43	4.45
2014	NA	NA	NA	NA	2.55	3.91	4.55	2.18	4.43	4.36	2.33	1.23
2015	2.14	1.38	3.97	2.28	2.17	2.09	2.23	1.82	1.07	2.65	2.64	5.77
2016	NA	NA	NA	NA	3.00	3.27	2.75	1.92	2.71	2.60	2.45	4.08
2017	1.64	1.15	2.74	1.04	2.73	1.82	2.45	1.18	2.13	4.42	3.20	5.69

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011.

Date	County	Region	Sex	QBS	Latitude	Longitude
10/15/98	Rockingham	P	F	4-97-9	36.31167	-79.94500
01/06/99	Beaufort	C	M	17-39-15	35.70500	-76.76500
01/12/99	Bertie	C	F	17-4-16	35.94167	-76.74167
03/24/99	Clay	M	M	10-137-5	35.07833	-83.58500
04/03/99	Edgecombe	P	M	16-20-11	35.88500	-77.40167
04/29/99	Beaufort	C	F	17-66-8	35.56167	-76.54167
05/01/99	Washington	C	M	17-16-15	35.88500	-76.66833
05/04/99	Beaufort	C	F	17-97-15	35.28833	-76.91833
05/05/99	Tyrrell	C	M	17-46-18	35.70167	-76.20167
05/12/99	Dare	C	M	18-39-4	35.75167	-75.76833
05/14/99	Washington	C	M	17-28-12	35.79167	-76.72500
05/20/99	Avery	M	F	2-122-19	36.10833	-81.85167
06/01/99	Washington	C	M	17-16-2	35.91167	-76.72167
06/03/99	Craven	C	M	16-120-17	35.18833	-77.05167
06/03/99	Hyde	C	M	17-79-2	35.48500	-76.47167
06/03/99	Pamlico	C	F	17-122-9	35.15167	-76.85167
06/05/99	Hyde	C	-	17-67-22	35.50500	-76.46833
06/07/99	Tyrrell	C	F	17-10-8	35.97500	-76.20833
06/10/99	Pitt	C	M	16-79-5	35.49833	-77.42500
06/11/99	Jones	C	M	24-10-16	35.94500	-77.24167
06/13/99	Lincoln	P	M	12-70-17	35.52833	-81.22500
06/18/99	Chowan	C	M	7-138-1	36.08167	-76.58167
06/25/99	Dare	C	M	18-15-14	35.88500	-75.76833
06/30/99	Pitt	C	M	16-32-3	35.82833	-77.37833
07/01/99	Dare	C	M	17-15-12	35.88500	-76.80167
07/06/99	Craven	C	M	16-120-17	35.19167	-77.05500
07/08/99	Brunswick	C	M	23-108-23	34.25833	-78.04167
07/10/99	Buncombe	M	M	11-66-21	35.50833	-82.57500
07/14/99	Buncombe	M	M	11-56-18	35.61500	-82.37833
07/15/99	Bladen	C	F	23-81-13	34.45833	-78.28500
07/22/99	Bladen	C	M	23-24-4	34.90500	-78.02167
07/25/99	Pamlico	C	F	17-122-9	35.15167	-76.85167
07/26/99	Beaufort	C	F	16-84-16	35.44167	-77.06833
07/28/99	Brunswick	C	M	23-131-10	34.14833	-78.09167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
07/29/99	Craven	C	M	16-131-6	35.15167	-77.15167
08/13/99	Chowan	C	M	7-126-22	36.10167	-76.55167
08/21/99	Buncombe	M	M	11-67-20	35.52833	-82.42500
08/23/99	Catawba	P	M	12-44-12	35.70833	-81.39500
09/03/99	Jones	C	M	16-137-12	35.05167	-77.63500
09/13/99	Jones	C	M	24-7-1	35.00167	-77.48500
09/13/99	Wilson	C	M	16-40-21	34.68500	-77.73500
09/20/99	Haywood	M	M	10-35-20	35.77167	-83.08500
10/03/99	Dare	C	F	18-27-2	35.83500	-75.80167
10/07/99	Dare	C	-	18-13-14	35.88500	-75.93500
10/13/99	Granville	P	M	5-88-8	36.39500	-78.71167
10/17/99	Jackson	M	M	10-84-21	35.43167	-83.08167
10/18/99	Northampton	C	M	6-95-11	36.38500	-77.15167
10/20/99	Dare	C	F	18-14-12	35.88500	-75.88500
10/20/99	Pitt	C	M	16-82-22	35.43500	-77.21833
10/21/99	Dare	C	M	18-14-12	35.88500	-75.88500
10/21/99	Dare	C	F	18-14-12	35.88500	-75.88500
10/21/99	Martin	C	M	17-37-16	35.68833	-76.98500
10/21/99	Swain	M	F	10-90-15	35.37500	-83.50833
10/23/99	Jones	C	F	24-9-19	34.95167	-77.26833
10/27/99	Beaufort	C	M	17-62-17	35.53500	-76.88500
10/27/99	Washington	C	F	17-16-13	35.87500	-76.71500
10/28/99	Haywood	M	M	10-48-19	35.68833	-83.03167
11/11/99	Craven	C	F	16-130-2	35.15833	-77.22500
11/11/99	Pitt	C	F	16-68-19	35.53500	-77.35167
11/12/99	Hyde	C	F	18-61-12	35.51467	-75.97500
11/14/99	Beaufort	C	F	17-98-9	35.30167	-76.86500
11/15/99	Ashe	M	F	2-78-2	36.48500	-81.55833
11/17/99	Beaufort	C	F	16-84-24	35.43500	-77.01833
11/18/99	Beaufort	C	-	16-85-14	35.36833	-77.94167
11/21/99	Beaufort	C	M	17-100-11	35.29833	-76.73833
11/27/99	Bertie	C	M	6-119-13	36.20167	-77.12167
12/02/99	Craven	C	M	16-132-9	35.13833	-77.02833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/03/99	McDowell	M	F	11-58-11	35.62500	-82.23500
12/04/99	Beaufort	C	-	17-98-14	35.30167	-76.85167
12/09/99	Cherokee	M	M	10-121-14	35.13500	-83.93500
12/11/99	Pitt	C	M	16-81-14	35.46833	-77.26833
01/08/00	Avery	M	M	2-122-20	36.11500	-81.84833
01/28/00	Martin	C	F	17-25-7	35.80833	-76.97167
02/01/00	Washington	C	M	17-27-13	35.80167	-76.78500
04/05/00	Lenoir	C	F	16-125-7	35.13500	-77.64500
04/07/00	Dare	C	M	18-15-12	35.87167	-75.80167
04/12/00	Watauga	M	M	2-111-1	36.24833	-81.81833
04/26/00	Onslow	C	M	24-18-23	34.84833	-77.53833
04/27/00	New Hanover	C	M	24-87-11	34.37167	-77.82500
05/04/00	Beaufort	C	M	17-64-5	35.58500	-76.66833
05/05/00	Bertie	C	-	6-119-18	36.18833	-77.13167
05/10/00	Beaufort	C	M	16-84-1	35.50167	-77.06833
05/19/00	Haywood	M	M	10-48-18	35.69833	-83.04167
05/19/00	Tyrrell	C	F	17-11-21	35.93167	-76.15500
05/19/00	Tyrrell	C	F	17-23-3	35.91833	-76.11833
05/24/00	Iredell	P	M	13-26-24	35.75500	-80.86167
05/27/00	Beaufort	C	-	17-87-23	35.35167	-76.78500
05/27/00	Jones	C	M	16-139-17	35.01833	-77.47167
06/09/00	Henderson	M	M	11-104-18	35.27500	-82.37167
06/10/00	Wilson	C	M	16-25-22	35.76833	-77.96833
06/11/00	Pender	C	F	24-86-6	34.39167	-77.90833
06/14/00	Halifax	C	M	6-88-10	36.40167	-77.66833
06/15/00	Avery	M	M	2-133-5	36.07500	-81.92167
06/16/00	Gates	C	M	7-74-11	36.45167	-76.90500
06/19/00	Perquimans	C	M	7-127-6	36.14167	-76.49167
06/20/00	Beaufort	C	M	16-83-17	35.45167	-77.13500
06/20/00	Tyrrell	C	M	17-21-4	35.91833	-76.26833
06/22/00	Tyrrell	C	M	17-58-3	35.65833	-76.20833
06/23/00	Beaufort	C	M	17-77-7	35.46833	-76.63500
06/26/00	Davie	P	M	13-18-6	35.89500	-80.56833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/28/00	Yancey	M	M	11-46-7	35.72167	-82.22500
07/03/00	Martin	C	F	17-26-8	35.81833	-76.86833
07/10/00	Washington	C	M	17-28-18	35.77167	-76.70500
07/13/00	McDowell	M	-	12-38-16	35.68500	-81.90500
07/13/00	Pender	C	M	24-61-2	34.57167	-77.97833
07/24/00	Buncombe	M	M	11-55-7	35.64167	-82.46833
07/28/00	Buncombe	M	F	11-56-10	35.64167	-82.34500
07/30/00	Martin	C	M	17-26-8	35.81167	-76.87500
08/03/00	Hertford	C	-	7-99-6	36.31500	-76.82167
08/04/00	Beaufort	C	M	17-52-17	35.60833	-76.71833
08/08/00	Beaufort	C	F	17-61-18	35.53167	-76.95500
08/09/00	Beaufort	C	F	17-51-3	35.66500	-76.78833
08/12/00	Jones	C	F	24-9-25	34.92500	-77.25167
08/15/00	Dare	C	M	18-13-15	35.86833	-75.92167
08/17/00	Jones	C	M	24-28-10	34.80167	-77.66833
08/18/00	Buncombe	M	F	11-54-22	35.59833	-82.55833
08/24/00	Graham	M	M	10-74-16	35.44167	-83.91500
09/07/00	Beaufort	C	M	17-63-10	35.56500	-76.76167
09/08/00	Bertie	C	F	17-4-11	35.96833	-76.73500
09/10/00	Bertie	C	F	7-136-12	36.03833	-76.72500
09/12/00	Pender	C	M	24-86-12	34.36833	77.89167
09/15/00	Hertford	C	F	7-86-19	36.35833	-76.85833
09/15/00	Pender	C	F	24-86-3	34.40167	-77.87833
09/15/00	Transylvania	M	M	11-125-8	35.14167	-82.62500
09/18/00	Duplin	C	-	15-143-12	35.05167	-78.13500
09/18/00	Duplin	C	M	24-11-10	34.98167	-77.09500
09/26/00	Yancey	M	F	11-22-5	35.90167	-82.18167
09/30/00	Bertie	C	M	6-130-5	36.16500	-77.16833
10/03/00	Haywood	M	M	10-48-13	35.70500	-83.04167
10/05/00	McDowell	M	-	11-60-6	35.63500	-82.07833
10/08/00	Buncombe	M	M	11-31-13	35.79500	-82.45167
10/09/00	Bertie	C	F	6-120-16	36.19500	-77.12833
10/16/00	Jones	C	M	16-115-15	35.20500	-77.42500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/16/00	Madison	M	F	11-6-5	35.99167	-82.51167
10/16/00	Swain	M	M	10-100-15	35.30167	-83.66833
10/17/00	McDowell	M	F	11-57-17	35.60167	-82.30833
10/23/00	Jones	C	F	16-142-6	35.06833	-77.23500
10/25/00	Beaufort	C	F	17-100-5	35.32500	-76.68167
10/25/00	Duplin	C	M	16-133-17	35.03167	-77.96833
10/29/00	Haywood	M	M	11-49-1	35.66500	-82.99167
10/31/00	Washington	C	-	17-16-17	35.86833	-76.71833
11/06/00	Transylvania	M	M	11-112-21	35.18500	-82.73500
11/08/00	Beaufort	C	M	17-98-3	35.31833	-76.86833
11/08/00	Craven	C	F	16-129-1	35.15833	-77.32833
11/12/00	McDowell	M	M	11-57-18	35.60500	-82.29500
11/14/00	McDowell	M	M	11-58-14	35.62167	-82.19500
11/16/00	Haywood	M	-	10-36-23	35.75833	-83.03500
11/16/00	Jones	C	F	16-115-20	35.19833	-77.42167
11/18/00	Beaufort	C	F	17-51-13	35.62833	-76.79167
11/22/00	Beaufort	C	-	17-65-10	35.55833	-76.59500
11/22/00	Washington	C	M	17-28-12	35.80167	-76.71833
11/23/00	Caldwell	M	M	2-138-21	36.01167	-81.57500
11/30/00	Henderson	M	M	11-90-5	35.40167	-82.51167
12/13/00	Cumberland	C	M	23-16-21	34.83500	-78.73833
12/18/00	Pender	C	M	24-62-6	34.55500	-77.91167
02/18/01	Dare	C	M	18-39-15	35.71167	-75.75500
03/27/01	Pender	C	M	23-59-2	34.65833	-78.14833
04/01/01	Watauga	M	M	2-110-18	36.20167	-81.86833
04/12/01	Pender	C	M	23-59-2	34.65833	-78.14833
04/18/01	Bertie	C	M	7-109-15	36.21833	-76.91833
04/30/01	Surry	M	M	3-63-12	36.55167	-80.80167
05/07/01	Beaufort	C	-	17-66-	35.60167	-76.50167
05/14/01	Beaufort	C	M	17-65-4	35.58500	-76.60167
05/24/01	Pitt	C	F	16-32-15	35.78833	-77.33500
05/25/01	New Hanover	C	M	24-86-18	34.35167	-77.87833
05/25/01	Transylvania	M	F	11-123-18	35.11833	-82.78500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
05/25/01	Tyrrell	C	M	17-24-6	35.89833	-76.07500
05/29/01	Beaufort	C	M	16-72-7	35.56500	-77.06500
05/30/01	Craven	C	M	16-106-16	35.28500	-77.23500
05/31/01	Graham	M	F	10-88-14	35.38500	-83.68500
06/01/01	Pender	C	F	24-74-18	34.44167	-77.88167
06/04/01	Haywood	M	M	10-61-20	35.53500	-83.91833
06/08/01	Craven	C	F	16-130-3	35.15167	-77.21167
06/09/01	McDowell	M	M	11-59-6	35.63833	-82.15167
06/10/01	Jones	C	F	16-116-23	35.18500	-77.36833
06/13/01	Buncombe	M	F	11-44-23	35.68500	-82.36833
06/13/01	Martin	C	M	17-25-10	35.81833	-76.91833
06/18/01	Washington	C	F	17-16-9	35.89500	-76.69167
06/19/01	Beaufort	C	M	17-99-7	35.31833	-76.80167
06/21/01	Dare	C	M	18-27-20	35.78500	-75.75167
06/23/01	Martin	C	M	17-25-8	35.80833	-76.96167
06/29/01	Jones	C	M	16-115-6	35.23500	-77.48500
07/05/01	Watauga	M	F	2-123-7	36.15167	-81.80167
07/07/01	Buncombe	M	F	11-67-1	35.58500	-82.48500
07/08/01	Pender	C	F	24-86-13	34.37500	-77.87500
07/08/01	Pender	C	F	24-86-13	34.37500	-77.87500
07/21/01	Henderson	M	M	11-104-18	35.28500	-82.36833
07/22/01	Cumberland	C	M	15-124-16	35.11833	-78.73500
07/24/01	Bertie	C	F	17-4-16	35.93833	-76.73500
07/25/01	Buncombe	M	F	11-67-6	35.56833	-82.48500
08/02/01	Onslow	C	M	24-54-16	34.61833	-77.56833
08/04/01	Jones	C	F	16-142-8	35.06833	-77.20167
08/06/01	Cumberland	C	M	15-134-18	35.03500	-78.86833
08/14/01	Craven	C	F	16-116-20	35.20167	-77.33500
08/21/01	Beaufort	C	M	17-64-5	35.58500	-76.66833
09/03/01	Carteret	C	F	25-30-24	34.76833	-76.51833
09/05/01	Craven	C	M	16-130-3	35.16833	-77.20167
09/16/01	Beaufort	C	M	16-72-16	35.53500	-77.06833
09/16/01	Jones	C	M	16-128-5	35.16833	-77.33500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
09/17/01	Jones	C	F	16-126-9	35.15167	-77.51833
09/20/01	Beaufort	C	F	17-85-14	35.38500	-76.93500
09/24/01	Beaufort	C	M	17-62-10	35.56833	-76.83500
09/25/01	Bertie	C	F	17-121-13	35.13500	-76.95167
09/25/01	McDowell	M	M	11-58-15	35.62500	-82.17500
10/01/01	Craven	C	M	16-115-14	35.21833	-77.43500
10/06/01	Pamlico	C	M	17-136-12	35.05167	-76.71833
10/10/01	Jones	C	F	24-9-25	34.93500	-77.25167
10/14/01	Jones	C	F	16-128-18	35.11833	-77.36833
10/15/01	Gates	C	F	7-87-1	36.41833	-76.81833
10/17/01	Cumberland	C	F	15-112-23	35.18500	-78.70167
10/17/01	Jones	C	M	16-115-14	35.21833	-77.43500
10/19/01	Pender	C	F	23-72-15	34.54167	-78.00167
10/21/01	Bertie	C	F	17-2-23	35.93500	-76.86833
10/21/01	Buncombe	M	M	11-54-18	35.61833	-82.53500
10/22/01	Beaufort	C	F	17-100-12	35.30167	-76.71833
10/26/01	Haywood	M	M	10-48-18	35.70167	-83.03500
10/26/01	Lenoir	C	F	16-126-1	35.16833	-77.56833
10/28/01	Beaufort	C	M	17-61-3	35.58500	-76.95167
10/30/01	Yancey	M	F	11-34-13	35.80167	-82.20167
11/07/01	Beaufort	C	M	17-62-23	35.51833	-76.86833
11/08/01	Greene	C	F	16-64-3	35.55167	-77.70167
11/14/01	Bertie	C	M	7-135-9	36.06833	-76.76833
11/14/01	Gates	C	F	7-76-6	36.48500	-76.73500
11/15/01	Pitt	C	M	16-59-17	35.61833	-77.13500
11/17/01	Onslow	C	F	24-32-16	34.78500	-77.40167
11/18/01	McDowell	M	F	11-58-11	35.62500	-82.23500
11/21/01	Beaufort	C	F	17-77-2	35.50167	-76.63500
11/21/01	Beaufort	C	F	17-87-19	35.36833	-76.76833
11/21/01	Madison	M	M	11-15-3	35.91833	-82.78500
11/28/01	Haywood	M	M	10-48-18	35.70167	-83.03500
11/28/01	Martin	C	M	16-35-4	35.83500	-77.10167
12/01/01	Onslow	C	M	24-53-14	35.63500	-77.60167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/02/01	McDowell	M	M	11-72-20	35.52500	-82.00500
12/03/01	Jones	C	M	16-127-6	35.15167	-77.48500
12/08/01	Bertie	C	M	7-135-15	36.05167	-76.75167
12/12/01	Onslow	C	M	24-67-3	34.58500	-77.45167
12/14/01	Craven	C	F	16-130-10	35.15167	-77.16833
12/19/01	Hertford	C	M	7-85-24	36.35167	-76.93500
12/20/01	Hyde	C	M	17-54-12	35.63500	-76.55167
12/22/01	Cherokee	M	M	10-112-1	35.24500	-83.74167
12/27/01	Washington	C	F	17-6-23	35.93500	-76.53500
12/29/01	Washington	C	M	17-6-21	35.93500	-76.56833
03/31/02	Buncombe	M	M	11-57-7	35.65167	-82.30167
04/13/02	Beaufort	C	F	17-61-19	35.53500	-76.93500
04/17/02	Pender	C	M	24-61-12	34.55167	-77.96833
04/22/02	Craven	C	M	17-132-17	35.11833	-76.05167
04/25/02	Johnston	P	M	15-55-15	35.63500	-78.41833
05/03/02	Jones	C	F	16-126-20	35.11833	-77.50167
05/09/02	Transylvania	M	M	11-121-6	35.15167	-82.98500
05/13/02	Dare	C	M	18-14-19	35.86500	-75.85833
05/14/02	Madison	M	F	11-15-4	35.91833	-82.76833
05/14/02	Madison	M	F	11-15-3	35.91833	-82.78500
05/14/02	Pender	C	M	24-74-3	34.48500	-77.87833
05/15/02	Pamlico	C	M	17-112-23	35.18500	-76.70167
05/21/02	Dare	C	M	18-13-7	35.89500	-75.97500
05/21/02	Pender	C	M	24-62-6	34.56167	-77.91500
05/23/02	McDowell	M	F	11-58-11	35.63500	-82.23500
05/23/02	Sampson	C	M	15-116-	35.26833	-78.33500
05/24/02	Haywood	M	-	10-48-3	35.75167	-83.03500
05/27/02	Polk	M	-	11-104-25	35.26833	-82.33500
05/28/02	Cumberland	C	M	23-3-	35.01833	-78.75167
05/31/02	Buncombe	M	M	11-54-11	35.63500	-82.56833
06/05/02	Jones	C	M	16-137-23	35.01833	-77.61833
06/06/02	Martin	C	M	16-22-10	35.90167	-77.16833
06/06/02	Pender	C	M	23-84-21	34.42167	-78.07833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/09/02	Sampson	C	M	23-9-	35.01833	-78.25167
06/10/02	Lenoir	C	M	16-125-11	35.13500	-77.65167
06/11/02	Buncombe	M	F	11-54-18	35.61833	-82.53500
06/11/02	Dare	C	M	18-15-13	35.87167	-75.79167
06/11/02	Madison	M	M	11-30-8	35.81833	-82.53500
06/12/02	Camden	C	F	7-68-10	36.56833	-76.33500
06/13/02	Martin	C	M	16-36-16	35.78500	-77.06833
06/16/02	Beaufort	C	M	16-83-8	35.48500	-77.11833
06/19/02	Duplin	C	M	23-24-	34.93500	-78.00167
06/27/02	Pender	C	M	24-74-6	34.47500	-77.90833
06/28/02	Brunswick	C	M	23-129-13	34.13500	-78.28500
07/02/02	Dare	C	M	18-50-8	35.63833	-75.86833
07/07/02	Pitt	C	F	16-81-15	35.46833	-77.25167
07/11/02	Jones	C	M	16-115-14	35.21833	-77.43500
07/14/02	Onslow	C	M	24-56-23	34.59167	-77.37500
07/16/02	Onslow	C	M	24-6-20	34.93500	77.50500
07/19/02	Hyde	C	F	17-83-21	35.43500	-76.15167
07/22/02	McDowell	M	M	12-13-9	35.90167	-81.93500
07/23/02	Pitt	C	M	16-69-11	35.55167	-77.31833
07/25/02	Buncombe	M	-	11-54-18	35.61833	-82.53500
07/25/02	Henderson	M	M	11-114-2	35.25167	-82.55167
08/11/02	Beaufort	C	F	17-85-13	35.38500	-76.95167
08/14/02	Onslow	C	M	24-11-12	34.96833	-77.13500
08/21/02	Bertie	C	M	6-119-9	36.23500	-77.10167
08/25/02	Bladen	C	M	23-78-20	34.45167	-78.50167
08/26/02	Buncombe	M	M	11-69-15	35.55167	-82.25167
08/29/02	Martin	C	M	17-25-22	35.76833	-76.96833
09/01/02	Dare	C	-	18-13-15	35.86833	-75.91833
09/04/02	Lenoir	C	M	16-114-22	35.18500	-77.55167
09/05/02	Onslow	C	M	24-45-14	34.71833	-77.26833
09/14/02	Camden	C	M	7-8-16	36.95167	-76.40167
09/16/02	Beaufort	C	-	17-39-15	35.71833	-76.75167
09/18/02	Haywood	M	M	10-48-14	35.71833	-83.01833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
09/23/02	Transylvania	M	M	11-121-16	35.11833	-82.28500
09/26/02	Dare	C	F	18-13-7	35.88500	-75.97833
09/28/02	Pamlico	C	F	17-112-15	35.21833	-76.66833
09/30/02	Dare	C	M	18-39-24	35.66833	-75.77833
09/30/02	Dare	C	M	18-39-24	35.66833	-75.77833
09/30/02	Dare	C	F	18-39-24	35.66833	-75.77833
10/02/02	Gates	C	F	7-78-19	36.45167	-76.51833
10/05/02	McDowell	M	F	11-58-20	35.61167	-82.17167
10/07/02	Gates	C	M	7-74-??	36.51833	-76.83500
10/11/02	Tyrrell	C	F	17-58-3	35.66833	-76.20167
10/13/02	Buncombe	M	F	11-67-13	35.55167	-82.45167
10/13/02	Buncombe	M	F	11-67-13	35.55167	-82.45167
10/13/02	Buncombe	M	M	11-67-13	35.55167	-82.45167
10/14/02	Macon	M	M	10-126-18	35.11833	-83.53500
10/15/02	Graham	M	M	10-99-14	35.30167	-83.75833
10/18/02	Dare	C	-	18-13-14	35.88500	-75.93500
10/18/02	Dare	C	F	18-13-15	35.87167	-75.92833
10/19/02	Haywood	M	M	10-48-18	35.70167	-83.03500
10/21/02	Bladen	C	M	23-41-14	34.71833	-78.60167
10/22/02	Buncombe	M	M	11-67-13	35.55167	-82.45167
10/22/02	Jones	C	M	24-23-4	34.91833	-77.10167
10/26/02	Haywood	M	-	10-48-4	35.75167	-83.01833
10/30/02	Buncombe	M	-	11-42-21	35.68500	-82.56833
11/01/02	Buncombe	M	M	11-54-24	35.60167	-82.51833
11/01/02	Craven	C	M	16-129-1	35.16833	-77.90167
11/01/02	Dare	C	M	18-51-14	35.62833	-75.78167
11/02/02	Jackson	M	M	10-93-13	35.68500	-83.28500
11/06/02	Craven	C	M	25-1-19	34.95167	-76.93500
11/12/02	Buncombe	M	F	11-31-24	35.76833	-82.43500
11/13/02	Pender	C	F	24-50-16	34.61833	-77.90167
11/16/02	Bertie	C	M	17-3-20	35.95167	-76.75167
11/16/02	Lenoir	C	F	16-114-17	35.20167	-77.55167
11/19/02	Onslow	C	M	24-44-10	34.72500	-77.34833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/20/02	Martin	C	M	17-25-8	35.81833	-76.95167
11/21/02	Brunswick	C	M	23-95-18	34.36833	-78.11833
11/21/02	Martin	C	F	17-25-20	34.78500	-76.91833
11/26/02	McDowell	M	M	12-13-14	35.88500	-81.93500
12/01/02	Martin	C	-	16-35-3	35.83500	-77.11833
12/02/02	Johnston	P	F	15-55-	35.68500	-78.41833
12/06/02	Bladen	C	M	23-41-4	34.75167	-78.60167
12/16/02	Bladen	C	M	23-18-22	34.85167	-78.55167
12/18/02	Craven	C	-	17-131-2	35.16833	-76.13500
12/19/02	Camden	C	F	7-108-18	36.28500	-76.03500
12/19/02	Camden	C	F	7-108-18	36.28500	-76.03500
12/21/02	Camden	C	-	7-68-10	36.56833	-76.33500
12/30/02	Buncombe	M	F	11-56-22	35.60167	-82.38500
12/30/02	Tyrrell	C	M	17-22-7	35.90167	-76.21833
01/03/03	Madison	M	F	11-30-8	35.81833	-82.53500
01/10/03	Jones	C	M	16-128-5	35.16833	-77.33500
01/21/03	Dare	C	M	18-14-15	35.88500	-75.83500
02/24/03	Bertie	C	F	17-3-15	35.96833	-76.75167
03/15/03	Beaufort	C	M	16-71-20	35.53500	-77.08500
04/05/03	Dare	C	F	18-26-15	35.80167	-75.83500
04/15/03	Craven	C	M	16-94-13	35.38500	-77.20167
04/17/03	Martin	C	F	16-35-18	35.78500	-77.11833
04/17/03	Martin	C	F	16-35-18	35.78500	-77.11833
04/17/03	Martin	C	F	16-35-18	35.78500	-77.11833
04/27/03	Duplin	C	M	23-24-4	34.91833	-78.01833
04/28/03	Beaufort	C	F	17-62-17	35.53500	-76.88500
05/04/03	Duplin	C	M	23-24-25	34.85167	-78.00167
05/05/03	Craven	C	F	16-107-1	35.33500	-77.15167
05/07/03	Chowan	C	M	7-138-19	36.03500	-76.51833
05/08/03	Buncombe	M	M	11-55-8	35.65167	-82.45167
05/08/03	Dare	C	F	18-50-15	35.63500	-75.83500
05/12/03	Lenoir	C	F	16-99-13	35.30167	-77.78500
05/13/03	Dare	C	M	18-50-15	35.63500	-75.83500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
05/16/03	Buncombe	M	-	11-55-21	35.60167	-82.48500
05/17/03	Buncombe	M	M	11-54-18	35.61833	-82.53500
05/28/03	Beaufort	C	F	17-66-6	35.56833	-76.56833
05/31/03	Beaufort	C	M	17-75-19	35.45167	-76.76833
06/01/03	Beaufort	C	F	17-75-12	35.46833	-76.80167
06/01/03	Edgecombe	P	M	16-9-16	35.95167	-77.31833
06/04/03	New Hanover	C	M	24-98-13	34.30167	-77.86833
06/07/03	Clay	M	M	10-134-8	35.06833	-83.86833
06/07/03	Pitt	C	M	16-91-5	35.41833	-77.41833
06/10/03	Transylvania	M	M	11-122-8	35.15167	-82.86833
06/11/03	Chatham	P	M	14-60-11	35.63500	-79.06833
06/12/03	Halifax	C	M	6-112-1	36.25167	-77.73500
06/15/03	Northampton	C	F	6-104-25	36.26833	-77.33500
06/20/03	McDowell	M	F	11-48-3	35.75167	-82.03500
06/21/03	Pender	C	M	23-84-23	34.43500	-78.03500
06/27/03	Hertford	C	F	6-107-11	36.30167	-77.15167
06/30/03	Avery	M	F	2-134-2	36.08500	-81.88500
07/11/03	Buncombe	M	M	11-67-1	35.58500	-82.48500
07/15/03	Craven	C	M	24-25-9	34.81833	-77.93500
07/19/03	Onslow	C	M	24-43-22	34.68500	-77.46833
07/21/03	Currituck	C	F	8-97-15	36.30167	-75.91833
07/23/03	Jackson	M	F	10-132-20	35.11833	-83.01833
08/01/03	Jones	C	F	16-140-15	35.05167	-77.33500
08/05/03	Buncombe	M	F	11-68-8	35.56833	-82.36833
08/09/03	Jones	C	M	16-128-25	35.10167	-77.33500
08/10/03	Bladen	C	M	23-55-11	34.63500	-78.48500
08/15/03	Jones	C	F	16-139-17	35.03500	-77.46833
08/16/03	Hyde	C	M	17-70-2	35.58500	-76.21833
08/21/03	Beaufort	C	F	17-51-3	35.66833	-76.78500
08/21/03	Pamlico	C	M	17-110-4	35.25167	-76.85167
08/22/03	Columbus	C	M	23-101-20	34.28500	-78.58500
08/23/03	Yancey	M	M	11-22-18	35.86833	-82.20167
08/27/03	Onslow	C	M	24-69-1	34.58500	-77.31833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
09/02/03	Dare	C	M	18-27-19	35.78500	-75.76833
09/07/03	Onslow	C	-	24-5-25	34.93500	-77.58500
09/11/03	Transylvania	M	F	11-112-21	35.18500	-82.73500
09/13/03	Halifax	C	M	6-123-3	36.16833	-77.78500
09/17/03	Craven	C	M	16-117-25	35.18500	-77.25167
09/21/03	Brunswick	C	F	23-127-21	34.10167	-78.48500
09/22/03	Buncombe	M	M	11-66-10	35.56833	-82.50167
09/25/03	McDowell	M	M	11-36-23	35.76833	-82.03500
10/01/03	Buncombe	M	M	11-65-11	35.55167	-82.65167
10/01/03	Dare	C	M	18-40-11	35.71833	-75.73500
10/02/03	Jackson	M	M	10-83-24	35.43500	-83.10167
10/02/03	Pamlico	C	M	17-136-10	35.06833	-76.66833
10/05/03	Onslow	C	M	24-66-11	34.55167	-77.56833
10/06/03	Buncombe	M	M	11-64-18	35.53500	-82.70167
10/06/03	Dare	C	M	18-39-24	35.68500	-75.76833
10/06/03	McDowell	M	M	11-59-7	35.65167	-82.13500
10/07/03	Buncombe	M	M	11-67-14	35.55167	-82.43500
10/07/03	Craven	C	M	16-130-2	35.16833	-77.21833
10/07/03	Pamlico	C	F	17-102-12	35.30167	-76.55167
10/08/03	Buncombe	M	F	11-31-19	35.78500	-82.43500
10/08/03	Jones	C	M	16-140-15	35.05167	-77.33500
10/09/03	Gates	C	M	7-78-20	36.45167	-76.50167
10/09/03	Jones	C	M	16-141-17	35.03500	-77.30167
10/09/03	Tyrrell	C	M	17-34-24	35.76833	-76.18500
10/10/03	McDowell	M	F	11-36-18	35.78500	-82.03500
10/12/03	Madison	M	F	11-4-16	35.95167	-82.73500
10/13/03	Craven	C	-	17-121-6	35.15167	-76.98500
10/13/03	Macon	M	F	10-128-2	35.16833	-83.38500
10/14/03	Dare	C	M	18-13-7	35.90167	-75.96833
10/14/03	Dare	C	M	18-27-2	35.83500	-75.80167
10/14/03	Jackson	M	F	10-95-6	35.40167	-83.15167
10/16/03	Lenoir	C	M	16-99-4	35.33500	-77.76833
10/17/03	Tyrrell	C	F	17-21-10	35.90167	-77.76833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/20/03	McDowell	M	F	11-48-8	35.73500	-82.03500
10/21/03	Craven	C	-	16-130-10	35.15167	-77.16833
10/21/03	Hyde	C	M	17-93-4	35.41833	-76.26833
10/21/03	Jackson	M	M	10-131-13	35.13500	-83.11833
10/22/03	Dare	C	F	18-13-8	35.90167	-75.95167
10/24/03	Pender	C	F	23-83-13	34.46833	-78.11833
10/26/03	Buncombe	M	M	11-66-6	35.56833	-82.56833
10/27/03	McDowell	M	M	11-58-14	35.63500	-82.18500
10/28/03	Lenoir	C	M	16-124-22	35.10167	-77.71833
10/29/03	Yancey	M	M	11-19-4	35.91833	-82.43500
10/30/03	Clay	M	M	10-136-11	35.05167	-83.73500
10/30/03	Tyrrell	C	M	7-23-5	36.91833	-76.08500
