2013

Temporal, Spatial, and Environmental Influences on the Demographics and Harvest Vulnerability of American Black Bears (Ursus americanus) in Urban Habitats in New Jersey, Pennsylvania and West Virginia

Andrew Tri
West Virginia University

Temporal, Spatial, and Environmental Influences on the Demographics and Harvest Vulnerability of American Black Bears (*Ursus americanus*) in Urban Habitats in New Jersey, Pennsylvania and West Virginia

Andrew Tri

Dissertation submitted
to the Davis College of Agriculture, Natural Resources and Design
at West Virginia University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
Forest and Resources Sciences

John W. Edwards, PhD., Chair
Colin Carpenter, M.S.
Dr. J. Todd Petty, PhD.
Dr. Christopher W. Ryan, PhD.
Dr. Michael P. Strager, PhD.

Division of Forestry and Natural Resources

Morgantown, West Virginia
2013

Keywords: black bear, harvest, New Jersey, Pennsylvania, spatial ecology, urban, *Ursus americanus,* West Virginia

ABSTRACT

Temporal, Spatial, and Environmental Influences on the Demographics and Harvest Vulnerability of American Black Bears (*Ursus americanus*) in Urban Habitats in New Jersey, Pennsylvania, and West Virginia

Andrew Nathan Tri

To date, no research studies in the eastern United States have addressed the spatial ecology of black bears (*Ursus americanus*) in urban and suburban habitats, and there is limited information regarding black bear space use, habitat selection, and harvest vulnerability. I assessed the harvest vulnerability, home range size, and spatial ecology of black bears in New Jersey, Pennsylvania, and West Virginia in collaboration with the New Jersey Division of Fish and Wildlife, Pennsylvania Game Commission, and the West Virginia Division of Natural Resources. The major objectives of my study were to identify and quantitatively assess: (1) if black bears shift home ranges seasonally with respect to urban/suburban habitats; (2) harvest vulnerability and cause-specific mortality of black bears in urban/suburban habitats; (3) if black bears captured as result of nuisance complaints are transient or reside in urban/suburban habitats; (4) habitat characteristics of movement corridors utilized by black bears in urban/suburban habitats; and (5) if corridors likely to be used by black bears accessing urban/suburban environments can be predicted by habitat modeling.

Over the course of the study (2010–2012), agency employees trapped, handled, and fit 119 bears with GPS-GSM collars. Individual study areas in each state were centered around West Milford, Stillwater/Branchville, and Vernon, NJ; Johnstown, Scranton/Wilkes-Barre, and State College, PA; Beckley, Charleston, and Morgantown, WV. A total of 57,816 bear locations were recorded in New Jersey, 114,451 locations were recorded in Pennsylvania, and 33,217 in West Virginia.

Black bears shifted spatial distribution on the landscape in response to resource availability, and consequently I expected bears in urban areas to shift their home ranges seasonally in urban environments. On average, bears were most often found near city limits (<5 km). Home range centers of male bears were twice as far from city limits as female bears (2.31 km vs. 0.91 km, respectively). Bear home range size did not differ among seasons, but did differ between sexes (male home ranges were 5.6 times larger than female bears) and among study areas. Bears did not shift their home ranges closer to urban areas during times of food shortage (spring or late fall). Urban bears lived near town and were resident to the edge of the urban area, but this distance varied with the study area in which they resided. As a result, managers seeking to understand where potential bear conflicts may occur should focus their efforts on the edge of urban and suburban areas (known as the exurban areas) in the Mid-Atlantic Region.

Regulated harvests have reduced mortality and allowed black bear populations to increase throughout the eastern United States over the past 30 years. This rapid and dramatic recovery in population size has led to increased human-bear interactions in New Jersey, Pennsylvania, and West Virginia. Harvest vulnerability of black bears is dependent on a variety of factors and therefore difficult to estimate. I measured harvest vulnerability by generating maximum entropy (Maxent) models of bear occurrence during the prehunting period and hunting season for each study area. I used Maxent to generate models of bear occurrence. In all but one study area, black bear occurrence was 5–75% less in the hunting season than in the prehunting period. Bear occurrence decreased from prehunting period to hunting season in both public hunting lands and urban areas. Bear occurrence probability shifted from public hunting areas to the periphery of the public hunting areas between the prehunting period and hunting season. Annual harvest rates of urban bears were highest in Pennsylvania (20.2%) and lower in New

Jersey (5.9%) and West Virginia (17.3%). Despite the short timeframe (3 years) of my study, regulated hunting was effective in killing urban black bears Pennsylvania and West Virginia. Hunters in Pennsylvania harvested a similar proportion of urban bears to the long-term harvest rate of all bears in the state (20.2% vs. 20.0%, respectively). Probability of urban bear occurrence shifted from public hunting areas during the prehunting period to private lands on the periphery of urban areas during the hunting season. Average overall mortality rates of urban bears were highest in Pennsylvania (28.1%) and lower in West Virginia (17.5%) and New Jersey (15.1%). Despite the short timeframe of the study, regulated hunting was effective in killing a high number of urban black bears in New Jersey, Pennsylvania, and West Virginia, when all mortality sources were taken into account.

Black bear populations have increased nationwide over the past 4 decades due to reduction in direct mortality. Bear population sizes have increased over time and as a result, human-bear conflicts have increased. I sought to determine whether nuisance bears in urban/suburban areas are residents to the area or transient. I predicted that the majority of bears found in urban/suburban areas form resident populations on the urban perimeter, rather than transient individuals that leave the core forests and enter the urban areas periodically. There was considerable support for my prediction that bear populations in urban areas are resident and spend much of their time on the city's edge. Black bears used private lands on the periphery of urban areas. I posit that this may have been because these areas likely had abundant food and provided reduced risk of disturbance (e.g., hunting, human disturbance).

Given the recent explosive increase in urban bear populations, managers are charged to determine which areas of urban/suburban centers are likely to be used by bears. It is unknown whether black bears use travel corridors within urban/suburban matrix to travel between habitat patches. There exists a paucity of information on how black bears use urban and suburban habitats. We used boosted regression trees to create two predictive models of bear occurrence in urban and suburban habitats for (1) New Jersey and Pennsylvania, and (2) West Virginia. We separated West Virginia from New Jersey and Pennsylvania in the modeling process because West Virginia's topography is more rugged and the population density of people was the lowest of all three states. We randomly selected a subset of 40,000 bear locations in New Jersey and Pennsylvania, as well as, 30,000 bear locations in West Virginia from the full database of locations. We generated 40,000 random points within the study areas in New Jersey and Pennsylvania and 30,000 random points within the study areas of West Virginia. We built three models (1) for New Jersey and Scranton/Wilkes-Barre, PA, (2) State College and Johnstown, PA, and (3) West Virginia. We found that probability of bear occurrence was highest in New Jersey and Scranton/Wilkes-Barre study areas when bears were: (1) <1 km from edge forest, (2) <7.5 km from the nearest road, (3) <7.5 km from the nearest urban area, (4) land use/ land cover was forested, (5) <12 km from public land, and (6) NDVI < 0.3. We found that probability of bear occurrence was highest in Johnstown and State College study areas when bears were: (1) <1 km from edge forest, (2) <1 km from the nearest road, (3) <7 km from the nearest urban area, and (4) <7 km from public land. The highest probability of bear occurrence in West Virginia occurred when (1) NDVI was >0.6, (2) distance to public land was >22.0 km, (3) distance to urban areas was between 1–5 km, (3) topographic position index was >100 (steep, rugged terrain), (4) land use land cover was forested or "other", (5) distance to roads was >1.4 km, and (6) distance to core forest was >1.5 km. We found no support for our prediction that urban bears use corridors. Bears spent nearly 95% of their time on the edge of city limits and <5% of their time within city limits. We found no evidence that habitat quality on the edge of city limits was lower than that of "non-urban" bear habitat. There is likely not a physiological need for bears to traverse urban areas when they can remain in habitats where they would encounter less human disturbance. I found no support for my prediction that bears use corridors. Bears spent nearly 95% of their time on the edge of city limits and <5% of their time within city limits. I had no evidence that habitat quality on the edge of city limits was lower than that of non-urban bear habitat. There likely was no physiological need for bears to traverse urban areas because urban habitat patches are often safe from human disturbance and therefore, they did not use corridors. The final predictive model of the probability of bear occurrence will assist managers by identifying areas where urban bears are most likely to live and areas that require direct management actions.

For Matt,
For all your love, patience, and for always being there.

For Mom, Dad, Cal and Ruth,
it was you who taught me a strong conservation ethic
and inspired me to pursue the “family business”.

For Jake, a faithful dog whose wagging tail and smiling
face always kept me going. I promise— no more graduate school….

ACKNOWLEDGMENTS

This project would not have been possible without many people. I thank Mark Ternent and all of the PGC personnel who trapped bears for me; Patrick Carr, Kelcey Buerguess, Mike Madonia and all the NJ DFW personnel who trapped bears for me; and Colin Carpenter, Dr. Chris Ryan, Mike Peters, Steve Rauch, and all the other WVDNR personnel who trapped bears for me. Without this support, I never would have been able to do this project. I thank Dr. John Edwards, Dr. Todd Petty, and Dr. Mike Strager for the guidance and project direction. I thank Dr. Kyle and Mrs. Donna Hartman for serving as parents *pro tempore* and advisors in life and career trajectory. I thank the good people of New Jersey, Pennsylvania, and West Virginia for letting the bears in my project survive a bit longer than they would due to their nuisance behavior.

I also thank my family, Vicki, Jerry, and Chris Tri for being there over the years and dealing with my constant moving about the country and searching for a career path. I thank Matt, my fiancé, for being a constant source of pride and love. Without him, I would not have been able to push so hard to finish my PhD in such a short time. I thank Dr. Diana Doan-Crider and Mr. Cody Crider. You served as the original parents *pro tempore* and are role models for the person that I'd like to be. Your kindness and guidance have propelled me through this field quickly and with a steady path. I also thank Dr. Phil Turk for inspiring me to pursue the statistical portion of my program and helping me get my graduate certificate in applied statistics. Drs. Lenny Brennan, Steve DeMaso, and Joseph Sands, thank you for the *gratis* advice and assistance when I was in a jam. Your sage advice was duly noted.

I thank the graduate students at WVU and the graduate students from Dr. Edwards "non-lab". Geriann, Jacob, Mike, and Milu… We have been through a lot and together we accomplished more. Thank you for being there with a kind word and a cold "adult beverage" when needed. I thank the WVU community for allowing me to become a mountaineer. Because of your kindness and passion for life in this state, West Virginia will always hold a piece of my heart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

RESEARCH JUSTIFICATION AND RESEARCH OBJECTIVES

The American black bear (*Ursus americanus*; hereafter, black bear) is the most common and widely distributed bear species in North America (Schieck et al. 2011). From the time of European settlement until the mid-20th century, black bears were killed indiscriminately and excessively in an attempt to limit damage to crops and livestock. Management and regulated harvests have reduced mortality and allowed bear populations to increase over most of North America over the past 30 years (McConnell et al. 1997, Doan-Crider 2003, Clark et al. 2005, Garshelis and Hristienko 2006). This expansion is both in number and range of black bear (Williamson 2002). As of 2007, the estimated global black bear population ($n \approx 747{,}000$; Spencer et al 2007) was more than all other bear species worldwide (Garshelis et al. 1996, Servheen et al. 1999). Black bears now inhabit 40 states, 12 Canadian provinces, and at least 13 Mexican states, occupying 69% of their historic range (Schieck et al. 2011). In New Jersey, Pennsylvania and West Virginia, there has been a rapid expansion in the bear population over the past three decades (Carr and Burguess 2003a, Ternent 2006, Ryan 2009). Estimated populations number 3,400 in New Jersey, 16,000–18,000 in Pennsylvania, and 11,000 in West Virginia (Ternent 2006, Spencer at al. 2007, Carr and Burguess 2011).

The rapid and dramatic recovery in population size has led to increased interactions between humans and bears in New Jersey, Pennsylvania and West Virginia. Bear populations have been expanding into habitats near urban areas. Additionally, humans have continued to develop areas, fragmenting bear habitat. Both development and an increasing bear population has led to a higher number of human-bear encounters than in the past. In New Jersey, the Division of Fish and Wildlife (NJDFW) has documented an increased number of nuisance complaints from 2006–2010. They recorded 1,303 bear nuisance complaints during 2006, 1,411 during 2007, 2,806 during 2008, and 3,003 during 2009 (Wolgast et al. 2010). In 2003, The Pennsylvania Game Commission (PGC) logged over 1750 nuisance bear complaints in the summer of 2003 (Ternent 2006); in that same summer, the Maryland Department of Natural Resources logged 417 nuisance bear complaints (Spiker and Bittner 2004) and the West Virginia Division of Natural Resources (WVDNR) logged 706 nuisance complaints in 2003. The number of complaints costs each agency time and money that could be better spent elsewhere. As humans recreate, hunt, fish, develop, and live in bear habitat, conflicts and complaints will only keep rising (Clark and Pelton 1999, Treves and Karanth 2003).

Black bears in urban areas can have altered life-history parameters. Urban black bears in a Nevada study were documented to have a lower age of primiparity (age four in urban bears; age seven in non-urban bears), higher mortality in the first two years of life (65% mortality in urban bears in the sample; <1 % in non-urban bears), higher percentage of deaths due to vehicle collisions (100% in urban bears in the sample; < 1% in non-urban bears), and are likely to target garbage dumps as a food source (Beckmann and Lackey 2008). They also may be more likely to depredate livestock (Horstman and Gunson 1982, Doan-Crider 2003). In more mesic habitats of the east and southeast, similar patterns occur. Urban bears have higher annual mortality (Wooding and Hardisky 1994), and are likely to use anthropogenic food sources—garbage dumps, trash cans, dog food and roadkill carcasses—especially during years of poor mast crops and wild food supply (Landers et al. 1979, Young and Ruff 1982, McConnell et al. 1997). Despite these altered life-history parameters, little is known about the spatial ecology of urban black bears.

In most non-urban populations, male bears tend to be more vulnerable to harvest than females. Males forage over a wider range of areas than females, increasing vulnerability to hunters (Noyce and Garshelis 1997). The New Jersey bear population is dominated by females due to a hunting ban from 1971–2002 ; during each of the 5 bear hunting seasons conducted in New Jersey since the reinstatement of the season, females were harvested in greater numbers than males (average 62% females vs. 38% males in the harvest; NJDFW 2013. Patrick C. Carr-personal communication). Harvest vulnerability of black bears may become exacerbated in times of mast failure. Harvest vulnerability of black bears varies with forest composition and hunting methods (Malcolm and Van Deelen 2010). If bears are using urban areas as refugia, hunting vulnerability will substantially decrease. Bears that have low harvest vulnerability pose a problem for managers trying to maintain a low black bear population. To date, there have been very few intensive studies of urban bear ecology east of the Mississippi river. Of the three major, research studies on urban black bear ecology, one dealt solely with the human dimensions and human-bear conflicts in Aspen, Colorado (Baruch-Mordo 2007, Baruch-Mordo et al. 2008, 2009, 2011). The second focused on human-bear conflicts and demographic parameters in the Lake Tahoe basin (Beckmann and Lackey 2005, 2007) of Nevada. The third study focused on predicting human-bear interactions using a GIS framework in Missoula, Montana (Merkle et al. 2011). All three studies focused on an individual municipal area and have relatively limited spatial scale. Additionally, there are few studies that document how bears use the urban environment in eastern cities.

Urbanization in the eastern United States is widespread. Roughly 50% of the nation's population resides within an 800-km radius of West Virginia (United States Census Bureau 2011). As of the year 2011, >80% of West Virginia was forested; however, the forests of West Virginia are more fragmented than ever (WVU NRAC 2011). This is the case for most of the mid-Appalachian states. The state of West Virginia has a similar population density (29.8 people/km^2) to other published urban bear studies. New Jersey and Pennsylvania's population density is effectively 15 and 3.5 times denser than the state of West Virginia (462 and 109.6 people/km^2, respectively). Colorado, Montana, and the Tahoe Basin have a population density of 18.6, 6.8 and 9.5 people/km^2, respectively. There is a paucity of research on urban bear ecology. Because of the vast increase in bear population size and human population size over the past 30 years, a study in the mid-Appalachian region is warranted.

Increased numbers of reported human-bear conflicts have directly influenced management decisions for bears in New Jersey, Pennsylvania, and West Virginia for at least the last decade. This pattern is reflected in most jurisdictions that manage bears east of the

Mississippi River. As a result of increased population growth, hunting opportunities have been provided to reduce bear abundance in eastern states in which high numbers of nuisance complaints have been logged (Spiker and Bittner 2004, Wolgast et al. 2005, Ternent 2006). Hunting is a management tool recommended for reducing some types of human-bear conflicts (Will 1980, Peolker and Parsons 1980, Treves et al. 2010). However, the efficacy of hunting near urban areas to reduce nuisance complaints is unknown due to a lack of fundamental understanding of bear home range use and seasonal bear activity in urban and suburban areas. Understanding black bear spatial ecology in urban and suburban habitats is key to developing and implementing a comprehensive bear management program.

The major objectives of my study were to identify and quantitatively assess: (1) if black bears shift home ranges seasonally with respect to urban/suburban habitats; (2) harvest vulnerability and cause-specific mortality of black bears in urban/suburban habitats; (3) if black bears captured as result of nuisance complaints are transient or reside in urban/suburban habitats; (4) if urban/suburban areas create an attractive population sink for black bears, (5) habitat characteristics of movement corridors utilized by black bears in urban/suburban habitats; and (6) if corridors likely to be used by black bears accessing urban/suburban environments can be predicted by habitat modeling.