11/01/03	Avery	M	M	11-12-9	35.98500	-82.01833
11/01/03	Jones	C	F	24-10-2	35.00167	-77.21833
11/03/03	Buncombe	M	F	11-43-17	35.70167	-82.46833
11/03/03	Buncombe	M	M	11-54-22	35.60167	-82.55167
11/04/03	Madison	M	M	11-18-8	35.90167	-82.53500
11/06/03	Beaufort	C	M	17-61-6	35.56833	-76.98500
11/09/03	Bertie	C	M	17-4-16	35.95167	-76.73500
11/09/03	McDowell	M	M	11-58-12	35.63500	-82.21833
11/09/03	Perquimans	C	F	7-103-22	36.26833	-76.46833
11/11/03	Gates	C	F	7-78-19	36.44167	-76.52500
11/12/03	Dare	C	M	18-15-22	35.85167	-75.80167
11/12/03	Martin	C	M	16-35-2	35.83500	-77.13500
11/14/03	Hyde	C	M	17-80-19	35.45167	-76.35167
11/14/03	Martin	C	M	16-35-1	35.83500	-77.15167
11/14/03	Pender	C	M	24-52-1	34.66833	-77.73500
11/14/03	Tyrrell	C	M	17-58-8	35.65167	-76.20167
11/15/03	Pender	C	M	23-95-6	34.40167	-78.15167
11/16/03	Madison	M	F	11-18-25	35.85167	82.50167
11/18/03	Buncombe	M	F	11-56-21	35.60167	-82.40167
11/18/03	Buncombe	M	-	11-56-21	35.60167	-82.40167
11/21/03	Pender	C	F	23-83-17	34.45167	-78.13500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/05/03	Martin	C	F	17-15-21	35.85167	-76.81833
12/05/03	Martin	C	M	17-15-21	35.85167	-76.81833
12/08/03	Jones	C	F	16-140-9	35.06833	-77.35167
12/09/03	Beaufort	C	M	17-75-6	35.48500	-76.81833
12/09/03	Jones	C	M	16-116-16	35.20167	-77.40167
12/11/03	Henderson	M	M	11-104-18	35.28500	-82.36833
12/12/03	Martin	C	M	16-21-3	35.91833	-77.28500
12/15/03	Beaufort	C	F	16-71-24	35.51833	-77.10167
12/15/03	Bladen	C	M	23-54-4	34.66833	-78.51833
12/18/03	Dare	C	M	17-39-5	35.74833	-76.75167
12/18/03	Lenoir	C	M	24-18-7	34.90167	-77.55167
12/23/03	Washington	C	F	17-5-25	35.93500	-76.58500
12/30/03	Jones	C	F	16-142-18	35.03500	-77.20167
01/05/04	Pitt	C	M	16-81-24	35.43500	-77.26833
01/06/04	Jones	C	F	24-10-2	35.00167	-77.21833
01/24/04	Pitt	C	M	16-81-7	35.48500	-77.30167
02/09/04	Hyde	C	-	18-61-9	35.56833	-75.93500
02/09/04	Hyde	C	-	18-61-9	35.56833	-75.93500
04/11/04	Pitt	C	M	16-69-13	35.55167	-77.28500
04/25/04	Tyrrell	C	M	17-20-8	35.90167	-76.36833
04/30/04	Beaufort	C	F	16-95-2	35.41833	-77.13500
04/30/04	Craven	C	M	16-118-21	35.18500	-77.23500
05/01/04	Buncombe	M	F	11-66-25	35.51833	-82.50167
05/04/04	Pitt	C	M	16-45-3	35.75167	-77.28500
05/08/04	Burke	M	M	12-40-6	35.73500	-81.73500
05/15/04	Duplin	C	M	24-25-18	34.78500	-77.95167
05/19/04	Pitt	C	M	16-70-21	35.51833	-77.23500
05/24/04	Haywood	M	M	10-60-20	35.61833	-83.00167
05/25/04	Wilson	C	M	16-50-6	35.65167	-77.90167
05/26/04	Polk	M	M	11-117-1	35.25167	-82.31833
06/01/04	Pender	C	M	24-86-12	34.38500	-77.88500
06/08/04	Tyrrell	C	M	17-10-25	35.93500	-76.16833
06/09/04	Buncombe	M	M	11-30-13	35.80167	-82.53500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/09/04	McDowell	M	F	11-35-13	35.80167	-82.11833
06/12/04	Burke	M	M	12-38-20	35.70167	-81.83500
06/14/04	Martin	C	M	17-27-2	35.83500	-76.80167
06/16/04	Jones	C	M	24-10-2	35.00167	-77.21833
06/17/04	Tyrrell	C	M	17-46-5	35.75167	-76.16833
06/24/04	Beaufort	C	-	17-53-9	35.65167	-76.60167
06/26/04	Pitt	C	-	16-80-25	35.43500	-77.33500
06/27/04	Craven	C	M	16-94-15	35.38500	-77.16833
06/28/04	Macon	M	M	10-140-12	35.05167	-83.38500
06/29/04	McDowell	M	M	11-59-8	35.65167	-82.11833
07/01/04	Beaufort	C	U	16-71-17	35.53500	-77.13500
07/03/04	Pitt	C	M	16-82-23	35.43500	-77.20167
07/04/04	New Hanover	C	M	24-98-18	34.28500	-77.86833
07/05/04	Craven	C	M	16-130-3	35.16833	-77.20168
07/07/04	Polk	M	M	11-108-1	35.33500	-82.06833
07/09/04	Washington	C	M	17-16-15	35.88500	-76.66833
07/16/04	Henderson	M	M	11-104-25	35.26833	-82.33500
07/19/04	Northampton	C	F	6-94-24	36.35167	-77.18500
07/20/04	Washington	C	M	17-16-18	35.86833	-76.70167
07/22/04	Lenoir	C	M	16-102-8	35.31833	-77.53500
07/28/04	Onslow	C	M	24-55-17	34.61833	-77.46833
08/13/04	Craven	C	M	16-120-20	35.20167	-77.00167
08/20/04	Craven	C	M	16-107-7	35.31833	-77.13500
08/25/04	Sampson	C	M	15-137-23	35.01833	-78.61833
08/27/04	Beaufort	C	F	17-51-7	35.65167	-76.80167
08/27/04	Beaufort	C	-	17-51-7	35.65167	-76.80167
08/29/04	Craven	C	M	16-129-2	35.16833	-77.30167
09/03/04	Beaufort	C	M	17-101-16	35.28500	-76.65167
09/03/04	Beaufort	C	F	17-61-14	35.55167	-76.93500
09/07/04	Dare	C	F	18-15-13	35.88500	-75.78500
09/11/04	Jones	C	M	16-116-17	35.20167	-77.38500
09/13/04	Dare	C	M	18-50-15	35.63500	-75.83500
09/14/04	Dare	C	M	18-15-17	35.86833	75.80167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
09/15/04	Chowan	C	M	7-101-6	36.31833	-76.65167
09/18/04	Martin	C	M	16-20-20	35.86833	-77.33500
09/21/04	Beaufort	C	M	17-62-6	35.56833	-76.90167
09/29/04	Beaufort	C	M	17-85-2	35.41833	-76.96833
09/29/04	Martin	C	F	17-25-22	35.76833	-76.96833
10/05/04	Lenoir	C	F	16-125-14	35.13500	-77.60167
10/07/04	Martin	C	M	16-9-8	35.98500	-77.28500
10/10/04	Beaufort	C	M	17-50-25	35.60167	-76.83500
10/15/04	Buncombe	M	M	11-66-19	35.53500	-82.51833
10/17/04	Jones	C	F	16-129-21	35.10167	-77.31833
10/22/04	Washington	C	M	17-16-5	35.91833	-76.66833
10/25/04	McDowell	M	M	11-59-3	35.66833	-82.11833
10/27/04	Lenoir	C	-	16-113-18	35.20167	-77.61833
10/30/04	Columbus	C	F	23-104-1	34.32500	-78.40833
10/30/04	Madison	M	M	11-39-11	35.71833	-82.81833
11/04/04	Craven	C	M	16-119-13	35.21833	-77.11833
11/06/04	Cumberland	C	M	23-16-10	34.90167	-78.66833
11/06/04	Henderson	M	F	11-89-23	35.35167	-82.61833
11/07/04	McDowell	M	M	11-59-6	35.65167	82.15167
11/09/04	Martin	C	M	16-21-25	35.85167	-77.25167
11/12/04	Beaufort	C	F	17-66-2	35.58500	-76.55167
11/12/04	Bladen	C	M	23-52-8	34.65167	-78.70167
11/13/04	Bertie	C	M	6-143-5	36.08500	-77.08500
11/13/04	Martin	C	F	17-25-7	35.81833	-76.96833
11/18/04	Beaufort	C	F	17-62-20	35.53500	-76.83500
11/18/04	Bertie	C	M	7-134-25	36.01833	-76.83500
11/20/04	Lenoir	C	F	16-113-9	35.23500	-77.60167
11/23/04	Hyde	C	F	17-54-25	35.60167	-76.50167
11/24/04	Lenoir	C	F	16-113-22	35.18500	-77.63500
11/25/04	Jones	C	F	16-126-9	35.15167	-77.51833
12/08/04	Martin	C	M	17-27-3	35.83500	-76.78500
12/09/04	Gates	C	M	7-85-5	36.41833	-76.91833
12/09/04	McDowell	M	M	11-58-11	35.63500	-82.23500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/13/04	Lenoir	C	F	16-125-7	35.15167	-77.63500
12/22/04	Edgecombe	P	F	16-4-25	35.93500	-77.66833
12/23/04	McDowell	M	-	11-57-15	35.63500	-82.25167
01/07/05	Dare	C	M	18-27-2	35.83500	-75.80167
01/07/05	Onslow	C	M	24-69-6	34.56833	-77.31833
01/10/05	Dare	C	M	17-15-4	35.91833	-76.76833
01/26/05	Brunswick	C	M	26-8-6	33.98500	-78.40167
01/31/05	Martin	C	F	16-20-15	35.88500	-77.33500
04/12/05	Buncombe	M	M	11-56-19	35.61833	-82.35167
05/02/05	Bladen	C	M	23-40-11	34.71833	-78.73500
05/03/05	Edgecombe	P	M	6-41-16	36.70167	-77.65167
05/11/05	Pender	C	M	24-74-8	34.48500	-77.86833
05/13/05	Columbus	C	M	23-104-3	34.33500	-78.36833
05/14/05	Haywood	M	M	10-48-4	35.75167	-83.01833
05/14/05	Jones	C	F	16-128-4	35.16833	-77.35167
05/21/05	Haywood	M	M	10-48-4	35.75167	-83.01833
05/21/05	McDowell	M	M	11-58-10	35.65167	-82.16833
05/22/05	Burke	M	M	12-38-20	35.70167	-81.83500
05/24/05	Pitt	C	M	16-92-13	35.38500	-77.36833
05/25/05	Buncombe	M	M	11-65-16	35.53500	-82.65167
05/25/05	Edgecombe	P	M	16-19-25	35.85167	-77.41833
05/26/05	Bladen	C	M	23-67-24	34.51833	-78.43500
05/26/05	Lenoir	C	M	16-103-13	35.30167	-77.45167
05/27/05	Haywood	M	M	11-62-10	35.56833	-82.83500
05/30/05	Bertie	C	M	7-122-5	36.16833	-76.83500
06/03/05	Beaufort	C	M	17-64-15	35.55167	-76.66833
06/03/05	Lenoir	C	M	16-112-20	35.20167	-77.66833
06/04/05	Pender	C	M	24-49-21	34.60167	-77.98500
06/07/05	Pender	C	M	24-74-23	34.43500	-77.86833
06/11/05	Cumberland	C	M	15-2-9	35.98500	-78.85167
06/15/05	Tyrrell	C	M	17-11-21	35.93500	-76.15167
06/17/05	Pitt	C	M	16-69-11	35.55167	-77.31833
06/17/05	Washington	C	M	17-16-3	35.91833	-76.70167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/19/05	Beaufort	C	M	17-101-17	35.28500	-76.63500
06/19/05	Bladen	C	M	23-31-7	34.81833	-78.46833
06/19/05	Pender	C	M	24-37-19	34.70167	-77.93500
06/21/05	Pitt	C	M	16-53-20	35.61833	-77.58500
06/23/05	Avery	M	M	2-122-19	36.11833	-81.85167
06/23/05	Beaufort	C	F	17-66-6	35.56833	-76.56833
06/23/05	Pender	C	M	24-88-14	34.38500	-77.68500
06/23/05	Tyrrell	C	M	17-24-2	35.91833	-76.05167
06/24/05	Halifax	C	M	6-111-15	36.21833	-77.75167
06/25/05	Camden	C	M	7-68-19	36.53500	-76.35167
06/25/05	Duplin	C	M	16-133-8	35.06833	-77.95167
06/25/05	McDowell	M	-	11-57-15	35.63500	-82.25167
06/28/05	Johnston	P	M	15-66-21	35.51833	-78.56833
06/29/05	Hertford	C	F	6-109-4	36.25167	-77.93500
07/01/05	Brunswick	C	M	26-141-23	33.01833	-78.28500
07/01/05	Currituck	C	F	7-83-8	36.48500	-76.11833
07/07/05	Pender	C	M	24-37-14	34.71833	-77.93500
07/08/05	Beaufort	C	F	16-71-18	35.53500	-77.11833
07/11/05	Pitt	C	M	16-53-21	35.60167	-77.65167
07/11/05	Wilson	C	M	16-52-7	35.65167	-77.71833
07/13/05	Dare	C	M	18-13-7	35.90167	-75.96833
07/16/05	Columbus	C	M	22-101-5	34.33500	-79.58500
07/16/05	Onslow	C	M	24-19-22	34.85167	-77.46833
07/17/05	Columbus	C	M	23-102-1	34.33500	-78.56833
07/17/05	Craven	C	M	16-131-6	35.15167	-77.15167
07/19/05	Buncombe	M	F	11-57-14	35.63500	-82.26833
07/20/05	Hertford	C	M	7-98-5	36.33500	-76.83500
07/20/05	Washington	C	M	17-27-3	35.82833	-76.78500
07/26/05	Buncombe	M	M	11-55-25	35.60167	-82.41833
08/02/05	Buncombe	M	F	11-65-16	35.53500	-82.65167
08/03/05	Avery	M	M	2-122-24	36.10167	-81.85167
08/03/05	Martin	C	F	16-48-11	35.71833	-77.06833
08/10/05	Pitt	C	-	16-80-20	35.45167	-77.33500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/11/05	Watauga	M	M	2-114-10	36.23500	-81.50167
08/14/05	Sampson	C	M	15-130-14	35.13500	-78.18500
08/20/05	Cumberland	C	F	15-124-19	35.11833	-78.68500
08/27/05	Currituck	C	M	7-96-11	36.38500	-76.06833
08/30/05	Haywood	M	M	10-60-13	35.63500	-83.03500
08/31/05	Northampton	C	M	6-106-18	36.27500	-77.21500
09/22/05	Craven	C	M	16-130-10	35.15167	-77.16833
09/23/05	Avery	M	F	2-122-15	36.13500	-81.83500
09/25/05	Buncombe	M	M	11-56-19	35.61833	-82.35167
09/25/05	Lenoir	C	F	16-125-22	35.10167	-77.63500
09/27/05	Halifax	C	M	6-88-20	36.36833	-77.66833
09/28/05	Onslow	C	M	24-55-2	34.66833	-77.46833
09/28/05	Washington	C	F	17-28-7	35.81833	-76.71833
09/30/05	Pender	C	-	24-74-23	34.43500	-77.86833
10/02/05	Beaufort	C	F	16-84-16	35.45167	-77.06833
10/02/05	Washington	C	F	17-16-5	35.91833	-76.66833
10/04/05	Pender	C	M	24-51-12	34.63500	-77.80167
10/04/05	Pitt	C	F	16-67-25	35.51833	-77.41833
10/04/05	Wilson	C	F	16-27-5	35.83500	-77.75167
10/05/05	Jones	C	M	16-115-14	35.21833	-77.43500
10/05/05	Polk	M	M	11-105-25	35.26833	-82.25167
10/10/05	Lenoir	C	F	16-114-14	35.21833	-77.51833
10/12/05	Onslow	C	M	24-56-24	34.60167	-77.35167
10/13/05	Camden	C	F	7-120-4	36.25167	-76.01833
10/13/05	Perquimans	C	M	7-114-17	36.20167	-76.55167
10/17/05	Jackson	M	F	10-83-24	35.43500	-83.10167
10/17/05	Jackson	M	F	10-83-24	35.43500	-83.10167
10/18/05	Washington	C	M	17-20-12	35.88500	-76.38500
10/20/05	Madison	M	M	11-15-3	35.91833	-82.78500
10/21/05	Chowan	C	-	7-125-17	36.11833	-76.63500
10/21/05	Madison	M	M	11-18-24	35.85167	-82.51833
10/23/05	McDowell	M	M	11-57-15	35.63500	-82.25167
10/24/05	McDowell	M	F	11-48-19	35.70167	-82.01833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/24/05	McDowell	M	F	11-48-19	35.70167	-82.01833
10/24/05	McDowell	M	F	11-48-19	35.70167	-82.01833
10/26/05	McDowell	M	F	11-48-19	35.70167	-82.01833
10/26/05	Perquimans	C	-	7-103-24	36.26833	-76.43500
10/28/05	Onslow	C	M	24-44-15	34.71833	-77.33500
10/30/05	Currituck	C	F	8-98-17	36.28500	-75.88500
10/30/05	Nash	P	M	15-46-8	35.73500	-78.20167
11/01/05	Avery	M	M	2-122-19	36.11833	-81.85167
11/01/05	Currituck	C	-	7-83-15	36.46833	-76.08500
11/01/05	Jones	C	F	16-115-20	35.20167	-77.41833
11/05/05	Bertie	C	M	6-120-21	36.18500	-77.06833
11/05/05	Gates	C	F	7-74-15	36.46833	-76.83500
11/05/05	Hertford	C	F	7-98-15	36.30167	-76.83500
11/05/05	Madison	M	M	1-6-16	36.95167	-82.56833
11/05/05	Perquimans	C	F	7-103-23	36.26833	-76.45167
11/05/05	Polk	M	M	11-105-25	35.26833	-82.25167
11/13/05	Jones	C	M	16-139-14	35.05167	-77.43500
11/17/05	Gates	C	F	7-77-11	36.46833	-76.65167
11/18/05	Beaufort	C	M	17-41-17	35.70167	-76.63500
11/19/05	Onslow	C	M	24-9-21	34.93500	-77.31833
11/20/05	Caldwell	M	F	2-137-10	36.06833	-81.58500
11/21/05	Pitt	C	F	16-81-20	35.45167	-77.25167
11/21/05	Tyrrell	C	M	17-24-3	35.91833	-76.03500
11/21/05	Washington	C	M	17-17-7	35.90167	-76.63500
11/25/05	Dare	C	M	18-15-18	35.86833	-75.78500
11/26/05	Bladen	C	M	23-43-4	34.75167	-78.43500
11/27/05	Washington	C	M	17-17-13	35.88500	-76.61833
12/02/05	Tyrrell	C	M	17-58-22	35.60167	-76.21833
12/02/05	Tyrrell	C	-	17-58-	35.68500	-76.16833
12/03/05	Buncombe	M	F	11-67-5	35.58500	-82.41833
12/04/05	Bladen	C	M	23-29-17	34.78500	-78.63500
12/05/05	Currituck	C	F	7-196-7	36.31833	-76.71833
12/06/05	Craven	C	M	16-118-25	35.18500	-77.16833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/06/05	Dare	C	M	18-13-15	35.88500	-75.91833
12/09/05	Martin	C	M	16-33-2	35.83500	-77.30167
12/20/05	Dare	C	M	18-13-15	35.88500	-75.91833
12/23/05	Bertie	C	M	17-4-16	35.95167	-76.73500
12/23/05	McDowell	M	M	11-48-18	35.70167	-82.03500
12/27/05	Hertford	C	-	7-85-4	36.41833	-76.93500
01/06/06	Martin	C	M	16-36-17	35.78500	-77.05167
01/07/06	Cumberland	C	-	15-135-15	35.05167	-78.75167
01/12/06	Gates	C	M	7-88-5	36.41833	-76.66833
01/20/06	Hertford	C	F	7-98-22	36.26833	-76.88500
01/25/06	Currituck	C	F	7-70-16	36.53500	-76.23500
02/21/06	Cumberland	C	F	15-136-11	35.05167	-78.73500
03/08/06	Perquimans	C	F	7-103-22	36.26833	-76.46833
03/19/06	Edgecombe	P	F	15-17-10	35.90167	-78.58500
04/23/06	Gates	C	M	7-77-18	36.45167	-76.61833
04/25/06	Hyde	C	M	17-60-19	35.61833	-76.01833
04/30/06	Bertie	C	M	7-123-6	36.15167	-76.81833
05/02/06	Buncombe	M	M	11-55-18	35.61833	-82.45167
05/04/06	Hyde	C	M	17-56-16	35.61833	-82.48500
05/05/06	Hyde	C	F	17-67-2	35.58500	-76.46833
05/09/06	Dare	C	M	18-13-15	35.88500	-75.91833
05/11/06	Beaufort	C	M	17-64-25	35.51833	-76.66833
05/14/06	Polk	M	M	11-106-22	35.26833	-82.21833
05/18/06	Bertie	C	M	7-110-21	36.18500	-76.90167
05/18/06	Cherokee	M	M	10-121-21	35.10167	-83.98500
05/22/06	Duplin	C	M	16-1-8	35.98500	-77.95167
05/23/06	Pitt	C	M	16-52-15	35.63500	-77.66833
05/29/06	Washington	C	-	17-16-8	35.90167	-76.70167
05/30/06	Pender	C	F	24-87-13	34.38500	-77.78500
05/30/06	Yancey	M	F	11-20-15	35.88500	-82.33500
05/31/06	Currituck	C	M	8-98-16	36.28500	-75.90167
06/05/06	Duplin	C	M	16-136-11	35.05167	-77.73500
06/08/06	Craven	C	M	16-107-2	35.33500	-77.13500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/08/06	Macon	M	M	10-115-23	35.18500	-83.45167
06/09/06	Pender	C	F	23-72-12	34.55167	-78.05167
06/09/06	Pitt	C	M	16-56-4	35.66833	-77.35167
06/11/06	Camden	C	M	7-94-12	36.38500	-76.21833
06/11/06	Duplin	C	M	23-11-20	34.95167	-78.08500
06/13/06	Pender	C	M	24-74-20	34.45167	-77.83500
06/15/06	Hertford	C	M	7-99-7	36.31833	-76.80167
06/25/06	Dare	C	F	18-13-15	35.88500	-75.91833
06/28/06	Beaufort	C	F	17-63-21	35.51833	-76.81833
06/29/06	Buncombe	M	M	11-65-19	35.53500	-82.60167
06/29/06	Transylvania	M	-	11-99-8	35.31833	-82.78500
07/04/06	Onslow	C	F	25-57-16	34.61833	-76.31833
07/05/06	Currituck	C	M	8-96-10	36.40167	-75.00167
07/07/06	Hyde	C	F	17-53-10	35.65167	-76.58500
07/07/06	Northampton	C	M	6-94-19	36.36833	-77.18500
07/09/06	Columbus	C	F	23-89-25	34.35167	-78.58500
07/13/06	Surry	M	-	3-64-11	36.55167	-80.73500
07/19/06	Tyrrell	C	M	17-34-24	35.76833	-76.18500
07/20/06	Perquimans	C	M	7-126-19	36.11833	-76.51833
07/22/06	Beaufort	C	F	17-53-14	35.63500	-76.60167
07/22/06	Craven	C	M	16-129-5	35.16833	-77.25167
07/28/06	Tyrrell	C	M	17-23-3	35.91833	-76.11833
07/31/06	Carteret	C	F	25-47-5	34.75167	-76.08500
08/02/06	Craven	C	F	16-130-2	35.16833	-77.21833
08/02/06	Craven	C	M	25-1-13	34.96833	-76.95167
08/05/06	Watauga	M	M	2-123-4	36.16833	-81.76833
08/13/06	Hyde	C	M	17-67-24	35.51833	-76.43500
08/14/06	Hertford	C	F	7-98-20	36.28500	-76.83500
08/14/06	Jones	C	M	16-128-5	35.16833	-77.33500
08/15/06	Hyde	C	F	17-60-11	35.63500	-76.06833
08/17/06	Jackson	M	F	10-132-15	35.13500	-83.00167
08/17/06	Jones	C	M	16-128-4	35.16833	-77.35167
08/18/06	Martin	C	F	16-33-3	35.83500	-77.28500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/19/06	Lenoir	C	M	16-114-9	35.23500	-77.51833
08/21/06	Gates	C	M	7-77-12	36.46833	-76.63500
08/25/06	Yancey	M	M	11-9-4	36.00167	-82.26833
08/28/06	Buncombe	M	F	11-65-25	35.51833	-82.58500
08/30/06	Bertie	C	M	17-2-23	35.93500	-76.86833
09/05/06	Tyrrell	C	M	17-46-5	35.75167	-76.16833
09/10/06	Columbus	C	M	23-104-12	34.30167	-78.38500
09/16/06	Currituck	C	F	8-85-1	36.41833	-75.98500
09/17/06	Pender	C	F	24-86-17	34.36833	-77.88500
09/17/06	Tyrrell	C	M	17-21-3	35.91833	-76.28500
09/19/06	Bladen	C	M	23-53-10	34.65167	-78.58500
09/20/06	Gates	C	F	7-78-19	36.45167	-76.51833
09/23/06	Beaufort	C	M	17-66-8	35.56833	-76.53500
09/25/06	Beaufort	C	F	17-111-4	35.25167	-76.76833
09/25/06	Pamlico	C	M	17-113-13	35.21833	-76.61833
09/29/06	Madison	M	F	11-19-14	35.88500	-82.43500
10/01/06	Edgecombe	P	F	16-16-17	35.86833	-77.71833
10/03/06	Onslow	C	M	24-67-6	34.56833	-77.48500
10/05/06	Duplin	C	F	16-3-5	36.00167	-77.75167
10/08/06	Beaufort	C	M	17-51-16	35.61833	-76.81833
10/09/06	Beaufort	C	M	17-98-14	35.30167	-76.85167
10/13/06	Pitt	C	M	16-81-11	35.46833	-77.31833
10/14/06	Beaufort	C	M	16-84-18	35.45167	-77.03500
10/14/06	Beaufort	C	F	16-83-17	35.45167	-77.13500
10/14/06	Haywood	M	M	10-47-5	35.75167	-83.08500
10/15/06	Hertford	C	F	7-86-23	36.35167	-76.86833
10/15/06	Jones	C	-	16-141-11	35.05167	-77.31833
10/15/06	Jones	C	-	16-140-2	35.08500	-77.38500
10/17/06	Carteret	C	M	25-26-	34.85167	-76.83500
10/17/06	Craven	C	M	17-121-18	35.11833	-76.95167
10/17/06	Washington	C	M	17-21-2	35.91833	-76.30167
10/20/06	Buncombe	M	F	11-53-20	35.61833	-82.58500
10/20/06	Cherokee	M	M	9-132-19	35.11833	-84.01833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/25/06	Buncombe	M	-	11-66-20	35.53500	-82.50167
10/25/06	Chowan	C	M	7-101-12	36.30167	-76.63500
10/25/06	Northampton	C	M	6-95-6	36.40167	-77.15167
10/26/06	Buncombe	M	M	11-78-1	35.50167	-82.56833
10/29/06	Beaufort	C	F	17-99-9	35.31833	-76.76833
10/29/06	Graham	M	F	10-86-14	35.38500	-83.85167
10/30/06	Beaufort	C	F	17-99-9	35.31833	-76.76833
10/30/06	Bladen	C	F	23-44-18	34.70167	-78.36833
10/30/06	Haywood	M	M	10-48-14	35.71833	-83.01833
10/31/06	Camden	C	M	7-108-24	36.26833	-76.01833
10/31/06	Haywood	M	M	10-48-4	35.75167	-83.01833
10/31/06	Haywood	M	-	11-49-6	35.65167	-82.28500
11/02/06	Gates	C	M	7-78-18	36.45167	-76.53500
11/06/06	Bertie	C	F	6-119-14	36.21833	-77.10167
11/06/06	Bladen	C	M	23-43-8	34.73500	-78.45167
11/07/06	Buncombe	M	F	11-79-1	35.50167	-82.48500
11/08/06	Tyrrell	C	M	17-23-3	35.91833	-76.11833
11/10/06	Macon	M	F	10-128-13	35.13500	-83.36833
11/10/06	Swain	M	M	10-80-17	35.45167	-83.38500
11/12/06	Buncombe	M	M	11-41-25	35.68500	-82.58500
11/15/06	Jones	C	M	16-115-15	35.21833	-77.41833
11/15/06	Lenoir	C	M	16-112-20	35.20167	-77.66833
11/17/06	Hyde	C	M	17-69-16	35.53500	-76.31833
11/18/06	Carteret	C	F	24-35-13	34.80167	-77.11833
11/19/06	Currituck	C	-	8-97-4	36.33500	-75.93500
11/21/06	Tyrrell	C	M	17-46-5	35.75167	-76.16833
11/23/06	Macon	M	F	10-126-24	35.10167	-83.51833
11/24/06	Martin	C	M	17-26-9	35.81833	-76.85167
11/24/06	Pamlico	C	F	17-113-13	35.21833	-76.61833
11/25/06	Craven	C	M	25-1-12	34.96833	-76.96833
11/25/06	Martin	C	F	17-37-7	35.73500	-76.96833
11/26/06	Beaufort	C	F	17-65-5	35.58500	-76.58500
11/26/06	Edgecombe	P	M	16-20-22	35.85167	-77.38500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/27/06	Bertie	C	M	7-110-11	36.21833	-76.90167
11/27/06	Jones	C	M	24-10-6	34.98500	-77.23500
11/28/06	Gates	C	M	7-88-12	36.38500	-76.71833
11/29/06	Jones	C	M	16-139-22	35.01833	-77.46833
11/29/06	Northampton	C	M	6-81-20	36.45167	-77.25167
11/29/06	Pitt	C	M	16-81-24	35.43500	-77.26833
11/30/06	Pitt	C	F	16-46-1	35.75167	-77.23500
11/30/06	Pitt	C	M	16-46-1	35.75167	-77.23500
12/02/06	Gates	C	F	7-78-19	36.45167	-76.51833
12/08/06	Tyrrell	C	M	17-24-3	35.91833	-76.03500
12/14/06	Jones	C	M	16-116-17	35.20167	-77.38500
12/14/06	Pitt	C	-	16-81-2	35.50167	-77.30167
12/16/06	McDowell	M	-	11-36-13	35.80167	-82.03500
12/17/06	McDowell	M	M	12-62-7	35.56833	-81.88500
12/19/06	Jones	C	M	16-115-15	35.21833	-77.41833
12/21/06	Hyde	C	-	17-55-21	35.60167	-76.48500
12/21/06	McDowell	M	-	11-58-11	35.63500	-82.23500
12/30/06	Beaufort	C	M	17-66-9	35.56833	-76.51833
12/31/06	Avery	M	F	2-134-8	36.06833	-81.86833
01/31/07	Lenoir	C	M	16-114-22	35.18500	-77.55167
02/23/07	Onslow	C	M	24-32-5	34.83500	-77.33500
03/27/07	Buncombe	M	M	11-67-3	35.58500	-82.45167
03/29/07	Bertie	C	M	7-111-9	36.23500	-76.76833
04/06/07	Jones	C	M	16-137-22	35.01833	-77.63500
04/12/07	Bertie	C	M	6-120-17	36.20167	-77.05167
04/12/07	Lenoir	C	M	16-113-9	35.23500	77.60167
04/12/07	Lenoir	C	F	16-113-9	35.23500	77.60167
04/12/07	Lenoir	C	M	16-113-9	35.23500	77.60167
04/18/07	Graham	M	M	10-100-102	35.35167	-83.66833
04/20/07	Bladen	C	F	23-67-12	34.55167	-78.46833
04/22/07	Gates	C	F	7-90-12	36.38500	-76.55167
04/23/07	Columbus	C	F	--	34.14467	-78.62933
04/24/07	Gates	C	M	7-89-9	36.40167	-76.60167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
04/25/07	Craven	C	F	16-132-3	35.16833	-77.03500
04/25/07	Currituck	C	F	7-96-10	36.40167	-76.00167
05/01/07	Lenoir	C	-	16-113-8	35.23500	-77.61833
05/01/07	Lenoir	C	F	16-113-8	35.23500	-77.61833
05/07/07	Buncombe	M	M	11-57-17	35.61833	-82.30167
05/07/07	McDowell	M	M	11-57-15	35.63500	-82.25167
05/07/07	Washington	C	M	17-19-2	35.90500	-76.47167
05/09/07	Currituck	C	M	7-84-20	36.45167	-76.00167
05/09/07	Madison	M	M	11-28-8	35.81833	-82.70167
05/10/07	Washington	C	M	17-29-14	35.80167	-76.60167
05/12/07	Bertie	C	M	7-135-15	36.05167	-76.75167
05/12/07	Carteret	C	M	17-14-23	35.85167	-76.86833
05/14/07	Bladen	C	M	23-78-4	34.54917	-78.56167
05/14/07	Pender	C	F	24-62-1	34.58500	-77.90167
05/15/07	Beaufort	C	F	17-39-24	35.68500	-76.76833
05/17/07	Dare	C	M	18-27-8	35.48401	-75.47296
05/17/07	Northampton	C	F	6-106-19	36.28266	-77.19701
05/18/07	Haywood	M	M	11-61-2	35.58500	-82.96833
05/18/07	Pender	C	M	24-50-21	34.60167	-77.90167
05/19/07	Currituck	C	M	7-96-10	36.40167	-76.00167
05/20/07	Sampson	C	M	15-18-9	35.90167	-78.51833
05/21/07	Burke	M	M	12-40-17	35.70167	-81.71833
05/24/07	Tyrrell	C	-	17-23-3	35.91833	-76.11833
05/25/07	Lenoir	C	F	16-26-2	35.83500	-77.88500
05/26/07	Lenoir	C	M	16-126-2	35.16833	-77.55167
05/27/07	Columbus	C	M	23-104-6	34.31833	-78.40167
05/29/07	Gates	C	M	7-74-6	36.48500	-76.90167
05/31/07	Franklin	P	M	5-129-19	36.12000	-78.27143
05/31/07	Yancey	M	M	11-34-9	35.81833	-82.18500
06/01/07	Currituck	C	F	7-96-10	36.40167	-76.00167
06/01/07	Johnston	P	M	15-90-10	35.38457	-78.51377
06/04/07	Buncombe	M	M	11-55-24	35.60167	-82.43500
06/04/07	Carteret	C	M	25-26-3	34.83500	-76.86833

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/05/07	Pender	C	M	24-62-2	34.58500	-77.88500
06/06/07	Bertie	C	M	7-135-15	36.05167	-76.75167
06/07/07	Pitt	C	M	16-81-14	35.46833	-77.26833
06/08/07	Buncombe	M	-	11-63-15	35.55167	-82.75167
06/08/07	Jackson	M	M	10-131-17	35.11833	-83.13500
06/08/07	Jones	C	M	24-9-18	34.95167	-77.28500
06/12/07	McDowell	M	F	11-59-8	35.65167	-82.11833
06/15/07	Gates	C	M	7-89-9	36.40167	-76.60167
06/16/07	Jones	C	M	16-128-4	35.16833	-77.35167
06/19/07	Tyrrell	C	M	7-77-12	36.46833	-76.63500
06/20/07	Hertford	C	F	7-85-10	36.40167	-76.91833
06/20/07	Tyrrell	C	M	17-24-7	35.90167	-76.05167
06/21/07	Currituck	C	M	7-95-8	36.40167	-76.11833
06/22/07	Gates	C	F	7-76-16	36.45167	-76.73500
06/22/07	Martin	C	M	16-23-23	35.85167	-77.11833
06/23/07	Tyrrell	C	M	17-20-9	35.90167	-76.35167
06/23/07	Tyrrell	C	M	17-58-3	35.66833	-76.20167
06/24/07	Tyrrell	C	M	17-34-25	35.76833	-76.16833
06/25/07	Bertie	C	M	7-135-15	36.05167	-76.75167
06/26/07	Currituck	C	M	7-84-25	36.43500	-76.00167
06/26/07	McDowell	M	M	11-58-13	35.63500	-82.20167
06/26/07	Pasquotank	C	M	7-93-22	36.35167	-76.30167
06/28/07	Macon	M	M	10-116-22	35.18500	-83.38500
06/30/07	Gates	C	M	7-77-24	36.43500	-76.60167
07/01/07	Hyde	C	M	17-56-22	35.61833	-82.40167
07/02/07	Currituck	C	F	7-96-16	36.36833	-76.06833
07/03/07	Clay	M	F	10-137-5	35.08500	-83.58500
07/03/07	Polk	M	M	11-104-25	35.26833	-82.33500
07/06/07	Perquimans	C	M	7-103-22	36.26833	-76.46833
07/07/07	Camden	C	-	7-95-18	36.36833	-76.11833
07/08/07	Perquimans	C	-	7-126-9	36.15167	-76.51833
07/09/07	Dare	C	F	18-14-19	35.86833	-75.85167
07/11/07	Beaufort	C	M	16-71-22	35.51833	-77.13500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
07/13/07	Surry	M	U	3-78-6	36.48500	-80.56833
07/17/07	Perquimans	C	F	7-115-15	36.21833	-76.41833
07/20/07	Gates	C	-	7-85-5	36.41833	-76.91833
07/26/07	Buncombe	M	F	11-42-7	35.73500	-82.55167
07/31/07	Hyde	C	M	18-49-20	35.61833	-75.91833
08/04/07	Tyrrell	C	M	17-21-5	35.91833	-76.25167
08/13/07	Buncombe	M	M	11-65-14	35.55167	-82.60167
08/13/07	Currituck	C	M	8-85-18	36.36833	-75.95167
08/17/07	Pitt	C	M	16-70-3	35.58500	-77.20167
08/23/07	Chowan	C	M	7-137-5	36.08500	-76.58500
08/26/07	Tyrrell	C	M	17-23-4	35.91833	-76.10167
08/27/07	Lenoir	C	F	16-113-18	35.20167	-77.61833
08/30/07	Currituck	C	F	7-84-16	36.45167	-76.06833
09/11/07	Beaufort	C	F	16-83-18	35.45167	-77.11833
09/11/07	Gates	C	F	7-89-25	36.35167	-76.58500
09/11/07	Onslow	C	M	24-18-2	34.91833	-77.55167
09/12/07	Camden	C	M	7-68-13	36.55167	-76.36833
09/12/07	Camden	C	F	7-68-13	36.55167	-76.36833
09/12/07	Camden	C	F	7-68-13	36.55167	-76.36833
09/12/07	Gates	C	F	7-88-6	36.40167	-76.73500
09/15/07	Camden	C	M	7-68-13	36.55167	-76.36833
09/16/07	Craven	C	F	16-129-1	35.16833	-77.31833
09/18/07	Hertford	C	M	6-108-21	36.26833	-77.06833
09/21/07	Craven	C	M	16-130-9	35.15167	-77.18500
09/26/07	Gates	C	F	7-74-10	36.48500	-76.83500
09/29/07	Hyde	C	M	17-53-5	35.66833	-76.58500
09/29/07	Washington	C	-	17-28-12	35.80167	-76.71833
09/30/07	Camden	C	M	7-68-13	36.55167	-76.36833
10/11/07	Hyde	C	F	17-53-4	35.16833	-76.60167
10/11/07	Jones	C	F	16-143-16	35.03500	-77.15167
10/15/07	Craven	C	F	16-129-1	35.16833	-77.31833
10/16/07	Bladen	C	M	23-57-6	34.65167	-78.31833
10/19/07	Bladen	C	F	23-41-16	34.70167	-79.65167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/25/07	Cumberland	C	M	23-3-9	34.98500	-78.76833
10/28/07	Onslow	C	M	24-43-4	34.75167	-77.43500
10/29/07	Tyrrell	C	M	17-23-3	35.91833	-76.11833
11/02/07	Bertie	C	M	16-119-15	35.21833	-77.08500
11/05/07	Hyde	C	F	17-67-19	35.53500	-76.43500
11/05/07	Hyde	C	F	17-67-24	35.51833	-76.43500
11/06/07	Hyde	C	F	17-53-5	35.66833	-76.58500
11/08/07	Cumberland	C	F	15-16-21	35.85167	-78.73500
11/13/07	Buncombe	M	-	11-65-9	35.56833	-82.60167
11/13/07	Craven	C	F	17-121-11	35.13500	-76.98500
11/14/07	Martin	C	M	16-9-17	35.95167	-77.30167
11/14/07	Tyrrell	C	M	17-23-4	35.91833	-76.10167
11/17/07	Tyrrell	C	M	17-23-4	35.91833	-76.10167
11/18/07	Bertie	C	M	16-131-6	35.15167	-77.15167
11/25/07	Craven	C	M	16-130-2	35.16833	-77.21833
11/25/07	Jones	C	M	16-115-8	35.23500	-77.45167
11/26/07	Jones	C	F	16-141-11	35.05167	-77.31833
11/26/07	Onslow	C	F	24-21-20	34.86833	-77.25167
11/28/07	Dare	C	M	18-13-14	35.88500	-75.93500
11/29/07	Bertie	C	F	7-135-15	36.05167	-76.75167
11/30/07	Bertie	C	M	7-135-15	36.05167	-76.75167
12/01/07	Bertie	C	M	7-136-13	36.05167	-76.70167
12/03/07	Dare	C	M	18-27-2	35.82237	-75.80149
12/03/07	Pitt	C	M	16-80-20	35.45167	-77.33500
12/04/07	Hyde	C	M	17-83-9	35.48500	-76.10167
12/04/07	Hyde	C	F	17-83-9	35.48500	-76.10167
12/06/07	Carteret	C	F	25-19-25	34.85167	-76.41833
12/06/07	Tyrrell	C	M	17-20-8	35.90167	-76.36833
12/07/07	Bladen	C	F	23-52-10	34.65167	-78.66833
12/08/07	Camden	C	M	7-108-8	36.31833	-76.03500
12/10/07	Lenoir	C	F	16-125-7	35.15167	-77.63500
12/13/07	McDowell	M	-	11-58-13	35.63500	-82.20167
12/13/07	Polk	M	-	11-106-21	35.26833	-82.23500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
12/15/07	Craven	C	F	17-121-6	35.15167	-76.98500
12/15/07	Dare	C	M	18-13-14	35.88500	-75.93500
12/16/07	Mitchell	M	M	11-24-1	35.91833	-82.06833
12/20/07	Hertford	C	M	7-87-16	36.36833	-76.81833
01/02/08	Craven	C	M	16-129-1	35.16833	-77.31833
01/15/08	Duplin	C	M	23-11-2	35.00167	-78.13500
01/18/08	Bertie	C	M	17-2-13	35.96833	-76.86833
02/11/08	Pitt	C	M	16-58-15	35.63500	-77.16833
02/23/08	Jones	C	M	24-9-5	35.00167	-77.25167
03/03/08	Tyrrell	C	F	17-23-3	35.91833	-76.11833
03/19/08	Hyde	C	M	17-80-24	35.43500	-76.35167
03/20/08	Yancey	M	M	11-020-15	35.88500	-82.33500
03/25/08	Hyde	C	M	17-54-19	35.61833	-76.51833
04/01/08	Hertford	C	F	7-99-1	36.33500	-76.81833
04/01/08	Hertford	C	-	7-87-22	36.35167	-76.80167
04/12/08	Craven	C	M	16-121-18	35.11833	-77.95167
04/12/08	Tyrrell	C	M	17-24-6	35.90167	-76.06833
04/12/08	Washington	C	M	17-29-18	35.76786	-76.62347
04/14/08	Madison	M	M	11-030-13	35.80167	-82.53500
04/14/08	Tyrrell	C	M	17-21-3	35.91833	-76.28500
04/14/08	Tyrrell	C	M	17-21-6	35.90167	-76.31833
04/17/08	Pamlico	C	F	16-22-6	35.90167	-77.23500
04/17/08	Pender	C	F	24-74-13	34.46833	-77.86833
04/25/08	Bertie	C	F	17-3-17	35.95167	-76.80167
04/25/08	Macon	M	M	10-126-21	35.10167	-83.56833
04/28/08	Buncombe	M	M	11-42-7	35.73500	-82.55167
05/07/08	Avery	M	M	11-012-09	35.98500	-82.01833
05/07/08	Carteret	C	M	24-35-14	34.80167	-77.10167
05/09/08	Dare	C	F	18-015-13	35.87110	-75.78629
05/09/08	Dare	C	-	18-50-15	35.62405	-75.84368
05/11/08	Chowan	C	M	7-125-25	36.10167	-76.58500
05/12/08	Buncombe	M	M	11-032-11	35.80167	-82.40167
05/12/08	Tyrrell	C	F	17-11-21	35.93500	-76.15167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
05/14/08	Henderson	M	M	11-91-7	35.40167	-82.46833
05/15/08	Hyde	C	M	17-81-18	35.45167	-76.28500
05/20/08	Bertie	C	M	7-109-18	36.19500	-76.95500
05/20/08	Currituck	C	M	8-97-15	36.28833	-75.91833
05/21/08	Onslow	C	F	24-56-21	34.60167	-77.40167
05/22/08	Henderson	M	M	11-092-01	35.41833	-82.40167
05/23/08	Columbus	C	F	23-102-5	34.33500	-78.50167
05/24/08	Jones	C	M	--	35.17500	-77.35833
05/24/08	Northampton	C	M	6-91-20	36.36833	-77.41833
05/26/08	Cherokee	M	M	10-121-09	35.15167	-83.93500
05/26/08	Hertford	C	M	6-120-1	36.24167	-77.07500
05/28/08	Pender	C	M	24-3-3	35.00167	-77.78500
05/29/08	Cumberland	C	M	15-124-2	35.15833	-78.73167
06/01/08	Currituck	C	M	8-98-16	36.26833	-75.90833
06/03/08	Buncombe	M	-	11-54-11	35.63500	-82.56833
06/04/08	Martin	C	M	16-35-3	35.83500	-77.11833
06/04/08	New Hanover	C	M	24-98-8	34.31833	-77.86833
06/04/08	Sampson	C	M	--	35.01622	-78.54090
06/05/08	Martin	C	M	17-25-1	35.83500	-76.98500
06/11/08	Hyde	C	F	17-67-14	35.55167	-76.43500
06/12/08	Buncombe	M	M	11-056-19	35.61833	-82.35167
06/12/08	Tyrrell	C	F	17-58-12	35.63500	-76.21833
06/15/08	Brunswick	C	M	23-120-9	34.23500	-78.01833
06/16/08	Onslow	C	-	24-55-7	34.65167	-77.46833
06/16/08	Tyrrell	C	F	17-24-4	35.91833	-76.01833
06/17/08	Currituck	C	F	8-85-18	36.35500	-75.95833
06/17/08	Tyrrell	C	F	17-46-10	35.73500	-76.16833
06/21/08	Polk	M	-	11-106-25	35.26833	-82.16833
06/22/08	Cherokee	M	M	10-144-04	35.08500	-83.01833
06/23/08	Cumberland	C	M	23-2-9	34.98500	-78.85167
06/24/08	Pasquotank	C	-	7-92-5	36.41500	-76.33833
06/25/08	Lenoir	C	M	16-114-1	35.25167	-77.56833
06/26/08	Orange	P	M	4-143-7	36.06833	-79.13500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/26/08	Pender	C	-	23-96-3	34.41833	-78.03500
06/27/08	Currituck	C	M	8-97-10	36.30500	-75.92833
06/28/08	Bladen	C	M	23-64-22	34.50833	-78.72167
06/29/08	Wilkes	M	M	2-116-16	36.19336	-81.41744
06/30/08	Dare	C	F	18-26-25	35.74775	-75.82417
07/01/08	Onslow	C	-	24-44-22	34.68500	-77.38500
07/02/08	Wilson	C	M	16-39-22	35.67285	-77.80333
07/04/08	Brunswick	C	F	23-126-24	34.10167	-78.51833
07/05/08	Hyde	C	F	17-67-2	35.58500	-76.46833
07/08/08	Gates	C	M	7-86-3	36.41833	-76.86833
07/12/08	Buncombe	M	M	11-063-15	35.55167	-82.75167
07/13/08	McDowell	M	F	--	35.66730	-82.11730
07/14/08	Haywood	M	M	11-63-6	35.56833	-82.81833
07/14/08	Pitt	C	F	16-32-13	35.80167	-77.36833
07/22/08	Onslow	C	-	24-43-12	34.71833	-77.46833
07/24/08	Bertie	C	F	17-2-13	35.96833	-76.86833
07/24/08	Hertford	C	F	7-86-11	36.38500	-76.90167
07/24/08	Transylvania	M	M	11-121-19	35.11833	-82.93500
07/25/08	Nash	P	-	16-3-12	35.96833	-77.80167
07/26/08	Martin	C	M	16-21-25	35.85167	-77.25167
07/30/08	Bertie	C	F	7-35-15	36.80167	-76.08500
08/01/08	Tyrrell	C	M	17-24-2	35.91833	-76.05167
08/01/08	Washington	C	M	17-16-18	35.85500	-76.70833
08/02/08	Tyrrell	C	M	17-10-22	35.93500	-76.21833
08/04/08	Martin	C	-	16-22-11	35.87833	-77.23833
08/10/08	Tyrrell	C	F	17-11-16	35.95167	-76.15167
08/12/08	Chowan	C	M	7-113-11	36.21833	-76.65167
08/12/08	Tyrrell	C	F	17-9-18	35.95167	-76.28500
08/15/08	Washington	C	M	17-19-1	35.91833	-76.48500
08/16/08	Gates	C	M	7-76-17	36.45167	-76.71833
08/17/08	Currituck	C	M	8-97-10	36.30167	-75.92500
08/18/08	Martin	C	M	16-34-13	35.80167	-77.20167
08/18/08	Washington	C	F	17-17-15	35.88500	-76.58500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/20/08	Chowan	C	M	7-125-15	36.13500	-76.58500
08/21/08	Washington	C	F	17-16-9	35.90167	-76.68500
08/26/08	Currituck	C	F	7-70-21	36.50167	-76.24500
08/26/08	Currituck	C	M	07-070-21	36.50167	-76.24500
09/03/08	Madison	M	F	11-6-12	35.96833	-82.55167
09/03/08	Onslow	C	-	24-32-10	34.81833	-77.33500
09/03/08	Onslow	C	-	24-32-10	34.81833	-77.33500
09/10/08	Hertford	C	F	6-107-19	36.28167	-77.10500
09/10/08	Washington	C	F	17-17-15	35.88500	-76.58500
09/15/08	Craven	C	M	24-13-4	34.91833	-77.93500
09/15/08	Hyde	C	F	17-67-14	35.55167	-76.43500
09/18/08	Dare	C	F	18-15-12	35.86647	-75.83064
09/23/08	Pender	C	M	4-82-4	36.50167	-79.18500
09/25/08	Madison	M	M	11-019-16	35.86833	-82.48500
09/28/08	Currituck	C	M	08-085-01	36.41167	-75.99833
09/29/08	Hyde	C	F	18-61-13	35.55167	-75.95167
10/01/08	Dare	C	M	18-14-11	35.86833	-75.90167
10/04/08	Gates	C	-	7-77-18	36.44500	-76.62500
10/06/08	Hyde	C	M	17-54-19	35.60833	-76.52833
10/06/08	Yancey	M	F	11-034-09	35.81833	-82.18500
10/07/08	Dare	C	M	18-014-20	35.86658	-75.83072
10/07/08	Dare	C	M	18-15-12	35.86901	-75.80732
10/08/08	Buncombe	M	M	11-76-6	35.48500	-82.73500
10/09/08	Camden	C	F	7-68-13	36.55167	-76.36833
10/10/08	Hertford	C	M	7-85-9	36.40833	-76.99500
10/11/08	Currituck	C	F	8-85-1	36.39500	-75.94833
10/12/08	Bertie	C	M	7-136-13	36.03500	-76.70833
10/13/08	Camden	C	M	07-094-06	36.38833	-76.24500
10/13/08	Currituck	C	F	8-85-1	36.40833	-75.99833
10/15/08	Tyrrell	C	M	17-34-14	35.79167	-76.19167
10/16/08	McDowell	M	F	11-58-14	35.63500	-82.18500
10/16/08	Tyrrell	C	F	17-20-10	35.90167	-76.33500
10/17/08	Hyde	C	M	17-41-24	35.67167	-76.61500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/18/08	Clay	M	M	10-137-14	35.05167	-83.60167
10/19/08	McDowell	M	M	--	35.62688	-82.20383
10/20/08	Jackson	M	F	10-106-9	35.31833	-83.18500
10/21/08	Craven	C	M	16-129-1	35.16833	-77.31833
10/21/08	Currituck	C	F	7-95-15	36.38500	-76.08500
10/27/08	Tyrrell	C	F	17-21-1	35.91833	-76.31833
10/27/08	Tyrrell	C	M	17-10-24	35.93500	-76.18500
10/28/08	Buncombe	M	M	11-41-25	35.68500	-82.58500
10/28/08	Onslow	C	F	24-32-6	34.81833	-77.40167
10/29/08	Gates	C	F	7-63-8	36.56833	-76.78500
10/30/08	Bladen	C	M	23-28-19	34.78500	-78.68500
10/30/08	Craven	C	F	25-15-11	34.88500	-76.81833
10/31/08	Brunswick	C	M	23-128-17	34.11833	-78.38500
11/01/08	Bertie	C	M	7-136-11	36.05167	-76.73500
11/02/08	Dare	C	M	18-014-19	35.86967	-75.87497
11/03/08	Bertie	C	M	7-136-11	36.05167	-76.73500
11/03/08	Tyrrell	C	F	17-22-18	35.86833	-76.20167
11/08/08	Beaufort	C	F	17-100-20	35.28500	-76.66833
11/10/08	Hyde	C	M	17-54-12	35.62500	-76.56167
11/10/08	Hyde	C	M	18-61-21	35.51833	-75.98500
11/10/08	Jones	C	F	16-140-2	35.08500	-77.38500
11/10/08	Washington	C	F	17-7-16	35.95167	-76.48500
11/11/08	Camden	C	M	07-095-21	36.34833	-76.15167
11/12/08	Buncombe	M	M	11-077-10	35.48500	-82.58500
11/12/08	Currituck	C	M	7-96-9	36.38833	-76.03167
11/12/08	Hyde	C	F	17-54-18	35.61167	-76.54167
11/12/08	Onslow	C	F	24-56-19	34.61833	-77.35167
11/12/08	Washington	C	F	17-16-14	35.88500	-76.68500
11/13/08	Hyde	C	M	17-54-18	35.60833	-76.53500
11/14/08	Currituck	C	M	7-96-7	36.38500	-76.06500
11/14/08	Hyde	C	M	17-54-12	35.62500	-76.56500
11/17/08	Buncombe	M	M	11-054-19	35.61833	-82.51833
11/17/08	Washington	C	M	17-018-10	35.89500	-76.51167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/22/08	Bertie	C	M	7-123-6	36.14167	-76.82500
11/22/08	Hertford	C	-	7-98-15	36.28500	-76.83500
11/23/08	Bertie	C	F	7-136-11	36.03833	-76.74833
11/23/08	Bertie	C	M	7-136-11	36.03833	-76.74833
11/23/08	Madison	M	F	11-019-12	35.88500	-82.46833
11/26/08	Jones	C	M	16-139-5	35.08500	-77.41833
11/26/08	Washington	C	F	17-18-10	35.89500	-76.51167
12/01/08	Onslow	C	-	24-45-16	34.70167	-77.31833
12/01/08	Washington	C	M	17-16-14	35.87167	-76.69167
12/02/08	Gates	C	M	7-89-21	36.35167	-76.65167
12/03/08	Gates	C	M	7-79-17	36.45167	-76.46833
12/03/08	Lenoir	C	F	16-113-16	35.20167	-77.65167
12/04/08	Onslow	C	M	24-56-25	34.60167	-77.33500
12/04/08	Tyrrell	C	-	17-34-19	35.78500	-76.18500
12/05/08	Beaufort	C	F	16-83-16	35.60167	-77.16500
12/06/08	Jones	C	F	16-139-10	35.06833	-77.41833
12/08/08	Greene	C	M	16-52-15	35.63500	-77.66833
12/08/08	Martin	C	F	17-27-3	35.82833	-76.78833
12/09/08	Haywood	M	-	10-48-24	35.68500	-83.01833
12/12/08	Gates	C	M	7-74-21	36.42167	-76.91167
12/13/08	Tyrrell	C	M	17-21-6	35.89833	-76.32500
12/14/08	Gates	C	F	7-78-18	36.44500	-76.54167
12/15/08	Camden	C	F	7-108-18	36.28500	-76.03500
12/15/08	Gates	C	M	7-78-18	36.44167	-76.54167
12/15/08	Northampton	C	M	06-116-09	36.23500	-77.35167
12/17/08	Onslow	C	M	24-43-16	34.70167	-77.48500
12/19/08	Washington	C	F	17-005-23	35.92167	-76.62833
01/02/09	Bertie	C	M	7-121-13	36.12167	-76.96167
01/04/09	Lenoir	C	F	16-125-2	35.15833	-77.64167
01/05/09	Hertford	C	M	7-99-17	36.26833	-76.80167
01/11/09	Dare	C	M	18-13-15	35.87194	-75.92757
01/28/09	Yancey	M	M	11-22-18	35.86833	-82.20167
01/30/09	Macon	M	F	10-126-17	35.11833	-83.55167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
02/08/09	Haywood	M	-	--	35.76622	-83.08024
03/09/09	Mitchell	M	M	1-143-17	36.03500	-82.13500
03/20/09	Currituck	C	M	8-97-10	36.31167	-75.93167
03/27/09	Avery	M	M	--	36.12000	-81.83400
04/10/09	Buncombe	M	M	11-76-6	35.47500	-82.74167
04/14/09	Pitt	C	M	16-68-11	35.54167	-77.40833
04/16/09	Dare	C	M	--	35.88469	-75.95232
04/16/09	Pitt	C	M	16-48-14	35.70833	-77.02500
04/21/09	Buncombe	M	M	11-42-11	35.70467	-82.57284
04/26/09	Northampton	C	M	--	36.25100	-77.31838
04/29/09	Nash	C	M	--	35.97945	-77.85381
04/30/09	Wilson	C	F	--	35.66578	-77.37614
05/01/09	Jones	C	M	16-139-	35.04167	-77.45833
05/03/09	Cumberland	C	M	--	34.89048	-78.58069
05/04/09	Currituck	C	M	7-83-15	36.45500	-76.08833
05/04/09	Currituck	C	M	7-83-14	36.46500	-76.10500
05/04/09	Pender	C	M	24-86-8	34.40960	-77.87075
05/12/09	Ashe	M	M	--	36.54659	-81.63290
05/15/09	Tyrrell	C	M	17-23-5	35.90500	-76.09500
05/18/09	Wilson	C	F	--	35.66160	-77.75410
05/21/09	Hyde	C	M	17-53-10	35.64833	-76.59167
05/22/09	Martin	C	F	17-27-3	35.82500	-76.79167
05/23/09	Surry	M	M	--	36.52288	-80.75397
05/28/09	Hyde	C	F	17-67-19	35.52167	-76.44833
05/29/09	Edgecombe	C	M	--	35.87401	-77.52808
06/01/09	Buncombe	M	M	--	35.60552	-82.31639
06/02/09	Buncombe	M	M	--	35.50780	-82.57274
06/02/09	Carteret	C	M	25-29-13	34.80386	-76.63106
06/03/09	Cumberland	C	M	--	35.20360	-78.66960
06/03/09	Tyrrell	C	-	--	35.89728	-76.07061
06/04/09	Hyde	C	M	17-67-24	35.50167	-76.44833
06/04/09	Mitchell	M	M	--	35.85900	-82.04800
06/04/09	Tyrrell	C	M	17-34-19	35.77500	-76.19167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/04/09	Tyrrell	C	F	17-46-23	35.67500	-76.20833
06/10/09	Currituck	C	-	8-85-7	36.38833	-75.97500
06/11/09	Dare	C	M	--	35.86188	-75.85749
06/12/09	Bertie	C	M	7-136-12	36.03833	-76.72167
06/12/09	Currituck	C	M	8-98-16	36.27500	-75.90833
06/17/09	Brunswick	C	M	--	34.09830	-78.30170
06/17/09	Richmond	P	M	--	34.91553	-79.67916
06/20/09	Hertford	C	M	7-98-5	36.31833	-76.83500
06/21/09	Jones	C	M	16-139-5	35.07500	-77.42500
06/22/09	Currituck	C	M	8-97-15	36.29500	-75.92167
06/23/09	Tyrrell	C	M	--	35.91621	-76.22467
06/25/09	Washington	C	M	17-19-2	35.90833	-76.47500
06/29/09	Orange	P	M	--	36.05243	-79.06311
07/02/09	Currituck	C	-	7-84-20	36.43500	-76.00833
07/02/09	Washington	C	F	--	35.88564	-76.69793
07/03/09	Bertie	C	M	7-135-12	36.03833	-76.72500
07/05/09	McDowell	M	M	--	35.69300	-82.08400
07/05/09	Robeson	C	M	23-73-18	34.44167	-78.95833
07/07/09	Washington	C	F	17-16-3	35.90833	-76.70833
07/10/09	Tyrrell	C	F	--	35.93211	-76.15816
07/13/09	Forsyth	P	M	3-129-11	36.11957	-80.33046
07/14/09	Jones	C	F	16-141-23	35.00833	-77.29167
07/15/09	Dare	C	F	--	35.84186	-75.80999
07/15/09	Tyrrell	C	M	--	35.81814	-76.19820
07/19/09	Granville	P	M	--	36.33389	-78.54639
07/22/09	Jackson	M	M	10-132-12	35.12500	-83.05833
07/24/09	Bertie	C	M	17-3-20	35.93833	-76.75167
07/25/09	Buncombe	M	F	11-56-23	35.59462	-82.36249
07/29/09	Clay	M	M	10-137-1	35.07389	-83.59056
07/31/09	Buncombe	M	M	--	35.63466	-82.58037
08/01/09	Dare	C	F	--	35.86885	-75.90782
08/05/09	Camden	C	M	7-68-13	36.53833	-76.37167
08/11/09	Carteret	C	M	25-28-1	34.82500	-76.74167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/11/09	Wilson	C	M	--	35.62386	-78.11914
08/15/09	Jackson	M	F	10-131-3	35.15028	-83.12306
08/17/09	Martin	C	M	17-27-2	35.82500	-76.80833
08/20/09	Buncombe	M	M	11-66-6	35.56380	-82.58092
08/20/09	Dare	C	F	--	35.86966	-75.79978
08/20/09	Washington	C	M	--	35.83167	-76.56167
09/01/09	Buncombe	M	M	11-67-2	35.57500	-82.47500
09/02/09	Jones	C	M	16-141-24	35.00833	-77.27500
09/08/09	Bertie	C	F	7-136-11	36.03833	-76.74833
09/08/09	Hyde	C	F	17-67-14	35.54167	-76.44167
09/10/09	Washington	C	-	--	35.89871	-76.50539
09/12/09	Dare	C	F	--	35.83764	-75.81170
09/18/09	Gaston	C	M	7-89-9	36.39167	-76.60833
09/19/09	Pender	C	M	24-74-23	34.42500	-77.87500
09/22/09	Currituck	C	F	7-96-16	36.36500	-76.06833
09/24/09	Currituck	C	F	7-83-14	36.46500	-76.10833
09/24/09	Currituck	C	M	7-83-14	36.46500	-76.10833
09/25/09	Caldwell	M	M	12-30-9	35.80833	-81.52500
09/25/09	Currituck	C	-	8-97-4	36.32500	-75.94167
09/28/09	Hertford	C	F	7-97-1	36.32500	-76.99833
09/29/09	Macon	M	F	10-126-4	35.15833	-83.52500
09/30/09	McDowell	M	M	--	35.78250	-82.04130
10/01/09	Swain	M	F	--	35.42715	-83.40605
10/03/09	Hertford	C	M	7-98-20	36.28167	-76.84500
10/04/09	Jones	C	-	16-143-14	35.04167	-77.10833
10/04/09	Jones	C	-	16-143-17	35.02500	-77.14167
10/04/09	Yancey	M	F	--	35.91700	-82.31400
10/04/09	Yancey	M	M	--	35.90900	-82.47600
10/05/09	Dare	C	F	--	35.87273	-75.92962
10/05/09	Jackson	M	M	10-83-25	35.42500	-83.09167
10/07/09	Haywood	M	F	10-48-24	35.67500	-83.02500
10/07/09	Haywood	M	-	10-48-24	35.67500	-83.02500
10/07/09	Haywood	M	-	10-48-24	35.67500	-83.02500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/07/09	Haywood	M	F	10-48-8	35.71714	-83.03515
10/08/09	Lenoir	C	M	16-100-16	35.27500	-77.74167
10/11/09	McDowell	M	-	--	35.62350	-82.21990
10/12/09	Beaufort	C	F	17-66-7	35.55833	-76.55833
10/12/09	Beaufort	C	F	17-66-7	35.55833	-76.55833
10/12/09	Haywood	M	-	10-48-24	35.67500	-83.02500
10/12/09	Haywood	M	M	--	35.69870	-83.04470
10/13/09	Buncombe	M	-	11-30-23	35.75839	-82.54350
10/13/09	Cherokee	M	F	--	35.02216	-84.11753
10/13/09	Graham	M	F	10-100-18	35.26925	-83.70155
10/13/09	Martin	C	F	17-27-2	35.82833	-76.80500
10/14/09	Buncombe	M	-	11-67-6	35.56433	-82.49937
10/14/09	Buncombe	M	-	11-67-6	35.56433	-82.49937
10/14/09	Dare	C	F	--	35.86231	-75.86164
10/16/09	Ashe	M	M	--	36.47023	-81.43916
10/18/09	Swain	M	M	10-79-12	35.44167	-83.46167
10/19/09	Beaufort	C	M	17-98-15	35.29167	-76.84167
10/19/09	Buncombe	M	M	--	35.62754	-82.45124
10/20/09	Beaufort	C	M	--	35.52269	-76.84249
10/21/09	Buncombe	M	F	--	35.60734	-82.38672
10/23/09	Buncombe	M	M	11-41-25	35.67381	-82.58380
10/24/09	Camden	C	-	7-68-19	36.52167	-76.36167
10/24/09	Swain	M	M	10-90-15	35.37167	-83.50167
10/26/09	Ashe	M	M	--	36.50288	-81.40715
10/26/09	Craven	C	M	16-129-5	35.15833	-77.25833
10/28/09	Cherokee	M	M	9-144-8	35.05833	-84.06472
11/01/09	Hyde	C	F	--	35.52579	-76.44270
11/01/09	Hyde	C	-	--	35.52579	-76.44270
11/02/09	Buncombe	M	M	--	35.75700	-82.54200
11/03/09	Buncombe	M	M	11-52-25	35.60932	-82.65355
11/04/09	Buncombe	M	M	--	35.55522	-82.64124
11/05/09	Bertie	C	F	7-134-16	36.02500	-76.90833
11/05/09	Tyrrell	C	F	17-23-5	35.90833	-76.09167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/06/09	Currituck	C	F	7-84-12	36.45167	-76.06500
11/06/09	Jones	C	F	16-129-1	35.15833	-77.32500
11/07/09	Clay	M	M	--	35.00178	-83.82536
11/10/09	Northampton	C	-	--	36.22663	-77.26918
11/12/09	Cherokee	M	M	10-112-17	35.18944	-83.72361
11/12/09	Haywood	M	M	--	35.60218	-83.00643
11/18/09	Hertford	C	M	6-95-15	36.37500	-77.08833
11/19/09	Currituck	C	-	7-84-25	36.42167	-76.00500
11/22/09	Macon	M	F	10-116-22	35.17833	-83.38500
11/24/09	Dare	C	M	--	35.82266	-75.80382
11/24/09	Haywood	M	-	--	35.75654	-83.03467
11/25/09	Onslow	C	M	--	34.84420	-77.29312
11/25/09	Tyrrell	C	M	--	35.92004	-76.13120
11/27/09	Washington	C	-	17-27-4	35.82500	-76.77500
11/27/09	Washington	C	-	17-27-3	35.82500	-76.79167
11/30/09	Currituck	C	-	7-83-8	36.48167	-76.13167
12/04/09	Northampton	C	F	--	36.24254	-77.23318
12/07/09	Tyrrell	C	M	17-58-3	35.65500	-76.20833
12/08/09	Dare	C	M	--	35.72048	-75.76896
12/09/09	Hertford	C	M	7-85-16	36.35167	-76.99500
12/11/09	Hyde	C	F	17-54-18	35.60833	-76.54167
12/15/09	Hertford	C	F	7-87-22	36.34500	-76.81167
12/15/09	Hertford	C	M	7-87-22	36.34500	-76.81167
12/16/09	Jones	C	M	16-128-9	35.14167	-77.35833
12/18/09	Currituck	C	F	7-96-16	36.35833	-76.07500
12/29/09	Dare	C	F	--	35.67329	-75.77970
12/31/09	Jones	C	M	16-116-16	35.19167	-77.40833
01/04/10	Martin	C	M	16-48-9	35.72500	-77.02167
01/07/10	Jones	C	M	16-142-9	35.05833	-77.19167
01/16/10	Yancey	M	M	--	35.54544	-82.14229
01/18/10	Dare	C	M	--	35.68023	-75.77998
02/19/10	Martin	C	M	16-33-1	35.83167	-77.32500
03/01/10	Hyde	C	F	17-81-1	35.50000	-76.31667