Chapter 1:

A Literature Review of Black Bears and Their Management in New Jersey, Pennsylvania and West Virginia

Chapter 1: A Literature Review of Black Bears and Their Management in New Jersey, Pennsylvania and West Virginia

New Jersey.—

Historically, black bear existed across the entire state of New Jersey (Lund et al. 1981). Bears have been documented in New Jersey as early as 1794 and were "very numerous higher up in the country and do much mischief" (Kalm 1794 in McConnel et al. 1997). They roamed the "pine woods…" with "its cohabitants the panther, timber wolf, and bobcat" (Harshberger 1917, Thomas 1967 in Lund 1981:6). In the southern portion of New Jersey dubbed the "Pine Barrens", bears were common throughout the 1800's until about 1885. By then, black bears were driven into remote areas (swamps and mountains) by forest clearing and direct mortality (McConnell et al. 1997). Bears persisted in the northern portion of the state until the early 1970s, where it was estimated that the population was critically low (Lund 1981).

Black bear were classified as a game animal in 1953 by the New Jersey Fish and Game Council. The limited, 10-county hunting season allowed for protection against year-round and indiscriminate killing. The black bear hunting season continued until 1971 when the Council closed the season due to low population assessments (Lund 1980). The population expanded, both in number and in range, over the past 30 years in New Jersey. Due to population recovery and increase, the number of bears in northern New Jersey is estimated to be ~3400 animals (Carr and Burguess 2011). The species was never given state threatened or endangered status and remained a game animal with a closed season until 2003. The NJDFW and the New Jersey Fish and Game Council recognized that the number of human-bear conflicts had increased to untenable levels in northern New Jersey and the population had recovered to a size large enough to sustain a limited, regulated hunting season (McConnell et al. 1997). As a result of an adopted Comprehensive Black Bear Management Policy, limited quota bear hunts occurred during 2003, 2005, 2010, and 2012, in the northwestern part of the state, the area of highest bear density and nuisance complaints. The 2004, 2006–2009 bear hunts were canceled due to litigation and political pressure. In 2010, a management hunt was reinstated (6 December–11 December) on four bear hunting zones after a 4-year hiatus. This hunt typically occurs during the 2^{nd} full week after Thanksgiving (Appendix 1).

During the 2010 hunting season, 7,893 permits were issued and 592 bears were harvested (Carr and Burguess 2011). Bear hunters must have taken a bear hunting seminar from the NJDFW before applying for a bear hunting permit. The season was timed to correspond with the 6-Day Firearm Buck white-tailed deer (*Odocoileus virginianus*) hunting season. Single-projectile firearms were allowed. All age classes and sexes were fair game. Use of dogs was prohibited; however baiting was permitted. Hunters could use a blind, provided that a hunter's blind or elevated stand was located > 91.4 m from any bait. Hunters were allowed to stand hunt, still hunt or drive-hunt (flushing the animal out of cover towards another hunter). The limit was one bear per hunter, per season; mandatory harvest registration was required.

Pennsylvania.—

Pennsylvania first established a regulated hunting season for bear in 1905, a mere 10 years after the creation of the Pennsylvania Game Commission (PGC). This season eliminated year-round hunting and indiscriminate hunting (Ternent 2006). From this point, changes to regulations were numerous over the next century. The trend was to shorten season length and move opening dates later into the fall. Bear hunting occurred from 1 October–1 March in 1905; 1 October–1 January in 1911; 15 October –15 December in 1915; and 1 November–15 December in 1930. By 1936, the season was just over 1.5 weeks long in November. Between 1934 and 1979, the PGC closed the bear season 4 times. By 1979, the season was a single day hunt in mid-December (Ternent 2006). Since 1979, Pennsylvania bear seasons have lengthened to the current regulations (Appendix 1). Today, bear hunting is permitted across the entire state of Pennsylvania (Ternent 2006).

Progressively restrictive regulations occurred with method of harvest, bag limit and animal demographic. There were no restrictions during the 1905 season; however by 1911, steel-jawed traps and deadfalls were prohibited. Log-pen traps were banned in 1915, ammunition was limited to single-projectile cartridges in 1921, and hunting with dogs was banned in 1935 (Ternent 2006). Hunting bears while using bait was prohibited about the same time. Bag limits were reduced to one bear per hunter in 1915. Cubs less than one-year-old received protection in 1925. Each and every restriction remains in place today, save for the law protecting cubs (removed in 1980). Mandatory harvest registration began in 1973. Hunters must bring their bear to a check station within 24 hours of harvest. Starting in 1981, bear hunters were required to purchase a bear tag in addition to a state hunting license (Ternent 2006). The current firearm bear season runs the prior Saturday and the week of Thanksgiving (Appendix 1).

West Virginia.—

Bear hunting in West Virginia has had a long and storied past. The indigenous people in West Virginia commonly hunted black bear. Archeological evidence from native American villages in the Kanawha River Valley date black bear bones to the 15th and 16th century (Pursley 1974). Black bear were numerous in West Virginia during the time of settlement by the Europeans. In the 1700s, bears were killed in substantial numbers along the Ohio, Kanawha, and Little Kanawha River valleys (Kellogg 1937).

Black bear were considered predatory pests by West Virginians and were a bounty species as early as 1886. In 1915, the state legislature adopted the “varmint law” in which bounties were paid out for wildlife species considered to be pests. In 1917, the “bounty law” was adopted by the state legislature. In 1929, Pendleton County adopted a bear bounty system and discontinued it the following year (Pursley 1974). Pocahontas County offered $10 per bear during that decade. By 1934, 40 West Virginia counties had some form of bounty on predators, black bears included (Lesser 1996). Game wardens were asked to destroy all predators encountered on patrol. Despite many counties offering bounties, there were some concerns for the state's bear population as early as the 1930's. The first West Virginia bear hunting season was established in 1935 and continued with uniform regulation across the state until 1948. By 1943, the state Game, Fish and Forestry Commission (precursor to the West Virginia Division of Natural Resources [WVDNR]) estimated that only 588 bears existed in the state. In 1947, wildlife became a public trust (managed by the state). There was a 1-year open season on bear in 1948. In 1949, the first records of black bear harvest were recorded. In the mountain counties (Randolph, Pocahontas, and Pendleton), an open season was declared on bears for one year; after that (1949–1979), there was a statewide season that was essentially continuous from 1953-1964. The first split season (an early and a later season) was in 1953 and again from 1965-1978. The 1964 split was due to fire danger (Rieffenberger et al. 1981). The state Game, Fish, and Forestry Commission restored a uniform bear season for the state in 1965. The bear hunting season was a split season—one week during early November and three weeks during December (Lesser 1996). By the mid 1950's, most of the bear bounties were slowly rescinded. Despite this, Pendleton County reenacted their bear bounty; Pocahontas County still had a bear bounty in place until 1969. In 1955, West Virginia residents voted the black bear to be the state animal (Pursley 1974). The black bear was also chosen as the centennial symbol in 1963.

The State Game, Fish and Forestry Commission initiated a black bear research project in 1957, but this project was discontinued in 1959. In 1969, the state legislature recognized the black bear as a state game animal. This afforded the bear protection from unmitigated direct mortality by hunters and livestock farmers. The West Virginia Black Bear Research Project was initiated in 1971 by the WVDNR. The dropping of the early November season in 1979 protected most pregnant female bears from harvest, and allowed for significant population increase. This eventually allowed for ~10% annual population increase from 1979–1995 (Lesser 1996).

Currently, West Virginia has one of the most liberal harvest management regulations in the United States (Garshelis and Hristienko 2006), with a 2-bear bag limit in some counties. In West Virginia, regulations prohibit hunting bears with bait, buckshot (multiple-projectile bullets), killing sows with cubs, trapping, or killing bears weighing < 34 kg (75 lbs) live weight. For most of West Virginia, there is a one bear limit per season; however, in 2008 the bag limit was increased to 2, provided at least one was taken in Boone, Fayette, Kanawha, Raleigh counties. As of 2011, archery season runs from 16 October–20 November. Firearms season runs from 27 September–2 October, 21 November – 3 December, and 5 December – 31 December in certain counties.31 Hunting bears with the aid of hounds is allowed during the 1-week September and 4-week December seasons; however the season in which dogs are allowed varies by county and wildlife management unit (West Virginia Division of Natural Resources 2011).

Human-bear conflict

Human-bear conflicts have occurred since colonial settlement of the United States (Garshelis 1989). Bears are a very intelligent group of carnivores and behavior greatly influences learning (Herrero 2002). "Problem bears" learn that living around humans will result in a food reward (Baruch-Mordo 2009). This behavior can perpetuate through generations, resulting in conflicts with humans (Gilbert 1989, Beckmann and Berger 2003). Studies from the western United States indicate that potential for conflicts is great due to ever increasing human populations developing and living in bear habitat (Beckmann and Berger 2003, Zack et al. 2003). In the eastern United States, development in bear habitat and range is also on the rise, resulting in the potential for increased conflicts between humans and bears. The potential for conflicts is exacerbated because bears can cause property damage and present a potential threat to human safety (Conover 2002).

Black bears can cause a number of problems when they come into conflict with humans. They can damage apiaries, orchards, livestock, human structures, and regenerating forests (Pelton 2000, Witmer and Whittaker 2001). Black bears habituated to human food sources can cause problems for people and wildlife management agencies (McCarthy and Seavoy 1994, Schirokauer and Boyd 1998). In Massachusetts, Jonker et al. (1998) found a 15% increase in bear depredations on crops and apiaries over a 5-year period. These damages averaged < $ 1,000 USD per person per year and were viewed as an annoyance to agricultural producers. From 1997–

2008, WVDNR received roughly 750 nuisance complaints per year during a 12-year period (Ryan 2009). From 2003–2005, PGC received roughly 1,500 nuisance complaints annually (Ternent 2006). From 1999–2003, NJDFW received roughly 1,400 complaints annually (NJDFW 2004). In each of these instances, it was not known if nuisance bears were residents of the area or transient, dispersing bears. Determining whether the bear nuisance problem is caused by resident vs. transient bears can be a potential issue for managing agencies (Beckman et al. 2004).

Attempts to decrease human-bear conflicts can be a daunting task with equivocally effective solutions. The four most commonly used management techniques to decrease human-bear conflicts are (1) lethal (sport and non-sport), (2) non-lethal (e.g., trap and relocate, aversive conditioning, exclusion), (3) education, and (4) litigation/citation. These methods can be used in combination with one another or used separately. Each solution to mitigating human-bear conflicts has its own merits and shortfalls. Human-bear conflict mitigation and management techniques have been refined over the past 30 years (Pelton 1972, Bacon 1974, LeCount 1979, LeCount and Baldwin 1986, Johnson 1990, Ciarniello 1997, Clark et al. 2002, Ricklefs 2005). The public acceptance of each method can be highly contentious when changes to management plans are introduced, especially when tensions from black bear nuisance complaints are high.

Managers of black bear have two forms of lethal control at their disposal: sport hunting and euthanasia. Bear hunting seasons are open in 27 states: 11 (41%) permit the option of hunting with hounds, 3 (11%) permit the option of hunting over bait, 7 (26%) permit the option of hunting with both methods and 7 (26%) allow neither method (Hristienko and Mcdonald 2007). States and provinces with liberal hunting regimes maintained human–bear conflict at stable levels, whereas those with more conservative regimes seemed to experience a growing trend in the number of conflicts. Adding a spring hunting season seemed to further reduce human-bear conflicts. From 1991–2001, black bear license sales and harvest increased by 62% and 65% respectively in jurisdictions that allowed hunting (Hristienko and McDonald 2007). With increasing numbers of bear hunters and harvest, one would hypothesize that nuisance complaints would decrease, but this is not always the case.

Because the number of bear complaints can vary from a myriad of environmental and sociological factors, increased bear harvest does not always result in reduced nuisance complaints (Treves et al. 2010). Hunting quotas of bears are generally set in part on the number of nuisance complaints or allowing unlimited hunting in agricultural zones (Jorgenson et. al 1978, Garshelis 1989, Huygens et al. 2004). Forbes et al. (1994) documented that increased hunting reduced human-bear conflicts in a Canadian national park. Other studies have failed to find such a direct link between increased hunter take and reduced nuisance complaints (Garshelis 1989, Obbard et al. 1997, Huygens et al. 2004, Howe et al. 2010). Treves et al. (2010) documented that hunter take in Wisconsin did not correlate with nuisance complaints. They found that increased bear population size resulted in increased nuisance complaints and human-bear conflicts. Moreover, it was likely that Wisconsin hunters took too few bears out of the population to mitigate the effect of population increase over a 10-year period (Treves et al. 2010). Hunting reduces bear numbers in the fall (and spring depending on the state) so managers may rely on euthanasia as another form of lethal control.

Euthanasia is often used with problem bears and is regarded as the most efficient means of controlling problem bears (Mazur 2010); however, it can be highly contentious with some members of the public. It allows for the specific target of a problem individual and its removal from the population. Based on a 2007 survey of bear biologists and managers in North America, the most common response of agency policy is to perform a site visit, trap/relocate a bear, and then euthanize it if problems continue (Spencer et al. 2007). In Juneau, Alaska, McCarthy and Seavoy (1994) documented that Alaska Fish and Game managers and biologists had dispatched ~ 2.1 black bears per year in town. This increased slowly to a boiling point during 1987 in which 14 bears were killed and the killings were covered by the local media. Public outcry and protest demanded a search for alternative methods. After garbage control methods and relocation ordinances were enacted, there was a slight decrease in bears killed by Fish and Game. The benefits were fleeting because two years later, Alaska Fish and Game received a record 580 bear complaints and killed a record 15 nuisance bears during one year (McCarthy and Seavoy 1994). In West Virginia, WVDNR has a multi-tiered response plan to deal with nuisance bears (WVDNR 2011). There are 4 categories of conflict with adult bears: (1) Non-offending black bears, (2) Nuisance black bear, (3) Black bears causing agricultural property damage, and (4) Black bears posing a threat to public safety (Figure 1); the fifth category deals with orphaned cub. Orphaned cubs are relocated back to the place from which they were removed or placed with a surrogate sow. Response from the WVDNR is not warranted with category 1 bears, save for public education of the landowner. Category 2 bears have caused repeat nuisance offenses (eating trash, destroying birdfeeders, destruction of personal property, excluding breaking into a dwelling or agricultural property). These bears are either aversively conditioned or destroyed, depending on severity of the offense and the rate of recidivism. Category 3 bears (bears that damage agricultural property) require an immediate response from agency personnel; the agency can either aversively condition or destroy the bear, depending on severity of the offense and the rate of recidivism. The State of West Virginia will compensate landowners for all bear damage, pursuant to West Virginia code 20-2-22a. Depredation permits can be issued for both category 2 and 3 black bears. Category 4 bears (threats to public safety) are trapped and destroyed or immediately destroyed by the most efficient means necessary.

Possible Responses	Category 1	Category 2	Category 3	Category 4	Category 5
Record Complaint	X	X	X	X	NA See Section II. E.
Public Education	X	X	X	NA	NA
Aversive Conditioning	NA	X	X	NA	NA
Trap and Relocate	NA	X	X	NA	NA
Trap and Destroy/Destroy by Most Efficient Means	NA	X	X	X	NA
Depredation Permit	NA	X	X	NA	NA
WVDNR Hunt	NA	X	X	NA	NA

Figure 1. Human bear conflict resolution diagram for West Virginia Division of Wildlife Resources (WVDNR 2011a:8).

Relocation (also known as translocation) is an option used by most (75%) of all North American wildlife agencies (Spencer et al. 2007). Of these agencies, 44% responded that they relocated bears due to "public pressure" and 41% indicated that they relocate bears due to a "2 or 3 strike" policy. Only 15% of all agencies felt that relocation was the best approach. Relocation is an alternative to killing bears involved in human-bear conflicts. In 65% of agencies, bears are always released whenever there is a human-bear conflict (Spencer et al. 2007). Translocation of nuisance bears was ineffective in a Florida study as there was a 50% rate of recidivism and 34% of bears became serial offenders (Annis 2007). Roughly 32% of all translocated bears returned to the capture site, many within six months of release. Of the 28% (n = 41) bears that stayed away from the site of nuisance behavior ~ 70% remained in the national forest. About 27% were killed via direct mortality (e.g. car crashes, poaching) (Annis 2007). Armistad et al. (1994) documented that despite low sample size (n = 5 bears), relocation was effective in reducing bear depredations on sheep. In a central Ontario study, >80% of all relocated nuisance bears homed back to the capture site (Landrialt 1998). In a similar study in Virginia, Fies et al. (1987) documented that

73% of bears relocated over 80 km were killed by hunters, 10% returned to the capture site, and 3% continued to cause human-bear conflicts. Comly-Gericke and Vaughan (1997) documented similar findings based on the translocation of 43 nuisance black bears from Shenandoah National Park to southwestern Virginia. Of the 43 translocated bears, 1 resumed nuisance activity, 10 were killed in automobile collisions, and 0 bears returned to the original capture site. Relocation is often combined with aversive conditioning upon release of the bear.