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
03/08/10	Swain	M	M	10-90-15	35.38121	-83.48923
03/12/10	Jackson	M	F	10-93-2	35.41833	-83.30167
04/05/10	Washington	C	-	17-16-8	35.89500	-76.70833
04/09/10	Wilson	P	M	--	35.59356	-77.98320
04/14/10	Washington	C	M	17-16-1	35.91500	-76.74167
04/17/10	Gates	C	-	7-89-21	36.37473	-76.65045
04/19/10	Tyrrell	C	M	17-22-15	35.88500	-76.16833
04/20/10	Edgecombe	P	F	--	35.84676	-77.41474
04/20/10	Gates	C	M	7-79-19	36.43833	-76.44500
04/23/10	Jones	C	M	24-22-	34.93500	-77.16833
04/24/10	Martin	C	M	16-24-21	35.85167	-77.06833
04/24/10	Martin	C	M	16-22-25	35.85167	-77.16833
04/30/10	Dare	C	M	--	35.70663	-75.76086
05/04/10	Nash	P	M	--	35.93470	-77.90667
05/04/10	Tyrrell	C	F	17-10-10	35.98500	-76.16833
05/07/10	Yancey	M	M	--	35.57572	-82.17029
05/08/10	Hyde	C	M	17-41-20	35.70167	-76.58500
05/09/10	Dare	C	M	--	35.61443	-75.82908
05/12/10	Dare	C	F	--	35.86729	-75.91017
05/14/10	Hyde	C	M	17-72-12	35.54500	-76.05833
05/14/10	Macon	M	M	10-140-12	35.05167	-83.38500
05/16/10	Johnston	P	M	--	35.26697	-78.38960
05/19/10	Edgecombe	C	M	--	35.85330	-77.44484
05/23/10	Washington	C	M	17-18-9	35.90167	-76.51833
05/27/10	Bertie	C	-	7-109-10	36.22167	-76.92833
05/27/10	Lenoir	C	M	--	35.11717	-77.71619
05/28/10	Columbus	C	M	23-99-3	34.33500	-78.78500
05/28/10	Hertford	C	-	7-86-25	36.33833	-76.84500
06/01/10	Polk	M	M	11-104-25	35.25100	-82.34100
06/02/10	Buncombe	M	-	11-56-23	35.60167	-82.36833
06/04/10	Dare	C	M	--	35.61738	-75.83337
06/04/10	Hertford	C	F	7-99-22	36.25833	-76.81500
06/04/10	Tyrrell	C	M	17-23-3	35.91500	-76.12500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/07/10	Avery	M	M	--	36.26926	-81.89753
06/08/10	Clay	M	M	10-135-14	35.03833	-83.76583
06/09/10	Camden	C	M	7-108-8	36.30167	-76.04167
06/10/10	Jones	C	F	24-10-21	34.93500	-77.23500
06/16/10	Wilson	P	M	--	35.67512	-77.85670
06/17/10	Wayne	P	M	--	35.18085	-77.88323
06/22/10	Nash	P	M	15-22-9	35.89500	-78.19200
06/22/10	Pasquotank	C	M	7-93-6	36.40167	-76.31833
06/22/10	Tyrrell	C	M	17-21-4	35.91167	-76.26833
07/01/10	Dare	C	M	--	35.85202	-75.80229
07/02/10	Dare	C	M	--	35.90896	-75.77760
07/04/10	Lenoir	C	-	16-126-2	35.16833	-77.55167
07/04/10	Pamlico	C	-	--	35.02236	-76.49784
07/04/10	Pitt	C	-	16-53-20	35.61833	-77.58500
07/07/10	Macon	M	M	10-126-15	35.12500	-83.50167
07/08/10	Currituck	C	M	7-83-15	36.45500	-76.08833
07/10/10	Tyrrell	C	M	17-21-2	35.90500	-76.31500
07/11/10	Dare	C	M	--	35.83586	-75.81097
07/11/10	Dare	C	M	--	35.85752	-75.79736
07/11/10	Edgecombe	P	M	--	35.83843	-77.38838
07/12/10	Currituck	C	M	8-98-16	36.28500	-75.90167
07/17/10	Tyrrell	C	M	17-20-22	35.84500	-76.38500
07/17/10	Tyrrell	C	-	17-21-3	35.91500	-76.28500
07/19/10	Iredell	P	M	--	35.77260	-80.86324
07/19/10	Washington	C	-	17-20-22	35.84500	-76.38500
07/31/10	Chowan	C	M	7-102-11	36.30167	-76.56833
07/31/10	Columbus	C	M	23-101-3	34.33500	-78.61833
07/31/10	Martin	C	F	16-36-7	35.80500	-77.05833
08/02/10	Gates	C	-	7-78-1	36.50167	-76.56833
08/06/10	Dare	C	M	--	35.83668	-75.81104
08/08/10	Dare	C	M	--	35.84366	-75.80976
08/09/10	Hyde	C	M	17-67-9	35.55500	-76.44167
08/16/10	Camden	C	M	7-95-21	36.33833	-76.16167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/16/10	Washington	C	F	--	35.95300	-76.47700
08/19/10	Camden	C	M	7-68-24	36.50500	-76.35500
08/20/10	Beaufort	C	M	17-65-4	35.58500	-76.60167
08/20/10	Jones	C	M	16-116-16	35.20167	-77.40167
08/23/10	Currituck	C	M	8-97-4	36.32423	-75.94114
08/26/10	Pender	C	M	24-62-1	34.58500	-77.90167
08/26/10	Pender	C	M	--	34.57818	-77.90380
08/27/10	Bladen	C	F	23-30-6	34.81833	-78.56833
08/27/10	Halifax	P	M	--	36.38772	-77.60633
08/30/10	Northampton	P	-	--	36.26551	-77.30957
09/10/10	Dare	C	-	--	35.87323	-75.93091
09/15/10	Cumberland	C	M	15-124-2	35.16833	-78.71833
09/23/10	Gates	C	F	7-75-1	36.49167	-76.81833
09/23/10	Hyde	C	F	18-61-8	35.55167	-75.95500
09/23/10	Hyde	C	F	18-61-8	35.55167	-75.95500
09/23/10	Hyde	C	F	18-61-8	35.55167	-75.95500
09/23/10	Hyde	C	F	17-84-6	35.48167	-76.07833
09/25/10	Currituck	C	M	8-98-16	36.28500	-75.90167
09/27/10	Bertie	C	M	7-111-4	36.98833	76.10500
10/05/10	Tyrrell	C	M	17-58-3	35.65833	-76.20833
10/13/10	Craven	C	-	--	35.21770	-77.45220
10/13/10	Edgecombe	P	F	--	35.76942	-77.72328
10/14/10	Hyde	C	M	--	35.64746	-76.58973
10/15/10	Wilkes	M	M	--	36.19753	-81.42843
10/17/10	Carteret	C	-	25-30-24	34.76833	-76.51833
10/17/10	Onslow	C	F	24-55-7	34.65167	-77.46833
10/18/10	Buncombe	M	M	11-67-6	35.55990	-82.49320
10/18/10	Tyrrell	C	F	17-21-3	35.91167	-76.29167
10/19/10	Tyrrell	C	-	17-34-25	35.76833	-76.16833
10/20/10	Pitt	C	-	16-31-14	35.80167	-77.43500
10/20/10	Tyrrell	C	M	17-47-6	35.72500	-76.15500
10/21/10	Currituck	C	M	8-97-10	36.30167	-75.92500
10/22/10	Mitchell	M	M	--	35.90224	-82.13479