Aversive conditioning is the use of operant conditioning that uses a negative stimulus to cause pain, irritation, or avoidance in an animal that is performing unwanted behaviors (Shivek et al. 2003, Beckmann et al. 2004). Nausea-inducing chemicals have been used to create a taste aversion (Garcia et al. 1974, Burns 1983, Ternent and Garshelis 1999), but it only gets bears to avert to certain foods in certain packaging (Hastings et al. 1981, McCarthy and Seavoy 1994, Ternent and Garshelis 1999). Some managers trap bears using culvert traps and hold them in the trap so the bears will learn to associate the area with the discomfort of the trap (Clark et al. 2002). The conditioning can be strengthened with a "hard release" (e.g. using Karelian bear dogs, cracker shells, or non-lethal projectiles) as the bear leaves the trap (Beckmann et al. 2004). Bears may avoid the area (Chi et al. 1998, Clark et al. 2002), but most bears conditioned to anthropogenic foods will return (Beckmann et al. 2004, Leigh 2007). This technique is used, rarely, in West Virginia as part of their human-bear conflict resolution policy. In a study at Kings Canyon-Sequoia National Park, Mazur (2007) documented 16 of 29 bears responded to aversive conditioning by preventing bears from becoming food-conditioned. Aversive conditioning was more effective on adults than yearlings, and the 6 food-conditioned bears in the study were either killed or relocated. In New Jersey, all 4 bears that were aversively conditioned returned to an urban setting with the capture site in 3–17 days and to the original capture site within 85 days (Northeast Wildlife DNA Laboratory 2010). In the Lake Tahoe basin, Beckmann et al. (2004) relocated 62 bears and used multiple aversive conditioning techniques. Within 1.5 months, 70% of all bears returned to the trapping area; by the end of the study 92% of all bears returned to the trapping area. Because aversive conditioning is often viewed as ineffective, at best, a temporary measure to enable persons experiencing nuisance bear activity an opportunity to remove food attractants, agencies have decided that managing human behavior might be more effective.

Legislation and citation can work to influence available food to bears. In some cases, this is very effective in reducing nuisance complaints and human-bear conflicts (Spencer et al. 2007). In New Jersey, Pennsylvania, and West Virginia, it is illegal to feed bears. In Pennsylvania and West Virginia, it is illegal to feed bears and hunt directly over bait. About half (47%) of all jurisdictions that manage bears report that they have a law, statute or ordinance allowing fines to be levied against a citizen who creates a bear-conflict prone situation (feeding bears, poor garbage management, etc.) (Hristienko and McDonald 2007). This is surprisingly low, given the number of states dealing with nuisance complaints. Legislation can sometimes prevent or lower the probability of human-bear conflicts by reducing available garbage and removing attractants (Hristienko and McDonald 2007, Spencer et al. 2007). This assumes that the law is being enforced. In New Jersey, the Black Bear Feeding Ban (NJSA 23:2A-14) was deemed ineffective and needed improvement (Wolgast et al. 2005). Nine citations for the entire state from 2005–2009 were issued. In Juneau, bear-proof dumpsters and garbage controls (mandated by city ordinance) lowered the amount of nuisance complaints for a 2-year period, yet the following year nuisance complaints were at an all-time high (McCarthy and Seavoy 1994). This again could be due to lack of enforcement of the city's ordinances.

Education provides a means to alter the behavior of people and may reduce potential human-bear conflicts. Beckmann et al. (2004) suggested that education may be more effective than aversive conditioning of black bear; however, the efficacy of education programs about black bears is rarely studied and evaluated (Herrero 2003). In 2006, Gore et al. reviewed six North American education programs: Whistler (British Columbia, Canada), Lake Tahoe (California and Nevada, USA), West Yellowstone (Montana, USA), Central Florida (USA), Northern New Jersey (USA) and Adirondack State Park (New York, USA). Five of six agencies running these programs elected to shift funding from intervention-based (relocation, sterilization, garbage ordinance and legislation) programs to education based programs. Five of six programs resulted in a reduction of complaints from stakeholder groups (Gore et al. 2006). Eighty-one percent of all bear management agencies in the United States reported that they have some sort of education program for the public (Spencer et al. 2007).

Spatial Ecology and Home Range of Black Bear

Spatial ecology can help researchers and wildlife managers determine how animals use the landscape and resources. It allows one to understand what factors and resources (biotic and abiotic resources) may be important to individuals and populations of wildlife. As these resources can be heterogeneous across landscapes, it is important to understand why a specific species may be selecting a certain area (Tilman and Kareiva 1997). When populations recolonize or disperse into new areas, they may face new hazards (hunting, traffic, commercial activities) and managers need to know how vulnerable wildlife could be to these threats.

Global positioning system (GPS) collars can provide valuable data on animal movements, habitat use, and activity patterns (Obbard et al. 1998, Bowman et al. 2000). They can be relatively accurate and precise, depending on conditions (Hanson and Riggs 2008). GPS signal strength and fix rate are influenced by a variety of forest habitat variables—canopy cover, habitat type, slope, tree density, bole diameter, and terrain— and topographic variables—slope, aspect, elevation, and grade (Dussault et al. 1999, Di Orio et al. 2003, Hanson and Riggs 2008). Studies have attempted to document relations between these variables and location precision (D'Eon et al. 2002, Cain et al. 2005), but the relations seem to be nonlinear (DeCesare et al. 2005). Data precision and accuracy can affect home range estimation techniques (White and Garrot 1998).

Corridors and black bear.—

Corridors are patches of habitat that facilitate the movement of wildlife. They facilitate the movements among habitat patches (Hass 1995, Haddad 1999), increase rates of recolonization (Hale et al. 2001) and mitigate some of the effects of fragmentation (Tewksbury et al. 2002).

Wildlife using corridors can potentially have higher survival and population viability (Fahrig and Merriam 1985, Beier 1993, Beier 1995, Coffman et al. 2001). In endangered sub-populations of black bear, corridors show some success in linking populations and increasing gene flow (Dixon et al. 2004). Bear populations in New Jersey, Pennsylvania and West Virginia are healthy and robust (Hristienko and McDonald 2007); however this high population mixed with a high degree of fragmentation caused by human development has high potential for human-bear conflict. At Yellowstone National Park, black bears use movement corridors (areas that facilitate movement between habitat patches) to feed during the diurnal hours. This creates potential for car accidents, safety issues due to human habituation and human-caused bear mortality (Gunther 1994). With the exception of a few studies in the western United States (Lyons 2005, Baruch-Mordo 2007, Beckmann and Lackey 2008, Merkle et al. 2011), there is very little known about where black bears move in urban/suburban areas. In the western studies, bears extensively used city/urban habitat for food resources. Males used the urban areas in summer exclusively (Lyons 2005) and females used urban habitats in most other seasons (Lyons 2005, Baruch-Mordo 2007).

Home range estimation.—

Home range is a biological concept described as "the area, usually around a home site, over which the animal normally travels in search of food" (Burt 1943:351). Its size can vary by species, location, life stage, age, sex, animal condition, and breeding status (Hayne 1949, Odum and Kuenzler 1955); it can further vary by time interval between locations (Swihart and Slade 1985, Swihart and Slade 1997, Otis and White 1999), estimation technique (Adams and Davis 1967, Dunn and Gipson 1977, Smith et al. 1981, Powell 2000) and sample size (Schoener 1981, Bekoff and Mech 1984, Arthur and Schwartz 1999, Seaman et al. 1999). Each variable could drastically alter home range estimates and cause spurious results. Due to this problem, comparing home range estimates between studies is problematic (White and Garrott 1990). Black bear home range size varies among studies and different locations. Documented home range size spans an incredibly wide range in North America (1 km^2 – 606 km^2; Table 1). With large sample sizes, home range accuracy increases (Seaman et al. 1999) and GPS collars can offer a relatively easy way to obtain that data.

The Minimum Convex Polygon (MCP) was one of the first home range estimation techniques and is still used today. Mohr (1947) pioneered this method of estimation by closing a convex polygon around animal locations to estimate the minimum area used by an animal over time. It is often used because it is simple and non-parametric. It also allows one to compare home range estimates with other peer-reviewed studies. Its drawbacks are many. Because it is non-parametric, the MCP cannot be used for utilization distributions (high use areas are valued the same as low or no use areas). It is sensitive to sample size—the bigger the sample size, the bigger the MCP—and if sample sizes are unequal between studies, they are incomparable (White and Garrott 1990). It is not robust to outliers, and it includes movement barriers that would not necessarily be included in a home range (such as lakes, deserts, cliff faces, etc.)

The Kernel Density Estimator (KDE) (Worton 1989) is one of the most widely used home range estimators (Hemson et al. 2005). This estimator uses a utilization distribution—a probability distribution built from an individual's location data at different points in time— to determine the probability of an animal being located within an area. KDE creates lines of utilization intensity by calculating the mean influence of data points at grid intersections on a raster Geographic Information System map (Hemson et al. 2005). In the calculation of KDE, there is a smoothing factor (h) used to determine how much influence each intersection gets in the utilization distribution. The higher the value of h, the larger and less detailed the home range estimate (and vice-versa) (Worton 1989). A common method for estimating h is least squares cross-validation (LSCV). Least squares cross-validation minimizes the integrated square error in the location data to converge on a value for h. When used with small sample sizes, the KDE produces variable and inaccurate estimates (Seaman and Powell 1996). KDE with LSCV works well with moderate sample sizes (n = 20–250 points) (Girard et al. 2002, Gitzen and Millspaugh 2003). With sufficient sample size, the KDE can be a good estimate of habitat use and spatial utilization. Additionally, likelihood-based cross-validation techniques based on information theory have been developed (CVh; Horne and Garton 2006a). Rather than minimizing the integrated square error in the relocations, CVh minimizes the Kullback-Leibler distance. Likelihood cross-validation provides estimates of home range size with better fit and less variability (Horne and Garton 2006a).

The recent changes in the ability of researchers to collect copious amounts of very precise data with relative ease have shifted the paradigm of home range analysis and animal spatial ecology. Biologists have had problems with determining an *a priori* smoothing factor for KDE and often use default setting in home range estimation programs (Hemson et al. 2005). This can be problematic and generate spurious results. Most home range techniques—MCP, KDE, Harmonic Mean (Jennrich and Turner 1969) — become biased when outliers are included in the analysis and become poor estimators of true home range size (Getz et al. 2007). In the past, researchers used KDE in part because it allows one to generate a utilization distribution of animal locations. Ability to generate a utilization distribution, coupled with the ability to account for imprecise data (telemetry error), made for a great leap forward in home range estimation (Hemson et al. 2005). With GPS technology, the need for buffering probability for each point is less crucial due to highly precise data. Additionally, using a KDE assumes that the underlying cumulative probability density function of the relocation data is distributed bivariate, Gaussian (Hemson et al. 2005). This may not always be the case, resulting in potentially spurious results and conclusions.

To avoid this, a new technique has been developed. A Local Convex Hull home range estimator (LoCoH; Getz et al. 2007) is a non-parametric estimation technique (it makes no assumption of underlying probability distribution). It functions as a union between the MCP method and a non-parametric kernel method. It applies MCP construction of a subset of data and the local convex polygon (local hull) is created using *k-1* nearest neighbors. When these two techniques work together, they create a utilization distribution. LoCoH uses kernels created from the data, unlike parametric kernels defined by a one parameter function (bivariate Gaussian distribution on each data point with a width of *h*) (Getz et al. 2007). This union of MCP and non-parametric kernels allows home ranges to exclude areas that were never or could never be used. It does not extrapolate probability of occurrence over areas that were never used (fenced areas, mountains, lakes, oceans, etc.). One can also link this data with remote sensing images to address resource use, movements, or social behavior (Getz et al. 2007).

Individual black bear home range size can shift dramatically by season. Distribution and availability of food can alter home range size between seasons (Jonkel and Cowan 1971, Amstrup and Beecham 1976, Young and Ruff 1982, Powell 1987, Doan-Crider 2003); when food is abundant, home ranges are smaller. Extreme changes in home range size are more typical in arid environments when food is either scarce or abundant (Crider 2003). Sex and age can alter home range size. Males and juveniles typically have larger home ranges, females typically have smaller home ranges (Reynolds and Beecham 1980, Garshelis and Pelton 1981, Hellgren 1988). In Pennsylvania, this relation holds true—reported mean male home range size is 173 km^2 and 72 km^2 for females (Alt et al. 1980). Home range is hypothesized to be an artifact of habitat quality (Young and Ruff 1982, Smith and Pelton 1990). Habitats in the southern and central Appalachian hardwood forests are of high quality—areas in which each animal's individual fitness is maximized (Garshelis and Pelton 1981, VanHorne 1983). In these areas, there is home range overlap and high female productivity (Garner 1986, Powell 1987, Hellgren 1988); however, urban and suburban areas may not provide high quality habitat yet may hold abundant supplemental food resources (trash, agricultural crops, ornamental fruit trees, etc). In both New Hampshire and New Jersey, urban female bears had smaller home ranges than those reported in nearby less developed areas (Ellingwood 2003, MacKenzie 2003).

Black Bear Habitat Selection

Black bear habitat selection has been intensively studied in the mid-Appalachian area of the United States (Garshelis 1978, Quigley 1982, Carr 1983, Brody 1984, Clevenger 1986, Coley

1995, Vaughan et al. 2002). Based on previous research, bear habitat quality is a function of many landscape components —elevation, topography, vegetation community structure, road density, distance to urban areas, etc. (Van Manen 1994). Quantifying and modeling these habitat components can be a tricky venture because bears are habitat generalists that rely on several different food sources and landscape components. Acknowledging a small sample (n = 5 females), black bears select mixed forest and wetlands, as well as habitat with high stream densities, in western Maryland (Fecske et al. 2002). Additionally, females used conifer stands year-round. Bears tend not to use areas around primary highways, but use other road classes. Females with cubs selected areas with lower road densities (Fescke et al. 2002). In the mountain counties of West Virginia (Pocahontas and Randolph counties), black bears selected mixed coniferous and northern hardwood forests, dominated by sugar maple (*Acer saccharum*), American beech, yellow birch (*Betula lutea*), red oak (*Q. rubra*), and black cherry (Brown 1980). In northern West Virginia, bears selected mixed forest areas and heavily utilized clear-cuts in the summer months (10–30% of telemetry locations) due to abundant herbaceous food sources (Miller 1975).

Inherent flexibility in both caloric and habitat requirements allows black bears to use a wide variety of foods and habitat types across their range. One of the biggest drivers of bear habitat selection is food (Doan-Crider 1999). In mid-Appalachian habitats, black bears tend to use mixed hardwood forests as habitat. Their diet is predominantly vegetation, with blackberries, cherries and other soft–mast species providing the vast majority of spring and summer forage (Pelton 1982, Pelton 1985, Elowe and Dodge 1989, Pelton 1996). Hard mast, (oak, hickory and beech) provide high energy needed during hyperphagia, a period in which black bears increase daily caloric intake from 8,000 kcals per day to 15,000 – 20,000 kcals per day (Nelson et al. 1983). In West Virginia, hard mast typically consists of American beech, hickory, white oak (*Q. alba*), chestnut oak (*Q. prinus*), black–red oak (*Q. velutina*–*Q. rubra*), scarlet oak (*Q. coccinea*), and scrub oak (*Q. ilicifolia*). West Virginia soft mast species consist of black cherry, grapes (*Vitis* *spp.*), hawthorn (*Crataegus spp.*), crabapple (*Pyrus spp.*), flowering dogwood (*Cornus florida*), blackberry (*Rubus spp.*), greenbrier (*Smilax spp*.), sassafras (*Sassafras albidum*) and apple (*Malus spp.*) (Ryan et al. 2007). Oaks are considered the most important food source to black bears in the southern Appalachian region (Huntley 1989). Interestingly, squawroot (*Conopholis americana*) is the secondmost important bear food in the southern Appalachians. Squawroot is a parasitic plant that grows on the roots of oak trees in early summer (Vaughan 2002). Therefore, 2 of the most important bear foods grow in the oak forests of the southern Appalachians. In the absence of anthropogenic direct mortality, oaks are a driving force for black bear movements and population dynamics (Pelton 1989, Vaughan 2002, Ryan et al. 2007).

During the autumn months, bears will commonly gain 0.5–1 kilograms (1 to 2 pounds) of fat per day in preparation for winter (Pelton 1982). Most of the natural food sources are easily found in continuous forest cover with relatively dense understory vegetation. If there is a failure in either soft or hard mast species, bears will switch to any other source of food that they can find (nuts, trash, birdseed, suet, standing crops, and beehives). Cornfields and abandoned apple orchards serve as popular feeding sites in the upper Midwest (D. Garshelis, Personal Communication). Black bears have been documented to eat animal matter (scavenged roadkill deer or newborn fawns). In New Brunswick, black bear predation accounted for 23% of white-tailed deer fawn mortality (Ballard et al. 1999). In Pennsylvania, black bears predation explained 7% of the white-tailed deer fawn mortality (Vreeland et al. 2004). Leopold et al. (1951) documented heavy predation on newborn fawns by black bear in a California population of mule deer (*Odocoileous hemionus*).

Human disturbance was previously thought to restrict bear habitats. Bears typically occupy remote areas characterized by rough terrain, which protects them from direct mortality and over–harvest. However, in the eastern U.S., bears exist in close proximity to humans (MacKenzie 2003, Hristienko and McDonald 2007, Baruch-Mordo 2009). Roads can pose a problem for bears attempting to cross roads or forage on roadsides (Beringer et al. 1990).

Interstate highways are often barriers to bear movement, thereby isolating bear populations from one another (Wooding and Maddrey 1994). Additionally, Proctor et al. (2005) suggested that female bears may be more affected by human influences such as roads and associated human settlements than males, not because of their dispersing ability but because of high mortality and their avoidance of these areas. However, not all roads degrade bear habitat areas. Unimproved roads with low human traffic (forest service roads, county roads) may in fact facilitate bear movements and provide foraging areas with abundant food (Carr and Pelton 1984). In developed areas containing bears in Florida, bears regularly crossed roads with lower traffic density with higher success (3.1 times higher odds) than in the areas with higher traffic volume (McCown et al. 2004). Development can cause disturbance and fragmentation of wildlife habitat, especially when urban areas start to sprawl into rural areas.

Exurbia is residential land use outside of city limits, situated among working farms or undeveloped land (Nelson 1992). It has a human population density and mean property size between the suburbs and rural areas. The difference between exurban and suburban landscapes is that human dwellings in exurbia are interspersed throughout wildlife habitat rather than habitat existing in patches within suburban non-habitat (Odell and Knight 2001). Generally, residential development in exurbia has a higher impact on the landscape than suburban and urban growth patterns (Theobald et al. 1997). There has been little research of wildlife in exurban areas (Hansen et al. 2005), most of which has been on white-tailed deer (Odell and Knight 2001, Grund et al. 2002, Storm et al. 2007).

Black Bear Survival Estimates and Population Demographics

Survival estimation techniques have advanced in the past two decades (Murray and Patterson 2006). To calculate useful survival estimates from telemetry data, two conditions must be satisfied: (1) radiomarked individuals should have the same survival and habitat use as individuals that are not radiomarked, and (2) the tracking device must continuously monitor the animal, resulting in 100% detection probability of the animal (White and Garrott 1990). In our study, the mass of the collars is < 3% of the overall black bear body mass. Additionally, the GPS-GSM collars send > 7 locations per day, allowing for continuous monitoring of each study animal, but collar loss can be high.

Human-caused, direct mortality is the major cause of death in black bear populations. Hunting is by far the leading cause of mortality for black bears (Kasworm and Thier 1994, Wooding and Hardisky 1994, Ryan 1997). Kasbohm (1994) documented that survival for adult males was 57%–60%, and 90–95% for females in Shenandoah National Park, Virginia. In George Washington and Jefferson National Forest, Ryan (1997) found that annual male survival was 33.8%–34.6%. Yodzis and Kolenosky (1986) documented overall survival of adult black bears in Ontario ranged between 74% and 83% (90% adult male survival in an unhunted population). In Montana, annual black bear survival was 73% for adult males and 79% for adult females (Kasworm and Thier 1994). In West Virginia, (Ryan 2009) reported annual survival was 91% for adult females in West Virginia. Non-hunting mortalities of black bears in West Virginia increased in years of mast failure (Rieffenberger et al. 2000, Ryan et al. 2007).

Subadults and juveniles have lower survival rates than adults (Elowe and Dodge 1989). Subadult males disperse from their natal home range (to reduce inbreeding); females will often stay within their natal home range or will disperse to an adjacent home range. Of 51 subadults in an Alaskan study, 100% of male bears dispersed, while 97% of female black bears remained in their natal range; dispersal increases the risk of mortality from car collisions (Schwartz and Franzmann 1992). Yearlings in Shenandoah National Park had the highest mortality rate (54%) of any age class (Carney 1985). Ryan (2009) documented survival in West Virginia as 78% for subadults females and 77% for juvenile females.

Urban areas may act as attractive sinks for black bears. Pulliam (1988) first described a population sink as an area in which mortality rates were greater than natality rates, resulting in a population decline toward extinction unless immigration from a population source offsets the high mortality. A trap is a patch of habitat that has rates of immigration so low that the population inhabiting it is driven toward extinction (Battin 2004). Urban population sinks have been intensively studied in passerines (*Passiformes*), raptors (*Falconiformes*), and waterfowl (*Anseriformes*) (Battin 2004). In mammals, a similar phenomenon exists. Roads caused a attractive sink for common brushtail possum (*Trichosurus vulpecula*) and common ringtail possum (*Pseudocheirus peregrinus*) in the exurban areas of Sydney, Australia (Russell et al. 2010). Weir et al. (2004) documented that roads near Kamloops, British Columbia, caused a population sink in the valley for badgers (*Taxidea taxus jeffersonii*). In a case study from the Tahoe basin, the intrinsic growth rate of the resident black bear population (λ) was significantly less than 1 ($\lambda = 0.749$) (Beckmann and Lackey 2008). Despite an increase in fecundity, female black bears ($n = 12$) in urban areas had much higher age-specific mortality rates than wildland bears ($n = 10$). McCown et al. (2004) documented high anthropogenic mortality in Florida. Of the 17 bears killed in the study, 10 mortalities were caused by vehicle collisions, 5 mortalities were caused by illegal killing and the final 2 were instances of intraspecific predation. In West Virginia, strip and mountaintop mines can function as population sources by providing habitat in which females are free from hunting pressure and other human-caused mortality, thereby increasing their individual fitness (J. Daniels, unpublished data).

LITERATURE CITED

Abler, W. A. 1985. Bear population dynamics on a study area in southeast Georgia. Georgia Department of Natural Resources, Atlanta, GA. Final Project Report.

Adams, L. and S. D. Davis. 1967. The internal anatomy of home range. Journal of Mammalogy 48: 529–536.

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Alldredge, J. R. and J. T. Ratti. 1992. Further comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 56:1–9.

Alt, G. L., F. W. Alt, and J. S. Lindzey. 1976. Home range and activity patterns of black bears in northeastern Pennsylvania. Proceedings of the Northeast Section of the Wildlife Society 33:45–56.

Alt, G. L., G. J. Matula, Jr., F. W. Alt, and J. S. Lindzey. 1977. Movements of translocated nuisance black bears of northeastern Pennsylvania. Transactions of the Northeastern Fish and Wildlife Conference 34:119–126.

Alt, G. L., G. J. Matula, Jr., F. W. Alt, and J. S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Ursus 4: 131–136.

Amstrup, S. C., and J. Beecham. 1976. Activity patterns of radio-collared black bears in Idaho. Journal of Wildlife Management 40(2): 340–348.

Anderson, D. R. 1997. Corridor use, feeding ecology, and habitat relationships of black bears in a fragmented landscape in Louisiana. M.S. thesis. University of Tennessee, Knoxville. USA.

Annis, K. M. 2007. Impact of translocation on nuisance Florida Black Bears. MS thesis. University of Florida.

Armistead, A. R., K. Mitchell, and G. E. Connolly. 1994. Bear relocations to avoid bear/sheep conflicts. Proceedings of the 16th Vertebrate Pest Conference: 30–35.

Arthur, S. M. and C. C. Schwartz. 1999. Effects of sample size on accuracy and precision of brown bear home range models. Ursus 11: 139–148.

Bacon, E.S. 1974. Man and black bear relationships. Eastern Black Bear Workshop 2:207–213.

Ballard, W. B., H A. Whitlaw, S. J. Young, R. A. Jenkins and G. J. Forbes. 1999. Predation and Survival of White-Tailed Deer Fawns in Northcentral New Brunswick. The Journal of Wildlife Management 63: 574–579.

Barker, R. J. 1997. Joint modeling of live-recapture, tag-resight, and tag-recovery data. Biometrics 53:666–677.

Barker, R. J. 1999. Joint analysis of mark-recapture, resighting and ring-recovery data with age-dependence and marking-effect. Bird Study 46 Supplement:82–91.

Barker, R. J., G. C. White, and M. McDougal. 2005. Movement of paradise shelduck between molt sites: a joint multistate-dead recovery mark recapture model. Journal of Wildlife Management 69:1194–1201.

Baruch-Mordo, S. 2007. Black human-bear conflicts in Colorado: Spatiotemporal patterns and predictors. M. S. Thesis. Colorado State University, Fort Collins.

Baruch-Mordo, S., S.W. Breck, K.R. Wilson, and J. Broderick. 2011. The carrot or the stick? Evaluation of education and enforcement as management tools for human-wildlife conflicts. PLoS ONE e15681

Baruch-Mordo, S., S. W. Breck, K. R. Wilson, and J. Broderick. 2009. A tool box half full: how social science can help solve human-wildlife conflict. Human Dimensions of Wildlife 14:219–223.

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

Bates, S. B. 1991. Home range, habitat selection, and food habits of central Utah black bears. M.S. Thesis. Brigham Young University.

Battin, J. 2004. When good animals love bad habitats: ecological traps and the conservation of animal populations. Conservation Biology 18: 1482–1491.

Beausoleil II, R. A. 1999. Population and spatial ecology of the Louisiana black bear in a fragmented bottomland hardwood forest. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Beck, T. D. I. Black bears of west-central Colorado. Colorado Division of Wildlife technical Publication #39.

Beckmann, J. P., and J. Berger. 2003. Rapid ecological and behavioural changes in carnivores:

The responses of black bears (*Ursus americanus*) to altered food. Journal of Zoology 261:207–212.

Beckmann, J. P., and C. W. Lackey. 2005. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human–Wildlife Conflicts 2(2):168–174.

Beckmann, J. P., Lackey, C. W. and Berger, J. 2004. Evaluation of deterrent techniques and dogs to alter behavior of "nuisance" black bears. Wildlife Society Bulletin 32: 1141–1146.

Beecham, J. J., and J. Rohlman. 1994. A shadow in the forest: Idaho's black bear. Idaho Department of Fish and Game, Boise, and University of Idaho Press, Moscow.

Beeman, L. E. 1975. Population characteristics, movements and activities of the black bear (*Ursus americanus*) in the Great Smoky Mountains National Park. Ph.D. Thesis. University of Tennessee, Knoxville.

Beeman, L.E. and M. R. Pelton. 1980. Seasonal foods and feeding ecology of black bears in the Smoky Mountains. Ursus 4: 141–147.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars. Conservation Biology 7:94–108.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59:228–237.

Bekoff, M. and L. D. Mech. 1984. Simulation analyses of space use: Home range estimates, variability, and sample size. Behavior Research Methods and Instrumentation 16:32–37.

Benson, J. F. and M. J. Chamberlain. 2007. Space use and habitat selection by female Louisiana black bears in the Tensas River Basin of Louisiana. Journal of Wildlife Management 71:117–126.

Berringer, J. J., S.G. Seibert, and M.R. Pelton. 1990. Incidence of road crossings by bears on Pisgah National Forest, North Carolina. International Conference on Bear Research and Management 8:85–92.

Bivand, R.S., E.J. Pebesma and V. Gómez-Rubio. 2008. Applied Spatial Data Analysis with R.

Springer: New York, NY.

K. M. Blejwas, C. L. Williams, G. T. Shin, D. R. McCullugh, and M. M. Jaegar. 2006. Salivary DNA evidence convicts breeding male coyotes of killing sheep. Journal of Wildlife Management 70:1087–1093.

Bowman, J. L., C.O. Kochanny, S. Demarais, and B.D. Leopold. 2000. Evaluation of a GPS collar for white-tailed deer. Wildlife Society Bulletin 28:141–145.

Braden, G. T. 1991. Home ranges, habitat use, and denning characteristics of black bears (*Ursus americanus*) in the San Gabriel Mountains of southern California. M.S. thesis, California State Polytechnic Univ., Pomona, California.

Brody. J.A. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tennessee, Knoxville.

Brown, W.S. 1980. Black bear movements and activities in Pocahontas and Randolph counties, West Virginia. M.S. Thesis. West Virginia University, Morgantown.

Bunnel, F. L., and D. E. N. Tait. 1981. Population dynamics of bears-implications. Pages 75–98 in C. W. Fowler and T. D. Smith, eds. Dynamics of large mammal populations. John Wiley and Sons, New York.

Burns, R. J. 1983. Microencapsulated lithium chloride bait aversion did not stop coyote predation on sheep. Journal of Wildlife Management 47:1010–1017.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammology 24: 346–52.

Butfiloski, J.W. 1996. Home range, movements and habitat utilization of female black bears in the mountains of South Carolina. M.S. Thesis, Clemson University. Clemson, South Carolina.

Cain, J. W., P. R. Krausman, B. D. Jansen, and J. R. Morgart. 2005. Influence of topography and GPS fix interval on GPS collar performance. Wildlife Society Bulletin 33:926–934.

Carlock, D. M., R. H. Conley, and J. M. Collins. 1983. Tri-state Bear Study. Technical Report

83-9, Tennessee Wildlife Resources Agency, Nashville.

Carr, P.C. 1983. Habitat utilization and seasonal movements of black bears in the Great Smoky Mountains National Park. M.S. Thesis. University of Tennessee, Knoxville.

Carr, P.C. and K. Burguess. 2003a. New Jersey Status Report. 17th Eastern Black Bear Workshop 17:65–76.

Carr, P.C. and K. Burguess. 2011. New Jersey Black Bear Annual Status Report for NEBBTC. New Jersey Division of Fish and Wildlife, Hampton NJ.

Carr, P.C. and M.R. Pelton. 1984. Proximity of Adult Female Black Bears to Limited Access Roads. Proc. Ann. Conf. Southeast. Assoc. Fish and Wildlife Agencies 38:70-77.

Carter, N. H., D. G. Brown, D. R. Etter, and L. G. Visser. 2010. American black bear habitat selection in northern Lower Peninsula, Michigan, USA, using discrete choice modeling. Ursus 21:57–71.

Chaulk, K. 2001. Black Bears (*Ursus americanus*) in Northeastern Labrador. MS Thesis. Acadia University, Wolfville, Nova Scotia.

Chi, D. K., D. Chester, and B. K. Gilbert. 1998. Effects of capture procedures on black bear activity at an Alaskan salmon stream. Ursus 10:563–569.

Ciarniello, L.M. 1997. Managing negative human–black bear interactions: Liard River Hotsprings Provincial Park, British Columbia. Western Black Bear Workshop 6:84–92.

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

Clark, J. D., and M. R. Pelton. 1999.Management of a large carnivore: Black bear. Pages 209–224 *in* J. D. Peine. Ecosystem management of sustainability: Principles and practices illustrated by a regional biosphere reserve cooperative. Lewis Publishers, Boca Raton, Florida, USA.

Clark, J.D., F. T, VanManen, and M. R. Pelton. 2003. Survival of nuisance American black bears in Great Smoky Mountains National Park. Ursus 14:210–214.

Clark, J.D., F. T, VanManen, and M. R. Pelton. 2005. Bait stations, hard mast, and black bear population growth in Great Smoky Mountains National Park. Journal of Wildlife Management 69:1633–1640.

Clevenger, A.P. 1986. Habitat and space utilization of black bears in Cherokee National Forest. M.S. Thesis, University of Tennessee, Knoxville.

Clevenger, A. P., J. Wierzchowski, B. Chruszcz, and K. Gunson. 2002. GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. Conservation Biology 16: 503–514.

Coffman, C. J., J. D. Nichols, and K. H. Pollock. 2001. Population dynamics of *Microtus pennsylvanicus* in corridor-linked patches. Oikos 93:3–21.

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

Comly-Gericke, L. and M. Vaughan. 1997. Survival and reproduction of translocated Virginia black bears. Ursus 9:113–117.

Conover, M. R. 2002. Resolving human-wildlife conflicts: the science of wildlife damage management. CRC press, Boca Raton, Florida, USA.

Cooper, A. B. and J. J. Millspaugh. 1999. The application of discrete choice models to wildlife resource selection studies. Ecology 80:566–575.

Costello, C. M. 1992. Black bear habitat ecology in the central Adirondacks as related to food abundance and forest management. Thesis, State University of New York, New York, USA.

Costello C.M. 2008. The spatial ecology and mating system of black bears (*Ursus americanus*) in New Mexico. PhD Thesis. Montana State University.

Cottam, C., A. L. Nelson, and T. E. Clarke. 1939. Notes on early winter food habits of black bear in George Washington National Forest. Journal of Mammalogy 20:310–314.

Dailey, M. C., A. I. Gitelman, F. L. Ramsey, and S. Starcevich. 2007. Habitat selection models to account for seasonal persistence in radio telemetry data. Environmental and Ecological Statistics 14:55–68.

Davenport, L. B.1953. Agricultural depredation by the black bear in Virginia. Journal of Wildlife Management 17:331–340.

Day, S. M. 1997. Aspects of Newfoundland black bear, *Ursus americanus hamiltoni*, food habits and habitat use in human-influenced environments. M.S. Thesis. Acadia University, Newfoundland, Canada.

DeBruyn, T. D. 1997. Habitat use, food habits and population characteristics of female black bears in the central Upper Peninsula of Michigan: a geographic information system approach. Dissertation. Michigan Technological University, Houghton, Michigan, USA.

DeCesare, N. J., J. R. Squires, and J. A. Kolbe. 2005. Effect of forest canopy on GPS-based movement data. Wildlife Society Bulletin 33:935–941.

Delibes, M., P. Gaona, and P. Ferreras. 2001. Effects of an attractive sink leading into maladaptive habitat selection. American Naturalist 158:277–285.

Di Orio, A. P., R. Callas, and R. J. Schaefer. 2003. Performance of Two GPS telemetry collars under different habitat conditions. Wildlife Society Bulletin 31:372–379.

Dingle, H. 1996. Migration: the biology of life on the move. Oxford University Press, Cambridge, UK.

Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCown, and D. Paetkau. 2006. Effectiveness of a regional corridor in connecting two Florida black bear populations. Conservation Biology 20:155–162.