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/24/10	Hertford	C	-	6-107-19	36.27167	-77.10833
10/25/10	Haywood	M	M	10-84-15	35.46833	-83.00167
10/26/10	Bertie	C	M	7-121-2	36.15833	-76.96833
10/27/10	Currituck	C	M	8-110-3	36.24500	-75.86833
10/27/10	Gates	C	M	7-85-5	36.41464	-76.91775
10/30/10	Dare	C	F	--	35.87383	-75.93167
10/30/10	Macon	M	F	10-112-25	35.18500	-83.66833
10/31/10	Jones	C	-	24-6-10	34.98500	-77.50167
11/02/10	Cherokee	M	M	9-142-17	35.00861	-84.24167
11/02/10	Jones	C	M	--	34.98121	-77.50168
11/03/10	Bertie	C	F	7-136-12	36.03833	-76.73167
11/03/10	Craven	C	-	24-15-11	34.88500	-77.81833
11/05/10	Hyde	C	F	17-82-19	35.44167	-76.18833
11/05/10	Hyde	C	M	17-54-25	35.58833	-76.51500
11/05/10	Washington	C	M	17-32-2	35.82500	-76.39167
11/07/10	Washington	C	M	17-17-17	35.86908	-76.64746
11/09/10	Bertie	C	F	7-135-15	36.05167	-76.75167
11/09/10	Bertie	C	F	7-135-15	36.05167	-76.75167
11/09/10	Craven	C	-	16-142-5	35.08500	-77.16833
11/10/10	Bertie	C	M	7-135-15	36.03833	-76.75500
11/11/10	Dare	C	M	--	35.86692	-75.91704
11/11/10	Martin	C	M	17-26-10	35.81500	-76.84500
11/12/10	Beaufort	C	-	16-71-20	35.53500	-77.08500
11/12/10	Craven	C	-	16-119-18	35.20167	-77.11833
11/13/10	Gates	C	F	7-63-18	36.52167	-76.79833
11/13/10	Hyde	C	M	17-81-18	35.43500	-76.29500
11/13/10	Jones	C	-	16-141-11	35.05167	-77.31833
11/15/10	Gates	C	M	7-63-18	36.52167	-76.79833
11/15/10	Washington	C	M	17-28-1	35.83500	-76.73500
11/16/10	Currituck	C	M	8-85-23	36.33833	-75.95167
11/17/10	Hyde	C	M	17-54-12	35.63500	-76.55167
11/17/10	Tyrrell	C	-	17-46-5	35.74167	-76.17833
11/17/10	Washington	C	M	17-17-1	35.91500	-76.66500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/18/10	Camden	C	M	7-68-24	36.50500	-76.35500
11/19/10	Beaufort	C	-	17-63-6	35.56833	-76.81833
11/19/10	Bertie	C	M	7-136-12	36.03833	-76.72833
11/19/10	Bertie	C	M	7-136-12	36.03833	-76.72833
11/20/10	Beaufort	C	-	17-53-13	35.63500	-76.61833
11/22/10	Cumberland	C	M	23-16-22	34.85167	-78.71833
11/29/10	Hyde	C	M	17-68-20	35.52833	-76.33833
11/29/10	Tyrrell	C	-	--	35.70533	-76.19750
11/29/10	Tyrrell	C	M	--	35.90725	-76.03703
11/30/10	Hyde	C	F	17-67-14	35.54833	-76.44500
12/01/10	Camden	C	M	7-68-19	36.53500	-76.35167
12/02/10	Dare	C	M	--	35.86894	-75.92198
12/02/10	Hyde	C	F	17-53-5	35.66833	-76.58500
12/04/10	Tyrrell	C	M	--	35.91413	-76.11776
12/07/10	Bertie	C	-	--	36.03716	-76.73068
12/08/10	Washington	C	M	--	35.90691	-76.47113
12/11/10	Bertie	C	F	16-12-25	35.92763	-77.00166
12/11/10	Currituck	C	M	8-98-16	36.27167	-75.91167
12/13/10	Dare	C	M	--	35.89680	-75.97131
12/13/10	Duplin	C	M	24-26-14	34.80167	-77.85167
12/13/10	Pasquotank	C	F	7-93-1	36.40833	-76.33167
12/14/10	Nash	P	-	--	36.05283	-77.76428
12/15/10	Dare	C	F	--	35.87201	-75.92904
12/20/10	Jones	C	M	16-140-14	35.05167	-77.35167
12/21/10	Washington	C	M	17-17-18	35.86833	-76.61833
12/22/10	Haywood	M	M	11-63-4	35.58500	-82.76833
12/24/10	Jones	C	M	16-115-16	35.20167	-77.48500
12/29/10	Pitt	C	-	16-46-6	35.73500	-77.23500
12/30/10	Beaufort	C	-	17-62-21	35.51833	-76.90167
12/30/10	Pasquotank	C	F	7-92-5	36.41500	-76.34167
01/03/11	Bertie	C	M	--	36.16965	-76.96152
01/05/11	Bertie	C	F	7-111-9	36.21737	-76.77085
01/05/11	Haywood	M	F	10-48-4	35.72110	-83.03723