Doan-Crider, D. L. 2003. Movements and spaciotemporal variation in relation to food productivity and distribution, and population dynamics of the Mexican black bear in the

Serranias Burro, Coahuila, Mexico. Ph.D. dissertation, Texas A&M University–Kingsville, Kingsville, Texas, USA.

Dobey, S., D. V. Masters, B. K. Scheick, J. D. Clark, M. R. Pelton, and M. E. Sunquist. 2005. Ecology of Florida black bears in the Okefenokee-Osceola ecosystem. Wildlife Monographs 158:1–41.

Don, B. A. C., and K. Rennolls. 1983. A home range model incorporating biological attraction points. Journal of Animal Ecology 52:69–81.

Dunn, J. E. and P. S. Gipson. 1977. Analysis of radio telemetry data in studies of home range. Biometrics 33: 85–101.

Dunn, P. O., and C. E. Braun. 1986. Summer habitat use by adult female and juvenile sage grouse. Journal of Wildlife Management 50:228–235.

Dusi, J. L., D. T. King, and L. K. Malo. 1987. Ecology of the black bear in southwest Alabama. Alabama Department of Conservation and Natural Resources, Alabama Agricultural Experiment Station, and U.S. Department of Interior, Washington, D.C., USA.

Dusi, J. L., D. T. King, and L. K. Malo. 1987. Ecology of the black bear in southwest Alabama. Final Rep. Proj. W-44, 10–12, Study XIV, Jobs A, B, and C. Alabama Dep. Conserv. Nat. Resources, Montgomery.

Dussault, C., R. Courtois, J.-P. Ouellet, and J. Huot. 1999. Evaluation of GPS telemetry collar performance for habitat studies in the boreal forest. Wildlife Society Bulletin 27:965–972.

Early, D. 2010. Intraspecific black bear spatial patterns and interactions at a small spatio-temporal scale. M.S. Thesis. Humboldt State University, Arcata, California, USA.

Edwards, A.S. 2002. Ecology of the black bear (*Ursus americanus floridanus*) in southwestern Alabama. M.S. Thesis. University of Tennessee.

Eiler, J.H., W.G. Wathen, and M.R. Pelton. 1989. Reproduction in black bears in the southern Appalachian mountains. Journal of Wildlife Management 53:353–360.

Ellingwood, M. R. 2003. Nuisance black bear habitat use and activity patterns. New Hampshire Federal Aid Grant W-89-R-3, Project VI, Job 5, Final Report, 7/1/02-6/30/03. Concord, New Hampshire, USA.

Elowe, K. D. 1984. Home range, movements, and habitat preferences of black bears (*Ursus americanus*) in western Massachusetts. M.S. Thesis, Univ. Massachusetts, Amherst.

____________, and W.E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. Journal of Wildlife Management 53:962–968.

Erickson A. W., and G. A. Petrides. 1964. Population structure, movements, and mortality of tagged black bears in Michigan. Michigan State University Agricultural Experiment Station Resource Bulletin 4:46–67.

Ernst, R. 1973. A pilot study of the black bear (*Ursus americanus*) in Georgia. Job completion report. W-37-R.

Etter, D. R., L. G. Visser, C. M. Schumacher, E. Carlson, T. Reis, and D. Rabe. 2002. Black bear population management techniques. Final Report. Federal Aid in Wildlife Restoration Project W-127-R-17, 18, 19. Michigan Department of Natural Resources, Lansing, Michigan, USA.

Eveland, J. F.1973. Population dynamics, movements, morphology, and habitat characteristics of black bears in Pennsylvania. MS Thesis. Pennsylvania State University, University Park.

Fahrig, L., and G. Merriam. 1985. Habitat patch connectivity and population survival. Ecology 66:1762–1768.

Farnsworth, M. L., L. L. Wolfe, N. T. Hobbs, K. P. Burnham, E. S. Williams, D. M. Theobald, M. M. Conner, and M. W. Miller. 2005. Human land use influences chronic wasting disease prevalence in mule deer. Ecological Applications 15:119–126.

Fersterer, P., D.L. Nolte, G.J. Ziegltrum, and H. Gossow. 2001. Effect of feeding stations on the home ranges of American black bears in western Washington. Ursus 12:51–54.

Feske, D. M., R. E. Berry, F. L. Precht, H.B. Quigley, S. L. Bittner and T. Webster. 2002.

Habitat use by female black bears in western Maryland. Southeastern Naturalist 1:77–92.

Fimbel, C. C. 1990. Characteristics of black bears in a residential area of New Jersey. MS Thesis. Rutgers University.

Forbes, G., P. Chamberland, E. Daigle, AND W. Ballard. 1994. The lack of problem bear issues in Fundy National Park. Pages 89–94 in G. Forbes and E.Daigle, editors. Black bear ecology and management issues for Atlantic Canadian National Parks. Parks Canada Ecosystem Science, New Brunswick, Canada.

Ford, R. G., and D. W. Krumme. 1979. The analysis of space use patterns. Journal of Theoretical Biology 76:125-155.

Fuller, D. P. 1993. Black bear population dynamics in western Massachusetts. M. S. Thesis, University of Massachusetts, Amhurst, USA.

Fuller, T.K. and L.B. Keith. 1980. Summer ranges, cover type use and denning of black bears near Fort McMurray, Alberta. Canadian Field Naturalist 94: 80–82.

Gaines, W. L., Lyons, A. L., Lehmkuhl, J. F., Raedeke, K. J. 2005. Landscape evaluation of female black bear habitat effectiveness and capability in the North Cascades, Washington. Biological Conservation. 125: 411–425.

Garcia, J., W. G. Hankins, and K. W. Rusiniak. 1974. Behavioral regulation of the milieu interne in man and rat. Science 185:824–831.

Garneau, D. G., T. Boudreau, M. Keech, and E. Post. 2008. Habitat use by black bears in relation to conspecifics and competitors. Mammalian Biology - Zeitschrift fur Saugetierkunde 73: 48–57.

Garner, N. P. 1986. Seasonal movements, habitat selection, and food habits of black bears *(Ursus americanus)* in Shenandoah National Park, Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Garshelis, D. L. 1978. Movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park. M.S. Thesis, University of Tennessee, Knoxville.

Garshelis, D. L. 1989. Nuisance bear activity and management in Minnesota. Pages 169–180 *in* M. Bromley, editor. Bear-people conflicts: proceedings of a symposium of management strategies. Department of Renewable Resources, Northwest Territories, Canada.

Garshelis, D. L., and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountain National Park. Journal of Wildlife Management 45: 912–925.

Garshelis, D. L. and H. Hristienko. 2006. State and provincial estimates of American Black Bear numbers versus assessments of population trend. *Ursus*, 17(1): 1–7.

Garshelis, D.L., Crider, D. & van Manen, F. 2008. *Ursus americanus*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. <www.iucnredlist.org>. Downloaded on 05 April 2011.

Garris, R.S. 1983. Habitat utilization and movement ecology of black bears in Cherokee National Forest. M.S. Thesis. University of Tennessee, Knoxville.

Geisser, S. 1975. The predictive sample reuse method with applications. Journal of the American Statistical Association 70:320–328.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2004. Bayesian data analysis. Second edition. Chapman and Hall, New York, New York, USA.

Gese, E. G., 0. J. Rongstaad, and W. R. Mytton. 1988. Home range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52:640-646.

Getz W.M. , S. Fortmann-Roe, P. C. Cross, A.J. Lyons, S. J. Ryan , and C. C. Willmers. 2007. LoCoH: Nonparameteric kernel methods for constructing home ranges and utilization distributions. PLoS ONE 2(2): e207.

Geweke, J. 1992. Evaluating the accuracy of sampling based approaches to calculating posterior moments. Pages 169–194 in J. M. Bernardo, J. O. Berger, A. P. Dawid, and A. F. M. Smith, editors. Bayesian statistics 4.Clarendon Press, Oxford University Press, London, United Kingdom.

Gilbert, B. K. 1989. Behavioral plasticity and human-bear conflicts. Pages 1–8 *in* M. Bromley, editor. Bear-people conflicts: proceedings of a symposium of management strategies. Department of Renewable Resources, Northwest Territories, Canada.

Girard, I., J.P. Ouellet, R. Courtois, C. Dussault and L. Breton. 2002. Effects of sampling effort based on GPS telemetry on home-range size estimations. Journal of Wildlife Management 66: 1290–1300.

Gitzen, R.A. and J.J. Millspaugh. 2003. Evaluation of least squares cross-validation bandwidth selection options for kernel estimation. Wildlife Society Bulletin 31: 823–831.

Goodrich, J. M. 1993. Nevada black bears: ecology, management, and conservation, Biological Bulletin 11. Nevada Department of Wildlife, Reno, Nevada.

Gore, M. L., B. A. Knuth, P. D. Curtis, and J. E. Shanahan. 2006. Education programs for reducing American black bear–human conflict: indicators of success? Ursus 17:75–80.

Gosselink, T. E., T. R.Van Deelen, R. E. Warner, and P. C. Mankin. 2007. Survival and cause-specific mortality of red foxes in agricultural and urban areas of Illinois. Journal of Wildlife Management 71: 1862–1873

Greer, S. C. 1987. Home range, habitat use, and food habits of black bears in south-central Montana. MS Thesis. Montana State University. Bozeman, USA.

Grund, M. D., J. B. McAninch, and E. P. Wiggers. 2002. Seasonal movements and habitat use of female white-tailed deer associated with an urban park. Journal of Wildlife Management 66:123–130.

Guo, Q., M. Taper, and M. Schoenberger. 2005. Spatial-temporal population dynamics across species range: from centre to margin. Oikos 108: 47–57.

Gunther, K.A. 1994. Bear management in Yellowstone National Park, 1960–93. Ursus 9:549–560.

Haddad, N. M. 1999. Corridor use predicted from behaviors at habitat boundaries. The American Naturalist 153:215–227.

Hale, M. L., P. W. W. Lurz, M. D. F. Shirley, S. Rushton, R. M. Fuller, and K. Wolff. 2001.

Impact of landscape management on the genetic structure of red squirrel populations. Science 293:2246–2248.

Hamilton, R.J. 1978. Ecology of the black bear in southeastern North Carolina. M.S. Thesis. University of Georgia, Athens.

Hammond, F. M. 2002. The effects of resort and residential development on black bears in Vermont. Final Report, Vermont Fish and Wildlife Department.

Hansen, M. C. and R. A. Riggs. 2008. Accuracy, Precision, and Observation Rates of Global Positioning System Telemetry Collars. Journal of Wildlife Management 72(2): 518–526.

Hansen, A. J., R. L. Knight, J. M. Marzluff, S. PoweU, K. Brown, P. H. Gude, and K. Jones. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. Ecological Applications 15:1893–1905.

Hardy, D. M. 1974. Habitat requirements of the black bear in Dare County, North Caorlina. M.S. thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Harestad, A. S. and F. L. Bunnel. 1979. Home range and body weight—a reevaluation. Ecology 66:389–402.

Harshyne, W. A., D. R. Diefenbach, G. L. Alt, and G. M. Matson. 1998. Analysis of error from cementum-annuli age estimates of known-age Pennsylvania black bears. Journal of Wildlife Management 62:1281–1291.

Harter, H.W. 2001. Biology of black bears in the northern coastal plain of South Carolina.Thesis, Clemson University, Clemson, South Carolina.

Hastings, B. C., B. K. Gilbert, and D. L. Turner. 1981. Black bear behavior and human–bear relationships in Yosemite National Park. Cooperative Park Studies Unit Technical Report 2, University of California, Davis, USA.

Hass, C. A. 1995. Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. Conservation Biology 9:845–854.

Hayne, D.W. 1949. Calculation of Size of Home Range. Journal of Mammalogy 30(1):1–18.

Hechtel, J. L. 1991. Population dynamics of black bear populations, Fort Wainwright, Alaska. Final report to the U.S. Army. Alaska Department of Fish and Game. U.S. Army 6th Infantry Division (Light). Natural Resources Report 91-2. Fairbanks, Alaska, USA.

Heisey, D. M. 1985. Analyzing selection experiments with log-linear models. Ecology 66:1744–1748.

Hellgren, E. C. 1988. Ecology and physiology of a black bear (*Ursus americanus*) population in Great Dismal Swamp and reproductive physiology in the captive female black bear. Ph.D. Thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Hellgren, E. C. and M. R. Vaughan. 1987. Home range and movements of winter active black bears in the Great Dismal Swamp. Ursus 7:224–234.

Hellgren, E. C. and M. R. Vaughan. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. Journal of Wildlife Management 53:969–977.

Hellgren, E. C., D. P. Onorato, and R. J. Skiles. 2005. Dynamics of a black bear population within a desert metapopulation. Biological Conservation 122:131–140.

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

Herrero, S.D. 2003. Bear attacks: their causes and avoidance. The Lyons Press, Guilford, Connecticut, USA.

Higgens, J.C. 1997. Survival, Home Range and Spatial Relationships of Virginia's Exploited Black Bear Population. MS Thesis. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Higgins, K.L. 1997. Hunting dynamics, condition estimates, and movement of black bears hunted with hounds in Virginia. Thesis, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Hilderbrand, G. V., S. G. Jenkins, C. C. Schwartz, T. A. Hanley, and C. T. Robbins. 1999. Effects of seasonal differences in dietary meat intake in body mass and composition in wild and captive brown bears. Canadian Journal of Zoology 77:1623–1630.

Hirsch, J. G., L. C. Bender, and J. B. Haufler. 1999. Black bear, *Ursus americanus*, movements and home ranges on Drummond Island, Michigan. Canadian Field-Naturalist 113:221–225.

Hogan, N. F. 1984. Home range and habitat preferences of female black bears (*Ursus americanus*) in the San Bernardino Mountains of southern California. M.S. thesis, California State Polytechnic University, Pomona, California.

Holm, G.W. 1998. Interactions of sympatric black and grizzly bears in northwest Wyoming. Master's Thesis, University of Wyoming, Laramie, Wyoming, USA

Holm, G.W., F.G. Lindzey, and D.S. Moody. 1999. Interactions of sympatric black and grizzly bears in northwest Wyoming. Ursus11:99–108.

Horne, J. S. and E. O. Garton. 2006a. Likelihood cross-validation versus least squares cross-validation for choosing the smoothing parameter in kernel home-range analysis. Journal of Wildlife Management 70:641–648.

Horne, J. S. and E. O. Garton. 2006b. Selecting the best home range model: an information-theoretic approach. Ecology 87:1146–1152.

Horne, Jon S., Edward O. Garton, and Janet L. Rachlow. 2008. A synoptic model of animal space use: simultaneous analysis of home range, habitat selection, and inter/intra-specific relationships. Ecological Modelling 214:338-348.

Horstman, L. P. and J. R. Gunson. 1982. Black bear predation on livestock in Alberta. Wildlife Society Bulletin 10:34–39.

Howe, E. J., Obbard, M. E., Black, R., and Wall, L. L. 2010. Do public complaints reflect trends in human-bear conflict? Ursus, 21:131–142.

Hristienko, H. and J. E. McDonald, Jr. 2007. Going into the 21st century: a perspective on trends and controversies in the management of the American black bear. Ursus 18:72–88.

Hugie, R. D. 1982. Black bear ecology and management in northern conifer-deciduous forests of Maine. PhD Dissertation. University of Montana, Missoula.

Huntley, J.C. 1989. Importance of mast species other than oaks. Pages 74–80 in C.E. McGee, editor. Proceedings of the workshop: Southern Appalachian Mast Management. University of Tennessee, Knoxville, Tennessee, USA.

Huygens, O.C., F.T. Van Manen, D.A. Martorello, H. Hayashi, and J. Ishida. 2004. Relationships between Asiatic black bear kills and depredation costs in Nagano Prefecture, Japan. Ursus 15:197–202.

Inman, R., and M. Pelton. 2002. Energetic production by soft and hard mast foods of American black bears in the smoky mountains. Ursus 13: 57–68.

James, B.H., C.P. Lo, and T.W. Hodler. 2004. Dasymetric estimation of population density and areal interpolation of census data. Cartography and Geographic Information Science 31:103–121.

Jeffreys, H. 1961. Theory of probability. Third edition. Oxford University Press, Oxford, UK.

Jensen R. 2009. The effects of roads and space use and movements of black bears in Eastern Kentucky. Master’s thesis. University of Kentucky, Lexington, USA

Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. Journal of Theoretical Biology 22(1): 227–237.

Johnson, K.G. 1990. An evaluation of ten eastern workshops on black bears and some suggested future directions. Eastern Black Bear Workshop 10:180–183.

Jones, M.D. and M.R. Pelton. 2003. Female American black bear use of managed forest and agricultural lands in Coastal North Carolina. Ursus 14(2):188–197.

Jonkel, C.J. 1960. Black bear population studies. Pittman- Robertson Job Completion Report.

W-98-R-3. Mont. Fish and Game Department, Helena, MT.

Jonkel, C. J., and I. McCowan. 1971. The black bear in the spruce-fir forest. Wildlife Monographs 27.

Jonker, S.A., J.A. Parkhurst, R. Field, and T.K. Fuller. 1998. Black bear depredation on agricultural commodities in Massachusetts. Wildlife Society Bulletin 26:318–324.

Johnson, J. B., and K. S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution 19: 101–108.

Jorganson, C.J., R.H. Conley, R.J. Hamilton, and O.T. Sanders. 1978. Management of black bear depredation problems. Proceedings of the Eastern Workshop on Black Bear Management and Research 4:297–321.

Kasworm, W. F. and T. J. Thier. 1994. Adult black bear reproduction, survival, and mortality sources in northwest Montana. International Conference on Bear Research and Management 9:223–230.

Kelsall, J. E. and P. J. Diggle. 1995. Kernel estimation of relative risk. Bernoulli 1:3–16.

Kellogg, R. 1937. Annotated list of West Virginia Mammals. Proceedings of the U.S. National Museum 84:3022. U.S. National Museum, Washington, D.C.

Kessler, G. P. 1994. Black bear reproductive biology, habitat use, and movements in northern Wisconsin. MS Thesis. University of Wisconsin - Stevens Point, USA.

Klenner, W. 1987. Seasonal movements and home range utilization patterns of the black bear, *Ursus americanus*, in Western Manitoba. Can. Field-Naturalist 101:558–567.

Koch, D.B. 1983. Population, home range and denning characteristics of black bears in Placer County California. M.S. Thesis, Calif. State Univ., Sacramento.

Koehler, G. M. , and D.J. Pierce. 2003. Black bear home-range sizes in Washington: climatic, vegetative, and social influences. Journal of Mammalogy 84:81–91.

Kohn, B. E. 1982. Status and management of black bears in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 129.

Kordek, W. S. 1973. An investigation of the structure, stability, and movements of Pennsylvania black bear with particular emphasis on Pike county. M.S. Thesis. The Pennsylvania State University, University Park.

Kraus, J. G. 1990. Home ranges and den site characteristics of female black bears and aspects of bear population structure in West Virginia. M.S. Thesis. West Virginia University, Morgantown.

Lamb, G. R. 1983. Home range and habitat use of female black bears in northern Maine. M.S. thesis, University of Maine, Orono.

Landers, J. L., R. J. Hamilton, A. S. Johnson, and R. L. Marchinton. 1979. Foods and habitat of black bears in southeastern North Carolina. Journal of Wildlife Management 43:143–153.

Landis, W. G. and J. K. Wiegers. 2007. Ten years of the relative risk model and regional scale ecological risk assessment. Human and Ecological Risk Assessment 13: 25–38.

Landriault, L. 1998. Nuisance black bear *(Ursus americanus)* behaviour in central Ontario. MS Thesis. Laurentian University, Ontario, Canada.

LeCount, A.L. 1979. Introductory comments. Western Black Bear Workshop 1:1–5.

LeCount, A. L. 1980. Some aspects of black bear ecology in the Arizona chaparral. Ursus 4: 175–179.

LeCount, A. L. and K.L. Baldwin. 1986. The bear in the classroom. International Conference on Bear Research and Management 6:209–217.

Lee, D.J., and M.R. Vaughn. 2004. Black bear family breakup in Western Virginia. Northeast Naturalist. 11:111–122.

Leigh, J. 2007. Effects of aversive conditioning on behavior of nuisance Louisiana black bears. Thesis, Louisiana State University, Baton Rouge, USA.

Lesser, W. 1996. History of Wildlife Management in West Virginia. Wonderful West Virginia 36: 27–32.

Leopold, A.S. , T. Riney, R. McCain, and L. Tevis, Jr., 1951, The Jawbone deer herd. California

Division of Fish and Game, Game Bulletin 4.

Lindzey, F.G., Meslow E.C. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41:413–425.

Linhart, H., and W. Zucchini. 1986. Model selection. John Wiley, New York, New York, USA.

Link, W. A., E. Cam, J. D. Nichols, and E. G. Cooch. 2002. Of BUGS and birds: Markov Chain Monte Carlo for hierarchical modeling in wildlife research. Journal of Wildlife Management 66:277–291.

Lund, R. C. 1980. New Jersey status report. Proceedings of the Eastern Black Workshop 5:12.

Lund, R. C., P. McConnell, and S. Smyser. 1981. Restoration of the Black Bear to the New Jersey Pine Barrens—a discussion of the proposal and assessment of impacts. New Jersey Depratment of Environmental Protection, Division of Fish, Game, and Wildlife. Trenton, NJ.

Lunn, D.J., A. Thomas, N. Best, and D. Spiegelhalter. 2000. WinBUGS -- a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing 10:325–337.

Lyda, S. B., E. C. Hellgren and D. M. Leslie Jr. 2007. Diurnal habitat selection and home-range size of female black bears in the Ouachita mountains of Oklahoma. Proceedings of the Oklahoma Academy of Science 87:55–64.

Lyons, A. J. 2005. Activity patterns of urban American black bears in the San Gabriel mountains of southern California. Ursus 16:255–262.

Maehr, D. S. 1996. The comparative ecology of bobcat, black bear, and Florida panther in south Florida. Ph.D. dissertation, University of Florida, United States.

Maehr, D. S. 1997. The comparative ecology of bobcat, black bear, and Florida panther in south Florida. Bulletin of the Florida Museum of Natural History 40:1–176.

Maehr, D. S., J. S. Smith, M. W. Cunningham, M. E. Barnwell, J. L. Larkin, and M. A. Orlando. 2003. Spatial characterisitics of an isolated Florida black bear population. Southeastern Naturalist 2:433–446.

Mack, J. A. 1998. Ecology of black bears on the Beartooth face, south-central Montana. M.S. Thesis, Montana State Univesity, Bozeman, USA.

MacKenzie, K. G. 2003. Nuisance vs. non-nuisance bears: seasonal movement and home range utilization of female New Jersey black bears (*Ursus americanus*). Thesis. East Stroudsburg State University. East Stroudsburg, Pennsylvania, USA.

Malcolm, K. D. and T. R. Van Deelen. 2010. Effects of habitat and hunting framework on American black bear harvest structure in Wisconsin. Ursus 21: 14–22.

Manly, B. F J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals; statistical design and analysis for field studies. Second edition. Klumer Academic, London, United Kingdom.

Manly, B. F J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic Publishers, Boston, Massachusetts, USA.

Manville, A. M., II. 1983 Human impact on the black bear in Michigan's lower peninsula. International Conference on Bear Research and Management 5:20–33.

Massopust, J. L. 1984. Black bear homing tendencies, response to being chased by hunting dogs, reproductive biology, denning behavior, home range, diel movements, and habitat use in northern Wisconsin. MS Thesis. University of Wisconsin Stevens Point, USA.

Marchington, F. B. 1995. Movement ecology of black bears in a fragmented bottomland hardwood habitat in Louisiana. M. S. Thesis, University of Tennessee, Knoxville.

Mazur, R. L. 2010. Does aversive conditioning reduce human-bear conflict? Journal of Wildlife Management 74(1):48–54.

Mazur, R. L. and V. Sehar. 2008. Socially learned foraging behaviour in wild black bears, *Ursus americanus*. Animal Behavior 75: 1503–1508.

McCarthy, T.M., and R.J. Seavoy. 1994. Reducing nonsport losses attributable to food conditioning: human and bear behavior modification in an urban environment. International Conference on Bear Research and Management 9:75–84.

McConnell, P.A., J.R. Garris, E. Pehek and J.L. Powers. 1997. Black Bear Management Plan. NJ Division of Fish, Game & Wildlife. Trenton, NJ.

McCown, W, P. Kubilis, T. Eason, and B. Schieck. 2004. Black bear movements and habitat use relative to roads in Ocala National Forest. Final Report Contract BD-016. Florida Department of Transportation and Florida Fish and Wildlife Commission.

McCracken, M. L., B. F. J. Manly, and M. Vander Heyden. 1998. The use of discrete-choice models for evaluating resource selection. Journal of Agricultural, Biological, and Environmental Statistics 3:268–279.

McDonald, J.E., Jr., and T.K. Fuller. 1993. Black bear food habits: beyond the same old scats. International Union of Game Biologists 21:293–298.

McLaughlin, C. R. 1981. Home range, movements, and denning behavior of female black bears in north-central Pennsylvania. M.S. Thesis. Pennsylvania State University, State College.

Meddleton, K. 1989. Movement Patterns and habitat use of black bears in northern New Hampshire. MS Thesis. University of New Hampshire, Manchester, USA.

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

Miller, T. O. 1975. Factors influencing black bear habitat selection on Cheat Mountain, West Virginia. M. S. Thesis. West Virginia University, Morgantown.

Miller, S. D. 1986. Sisitna Hydroelectric project final report. Big Game Studies, Volume 6. Alaska Department of Fish and Game.

Miller, S. D. 1990. Population management of bears in North America. International Conference on Bear Research and Management 8: 357-373.

Modafferi, R. D. 1982. Black bear movements and home range study. Alaska Department of Fish and Game. Federal Aid Wildlife Resource Final Report Project W-17-10, W-17-Il,W-21-1, andW-21-2J, ob 17.2R. Juneau.

Moran, P. A. 1950. Notes on Continuous Stochastic Phenomena. Biometrika 37: 17–23.

Moyer, M.A., J.W. McCown and M. K. Oli. 2007. Factors Influencing Home-Range Size of Female Florida Black Bears. Journal of Mammalogy 88:468–476.

Naves, J., T. Wiegand, E. Revilla, and M. Delibes. 2003. Endangered species constrained by natural and human factors: The case of brown bears in northern Spain. Conservation Biology 17:1276–1289.

Nelson R A. 1987. Black bears and polar bears—still metabolic marvels. Mayo Clinic Proceedings 62: 850–853.

Nelson, R. A., G. E. Folk, E. W. Pfeiffer, J. J. Craighead, C. J. Jonkel, and D. L. Steiger. 1983. Behavior, biochemistry, and hibernation in black, grizzly, and polar bears. Ursus 5:284–290.

Nelson, A. C. 1992. Characterizing exurbia. Journal of Planning Literature 6:350–368.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 42:172–174.

New Jersey Division of Fish and Wildlife. 20112013. 2011 Hunting Digest Webpage: http://www.njfishandwildlife.com/bearseason_info.htm. Trenton, NJ. Last Accessed 6 December 2013.

Northeast Wildlife DNA Laboratory. 2010. New Jersey aversive conditioning report. http://www.state.nj.us/dep/fgw/pdf/bear/policy_lit/avers_cond_rpt.pdf. Last Accessed 30 June, 2011.

Newton, I. 2006. Advances in the study of irruptive migration. Ardea 94:433–460.

Nielsen, S. E., G. B. Stenhouse, and M. S. Boyce. 2006. A habitat-based framework for grizzly bear conservation in Alberta. Biological Conservation 130:217–229.

Novick, H. J. 1979. Home range and habitat preferences of black bears (*Ursus americanus*) in the San Bernardino Mountains of southern California. M.S. thesis, California State Polytechnic Univ., Pomona, California.

Novick, H.J. and G.R. Stewart. 1982. Home range and habitat preferences of black bears in the San Bernadino Mountains of southern California. California Fish and Game Journal 67:21–35.

Noyce, K.V., and D.L. Garshelis. 1997. Influence of natural food abundance on black bear harvests in Minnesota. Journal of Wildlife Management 61:1067–1074.

Noyce, K. and D. L. Garshelis. 1998. Spring weight changes in black bears in northcentral Minnesota: the negative foraging period revisited. Ursus 10:521–531.

Noyce, K. and D. L. Garshelis. 2011. Seasonal migrations of black bears (*Ursus americanus*): causes and consequences. Behavioral Ecology and Sociobiology 65:823–835

O'Pezio, J., S. H. Clarke, and C. Hackford. 1983. Chronology of black bear denning in the Catskill region of New York. Ursus 5:87–94.

Obbard, M. E., B. A. Pond, and A. Perera. 1998. Preliminary evaluation of GPS collars for analysis of habitat use and activity patterns of black bears. Ursus 10: 209–217.

Obbard, M.E., B.A. Pond, and E.J. Howe. 1997. Appendix 10: Analysis of relationships among black bear nuisance activity, food availability, and harvest in Ontario. Wildlife Research and Development Section, Ministry of Natural Resources, Peterborough, Ontario, Canada, http://www.mnr.gov.on.ca/mnr/ebr/nbrc/appendix_10.pdf.

Odell, E. A., and R. L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. Conservation Biology 15:1143–1150.

Odum, E.P., and E.J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72:128–137.

Offenbuttel, C. 2005. Home range dynamics of black bears in the Alleghany Mountains of western Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Oli, M. K., H. A. Jacobson, and B. D. Leopold. 2002. Pattern of space use by female black bears in the White River National Wildlife Refuge, Arkansas, USA. Journal for Nature Conservation 10:87–93.

Onorato, D. P., Hellgren, E.C., Mitchell, F.S.,Skiles, J.R., Jr., 2003. Ecology of American black bears on a desert montane island. Ursus 14:120–129.

Otis, D. L. and G. C. White. 1999. Autocorrelation of location estimates and the analysis of radiotracking data. Journal of Wildlife Management 63:1039–1044.

Pacas, C. J., and P. C. Paquet. 1994. Analysis of black bear home range using a geographic information system. International Conference on Bear Research and Management 9:419–425.

Pederson, J. C., S. B. Bates, and J. T. Flinders. 2008. Black ghosts of the forest: a Utah black bear study.

Pelton, M. 2000. Black bear. pp. 389–408 in Ecology and Management of Large Mammals in North America (S. Demarais and P. Krausman, eds.). Prentice Hall, Upper Saddle River, New Jersey,USA.

Pelton, M.R. 1982. Black Bear. Pages 504–514 in J.A. Chapman and G.A. Feldhammer, eds. Wild Mammals of North America: Biology, Management and Economics. John Hopkins University Press, Baltimore, MD.

_________. 1985. Habitat needs of black bears in the east. Pages 49–53 in Kulhavy, D.L. and R.N. Conner, (eds.), Wilderness and Natural Areas in the Eastern United States: A Management Challenge, p. 49–53. Nacogdoches, Texas: Center for Applied Studies, Stephen F. Austin State University.

_________. 1989. The impacts of oak mast on black bears in the southern Appalachians. Pages

7–11 in C.E. McGee, editor. Proceedings of the Workshop: Southern Appalachian Mast Management. University of Tennessee, Knoxville, Tennessee, USA.

_________. 1996. The importance of old growth to carnivores in eastern deciduous forests. In M.B. Davis, ed., Eastern Old Growth Forests. New York: Island Press.

Pelton, M.R., and R.G. Nichols. 1972. Status of the black bear (*Ursus americanus*) in the southeast. Eastern Black Bear Workshop 1:18–23.

Pereira, J. M. C. and R. M. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: A study of the Mt. Graham red squirrel. Photogrammetric Engineering & Remote Sensing 57:1475–1486.

Poelker, R. J., and H. D. Hartwell. 1973. Black bear of Washington. Washington State Game Department Biological Bulletin 14.

Pollock, K. H., S. R. Winterstein, and C. M. Bunck. 1989. Survival analyses in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Powell, R. A. 1987. Black bear home range overlap in North Carolina and the concept of home range applied to black bears. International Conference on Bear Research and Management 7:235–242.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pages 65–110 in L. Boitani, and T. K. Fuller, editors. Research techniques in animal ecology: controversies and consequences. Columbia University, New York, New York, USA.

Powell, R.A., Zimmerman, J.W., and D.E. Seaman. 1997. Ecology and behaviour of North American black bears: home ranges, habitat, and social organization. Chapman & Hall, London.

Proctor, M. F., B. N. McLellan, C. Strobeck, and R. M. R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of Royal Society of London B Biological Sciences 272:2409–2416.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652–661.

Quigley, H. B. 1982. Activity patterns, movement ecology, and habitat utilization of black bears in the Great Smoky Mountains National Park, Tennessee. M.S. Thesis, University of Tennessee, Knoxville.

R Development Core Team. 2012. R: A language and environment for statistical computing, reference index version 2.14.1. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rainbolt, R. E, M. T. Wegan, C. A. Dobony, and P. D. Curtis. 2011. Black bear project on Fort Drum military installation. http://www.fortdrum.isportsman.net/file/Fort_Drum_ Bear_Project_Report_FINAL2011.pdf. Last Accessed, 20 July 2011.

Ramsey, F. L. and D. Usner. 2003. Persistence and heterogeneity in habitat selection studies using radio telemetry. Biometrics 59:332–340.

Reynolds, D. G., and J. J. Beecham. 1980. Home range activities and reproduction of black bears in west-central Idaho. International Conference on Bear Research and Management 4: 181–190.

Ricklefs, B. 2005. Human–bear management on Philmont Scout Ranch. Western Black Bear Workshop 8: 84–90.

Rieffenburger, J.C. 1973. Range and movements of West Virginia black bears during summer and autumn 1973. Proceedings of the Eastern Black Bear Workshop 2:139–142.

Rieffenburger, J. C. 1981. West Virginia Black Bear. West Virginia Division of Wildlife Resources, Bulletin 9. Charleston, WV.

Rieffenberger, J.C., J.C. Pack, W.K. Igo, and C.W. Ryan. 2000. Influence of mast production on black bear harvests in West Virginia. Proceedings of the Annual Northeast Fish and Wildlife Conference 56: 12–13.

Ripley, B.D. 1976. The second-order analysis of stationary processes. Journal of Applied Probability 13: 255–266.

Rogers, L. L. 1987. Effects of Food Supply and Kinship on Social Behavior, Movements, and Population Growth of Black Bears in Northeastern Minnesota. Wildlife Monographs 97.

Russell, T. C., C. A. Herbert and J. L. Kohen. 2010. High possum mortality on urban roads: implications for the population viability of the common brushtail and the common ringtail possum. Australian Journal of Zoology 57:391–397.