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
01/15/11	Beaufort	C	-	17-101-16	35.28500	-76.65167
01/15/11	Bertie	C	M	6-132-19	36.11635	-77.02193
01/20/11	Bertie	C	F	--	36.10509	-77.01563
01/20/11	Dare	C	M	--	35.88820	-75.95507
01/28/11	Pitt	C	-	16-69-17	35.53500	-77.30167
01/29/11	Pitt	C	-	16-82-23	35.43500	-77.20167
02/07/11	Washington	C	M	17-27-4	35.83188	-76.76673
02/16/11	Jackson	M	M	10-107-18	35.28500	-83.11833
02/16/11	Lenoir	C	F	16-114-6	35.23500	-77.56833
03/17/11	Buncombe	M	M	11-54-24	35.58439	-82.52148
03/17/11	Buncombe	M	-	11-54-24	35.59031	-82.51740
03/28/11	Hyde	C	M	17-53-5	35.64379	-76.58920
03/28/11	Hyde	C	F	17-53-5	35.64379	-76.58920
04/04/11	Hyde	C	M	--	35.54558	-75.96101
04/05/11	Craven	C	-	24-1-1	35.00167	-77.98500
04/09/11	Craven	C	-	25-1-6	34.98500	-76.98500
04/28/11	Tyrrell	C	-	--	35.87796	-76.33868
05/03/11	Washington	C	M	--	35.87129	-76.67663
05/05/11	Currituck	C	M	--	36.44581	-76.01389
05/09/11	Jones	C	M	24-9-19	34.95167	-77.26833
05/10/11	Hyde	C	M	--	35.43969	-76.19590
05/12/11	Bertie	C	F	--	35.92552	-76.73512
05/12/11	Currituck	C	M	--	36.38982	-76.03482
05/18/11	Hertford	C	M	--	36.30686	-77.02643
05/19/11	Currituck	C	M	--	36.41264	-76.00175
05/19/11	Mecklenburg	P	M	--	35.30441	-80.84726
05/20/11	Washington	C	M	--	35.89378	-76.43712
05/22/11	Pitt	C	-	16-55-19	35.61833	-77.43500
05/23/11	Lenoir	C	M	16-126-8	35.15167	-77.53500
05/23/11	Northampton	C	-	--	36.15692	-77.18484
05/23/11	Pasquotank	C	-	--	36.53660	-76.36992
05/26/11	Lenoir	C	F	16-113-13	35.21833	-77.61833
05/31/11	Haywood	M	M	11-63-14	35.54034	-82.78115

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
06/01/11	Warren	P	M	--	36.46600	-78.25400
06/04/11	Beaufort	C	-	16-71-25	35.51833	-77.08500
06/04/11	Craven	C	-	16-131-20	35.11833	-77.08500
06/07/11	Chowan	C	M	--	36.05833	-76.67278
06/08/11	Bertie	C	M	--	36.02111	-76.84841
06/09/11	Onslow	C	-	24-44-1	34.75167	-77.40167
06/10/11	Currituck	C	M	7-84-25	36.43436	-76.00833
06/13/11	Tyrrell	C	M	--	35.90737	-76.03758
06/14/11	Tyrrell	C	M	--	35.91113	-76.11311
06/16/11	Martin	C	M	--	35.83157	-77.34108
06/20/11	Washington	C	M	--	35.86845	-76.60536
06/25/11	Currituck	C	M	--	36.27441	-75.91081
06/27/11	Rutherford	M	M	--	35.28636	-81.79395
07/02/11	Craven	C	M	--	35.18101	-77.13136
07/02/11	Onslow	C	-	24-46-15	34.71833	-77.16833
07/05/11	Pasquotank	C	M	--	36.38741	-76.31864
07/08/11	Dare	C	M	--	35.89449	-75.97731
07/12/11	Bertie	C	-	--	36.02087	-76.90392
07/14/11	Onslow	C	-	24-46-12	34.71833	-77.21833
07/14/11	Wilson	C	M	16-52-6	35.64976	-77.73891
07/15/11	Chowan	C	M	--	36.14900	-76.65400
07/15/11	Sampson	C	M	23-33-23	34.76833	-78.28500
07/18/11	Buncombe	M	-	11-66-10	35.56492	-82.49955
07/22/11	Currituck	C	F	--	36.47054	-76.11191
07/22/11	Currituck	C	M	--	36.47054	-76.11191
07/22/11	Tyrrell	C	M	17-58-8	35.64452	-76.20523
07/25/11	Camden	C	-	--	36.29323	-76.04281
07/25/11	Washington	C	M	--	34.81033	-76.73318
07/29/11	McDowell	M	M	--	35.94041	-81.94035
08/03/11	Dare	C	F	18-15-22	35.83497	-75.81066
08/03/11	Martin	C	-	17-25-19	35.77627	-76.94092
08/03/11	McDowell	M	F	--	35.78690	-82.03998
08/03/11	McDowell	M	M	--	35.78690	-82.03998

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
08/07/11	Currituck	C	-	--	36.45492	-76.04585
08/09/11	Beaufort	C	F	17-98-3	35.32595	-76.89315
08/10/11	Camden	C	M	--	36.53716	-76.37016
08/11/11	Craven	C	-	--	34.96642	-76.96352
08/12/11	Perquimans	C	F	7-115-7	36.22309	-76.47503
08/15/11	Clay	M	M	10-134-14	35.05167	-83.85167
08/15/11	Cumberland	C	M	--	34.93130	-78.73990
08/17/11	Jones	C	M	16-114-15	35.21833	-77.50167
08/18/11	Beaufort	C	F	--	35.50847	-77.08814
08/22/11	Transylvania	M	M	10-122-17	35.11833	-83.88500
08/23/11	Hertford	C	M	--	36.31285	-76.81932
08/26/11	Buncombe	M	-	11-53-5	35.66301	-82.58456
08/29/11	Currituck	C	-	--	36.33873	-75.95200
08/31/11	Cumberland	C	M	--	34.93169	-78.73749
09/02/11	McDowell	M	F	--	35.86264	-81.95698
09/03/11	Martin	C	F	16-24-21	35.81814	-77.07479
09/04/11	Bladen	C	F	23-80-9	34.48500	-78.35167
09/06/11	Dare	C	M	--	35.95068	-75.82506
09/09/11	Haywood	M	-	11-48-14	35.71833	-82.01833
09/11/11	Macon	M	M	10-126-14	35.07774	-83.31284
09/12/11	Haywood	M	M	11-74-6	35.47194	-82.91372
09/12/11	Hyde	C	M	17-53-5	35.64686	-76.58964
09/13/11	Haywood	M	-	11-14-1	35.91833	-82.90167
09/13/11	Pitt	C	M	--	35.47102	-77.39988
09/15/11	Beaufort	C	-	--	35.69507	-76.76968
09/15/11	Buncombe	M	-	11-30-23	35.75725	-82.54314
09/15/11	Buncombe	M	-	11-30-23	35.75725	-82.54314
09/15/11	Dare	C	F	--	35.88749	75.95671
09/15/11	Dare	C	M	--	35.88749	-75.95671
09/15/11	Mitchell	M	M	--	35.90430	-82.10822
09/16/11	Sampson	C	M	23-44-18	34.69833	-78.39167
09/16/11	Transylvania	M	-	11-101-6	35.31122	-82.66593
09/17/11	Clay	M	M	10-134-6	35.06833	-83.90167

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
09/17/11	Graham	M	F	10-88-21	35.35167	-83.73500
09/17/11	Henderson	M	-	11-101-8	35.31409	-82.66228
09/19/11	Beaufort	C	F	17-39-19	35.67784	-76.78374
09/19/11	Clay	M	F	10-135-15	35.05167	-83.75167
09/19/11	Clay	M	M	10-135-15	35.05167	-83.75167
09/19/11	Currituck	C	M	--	36.28497	-75.91804
09/19/11	Dare	C	F	--	35.70585	-75.76898
09/19/11	Haywood	M	F	10-48-8	35.72228	-83.03549
09/19/11	Henderson	M	M	11-91-18	35.35039	-82.45368
09/19/11	Henderson	M	-	11-90-10	35.39936	-82.50728
09/19/11	Swain	M	F	10-91-3	35.41833	-83.45167
09/19/11	Swain	M	F	10-91-3	35.41833	-83.45167
09/19/11	Swain	M	M	10-91-3	35.41833	-83.45167
09/19/11	Tyrrell	C	M	--	35.63869	-76.21332
09/20/11	Haywood	M	-	11-60-15	35.63500	-82.00167
09/20/11	McDowell	M	M	--	35.64000	-82.15456
09/22/11	Haywood	M	F	10-60-20	35.60225	-83.00647
09/22/11	Haywood	M	M	10-72-21	35.51464	-83.07394
09/22/11	Madison	M	F	11-6-18	35.94103	-82.56277
09/22/11	Madison	M	M	11-6-18	35.94103	-82.56277
09/22/11	Madison	M	F	11-6-18	35.94103	-82.56277
09/24/11	Haywood	M	-	10-72-20	35.52838	-83.00264
09/26/11	Haywood	M	M	11-63-14	35.54112	-82.77072
09/27/11	Camden	C	F	--	36.28836	-76.04225
09/27/11	Tyrrell	C	M	--	35.71751	-76.19493
09/27/11	Tyrrell	C	F	--	35.73159	-76.15249
09/29/11	Swain	M	M	10-90-17	35.36833	-83.55167
10/01/11	Cherokee	M	F	10-111-19	35.20167	-83.76833
10/01/11	Haywood	M	F	10-48-6	35.73718	-83.02431
10/01/11	Henderson	M	F	11-102-15	35.29914	-82.51447
10/01/11	Macon	M	F	10-127-7	35.15167	-75.46833
10/01/11	Macon	M	F	10-127-7	35.15167	-83.46833
10/03/11	Macon	M	M	10-140-4	35.06857	-83.36450

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/04/11	Gates	C	F	--	36.43888	-76.52058
10/05/11	Haywood	M	M	10-71-18	35.51940	-83.12397
10/05/11	Tyrrell	C	-	--	35.76401	-76.18263
10/07/11	Haywood	M	M	11-63-12	35.54122	-82.80334
10/07/11	McDowell	M	M	--	35.62208	-82.18677
10/08/11	Haywood	M	-	11-62-10	35.55676	-82.84724
10/10/11	Bladen	C	F	23-27-17	34.77167	-78.80833
10/10/11	Dare	C	F	--	35.89405	-75.96890
10/10/11	Dare	C	M	--	35.83742	-75.81110
10/10/11	Haywood	M	F	11-63-12	35.53987	-82.80981
10/10/11	Hyde	C	M	--	35.55464	-76.95082
10/10/11	Jackson	M	M	--	35.44437	-83.31352
10/10/11	Onslow	C	-	--	34.66152	-77.60407
10/10/11	Polk	M	M	11-105-23	35.25190	-82.29435
10/11/11	Buncombe	M	F	11-41-25	35.67669	-82.58303
10/11/11	Haywood	M	F	11-49-11	35.62772	-83.00497
10/11/11	Hyde	C	F	--	35.49235	-75.45909
10/11/11	Polk	M	M	11-117-1	35.24940	-82.33193
10/12/11	Greene	C	M	--	35.51532	-77.76929
10/12/11	Jackson	M	M	--	35.40963	-83.32608
10/13/11	Currituck	C	M	--	36.38952	-76.02747
10/14/11	Jackson	M	M	--	35.39825	-83.12572
10/16/11	Buncombe	M	M	11-78-18	35.44473	-82.53933
10/16/11	Jackson	M	M	10-95-6	35.39500	-83.16167
10/17/11	Bladen	C	M	--	34.40067	-78.31681
10/17/11	Cherokee	M	-	10-111-15	35.21417	-83.75572
10/17/11	Gates	C	M	7-63-22	36.50646	-76.80899
10/17/11	Jackson	M	M	10-93-15	35.38500	-83.25167
10/19/11	Cherokee	M	F	10-111-20	35.20167	-83.75167
10/20/11	Chowan	C	M	--	36.18853	-76.69842
10/20/11	Henderson	M	M	11-102-21	35.25808	-82.40856
10/20/11	Jackson	M	F	10-95-6	35.40167	-83.16167
10/20/11	Tyrrell	C	F	17-21-13	35.87274	-76.28616

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
10/23/11	Bertie	C	F	--	36.10425	-76.76594
10/25/11	Brunswick	C	M	23-129-1	34.16833	-78.31833
10/25/11	Jones	C	M	16-140-15	35.05167	-77.33500
10/25/11	Moore	P	M	--	35.39102	-79.58264
10/25/11	Surry	M	M	--	36.55334	-80.74284
10/26/11	Hyde	C	F	--	35.49841	-76.44621
10/26/11	Transylvania	M	M	11-100-18	35.27950	-82.71289
10/27/11	Washington	C	F	--	35.91655	-76.47850
10/28/11	Bladen	C	M	23-39-13	34.71167	-78.79167
10/28/11	Bladen	C	F	23-39-13	34.71833	-78.78500
10/28/11	Currituck	C	F	--	36.38968	-76.03222
10/28/11	Robeson	C	M	22-13-13	34.88500	-79.95167
10/31/11	Avery	M	M	--	36.12073	-81.83361
10/31/11	Hyde	C	F	--	35.53173	-76.30929
11/01/11	Beaufort	C	M	--	35.47726	-77.03536
11/01/11	Beaufort	C	M	--	35.47726	-77.03536
11/01/11	McDowell	M	F	--	35.70951	-82.03454
11/02/11	Camden	C	-	--	36.49067	-76.34775
11/02/11	Cumberland	C	F	23-14-20	34.86833	-78.83500
11/02/11	Hyde	C	-	--	36.60340	-76.35567
11/02/11	Lenoir	C	-	16-114-8	35.23500	-77.53500
11/02/11	McDowell	M	M	--	35.64122	-82.11756
11/03/11	Beaufort	C	M	17-66-8	35.55833	-76.54500
11/03/11	Hyde	C	M	--	35.59803	-75.92519
11/04/11	Buncombe	M	F	11-64-23	35.51201	-82.71251
11/04/11	Buncombe	M	-	11-55-12	35.63327	-82.47630
11/06/11	Currituck	C	M	--	36.47515	-76.13396
11/06/11	Macon	M	-	10-116-22	35.18086	-83.38808
11/07/11	Buncombe	M	-	11-64-14	35.53599	-82.68773
11/07/11	Cherokee	M	M	9-143-15	35.05167	-84.08500
11/07/11	Henderson	M	-	11-90-5	35.40009	-82.51121
11/07/11	Lenoir	C	F	16-113-25	35.18500	-77.58500
11/07/11	Lenoir	C	F	16-124-19	35.11833	-77.68500

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/07/11	Tyrrell	C	M	17-46-23	35.67073	76.20488
11/08/11	Beaufort	C	F	17-66-8	35.55833	-76.54833
11/08/11	Beaufort	C	F	17-66-8	35.55833	-76.54833
11/08/11	Beaufort	C	M	17-66-8	35.56167	-76.53833
11/08/11	Madison	M	M	--	35.85027	-82.52775
11/08/11	Tyrrell	C	F	17-21-1	35.90415	-76.30746
11/09/11	Avery	M	M	--	36.17627	-81.92951
11/09/11	Edgecombe	C	M	--	35.84293	-77.40659
11/09/11	Gates	C	-	--	36.43790	-76.51160
11/09/11	Haywood	M	-	11-63-12	35.54053	-82.80528
11/09/11	Henderson	M	-	11-91-23	35.34719	-82.45011
11/09/11	Jones	C	F	16-128-5	35.16833	-77.33500
11/10/11	Haywood	M	-	10-60-15	35.61716	-83.01061
11/11/11	Bertie	C	M	--	36.02259	-76.94191
11/13/11	Northampton	C	F	--	36.12433	-77.18181
11/14/11	Bladen	C	M	23-53-8	34.65167	-78.61833
11/14/11	Buncombe	M	-	11-55-12	36.63327	-82.47630
11/15/11	Tyrrell	C	-	--	35.93293	-76.15183
11/16/11	Buncombe	M	M	11-57-13	35.61971	-82.28861
11/16/11	Haywood	M	-	11-35-20	35.78500	-82.08500
11/18/11	Jones	C	M	16-115-14	35.21833	-77.43500
11/18/11	Washington	C	F	17-16-13	35.87053	-76.70091
11/19/11	Washington	C	F	17-16-15	35.87236	-76.67870
11/20/11	Haywood	M	F	11-62-16	35.53500	-82.90167
11/20/11	Jones	C	F	--	35.07229	-77.37842
11/21/11	Macon	M	F	10-140-3	35.08500	-83.36833
11/21/11	Martin	C	M	16-35-7	35.80724	-77.13448
11/22/11	Buncombe	M	-	11-67-14	35.53541	-82.43474
11/22/11	Pamlico	C	M	17-121-9	35.15167	-76.93500
11/25/11	Haywood	M	-	10-36-21	35.75815	-83.07099
11/25/11	Haywood	M	F	10-36-21	35.75815	-83.07099
11/28/11	Haywood	M	M	10-36-21	35.75825	-83.07134
11/28/11	Haywood	M	M	10-48-14	35.70460	-83.02940

Appendix C. Locations of bear-vehicle collisions (BVCs) in North Carolina, 1998-2011. (Continued)

Date	County	Region	Sex	QBS	Latitude	Longitude
11/28/11	Washington	C	F	--	35.87058	-76.66848
11/29/11	Martin	C	F	16-33-2	35.83295	-77.32025
12/01/11	McDowell	M	M	--	35.64122	-81.98854
12/03/11	Buncombe	M	-	11-67-6	35.55651	-82.48460
12/05/11	Sampson	C	M	--	34.78664	-78.21111
12/06/11	Bertie	C	M	--	36.21509	-76.90548
12/06/11	Gates	C	M	--	36.43369	-76.48357
12/07/11	Gates	C	M	--	36.44076	-76.53261
12/08/11	Currituck	C	F	--	36.35944	-75.96291
12/08/11	Madison	M	F	11-6-12	35.95311	-82.56151
12/08/11	Madison	M	-	11-6-12	35.95311	-82.56151
12/09/11	Bladen	C	M	23-52-10	34.65167	-78.66833
12/09/11	Currituck	C	M	--	36.30604	-75.93089
12/11/11	Jones	C	F	16-140-15	35.05167	-77.33500
12/12/11	Currituck	C	M	--	36.30400	-75.92917
12/12/11	Jones	C	F	16-128-25	35.10167	-77.33500
12/12/11	Jones	C	F	16-115-14	35.21833	-77.43500
12/14/11	Currituck	C	M	--	36.35962	-75.96319
12/14/11	Jackson	M	F	10-94-18	35.36833	-83.20167
12/20/11	Bertie	C	M	--	36.21508	-76.90535
12/21/11	Currituck	C	F	7-96-16	36.35167	-76.07461
12/22/11	Hyde	C	M	17-54-18	35.59500	-76.52125
12/23/11	Currituck	C	M	--	36.32085	-75.93970
12/24/11	Gates	C	F	--	36.52826	-76.62449
12/27/11	Martin	C	-	16-21-6	35.89032	-77.32257
12/29/11	Martin	C	M	16-48-1	35.74072	-77.07563
Unknown	Cumberland	C	M	23-3-9	34.98500	-78.76833
Unknown	Northampton	C	-	6-66-11	36.55167	-77.56833

Appendix D. Age-at-harvest of male black bears from the Mountain region of North Carolina, 1969-2017.