Ryan, C. W. 1997. Reproduction, Survival, and Denning Ecology of Black Bears in Southwestern Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Ryan, C. W., J. C. Pack, W. K. Igo, and A. B. Billings. 2007. Influence of mast production on black bear non-hunting mortalities in West Virginia. Ursus 18: 46–53.

Ryan, C. W. 2009. Population ecology, residents' attitudes, hunter success, economic impact, modeling management options and retention time of Telazol of West Virginia black bears. PhD Dissertation. West Virginia University.

Ryan, C. W., J.W. Edwards, and M.D. Duda. 2009. West Virginia residents' attitudes and opinions toward American black bear hunting. Ursus 20:131–142.

Sager-Fradkin, K. A., K. J. Jenkins, P. J. Happe, J. J. Beecham, R. G. Wright, and R. A. Hoffman. 2008. Space and habitat use by black bears in the Elwha Valley prior to dam removal. Northwest Science Special Issue 82:164–178.

Sampson, C. and J. Huot. 1998. Movements of female black bears in relation to landscape vegetation type in southem Quebec. Journal of Wildlife Management 62: 718–727.

Schenk, A. 1994. Genetic relatedness, home range characteristics and mating patterns of black bears (*Ursus americanus*) in northern Ontario, Canada. MS Thesis. University of

Waterloo, Ontario, Canada.

Scheick, B. K. 1999. Black bear diet, movements, and habitat selection in North Florida and South Georgia. M.S. Thesis. University of Florida, Gainesville, FL.

Seaman, D. S. 1993. Home rang and male reproductive optimization in black bears. PhD. Dissertation. North Carolina State University.

Seaman, D.E. & Powell, R.A. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77: 2075–2085.

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

Servheen, C., S. Herrero, and B . Peyton, compilers. 1999. Bears: Status survey and conservation action plan. IUCN/SSC bear and polar bear specialist groups. IUCN, Gland, Switzerland and Cambridge, UK.

Schirokauer, D., and H. Boyd. 1998. Bear–human conflict management in Denali National Park and Preserve, 1982–94. Ursus 10:395–403.

Schoener, T. W. 1981. An empirically based estimate of home range. Theoretical Population Biology 20: 281–325.

Schrage, M. W. 1994. Influence of gypsy moth induced oak mortality on a black bear population. M. S. Thesis. Virginia Polytech. Inst. and State Univ., Blacksburg.

Scheick, B. K. 1999. Black bear diet, movements, and habitat selection in North Florida and South Georgia. M.S. Thesis. University of Florida, Gainesville, FL.

Schieck, B., W. McCown, and M. Orlando. 2011. Updated distribution of black bears in North America. Proceedings of the Eastern Black Bear Workshop 20:11.

Schwartz, C. C., and A. W. Franzmann. 1991. Interrelationship of black bears to moose and forest succession in the northern coniferous forest. Wildlife Monographs 113.

Schwartz, C. C., R. B. Harris, and M. A. Haroldson. 2006. Impacts of spatial and environmental heterogeneity on grizzly bear demographics in the Greater Yellowstone Ecosystem: A source–sink dynamic with management consequences. Pages. 57–67. in C.C. Schwartz, M.A. Haroldon, G.C. White, R.B. Harris, S. Cherry, K.A. Keating, D. Moody, and C. Servheen. Temporal, spatial, and environmental influences on the demographics of the Yellowstone grizzly bear. Wildlife Monograph 161.

Schwartz, C. C., M. A. Haroldson, and G. C. White. 2010. Hazards affecting grizzly bear survival in the Greater Yellowstone Ecosystem. Journal of Wildlife Management 74:654–667.

Seibert, S. G. 1993. Status and management of black bears in Apalachicola National Forest. Florida Game and Fresh Water Fish Commission, Tallahasee, Florida, USA.

Shivik, J. A., A. Treves, and P. Callahan. 2003. Nonlethal techniques for managing predation: primary and secondary repellents. Conservation Biology 17:1531–1537.

Shivik, J. A., D. Ruid, R. C. Willging, and K. E. Mock. 2011. Are the same bears repeatedly translocated from corn crops in Wisconsin? Ursus 22:114–119.

Schoener, T. W. 1981. An empirically based estimate of home range. Journal of Theoretical Population Biology 20:281–325.

Shramko, R. A. 2005. Analysis of Home Range Characteristics of New Jersey Black Bears Pre and Post Hunting Season. Thesis. East Stroudsburg State University. East Stroudsburg, Pennsylvania, USA.

Smith, M.E., 1994. Black bear denning ecology and habitat selection in interior Alaska. M.S. University of Alaska, Fairbanks, Fairbanks, AK.

Smith, J. S. 2001. Home range and habitat use characteristics of a west central Florida black bear population. MS Thesis. University of Kentucky, Lexington, USA.

Smith, T. R., and M. R. Pelton. 1990. Home range and movements of black bears in a bottomland hardwood forest in Arkansas. International Conference on Bear Research and Management 8: 213–218.

Smith, G. J., J. R. Cary and O.J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin 9:88–93.

Spencer, R. D., R. A. Beausoliel, and D. A. Martollo. 2007. How agencies respond to human-black bear conflicts: a survey of wildlife agencies in North America. Ursus 18: 217–229.

Spiker,Jr. H. A., and S. Bittner. 2004. Wildlife and Heritage Service, Black Bear Management Plan, 2004 – 2013. Maryland Department of Natural Resources, Annapolis. DNR-03-0105-0031.

Stone, M. 1974. Cross-validatory choice and assessment of statistical predictions. Journal of the Royal Statistical Society, Series B 36:111–147.

Stone, M. 1977. An asymptotic equivalence of choice of model by cross-validation and Akaike's criterion. Journal of the Royal Statistical Society, Series B 39:44–47.

Storlid, S. A. 1995. Spring and summer habitat use and food habits of black bears in northern Wisconsin. MS Thesis. University of Wisconsin - Stevens Point.

Storm, D. J., C. K. Nielsen, E. M. Schauber and A. Woolf. 2007. Space Use and Survival of White-Tailed Deer in an Exurban Landscape. The Journal of Wildlife Management 71:1170–1176.

Stratman, M. R. 1998. Habitat use and effects of prescribed fire on black bears in northwestern Florida. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Swihart, R. K. and N.A. Slade. 1985. Influence of sampling interval on estimates of home-range size. Journal of Wildlife Management 49:1019–1025.

Swihart, R. K. and N.A. Slade. 1997. On testing for independence of animal movements. Journal of Agricultural, Biological, and Environmental Statistics 2:48–63.

Taylor, D.F. 1971. A radio-telemetry study of the black bear (*Ursus americanus*) with notes on its history and present status. M.S. Thesis. Louisiana Polytechnic Institute.

Tenney, L. 1996. Home range in two Utah black bear populations. MS thesis. Bringham Young University.

Ternent, M. A., and D. L. Garshelis. 1999. Taste-aversion conditioning to reduce nuisance activity by black bears in a Minnesota military reservation. Wildlife Society Bulletin 27:720–728.

Ternent, M. A. 2006. Management and biology of black bears in Pennsylvania: Ten Year Plan (2006–2015). Pennsylvania Game Commission, State College, PA.

Tewksbury, J. J.,D. J. Levey,N.M. Haddad, S. Sargent, J. L. Orrock, A.Weldon, B. J. Danielson, J. Brinkerhoff, E. I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals and their interactions in fragmented landscapes. Proceedings of the National Academy of Sciences of the United States of America 99:12923–12926.

Theobald, D. M., J. R. Miller, and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and Urban Planning 39:25–36.

Thomas, D. L., C. Ianuzzi, and R. P. Barry. 2004. A Bayesian multinomial model for analyzing categorical habitat selection data. Journal of Agricultural, Biological, and Environmental Statistics 9:432–442.

Thomas, D. L., D. Johnson, and B. Griffith. 2006. A Bayesian random effects discrete-choice model for resources selection: population-level selection inference. Journal of Wildlife Management 70:404–412.

Thomasma, L. E., T. D. Drummer, and R. O. Peterson. 1991. Testing the habitat suitability index for the fisher. Wildlife Society Bulletin 19:291–297.

Tilman, D., and P. Kareiva, editors. 1997. Spatial ecology: the role of space in population dynamics and interspecific interactions. Princeton University Press, Princeton, New Jersey.

Trauba, D. R. 1996. Black bear population dynamics, home range and habitat on an island in Lake Superior. MS Thesis. University of Wisconsin - Stevens Point.

Treves, A., and K. U. Karanth. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology 17:1491–1499.

Treves, A., K. J. Kapp, and D. MacFarland. 2010. American black bear nuisance complaints and hunter take. Ursus 21: 30–42.

Ulrey W. 2008. Home range, habitat use, and food habits of the black bear in southcentral Florida. Master's Thesis, University of Kentucky, Lexington, Kentucky, USA

Unger D. 2007. Population dynamics, resource selection, and landscape conservation of a recolonizing black bear population. Ph.D. disertation, University of Kentucky, Lexington, USA.

United States Census Bureau. 2002. Urban Area Criteria for Census 2000. Federal Register 67: 11663.

VanHorne, B. 1983. Desnity as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901.

Van Manen, F. T. 1994. Black Bear Habitat Use in Great Smoky Mountains National Park. PhD. Dissertation, University of Tennessee, Knoxville.

VanderHeyden, M. and E. C. Meslow. 1999. Habitat selection by female black bears in the central Cascades of Oregon. Northwest Science 73:283–294.

Vaughan, M.R. 2002. Oak trees, acorns, and bears. Pages 224–240 in W.J. McShea and W.M. Healy, editors. Oak forest ecosystems: ecology and management for wildlife. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Villarrubia, C. R. 1982. Movement ecology and habitat utilization of black bears in Cherokee National Forest, Tennessee. M.S. Thesis. University of Tennessee, Knoxville.

Vreeland, J. K., D. R. Diefenbach, and B. D. Wallingford. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542–553.

Wagner, R. O. 1995. Movement patterns of black bears in south-central Louisiana. M.S. Thesis, Louisiana State University, Baton Rouge, Louisiana.

Waller, J. S. and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management 69:985–1000.

Warburton, G. S. 1984. An evaluation of a black bear sanctuary in western North Carolina. M.S. Thesis. North Carolina State University, Raleigh.

Weaver, K. M. 1999. The ecology and management of black bears in the Tensas River Basin of Lousiana. Ph.D. Dissertation. University of Tennessee, Knoxville. USA.

Weaver, H. W. 2004. Biometric analysis and aversive conditioning of black bears in southern West Virginia. MS Thesis. West Virginia University.

Weir, R. D., H. Davis, C. S. Hoodicoff, and K. W. Larsen. 2004. Life on a highway: sources of mortality in an endangered British Columbia badger population. In T. D. Hooper (editor), Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. March 2–6, 2004 Victoria, B.C. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, BC. pp. 1–9.

West Virginia Division of Natural Resources. 2011a. Recommendations for Resolving Black Bear Conflicts. South Charleston, WV.

West Virginia Division of Natural Resources. 2011b. 2011–2012 Hunting and trapping regulations summary. South Charleston, WV.

White, T. H. 1996. Black bear ecology in the forested wetlands of the Mississippi Alluvial Valley. Ph.D. Dissertation. Mississippi State University, Starkville, USA.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement: 120–138.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, CA. 383 pp.

Williamson, D. F. 2002. In the black. Status, management, and trade of the American black bear (Ursus americanus) in North America, North America, World Wildlife Fund, Washington, DC, USA.

Witmer, G. W. and D. G. Whittaker. 2001. Dealing with nuisance and depredating black bears. Proceedings of the 7th Western Black bear Workshop:73–81.

Wolgast, L.J., W. S. Ellis, and J. Vreeland. 2005. New Jersey Fish and Game Council comprehensive black bear (*Ursus amercianus*) management policy. New Jersey Fish and Game Council, New Jersey Department of Environmental Protection, Trenton, New Jersey.

Wolgast, L.J., W. S. Ellis, and J. Vreeland. 2010. New Jersey Fish and Game Council comprehensive black bear (*Ursus amercianus*) management policy. New Jersey Fish and Game Council, New Jersey Department of Environmental Protection, Trenton, New Jersey.

Wooding, J. B. and T. S. Hardisky. 1994. Home Range, Habitat Use, and Mortality of Black Bears in North-Central Florida. Bears: Their Biology and Management 9:349–356.

Wooding, J.B. and Maddrey, R.C.. 1994. Impacts of roads on black bears. Eastern Black Bear Workshop 12.

Worton, B.J. 1989 Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164–168.

Young, B. F. 1976. Numbers, distribution, and structure of a Black Bear population in east-central Alberta. M.S. thesis. University of Wisconsion, Madison.

Young, B. F., and R. L. Ruff. 1982. Population dynamics and movements of black bears in east central Alberta. Journal of Wildlife Management 46(4): 845–860.

Yodzis, P. and G.B. Kolensoky. 1986. A population dynamics model of black bears in east-central Ontario. Journal of Wildlife Management 50:602–612

Zack, C. S., B. T.Milne, and W. C. Dunn. 2003. Southern oscillation index as an indicator of encounters between humans and black bears in New Mexico. Wildlife Society Bulletin 31:517–520.

Zytaruk, B., and D. Cartwright. 1978. Black bear movements and food habits in New Brunswick. Proceedings of the Eastern Black Bear Workshop 4:227–239.

Table 1. Documented home range sizes (km2) of black bears across North America from the 1960s to the present. Home ranges denoted with an asterisk (*) denote missing values or studies in which a particular sex of bear was not studied. Methods (Minimum Convex Polygon, Fixed Kernel, and Adaptive Kernel) are abbreviated as MCP, FK, and AK, respectively.

				Estimate (km^2)		Estimate (km^2)		
Jurisdiction	Source	CI	Method	Male	n	Female	n	GPS/VHF
Alberta	Fuller and Keith 1980	100	Dot Grid	*	*	8	*	VHF
Alberta	Young 1976; Young and Ruff 1982	95	Minimum Area	119	*	20	*	VHF
Arizona	LeCount 1980	100	Minimum Area	29	*	18	*	VHF
Alabama (SW)	Dusi et al. 1987	100	MCP	21	*	10	*	VHF
Alabama (SW)	Edwards 2002	*	FK	115	*	18	*	VHF
Alaska	Modaferri 1982	100	Minimum Area	88	*	20	*	VHF
Alaska	Miller 1987	100	MCP	251	*	67	*	VHF
Alaska	Hechtel 1991	*	MCP	596	*	59	*	VHF
Alaska	Smith 1994	100	MCP	90	*	4	*	VHF
Alaska	Garneau et al. 2008	100	MCP	219	*	66	*	VHF
Arkansas	Smith and Pelton 1985	*	MCP	128	*	11	*	VHF
Arkansas	Smith and Pelton 1990	100	Minimum Area	116	6	12	6	VHF
Arkansas	Clark 1991	100	MCP	90	2	40	27	VHF
Arkansas	Smith 1994	100	MCP	90	*	4	*	VHF
Arkansas	Oli et al. 2002	95	MCP	*	*	5	16	VHF

Arkansas	Oli et al. 2002	95	Harmonic Mean	*	*	48	16	VHF
California	Novick and Stewart 1982	100	MCP	22	*	17	*	VHF
California	Koch 1983	100	MCP	64	*	29	*	VHF
California	Hogan 1984	100	MCP	*	*	20	4	VHF
California	Van Stralen 1998	*	MCP	19	*	5	*	VHF
California	Early 2009	*	FK	33	*	27	*	VHF
Coahuila	Doan-Crider 1995	100	MCP	97	*	20	*	VHF
Colorado	Beck 1991	*	MCP	113	*	34	*	VHF
Florida	Mykytka and Pelton 1988	95	Harmonic Mean	171	*	66	*	VHF
Florida	Seibert 1993	100	MCP	209	10	65	4	VHF
Florida (North FL)	Wooding and Hardisky 1994	100	MCP	170	12	28	8	VHF
Florida	Land 1994	100	MCP	303	18	57	22	VHF
Florida	Roof and Wooding 1996	*	MCP	57	*	25	*	VHF
Florida	Maehr 1996 & 1997	100	MCP	284	15	54	14	VHF
Florida	Stratman 1998	*	FK	351	*	88	*	VHF
Florida	Scheick 1999	100	MCP	*	*	28	19	VHF
Florida	Smith 2001	*	MCP	105	*	24	*	VHF
Florida	Maehr et al. 2003	100	MCP	105 (1998)	3	19 (1998)	3	VHF
Florida	Maehr et al. 2003	100	MCP	*	*	27 (1999)	5	VHF
Florida	McCown et al. 2004	*	FK	94	*	20	*	VHF
Florida(Osceola NF)	Dobey et al. 2005	95	FK	*	16	30	71	VHF
Florida (Okefenokee)	Dobey et al. 2005	95	FK	343	16	56	46	VHF
Florida	Moyer et al. 2007	95	FK	*	*	24	*	VHF
Florida	Moyer et al. 2007	95	MCP	*	*	23	*	VHF