	Age																						
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1969	0	3	3	2	3	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
1970	2	8	3	1	4	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1971	0	7	3	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	8	2	0	4	1	1	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	1	4	5	3	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1975	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	12	14	2	1	1	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	13	10	7	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1978	0	16	22	10	7	2	1	6	2	1	0	1	2	0	0	0	0	0	0	0	0	0	0
1979	3	11	12	9	5	2	1	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1980	3	12	23	11	9	5	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1981	4	21	20	12	1	3	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1982	3	26	31	13	8	6	4	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	28	39	17	12	4	2	4	1	1	0	0	0	2	0	1	0	0	0	0	0	0	0
1984	1	24	43	23	17	4	11	6	5	3	0	1	2	0	0	0	0	0	0	0	0	0	0
1985	3	38	25	7	4	5	2	4	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0
1986	0	28	42	6	11	5	4	3	6	2	0	1	0	0	0	0	0	0	0	0	0	0	0
1987	0	69	20	18	15	11	13	5	4	5	0	0	1	1	0	0	0	0	0	0	0	0	0
1988	5	24	35	9	6	1	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	3	35	30	21	7	6	3	1	3	1	0	3	0	0	0	0	0	0	0	0	0	0	0
1990	0	19	31	10	13	6	5	1	3	1	3	0	1	0	1	1	0	0	0	0	0	0	0
1991	3	21	41	28	1	8	3	2	2	1	2	1	0	1	0	0	0	1	0	0	0	0	0
1992	3	54	46	24	32	18	12	7	2	6	4	1	2	0	1	0	0	0	0	0	0	0	0
1993	5	45	28	18	12	12	2	6	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
1994	10	29	37	15	7	11	3	5	4	1	2	1	0	0	0	0	0	0	0	0	0	0	0

Appendix D. Age-at-harvest of male black bears from the Mountain region of North Carolina, 1969-2017. (Continued)

	Age																						
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1995	3	60	27	22	16	6	3	7	2	2	1	0	2	0	0	0	0	0	0	0	0	0	0
1996	9	50	47	11	14	5	5	3	2	3	0	2	0	0	1	0	0	0	0	0	0	0	0
1997	5	66	56	57	15	15	12	4	8	3	4	3	1	1	0	1	0	0	0	0	0	0	0
1998	4	53	54	18	31	9	7	5	6	1	0	1	0	0	2	0	0	0	0	0	0	0	0
1999	5	31	49	42	18	9	8	4	10	2	1	0	1	1	0	0	0	1	0	0	0	0	0
2000	2	69	43	29	19	9	11	2	9	4	2	1	2	0	0	0	0	0	0	0	0	0	0
2001	1	33	67	15	11	10	4	2	2	0	1	0	0	2	1	0	0	0	0	0	0	0	0
2002	2	39	59	35	13	9	8	5	1	4	1	2	0	0	0	0	0	0	1	0	0	0	0
2003	3	70	77	25	23	9	6	6	3	3	3	0	0	2	0	0	0	0	0	0	0	0	0
2004	3	47	54	25	9	11	2	3	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0
2005	1	41	34	25	22	5	6	6	3	2	2	0	0	0	0	0	1	0	0	0	0	0	0
2006	3	70	48	27	25	24	9	8	0	6	4	2	2	0	0	0	0	0	0	0	0	0	0
2007	4	63	68	26	21	4	9	5	1	0	2	0	0	1	0	1	0	0	0	0	0	0	0
2008	3	107	60	46	23	22	5	5	6	5	2	0	0	2	0	0	0	0	0	0	0	0	0
2009	9	116	117	43	39	18	14	8	11	4	3	0	1	0	2	0	0	0	0	0	0	0	0
2010	2	79	73	23	16	13	4	4	8	0	1	1	0	0	0	1	0	0	0	0	0	0	0
2011	8	77	121	73	44	20	15	8	10	10	2	6	3	1	3	0	0	0	0	0	0	0	0
2012	6	100	34	53	30	12	12	9	6	8	3	3	1	2	0	1	0	0	0	0	0	0	0
2013	6	47	113	37	18	19	17	12	8	7	3	1	1	0	1	0	1	0	0	0	0	0	0
2014	4	82	41	63	5	15	5	6	5	5	2	1	0	1	0	0	0	0	0	0	0	0	0
2015	6	137	153	51	34	12	12	10	2	3	2	0	0	1	1	0	1	0	0	0	0	0	0
2016	5	143	74	44	21	15	8	3	6	5	4	2	0	1	1	0	0	0	0	0	0	0	0
2017	6	101	191	46	26	17	12	2	1	4	5	0	3	0	0	0	1	0	0	0	0	0	0

Appendix E. Age-at-harvest of female black bears from the Mountain region of North Carolina, 1969-2017.

	Age																										
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1969	0	2	2	1	0	0	2	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1970	3	2	2	3	4	5	1	2	1	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	3	0	4	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	1	2	2	3	1	2	4	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	1	3	1	1	8	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	7	7	1	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	1	7	4	2	1	4	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	5	10	10	3	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	8	9	8	4	5	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	5	8	1	6	5	3	3	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	3	7	8	7	5	7	6	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	2	6	9	3	2	6	3	0	2	4	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	18	13	14	10	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	4	8	10	12	9	8	8	3	3	4	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	14	4	13	11	5	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	4	18	6	14	7	6	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	11	7	12	6	5	9	6	3	4	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	3	9	26	5	3	4	3	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	7	11	4	9	6	7	5	1	1	1	2	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0
1990	1	6	16	22	9	6	13	2	6	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	8	16	11	6	9	6	1	0	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	1	8	9	13	19	11	22	9	6	5	8	3	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0
1993	0	11	13	8	9	6	3	2	2	0	1	2	1	2	1	0	1	1	0	0	0	0	0	0	0	0	0
1994	4	11	18	24	8	8	10	5	3	4	2	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0

Appendix E. Age-at-harvest of female black bears from the Mountain region of North Carolina, 1969-2017. (Continued)

	Age																										
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1995	1	21	5	18	8	3	3	6	3	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
1996	6	12	18	10	10	12	3	3	2	2	1	0	1	0	2	1	1	0	0	0	0	0	0	0	0	0	0
1997	6	24	19	34	17	17	12	8	7	9	3	8	2	4	3	0	2	0	0	0	0	0	0	0	0	0	0
1998	0	9	26	20	12	10	7	6	3	3	5	4	2	1	0	1	0	0	0	0	1	0	0	1	0	0	0
1999	0	11	23	16	11	15	8	3	3	4	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2000	1	17	12	6	14	11	7	5	3	0	4	0	1	2	2	0	0	0	0	0	0	0	1	0	0	0	0
2001	1	6	49	7	8	9	5	5	3	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
2002	0	21	13	23	8	5	8	7	4	2	1	1	2	1	2	3	0	0	0	1	0	0	0	0	0	0	0
2003	1	16	27	24	27	7	11	16	5	9	3	5	2	1	1	0	0	0	0	0	0	0	0	1	0	0	1
2004	1	16	15	19	5	5	3	1	4	0	5	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
2005	2	9	15	14	12	11	9	4	2	5	4	4	2	1	1	1	0	0	0	0	0	0	0	1	0	0	0
2006	1	20	22	18	16	6	8	9	6	2	3	1	4	0	2	2	1	2	0	0	0	0	0	0	0	0	0
2007	2	20	36	23	16	7	11	9	10	3	1	3	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	33	29	40	19	16	13	11	8	7	5	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	1	31	30	25	22	16	15	16	7	8	5	7	1	0	4	2	1	2	0	1	1	0	1	0	0	0	0
2010	0	23	37	26	10	11	7	4	6	4	7	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2011	2	9	42	27	31	15	14	9	8	8	13	5	4	5	2	0	4	1	1	1	0	0	0	0	0	0	0
2012	3	33	25	30	21	19	13	17	7	5	3	0	2	5	0	1	0	0	0	0	0	0	0	0	0	0	0
2013	3	25	40	27	23	24	15	16	7	9	6	8	4	1	4	3	0	0	1	1	0	0	0	0	0	0	0
2014	0	35	18	38	10	8	10	7	3	4	2	2	3	1	1	0	0	1	0	0	0	0	0	0	0	0	0
2015	2	31	46	22	27	14	16	7	13	8	5	2	5	1	0	0	1	3	0	0	0	0	0	0	0	0	0
2016	2	46	32	27	13	23	11	11	8	3	9	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2017	0	35	59	15	20	8	11	8	9	5	2	2	4	1	2	1	0	0	0	0	0	0	0	0	0	0	0

Appendix F. Registered harvest of black bears from the Mountain region of North Carolina, 1983-2017.

Year	Males	Females
1983	134	69
1984	189	92
1985	118	67
1986	147	93
1987	220	87
1988	161	107
1989	163	109
1990	198	117
1991	174	107
1992	358	237
1993	201	97
1994	184	138
1995	231	108
1996	209	116
1997	408	318
1998	266	155
1999	311	174
2000	359	202
2001	270	156
2002	345	185
2003	425	292
2004	304	140
2005	371	219
2006	503	222
2007	409	269
2008	566	291
2009	745	452
2010	421	241
2011	755	415
2012	585	395
2013	697	510
2014	372	262
2015	784	415
2016	666	385
2017	872	392

Appendix G. Statistical Population Reconstruction code in R and Jags.

```
### Stage 1 #######
#Load libraries
library(R2WinBUGS)
library(rjags)
library(R2jags)
library(coda)
library(jagsUI)
library(mcmcplots)

# set directory to find WinBugs
bugs.dir <- "C:/Program files/WinBUGS14"

# set working directory
setwd ("D:/")  # set working directory

source("myfuncs.r")  # takes the cohorts off the diagonals and puts them in columns

############ Create a function code to create diagonals ##############
source("myfuncs.r") # the following 10 lines of code can be saved as a stand-alone function
#called “myfuncs.r”
#diags <- function(m, type = c("sub", "super"), offset = 1) {
# type <- match.arg(type)
#  FUN <-
#   if(isTRUE(all.equal(type, "sub")))
#      `+`
#  else
#    `-`
#  m[row(m) == FUN(col(m), offset)]
#}
#shift <- function (x, shift) c(rep(NA,times=shift), x[1:(length(x)-shift)])

# read ageathar matrix
myData <- read.table("females.txt",header=TRUE)  # females.txt is 1983-2017 only
#myData <- read.table("males.txt",header=TRUE)  # males.txt is 1983-2017 only

# read data
nyears <- nrow(myData)
nages <- 18  #this is the maximum age (= Max. age + 1 if using a 0-age class).  18 age classes is the maximum allowed with current code
ageathar <- myData[1:nages]

# read data
#nyears <- 35
#nages <- 18
```

```
# no. cohorts
#co <- (nyears+nages)-1

# read ageathar matrix
#ageathar <- read.table("females.txt", header=FALSE)
#ageathar <- as.matrix(ageathar[,1:18])

############### Telemetry Data #########################################
# data from North Carolina
#aged <- as.vector(c(69, 74, 54, 61, 65, 60, 58, 84, 61, 118, 63, 102, 73, 84, 175, 109, 98, 85, 95,
101, 154, 77, 96, 123, 146, 187, 193, 141, 199, 182, 214, 145, 203, 188, 182))
aged <- rowSums(ageathar)  #sum the number of animals aged each year

#killed <- as.vector(c(69, 92, 67, 93, 87, 107, 109, 117, 107, 237, 97, 138, 108, 116, 318, 155,
174, 202, 156, 185, 292, 140, 219, 222, 269, 291, 452, 241, 415, 395, 510, 262, 415, 385, 392) )
RegKilled <- read.table("RegisteredHarvestMt.txt", header=TRUE)
killed <- RegKilled[,3] #females
#killed <- RegKilled[,2] #males

#hunters = 1-percent tree canopy with acorns
mastData <- read.table("mastSPR.txt", header=TRUE)

hunters <- mastData[,4]
#hunters <- c(0.859, 0.911, 0.772, 0.875, 0.899, 0.601, 1.000, 0.796, 0.717, 0.913, 0.975, 0.765,
0.654, 0.520, 0.993, 0.735, 0.583, 0.998, 0.650, 0.789, 0.887, 0.477, 0.968, 0.819, 0.622, 0.922,
1.000, 0.556, 0.898, 0.793, 0.923, 0.411, 0.913, 0.668, 0.754)

# scale the number of hunters but do NOT subtract the mean (i.e., center=False).  # of SD away
#from the mean or z-score.  This is to compare vulnerability coefficients between sexes.
hunters <- as.vector(scale(hunters*1000, center = FALSE))

rows <- nrow(ageathar)  # number of rows
cols <- ncol(ageathar)  # number of columns

# to hold the principal cohorts
msub <- matrix(NA, nrow=rows, ncol=min(rows,cols))

# to hold the upper triangular cohorts
uptr <- matrix(NA, nrow=(nages-1), ncol=min(rows,(cols-1)))

# fill the cohorts from the main and sub-diagonals
for (i in 1:(dim(msub)[1])) {
   # fetch and store each cohort, one at a time
   tmp <- diags(ageathar, offset=i-1)
```

```
   # read each cohort into result matrix element-wise
   for (j in 1:length(tmp)) {
      msub[i,j] <- tmp[j]
   }
}

# fill the cohorts from above main diagonal
for (i in 1:(dim(uptr)[1])) {
   # fetch and store each cohort, one at a time
   tmp <- diags(ageathar, offset=-1*i)

   # read each cohort into result matrix element-wise
   for (j in 1:length(tmp)) {
      uptr[i,j] <- tmp[j]
   }
}

ld <- 10  #Distribution limit/parameters

# bundle the data (scaling hunters does not change answer)
win.data <- list(y=msub, m=uptr, ah=ageathar, nages=nages, nyears=nyears, aged=aged,
killed=killed, hunters=hunters, ld=ld)

# Define WinBUGS model
sink("OD_with_catch.txt")
cat("
   model {

   # priors for common elements

   S ~ dbeta(1.0, 1.0)          # survival rate, assumed common (Beta is a conjugate prior
probability distribution for Bernoulli, binomial, negative binomial, and geometric distributions)

   c ~ dunif(-10, 10)       # vulnerability coeff, assumed common (can't vary by year; otherwise,
you need another auxiliary data set)

   tau ~ dgamma(0.001, 0.001)  # gamma distribution describes the distribution of inter-spike
intervals, variance

   # likelihood for the recruitment cohorts (principal diagonal and sub-diagonals)
   for (i in 1:nyears) {

   # random cohort effects (intercept model only)
   alpha0[i] ~ dunif(-ld, ld)
```

```
   # model for Poisson intensity
   log(lambda[i]) <- alpha0[i]

   #flat prior on annual ageing rate
   theta[i] ~ dbeta(1, 1)

   hd[i] <- hunters[i]

   # Poisson catch (Seber 1982), where p = probability of catch or harvest, with a N(0, tau)
   p[i] <- (1-exp(-c*(hd[i]))) + eta[i]
   eta[i] ~ dnorm(0, tau)

   # multiplicitive catch (Chao and Chang 1999), gives virtually same result
   # p[i] <- min(c*hd[i], 1)

   # cell probs, column 1
   y[i,1] ~ dpois(p[i]*theta[i]*lambda[i])

   # predicted recruitment for cohort i
   R[i] ~ dpois(lambda[i])

   # reporting rate likelihood (comment out if missing or not used)
   aged[i] ~ dbin(theta[i], killed[i])


   ##### auxiliary data #####
   # Observed numbers of harvested, died and survived animals, drawn from binomial
distributions
   #h[i] ~ dbinom(p, ar[i])
# Harvested     with probability=p and size=number at risk (ar)
   #l[i] ~ dbinom((1-p)*S, ar[i])
# Lived with probability=(1-p)*S and size=number at risk (ar)
   #o[i] ~ dbinom((1-p)*(1-S), ar[i])
# Died of other (non-harvest) causes with probability=(1-p)*(1-S) and size=number at risk (ar)

   # catch-effort likelihood (do not use with this version!)
   # killed[i] ~ dbin(p[i], NN[i])
######################################################################

   # set the first column
   N[i,1] <- R[i]

   # add the row elements corresponding to years
   NN[i] <- round(sum(N[i,]))
   }
```

```
  # column 2
  for (i in 1:(nyears-1)) {
  y[i,2] ~ dpois((1-p[i])*S*p[i+1]*theta[i+1]*lambda[i])
  }

  # column 3
  for (i in 1:(nyears-2)) {
  y[i,3] ~ dpois((1-p[i])*S*(1-p[i+1])*S*p[i+2]*theta[i+2]*lambda[i])
  }

  # column 4
  for (i in 1:(nyears-3)) {
  y[i,4] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*p[i+3]*theta[i+3]*lambda[i])
  }

  # column 5
  for (i in 1:(nyears-4)) {
  y[i,5] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-
p[i+3])*S*p[i+4]*theta[i+4]*lambda[i])
  }

  # column 6
  for (i in 1:(nyears-5)) {
  y[i,6] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-
p[i+4])*S*p[i+5]*theta[i+5]*lambda[i])
  }

  # column 7
  for (i in 1:(nyears-6)) {
  y[i,7] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*p[i+6]*theta[i+6]*lambda[i])
  }

  # column 8
  for (i in 1:(nyears-7)) {
  y[i,8] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*p[i+7]*theta[i+7]*lambda[i])
  }

  # column 9
  for (i in 1:(nyears-8)) {
  y[i,9] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*p[i+8]*theta[i+8]*lambda[i])
  }
```

```
   # column 10
   for (i in 1:(nyears-9)) {
   y[i,10] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*p[i+9]*theta[i+9]*lambda[i])
   }

   # column 11
   for (i in 1:(nyears-10)) {
   y[i,11] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-
p[i+9])*S*p[i+10]*theta[i+10]*lambda[i])
   }

   # column 12
   for (i in 1:(nyears-11)) {
   y[i,12] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-
p[i+10])*S*p[i+11]*theta[i+11]*lambda[i])
   }

   # column 13
   for (i in 1:(nyears-12)) {
   y[i,13] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*p[i+12]*theta[i+12]*lambda[i])
   }

   # column 14
   for (i in 1:(nyears-13)){
   y[i,14] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*p[i+13]*theta[i+13]*lambda[i])
   }

   # column 15
   for (i in 1:(nyears-14)) {
   y[i,15] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*p[i+14]*theta[i+14]*lambda[i])
   }

   # column 16
   for (i in 1:(nyears-15)) {
   y[i,16] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*p[i+15]*theta[i+15]*lambda[i])
```

```
    }

    # column 17
    for (i in 1:(nyears-16)) {
    y[i,17] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-
p[i+15])*S*p[i+16]*theta[i+16]*lambda[i])
    }

    # column 18
    for (i in 1:(nyears-17)) {
    y[i,18] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-p[i+15])*S*(1-
p[i+16])*S*p[i+17]*theta[i+17]*lambda[i])
    }

    # likelihood for cohorts above principal diagonal
    for (i in 1:(nages-1)) {

    beta0[i] ~ dunif(-ld, ld)

    log(delta[i]) <- beta0[i]

    # cell probs
    m[i,1] ~ dpois(p[i]*theta[i]*delta[i])

    # predicted pseudo-recruitments for first row, index[1,2+]
    U[i] ~ dpois(delta[i])
    }

    # column 2
    for (i in 1:(nages-2)) {
    m[i,2] ~ dpois((1-p[i])*S*p[i+1]*theta[i+1]*delta[i])
    }

    # column 3
    for (i in 1:(nages-3)) {
    m[i,3] ~ dpois((1-p[i])*S*(1-p[i+1])*S*p[i+2]*theta[i+2]*delta[i])
    }

    # column 4
    for (i in 1:(nages-4)) {
    m[i,4] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*p[i+3]*theta[i+3]*delta[i])
    }
```

```
 # column 5
 for (i in 1:(nages-5)) {
 m[i,5] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*p[i+4]*theta[i+4]*delta[i])
 }

 # column 6
 for (i in 1:(nages-6)) {
 m[i,6] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-
p[i+4])*S*p[i+5]*theta[i+5]*delta[i])
 }

 # column 7
 for (i in 1:(nages-7)) {
 m[i,7] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*p[i+6]*theta[i+6]*delta[i])
 }

 # column 8
 for (i in 1:(nages-8)) {
 m[i,8] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*p[i+7]*theta[i+7]*delta[i])
 }

 # column 9
 for (i in 1:(nages-9)) {
 m[i,9] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*p[i+8]*theta[i+8]*delta[i])
 }

 # column 10
 for (i in 1:(nages-10)) {
 m[i,10] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*p[i+9]*theta[i+9]*delta[i])
 }

 # column 11
 for (i in 1:(nages-11)) {
 m[i,11] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*p[i+10]*theta[i+10]*delta[i])
 }

 # column 12
 for (i in 1:(nages-12)) {
```

```
    m[i,12] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-
p[i+10])*S*p[i+11]*theta[i+11]*delta[i])
    }

    # column 13
    for (i in 1:(nages-13)) {
    m[i,13] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*p[i+12]*theta[i+12]*delta[i])
    }

    # column 14
    for (i in 1:(nages-14)) {
    m[i,14] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*p[i+13]*theta[i+13]*delta[i])
    }

    # column 15
    for (i in 1:(nages-15)) {
    m[i,15] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*p[i+14]*theta[i+14]*delta[i])
    }

    # column 16
    for (i in 1:(nages-16)) {
    m[i,16] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*p[i+15]*theta[i+15]*delta[i])
    }

    # column 17
    for (i in 1:(nages-17)) {
    m[i,17] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-
p[i+15])*S*p[i+16]*theta[i+16]*delta[i])
    }

    # set the first row
    for (j in 2:nages) {
    N[1,j] <- U[j-1]
    }
```

```
    # reconstruct population
    for (i in 2:nyears) {
    for (j in 2:nages) {
    N[i,j] <- (N[i-1,j-1] - (ah[i-1,j-1]/theta[i]))*S
    }
    }

############# GoF Statistics ###########################
    # Compute Fit Statistics (Freeman-Tukey) for main cohorts
    for (i in 1:nyears) {
    E.R[i] <- lambda[i]
    E.org[i] <- pow((pow(R[i], 0.5)-pow(E.R[i], 0.5)), 2)  #observed
    }

    # Generate replicate data and compute fit stats
    for (i in 1:nyears) {
    R.new[i] ~ dpois(lambda[i])
    E.new[i] <- pow((pow(R.new[i], 0.5)-pow(E.R[i], 0.5)), 2)  #expected
    }

    fit <- sum(E.org)
    fit.new <- sum(E.new)
    bpv <- step(fit.new-fit)  #creates a Boolean variable that counts the number of simulations in
which fit.new >= fit; ideal = 0.50

    # Overdispersion ratio
    c.hat <- fit/fit.new  #ratio of observed to expected; ideal = 1.0
##############################################################

}
    ",fill=TRUE)
sink()

# initial values
inits <- function(){list(S = 0.95, c = 0.1, theta = rep(0.5, nyears), alpha0 = rep(-ld, nyears), beta0
= rep(-ld, (nages-1)), tau = 1)}

# parameters monitored
params <- c("S", "c", "NN", "R", "p", "fit", "fit.new", "c.hat", “bpv”)

# MCMC settings (Read Mike Meredith's blog on adapt)
nc <- 3   ;   ni <- 20000   ;   na <- 4000   ;   nb <- 1000   ;   nt <- 2

# run JAGS from R and summarize posteriors
model1 <- jags(win.data, inits, params,"goodbear_with_catch.txt", n.chains = nc, n.iter = ni,
n.adapt = na, n.burn = nb, n.thin = nt, parallel=FALSE)
```

```
print(model1, digits=3)

# plot posterior predictive check
plot(model1$sims.list$fit, model1$sims.list$fit.new, xlab="Discrepancy observed data",
ylab="Discrepancy expected data", las=1)
abline(0, 1, col="red", lwd=2)
legend("topright",legend=parse(text=sprintf("paste(c.hat,\" =
%s\")",round(model1$mean$c.hat,2))),bty="n")

# plot time plot with bci bands for population estimate (N)
pltdata <- as.data.frame(cbind(as.matrix(c(1:35)), model1$mean$NN, model1$q2.5$NN,
model1$q97.5$NN))
colnames(pltdata) <- c("Time", "Number", "lower", "upper")

# use ggplot to get a nice ribbon of the BCI
ggplot(pltdata, aes(Time)) + geom_line(aes(y=Number), colour="blue") +
   geom_ribbon(aes(ymin=lower, ymax=upper), alpha=0.2)

# plot time plot with bci bands for harvest probability (p)
pltdata <- as.data.frame(cbind(as.matrix(c(1:35)), model1$mean$p, model1$q2.5$p,
model1$q97.5$p))
colnames(pltdata) <- c("Time", "Rate", "lower", "upper")

# use ggplot to get a nice ribbon of the BCI
ggplot(pltdata, aes(Time)) + geom_line(aes(y=Rate), colour="blue") +
   geom_ribbon(aes(ymin=lower, ymax=upper), alpha=0.2)

MCMCtrace(model1, params = c("S", "p", "R", "NN", "c.hat"), ind = TRUE)

### Stage 2 #######
#Load libraries
library(R2WinBUGS)
library(rjags)
library(R2jags)
library(coda)
library(jagsUI)
library(mcmcplots)

# set directory to find WinBugs
bugs.dir <- "C:/Program files/WinBUGS14"

# set working directory
setwd ("D:/")  # set working directory

source("myfuncs.r")  # takes the cohorts off the diagonals and puts them in columns
```

```
############ Create a function code to create diagonals ##############
source("myfuncs.r") # the following 10 lines of code can be saved as a stand-alone function
#called “myfuncs.r”
#diags <- function(m, type = c("sub", "super"), offset = 1) {
# type <- match.arg(type)
#  FUN <-
#   if(isTRUE(all.equal(type, "sub")))
#     `+`
#  else
#   `-`
#  m[row(m) == FUN(col(m), offset)]
#}
#shift <- function (x, shift) c(rep(NA,times=shift), x[1:(length(x)-shift)])

# read ageathar matrix
myData <- read.table("females.txt",header=TRUE)  # females.txt is 1983-2017 only
#myData <- read.table("males.txt",header=TRUE)  # males.txt is 1983-2017 only

# read data
nyears <- nrow(myData)
nages <- 18  #this is the maximum age (= Max. age + 1 if using a 0-age class).  18 age classes is
the maximum allowed with current code
ageathar <- myData[1:nages]

# read data
#nyears <- 35
#nages <- 18

# no. cohorts
#co <- (nyears+nages)-1

# read ageathar matrix
#ageathar <- read.table("females.txt", header=FALSE)
#ageathar <- as.matrix(ageathar[,1:18])

############### Telemetry Data #########################################
# data from North Carolina
#aged <- as.vector(c(69, 74, 54, 61, 65, 60, 58, 84, 61, 118, 63, 102, 73, 84, 175, 109, 98, 85, 95,
101, 154, 77, 96, 123, 146, 187, 193, 141, 199, 182, 214, 145, 203, 188, 182))
aged <- rowSums(ageathar)  #sum the number of animals aged each year

#killed <- as.vector(c(69, 92, 67, 93, 87, 107, 109, 117, 107, 237, 97, 138, 108, 116, 318, 155,
174, 202, 156, 185, 292, 140, 219, 222, 269, 291, 452, 241, 415, 395, 510, 262, 415, 385, 392) )
RegKilled <- read.table("RegisteredHarvestMt.txt", header=TRUE)
killed <- RegKilled[,3] #females
#killed <- RegKilled[,2] #males
```

```
#hunters = 1-percent tree canopy with acorns
mastData <- read.table("mastSPR.txt", header=TRUE)

hunters <- mastData[,4]
#hunters <- c(0.859, 0.911, 0.772, 0.875, 0.899, 0.601, 1.000, 0.796, 0.717, 0.913, 0.975, 0.765,
0.654, 0.520, 0.993, 0.735, 0.583, 0.998, 0.650, 0.789, 0.887, 0.477, 0.968, 0.819, 0.622, 0.922,
1.000, 0.556, 0.898, 0.793, 0.923, 0.411, 0.913, 0.668, 0.754)

# scale the number of hunters but do NOT subtract the mean (i.e., center=False).  # of SD away
#from the mean or z-score.  This is to compare vulnerability coefficients between sexes.
hunters <- as.vector(scale(hunters*1000, center = FALSE))

rows <- nrow(ageathar)  # number of rows
cols <- ncol(ageathar)  # number of columns

# to hold the principal cohorts
msub <- matrix(NA, nrow=rows, ncol=min(rows,cols))

# to hold the upper triangular cohorts
uptr <- matrix(NA, nrow=(nages-1), ncol=min(rows,(cols-1)))

# fill the cohorts from the main and sub-diagonals
for (i in 1:(dim(msub)[1])) {
   # fetch and store each cohort, one at a time
   tmp <- diags(ageathar, offset=i-1)

   # read each cohort into result matrix element-wise
   for (j in 1:length(tmp)) {
      msub[i,j] <- tmp[j]
   }
}

# fill the cohorts from above main diagonal
for (i in 1:(dim(uptr)[1])) {
   # fetch and store each cohort, one at a time
   tmp <- diags(ageathar, offset=-1*i)

   # read each cohort into result matrix element-wise
   for (j in 1:length(tmp)) {
      uptr[i,j] <- tmp[j]
   }
}

ld <- 500  #Distribution limit/parameters, 500 for females, 1000 for males
```

```
# bundle the data (scaling hunters does not change answer)
win.data <- list(y=msub, m=uptr, ah=ageathar, nages=nages, nyears=nyears, ld=ld, aged=aged,
killed=killed, hunters=hunters)

# Define WinBUGS model
sink("with_catch.txt")
cat("
model {

  # priors for common elements

  S ~ dbeta(1.0, 1.0)         # survival rate, assumed common (Beta is a conjugate prior probability
#distribution for Bernoulli, binomial, negative binomial, and geometric distributions)
  c ~ dunif(-10, 10)          # vulnerability coeff, assumed common (can't vary by year; otherwise,
#you need another auxiliary data set)

  # likelihood for the recruitment cohorts (principal diagonal and sub-diagonals)
  for  (i in 1:nyears){

    lambda[i] ~ dunif(-ld, ld)

    theta[i] ~ dbeta(1, 1)

    hd[i] <- hunters[i]

    # Poisson catch (Seber 1982), where p = probability of catch or harvest
    p[i] <- 1-exp(-c*hd[i])

    # multiplicitive catch (Chao and Chang 1999), gives virtually same result
#    p[i] <- min(c*hd[i], 1)

    # cell probs, column 1
    y[i,1] ~ dpois(p[i]*theta[i]*lambda[i])

    # predicted recruitment for cohort i
    R[i] ~ dpois(lambda[i])

    # reporting rate likelihood (comment out if missing or not used)
    aged[i] ~ dbin(theta[i], killed[i])

    ##### auxiliary data #####

    # catch-effort likelihood (comment out if missing or not used)
    killed[i] ~ dbin(p[i], NN[i])
```

```
    # set the first column
    N[i,1] <- R[i]

    # add the row elements corresponding to years
    NN[i] <- round(sum(N[i,]))
  }

  # column 2
  for (i in 1:(nyears-1)){
    y[i,2] ~ dpois((1-p[i])*S*p[i+1]*theta[i+1]*lambda[i])
  }

  # column 3
  for (i in 1:(nyears-2)){
    y[i,3] ~ dpois((1-p[i])*S*(1-p[i+1])*S*p[i+2]*theta[i+2]*lambda[i])
  }

  # column 4
  for (i in 1:(nyears-3)){
    y[i,4] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*p[i+3]*theta[i+3]*lambda[i])
  }

  # column 5
  for (i in 1:(nyears-4)){
    y[i,5] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-
p[i+3])*S*p[i+4]*theta[i+4]*lambda[i])
  }

  # column 6
  for (i in 1:(nyears-5)){
    y[i,6] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-
p[i+4])*S*p[i+5]*theta[i+5]*lambda[i])
  }

  # column 7
  for (i in 1:(nyears-6)){
    y[i,7] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*p[i+6]*theta[i+6]*lambda[i])
  }

  # column 8
  for (i in 1:(nyears-7)){
    y[i,8] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*p[i+7]*theta[i+7]*lambda[i])
  }
```

```
  # column 9
  for (i in 1:(nyears-8)){
    y[i,9] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*p[i+8]*theta[i+8]*lambda[i])
  }

  # column 10
  for (i in 1:(nyears-9)){
    y[i,10] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*p[i+9]*theta[i+9]*lambda[i])
  }

  # column 11
  for (i in 1:(nyears-10)){
    y[i,11] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-
p[i+9])*S*p[i+10]*theta[i+10]*lambda[i])
  }

  # column 12
  for (i in 1:(nyears-11)){
    y[i,12] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-
p[i+10])*S*p[i+11]*theta[i+11]*lambda[i])
  }

  # column 13
  for (i in 1:(nyears-12)){
    y[i,13] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*p[i+12]*theta[i+12]*lambda[i])
  }

  # column 14
  for (i in 1:(nyears-13)){
    y[i,14] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*p[i+13]*theta[i+13]*lambda[i])
  }

  # column 15
  for (i in 1:(nyears-14)){
    y[i,15] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*p[i+14]*theta[i+14]*lambda[i])
  }
```

```
  # column 16
  for (i in 1:(nyears-15)){
    y[i,16] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*p[i+15]*theta[i+15]*lambda[i])
  }

  # column 17
  for (i in 1:(nyears-16)){
    y[i,17] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-
p[i+15])*S*p[i+16]*theta[i+16]*lambda[i])
  }

  # column 18
  for (i in 1:(nyears-17)){
    y[i,18] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-p[i+15])*S*(1-
p[i+16])*S*p[i+17]*theta[i+17]*lambda[i])
  }

  # likelihood for cohorts above principal diagonal
  for (i in 1:(nages-1)){

     delta[i] ~ dunif(-ld, ld)

     # cell probs
     m[i,1] ~ dpois(p[i]*theta[i]*delta[i])

     # predicted pseudo-recruitments for first row, index[1,2+]
     U[i] ~ dpois(delta[i])
  }

  # column 2
  for (i in 1:(nages-2)){
    m[i,2] ~ dpois((1-p[i])*S*p[i+1]*theta[i+1]*delta[i])
  }

  # column 3
  for (i in 1:(nages-3)){
    m[i,3] ~ dpois((1-p[i])*S*(1-p[i+1])*S*p[i+2]*theta[i+2]*delta[i])
  }
```

```
  # column 4
  for (i in 1:(nages-4)){
    m[i,4] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*p[i+3]*theta[i+3]*delta[i])
  }

  # column 5
  for (i in 1:(nages-5)){
    m[i,5] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*p[i+4]*theta[i+4]*delta[i])
  }

  # column 6
  for (i in 1:(nages-6)){
    m[i,6] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-
p[i+4])*S*p[i+5]*theta[i+5]*delta[i])
  }

  # column 7
  for (i in 1:(nages-7)){
    m[i,7] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*p[i+6]*theta[i+6]*delta[i])
  }

  # column 8
  for (i in 1:(nages-8)){
    m[i,8] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*p[i+7]*theta[i+7]*delta[i])
  }

  # column 9
  for (i in 1:(nages-9)){
    m[i,9] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*p[i+8]*theta[i+8]*delta[i])
  }

  # column 10
  for (i in 1:(nages-10)){
    m[i,10] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*p[i+9]*theta[i+9]*delta[i])
  }

  # column 11
  for (i in 1:(nages-11)){
    m[i,11] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*p[i+10]*theta[i+10]*delta[i])
  }
```

```
  # column 12
  for (i in 1:(nages-12)){
    m[i,12] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-
p[i+10])*S*p[i+11]*theta[i+11]*delta[i])
  }

  # column 13
  for (i in 1:(nages-13)){
    m[i,13] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*p[i+12]*theta[i+12]*delta[i])
  }

  # column 14
  for (i in 1:(nages-14)){
    m[i,14] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*p[i+13]*theta[i+13]*delta[i])
  }

  # column 15
  for (i in 1:(nages-15)){
    m[i,15] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*p[i+14]*theta[i+14]*delta[i])
  }

  # column 16
  for (i in 1:(nages-16)){
    m[i,16] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*p[i+15]*theta[i+15]*delta[i])
  }

  # column 17
  for (i in 1:(nages-17)){
    m[i,17] ~ dpois((1-p[i])*S*(1-p[i+1])*S*(1-p[i+2])*S*(1-p[i+3])*S*(1-p[i+4])*S*(1-
p[i+5])*S*(1-p[i+6])*S*(1-p[i+7])*S*(1-p[i+8])*S*(1-p[i+9])*S*(1-p[i+10])*S*(1-
p[i+11])*S*(1-p[i+12])*S*(1-p[i+13])*S*(1-p[i+14])*S*(1-
p[i+15])*S*p[i+16]*theta[i+16]*delta[i])
  }

  # set the first row
  for (j in 2:nages){
      N[1,j] <- U[j-1]
```

```
  }

  # reconstruct population
  for (i in 2:nyears){
    for (j in 2:nages){
      N[i,j] <- (N[i-1,j-1] - (ah[i-1,j-1]/theta[i]))*S
    }
  }

############# GoF Statistics on Recruitment (Lambda) ############################
  # Bayesian posterior predictive check
  # compute Fit Statistics (Freeman-Tukey) for main cohorts
  for (i in 1:nyears){
    E.R[i] <- lambda[i]
    E.org[i] <- pow((pow(R[i], 0.5)-pow(E.R[i], 0.5)), 2)  #observed
  }

  # generate replicate data and compute fit stats
  for (i in 1:nyears){
    R.new[i] ~ dpois(lambda[i])
    E.new[i] <- pow((pow(R.new[i], 0.5)-pow(E.R[i], 0.5)), 2)  #expected
  }

############# GoF Statistics pseudo-recruitment (Delta) ############################
  # Bayesian posterior predictive check
    # compute Fit Statistics (Freeman-Tukey) for main cohorts
    for (i in 1:(nages-1)){
    E.U[i] <- delta[i]
    E.orgU[i] <- pow((pow(U[i], 0.5)-pow(E.U[i], 0.5)), 2)  #observed
    }

    # generate replicate data and compute fit stats
    for (i in 1:(nages-1)){
    U.new[i] ~ dpois(delta[i])
    E.newU[i] <- pow((pow(U.new[i], 0.5)-pow(E.U[i], 0.5)), 2)  #expected
    }

  # derived quantites
  fit <- sum(E.org) + sum(E.orgU)
  fit.new <- sum(E.new) + sum(E.newU)

  # Bayesian p-value
  bpv <- step(fit.new-fit)  #creates a Boolean variable that counts the number of simulations in
which fit.new >= fit; ideal = 0.50

  # overdispersion ratio
```

```
  c.hat <- fit/fit.new    #ratio of observed to expected; ideal = 1.0
########################################################
}
",fill=TRUE)
sink()

# initial values
inits <- function(){list(S = .95, c = .1, theta = runif(nyears, 0.5, 1), lambda = runif(nyears, 0, ld),
delta = runif((nages-1), 0, ld))}

# parameters monitored
params <- c("S", "c", "NN", "R", "p", "fit", "fit.new", "c.hat", "bpv")

# MCMC settings (increase iterations and burn-ins for final)
nc <- 3   ;   ni <- 20000  ; na <- 4000   ;   nb <- 1000   ;      nt <- 2

# run JAGS from R and summarize posteriors (uses JAGSUI with parallel processing)
model1 <- jags(win.data, inits, params,"with_catch.txt", n.chains = nc, n.iter = ni, n.adapt = na,
n.burn = nb, n.thin = nt, parallel=FALSE)

print(model1, digits=3)

# plot posterior predictive check
plot(model1$sims.list$fit, model1$sims.list$fit.new, xlab="Discrepancy observed data",
ylab="Discrepancy expected data", las=1)
abline(0, 1, col="red", lwd=2)
legend("topright",legend=parse(text=sprintf("paste(c.hat,\" =
%s\")",round(model1$mean$c.hat,2))),bty="n")

# plot time plot with bci bands
pltdata <- as.data.frame(cbind(as.matrix(c(1:35)), model1$mean$NN, model1$q2.5$NN,
model1$q97.5$NN))
colnames(pltdata) <- c("Time", "Number", "lower", "upper")

# use ggplot to get a nice ribbon of the BCI
ggplot(pltdata, aes(Time)) + geom_line(aes(y=Number), colour="blue") +
  geom_ribbon(aes(ymin=lower, ymax=upper), alpha=0.2)

# plot time plot with bci bands
pltdata <- as.data.frame(cbind(as.matrix(c(1:35)), model1$mean$p, model1$q2.5$p,
model1$q97.5$p))
colnames(pltdata) <- c("Time", "Rate", "lower", "upper")

# use ggplot to get a nice ribbon of the BCI
ggplot(pltdata, aes(Time)) + geom_line(aes(y=Rate), colour="blue") +
  geom_ribbon(aes(ymin=lower, ymax=upper), alpha=0.2)
```

```
MCMCtrace(model1, params = c("S", "p", "R", "NN", "c.hat"), ind = TRUE)
```

VITAE

Joseph E. Folta, Certified Wildlife Biologist®

Birth: 25 October 1968 in Tunkhannock, PA

Education

- PhD, SUNY-ESF, Fish & Wildlife Biology & Management (2012-2020)
- Graduate Certificate in Geographic Information Science, NC State University (2006-2008)
- MS, University of Tennessee, Wildlife & Fisheries Science (1994-1997)
- BS, SUNY-ESF, Environmental & Forest Biology (1990-1992)
- AS, Finger Lakes Community College, Biology (1989-1990)
- AAS, Finger Lakes Community College, Natural Resources Conservation (1986-1988)

Employment

- **Visiting Instructor/Academic Advisor**, SUNY-ESF (2011 – 2016)
- **District 3 Wildlife Biologist**, NC Wildlife Resources Commission (2004-2011)
- **Forest Stewardship Biologist**, NC Wildlife Resources Commission (2000-2004)
- **Wildlife Technician**, NC Wildlife Resources Commission (1999-2000)
- **Seasonal Park Ranger 2**, Frances Slocum State Park - DENR (1999)
- **Biological Science (Wildlife) Technician**, Alligator River/Pea Island National Wildlife Refuge Complex - USFWS (1997-1999)
- **Graduate Research Assistant**, University of Tennessee (1994-1997)
- **Police Officer**, Laceyville Borough Police Department (1993-1994)
- **Wildlife Technician**, PA Game Commission (1993)
- **Seasonal Park Ranger 1**, Frances Slocum State Park - DENR (1990-1993)
- **Research Aide**, SUNY Research Foundation (1990)

Professional Memberships

- The Wildlife Society, 1992 – Present
- North Carolina Chapter of The Wildlife Society, 2006 – Present
- International Association for Bear Research & Management, 1994 – Present