Florida	Ulrey 2008	95	FK	96	*	32	*	BOTH
Florida	Ulrey 2008	100	MCP	163	*	69	*	BOTH
Georgia	Ernst 1973	100	MCP	*	*	15	2	VHF
Georgia	Abler 1985	100	MCP	*	*	6	6	VHF
Georgia	Scheick 1999	100	MCP	223	13	80	29	VHF
Idaho	Amstrup and Beecham 1976	100	MCP	111	2	49	7	VHF
Idaho	Reynolds and Beecham 1980	100	MCP	60	4	12	5	VHF
Idaho (Council population)	Beecham and Rohlman 1994	100	MCP	145	8	31	33	VHF
Idaho (Priest Lake Population)	Beecham and Rohlman 1994	100	MCP	41	5	13	6	VHF
Kentucky	Unger 2007	*	FK	397	*	40	*	*
Kentucky	Unger 2007	*	MCP	140	*	19	*	*
Kentucky	Unger 2007	*	FK	523	*	19	*	*
Kentucky	Unger 2007	*	MCP	437	*	29	*	*
Labrador	Chaulk 2001	*	MCP	108*	*	108*	*	*
Louisiana	Taylor 1971	100	MCP	111	2	20	2	VHF
Louisiana (Deltic)	Marchington 1995	95	AK	52	4	13	6	VHF
Louisiana (Deltic)	Anderson 1997	95	MCP	46	2	9	11	VHF
Louisiana (Deltic)	Anderson 1997	95	AK	42	2	13	11	VHF
Louisiana	Beausoleil 1999	95	MCP	38	5	9	12	VHF
Louisiana	Beausoleil 1999	95	AK	13	5	7	12	VHF
Louisiana (Tensas)	Weaver 1999	95	AK	112	3	7	6	VHF
Louisiana (Deltic)	Weaver 1999	95	AK	8	3	5	6	VHF
Louisiana (Deltic)	Weaver 1999	95	MCP	60	3	4	6	VHF
Louisiana (Tensas)	Benson and Chamberlain 2007	95	FK	*	*	12	*	VHF

Louisiana (Deltic)	Benson and Chamberlain 2007	95	FK	*	*	4	*	VHF
Louisiana	Leigh 2007	95	FK	13	*	1	*	VHF
Maine	Hugie 1982	100	MCP	17	5	4	9	VHF
Manitoba	Klenner 1987	95	Jennrich and Turner	2922 (1980)	1	29 (1980)	5	VHF
Manitoba	Klenner 1987	95	Jennrich and Turner	149 (1981)	1	14 (1981)	2	VHF
Manitoba	Pacas and Paquet 1994	*	Harmonic Mean	465	*	295	*	VHF
Maryland	Webster 1994	100	MCP	*	*	40	3	VHF
Maryland	Webster 1994	95	MCP	*	*	41	3	VHF
Maryland	Dateo 1997	100	MCP	*	*	36	5	VHF
Massachussetts	Elowe 1984	100	MCP	318	3	28	8	VHF
Massachussetts (southern)	Fuller 1993	95	Harmonic Mean	328	29	26	35	VHF
Massachussetts (central)	Fuller 1993	95	Harmonic Mean	*	*	23	41	VHF
Michigan	Erickson and Petridas 1964	n/a	Mark-Recapture	52	*	26	*	VHF
Michigan (LP)	Manville 1983	100	MCP	150	11	69	5	VHF
Michigan	DeBruyn 1997	*	Not Defined	*	*	3	*	VHF
Michigan (UP)	Etter et al. 2002	*	FK	20	*	10	*	*
Michigan (Drummond Island)	Etter et al. 2003	*	FK	29	*	19	*	*
Michigan (Drummond Island)	Hirsch et al. 1999	100	MCP	76	3	41	16	VHF
Michigan (Drummond Island)	Hirsch et al. 1999	95	Harmonic Mean	65	3	33	16	VHF

Michigan	Carter et al. 2010	95	FK	606	*	227	*	VHF
Minnesota	Rogers 1977	100	Subjective	*	*	7	*	VHF
Minnesota	Powell et al. 1997	*	FK	*	*	35	*	VHF
Minnesota	Garshelis in Powell et al. 1997	*	FK	*	*	33	*	VHF
Mississippi (White River National Wildlife Refuge)	White 1996	95	MCP	81	3	11	11	VHF
Mississippi (Big and Montgomery islands)	White 1996	95	MCP	64	8	10	4	VHF
Montana	Jonkel and McCowan 1971	*	Mark-Recapture	31	*	5	*	VHF
Montana	Greer 1987	*	MCP	163	*	16	*	VHF
Montana	Mack 1998	*	MCP	151	*	38	*	VHF
Newfoundland	Day 1991	*	MCP	*	*	48	*	VHF
New Hampshire	Meddleton 1989	*	Harmonic Mean	*	*	86	*	VHF
New Jersey	Fimbel 1990	*	MCP	182	*	16	*	VHF
New Jersey	MacKenzie 2003	*	MCP	*	*	4	*	*
New Jersey	Shramko 2005	*	MCP	*	*	5	*	*
New Mexico	Costello 2008	*	FK	463	*	87	*	*
New York	Costello 1992	*	Bivariate normal	383	*	38	*	VHF
New York	Costello 1992	*	MCP	170	*	31	*	VHF
New York	Rainbolt et al. 2011	95	FK	*	*	15	*	VHF
New York	Rainbolt et al. 2011	95	MCP	*	*	12	*	VHF
North Carolina (coast)	Hardy 1974	100	Minimum Area	175	*	11	*	VHF
North Carolina (coast)	Hamilton 1978	100	MCP	91	3	8	3	VHF
North Carolina (coast)	Landers et al. 1979	100	MCP	56	*	8	*	VHF

North Carolina (Harmon Sanctuary)	Brody 1984	95	MCP	32	*	9	*	VHF
North Carolina (Harmon Sanctuary)	Brody 1984	95	MCP	69	*	17	*	VHF
North Carolina (mountains)	Warburton 1984	100	MCP	79	2	18	2	VHF
North Carolina	Beringer 1986	100	MCP	*	*	15	7	VHF
North Carolina (Great Dismal)	Hellgren and Vaughan 1987	100	Minimum Area	30	*	18	*	VHF
North Carolina	Seibert 1989	100	MCP	39	4	12	9	VHF
North Carolina	Reagan 1991	100	MCP	*	*	9	11	VHF
North Carolina (Camp Lejeune)	Lombardo 1993	100	MCP	61	2	20	7	VHF
North Carolina	Seaman 1993	*	FK	42	*	18	*	VHF
North Carolina (coast)	Jones 1996	95	MCP	*	*	9	10	VHF
North Carolina (mountains)	Butfiloski 1996	*	MCP	44	2	16	3	VHF
North Carolina (Pisgah)	Powell et al. 1997	95	FK	44	43	17	38	VHF
North Carolina (coast, Big Pocosin)	Jones and Pelton 2003	95	Harmonic Mean	*	*	12	8	*
North Carolina (coast, Big Pocosin)	Jones and Pelton 2003	95	MCP	*	*	11	8	*
North Carolina (coast, Gum Swamp)	Jones and Pelton 2003	95	Harmonic Mean	*	*	7	8	*
North Carolina (coast, Gum Swamp)	Jones and Pelton 2003	95	MCP	*	*	5	8	*
Oklahoma	Lyda et al. 2007	*	MCP	*	*	15	*	*
Oklahoma	Lyda et al. 2007	*	AK	*	*	21	*	*

Oregon	VanderHeyden and Meslow 1999	95	AK	*	*	39	12	*
Oregon	VanderHeyden and Meslow 1999	95	MCP	*	*	30	14	*
Pennsylvania	Alt et al. 1976	*	Bivariate normal	196	*	37	*	VHF
Pennsylvania	Alt et al. 1980	100	Jennrich and Turner	173	5	41	12	VHF
Pennsylvania	Eveland 1973	100	Subjective Circle	102	*	20	*	VHF
Pennsylvania	Kordek 1973	100	Subjective Circle	148	*	20	*	VHF
Pennsylvania	McLaughlin 1981	*	MCP	*	*	25	*	VHF
Quebec	Sampson and Hout 1998	*	MCP	*	*	12	*	VHF
SE USA (GA, TN, GSMNP)	Carlock et al. 1983	100	MCP	75	*	12	*	VHF
SE USA (GA, TN, GSMNP)	Carlock et al. 1983	100	MCP	53	*	11	*	VHF
South Carolina	Harter 2001	*	*	80	*	30	*	*
South Carolina	Butfiloski 1996	*	*	44	*	17	*	VHF
Tennessee	Beeman 1975	100	MCP	21	1	7	7	VHF
Tennessee	Eubanks 1976	100	MCP	6	*	5	*	VHF
Tennessee	Garshelis 1978	*	Bivariate normal	21	*	8	*	VHF
Tennessee	Garshelis and Pelton 1980	100	MCP	21	10	8	14	VHF
Tennessee	Garshelis and Pelton 1981	95	Bivariate normal	41	8	15	12	VHF
Tennessee	Quigley 1982	100	MCP	30	*	6	*	VHF
Tennessee	Villarrubia 1982	100	MCP	30	9	12	12	VHF

Tennessee	Carr 1983	100	MCP	119 (poor mast year)	4	13(poor mast year)	3	VHF
Tennessee	Carr 1983	100	MCP	36 (good mast year)	4	6 (good mast year)	3	VHF
Tennessee	Garris 1983	100	MCP	192	5	23	8	VHF
Tennessee	Clevenger 1986	100	MCP	53	*	53	*	VHF
Tennessee	Van Manen 1994	95	MCP	250	11	11	12	VHF
Tennessee	Van Manen 1994	95	AK	299	11	17	12	VHF
Texas	Onorato et al. 2003	95	MCP	98	7	32	7	*
Utah	Bates 1991	*	MCP	112	*	41	*	VHF
Utah	Tenney 1996	*	MCP	193	*	77	*	VHF
Utah	Pederson et al. 2008	*	MCP	133	*	42	*	*
Vermont	Hammond 2002	*	FK	158	*	36	*	*
Virginia (Shenandoah Nat'l Park)	Garner 1986	100	MCP	195	*	38	*	VHF
Virginia (Shenandoah Nat'l Park)	Garner 1986	95	MCP	116	*	22	*	VHF
Virginia	Schrage 1994	*	MCP	*	*	10	*	VHF
Virginia	Hellgren 1988	*	MCP	*	*	15	*	VHF
Virginia	Hellgren and Vaughan 1990	100	MCP	112	10	27	11	VHF
Virginia	Higgens 1997	95	MCP	7	7	6	16	VHF
Virginia	Higgens 1997	95	FK	11	5	7	27	VHF
Virginia	Higgins 1997	95	MCP	7	21	6	62	VHF
Virginia	Higgins 1997	95	FK	11	21	7	62	VHF
Virginia (Shenandoah Nat'l Park)	Kasbohm et al. 1998	95	MCP	*	*	27 (Solitary)	17	VHF

Virginia (Shenandoah Nat'l Park)	Kasbohm et al. 1998	95	MCP	*	*	41 (Solitary)	17	VHF
Virginia (Shenandoah Nat'l Park)	Kasbohm et al. 1998	95	MCP	*	*	15 (w/Cubs)	7	VHF
Virginia (Shenandoah Nat'l Park)	Kasbohm et al. 1998	95	MCP	*	*	34 (w/Cubs)	12	VHF
Virginia	Lee and Vaughan 2004	100	FK	18	*	10	*	VHF
Virginia	Offenbuttel 2005	95	FK	*	*	30	*	VHF
Washington	Peolker and Hartwell 1973	100	MCP	52	*	5	*	VHF
Washington (island)	Lindzey and Meslow 1977	100	MCP	5	5	2	6	VHF
Washington	Festerer et al. 2001	*	MCP	21	*	7	*	VHF
Washington (Okanogan)	Koehler and Pierce 2003	95	FK	17	29	26	15	VHF
Washington (Snoqualmie)	Koehler and Pierce 2003	95	FK	91	12	18	28	VHF
Washington (Olympic Peninsula)	Koehler and Pierce 2003	95	FK	126	2	28	4	VHF
Washington (Olympic National Park)	Sager-Fradkin et al. 2008	*	FK	306	*	61	*	VHF
West Virginia	Rieffenburger 1973	100	Dot Grid	*	*	29	3	VHF
West Virginia	Brown 1980	95	Bivariate Normal	204	13	49	8	VHF
West Virginia	Kraus 1990	95	MCP	*	*	26	15	VHF
Wisconsin	Kohn 1982	100	MCP	71	13	14	7	VHF
Wisconsin	Massopust 1984	*	MCP	93	*	19	*	VHF
Wisconsin	Kessler 1994	*	MCP	11	*	14	*	VHF
Wisconsin	Storlid 1995	*	MCP	*	*	21	*	VHF
Wisconsin	Trauba 1996	*	MCP	33	*	7	*	VHF
Wyoming	Grogan 1997	*	AK	311	*	137	*	VHF

Wyoming	Holm et al. 1999	*	FK	299	*	93	*	VHF

Chapter 2.

Home range size and spatial shifts of urban black bears in the mid-Atlantic region

Chapter 2. Home range size, spatial shifts, and urban proximity of urban black bears in the mid-Atlantic region

Andrew N. Tri[1*], John W. Edwards[1], J. Todd Petty[1], Michael P. Strager[1], Christopher W. Ryan[2], Colin P. Carpenter[3], Mark A. Ternent[4], and Patrick C. Carr[5]

[1]Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506. [2]Wildlife Resources Section, West Virginia Division of Natural Resources, 324 Fourth Avenue, South Charleston, West Virginia 25303. [3]Wildlife Resources Section, West Virginia Division of Natural Resources, 2006 Robert C. Byrd Drive, Beckley, West Virginia 25801. [4]Bureau of Wildlife Management, Pennsylvania Game Commission, 2001 Elmerton Avenue, Harrisburg, PA 17110. [5]New Jersey Division of Fish and Wildlife, Mail Code 501-03, PO Box 420, Trenton, NJ 08625-0420. Corresponding author – Andrew.n.tri@gmail.com.

Abstract

Black bears (*Ursus americanus*) in rural populations shift their home range size and spatial distribution on the landscape in response to resource availability. Conversely, space use of urban black bears in the eastern United States has not been well studied. We conducted a study of urban black bear space use in New Jersey, Pennsylvania, and West Virginia. We estimated seasonal and annual home ranges of 120 bears. Bears were found mostly near the edge of urban areas (<5km) for all seasons and study areas and were considered residents. We found that male bears occurred twice as far from the urban edge as female bears (2.31 km vs. 0.91 km, respectively). Our results indicated that urban bear home range size was similar among seasons, but did differ between sexes (male home ranges were 5.6 times larger than female bears) and among study areas. We found no evidence that urban bears shifted their home ranges closer to town during times of food shortage (spring or late fall). We documented urban bears were most commonly found living near (<5 km) urban areas, but their proximity varied among municipalities in the study. Managers seeking to predict where potential bear conflicts may occur should focus their efforts on the edge of urban and suburban areas (known as the exurban areas) in the Mid-Atlantic region.

[1] This manuscript has been formatted in the style of Northeastern Naturalist. The singular I has been replaced with the collective "we" to allow for ease in preparation for journal submission.

Introduction

Black bears (*Ursus americanus*) in rural populations shift their activity patterns and home ranges in response to food availability (Beeman and Pelton 1980, Powell et al. 1997). Patchy concentrations of ephemeral foods can intensify this behavior (Young and Beecham 1983). During times of mast failure, bears in non-urban areas of the eastern United States exhibit long-distance movements and home range expansions (Garshelis and Pelton 1981, Garris 1983, Rogers 1987). Male and female bears respond to inter-annual variation in hard mast in fall (Powell et al. 1997). When hard mast is abundant, both annual and seasonal (fall) home ranges of female and male black bears in rural areas are smaller than in years of poor mast abundance (Powell et al. 1997). Powell et al. (1997) documented that, in the Appalachian Mountains of North Carolina, spring home ranges of bears are not affected by mast abundance because food sources are variable and mast is typically unavailable in spring. In other areas of the Appalachian Mountains, bears shift their home ranges seasonally (Garshelis and Pelton 1981, Offenbuttel 2005).

Bears in rural areas exhibit the most marked difference in home range size between summer and fall (Garshelis and Pelton 1981). Bears will make short term (1–2 months in duration) sallies from their core home range to areas with more abundant resources (Noyce and Garshelis 2011). According to optimal foraging theory, bears should leave a patch (and typically their seasonal home range) when resources drop below the average level found elsewhere; however, foraging theory assumes omniscience of food levels in surrounding patches (MacArthur and Piankka 1966, Kamil et al. 1987). However, bear behavior does not always follow optimal foraging theory because they are not omniscient. Bears with a lack of familiarity of an area are subject to an increased risk of harm (Nichelson et al. 1997, Noyce and Garshelis 2011). Bears are less likely to expand their search area when resources are scarce elsewhere, seeming to bet-hedge their risk of mortality against potential caloric gain and foraging efficiency (Noyce and Garshelis 2011). Bears in or near urban areas may be less likely to expand their search area because anthropogenic food levels are higher (e.g., more trash, birdfeeders, and other attractants) than in rural areas (Baruch-Mordo 2012).

Home range size of non-urban black bears in rural populations often change seasonally (Offenbuttel 2005, Powell et al. 1997) and is correlated with food availability and distribution (Jonkel and Cowan 1971, Young and Ruff 1982, Smith and Pelton 1990), with exception (Costello 1992). In the Adirondacks, food abundance did not correlate with seasonal home range size of non-urban black bears (Costello 1992). Mast is often patchy and ephemeral in the eastern United States (Costello 1992, Powell et al. 1997) and during hyperphagia (a time of year in which daily caloric consumption is >15,000 kcals/day), bears will temporarily to expand their search area to seek areas with higher food abundance to increase foraging efficiency (Noyce and Garshelis 2011). In Pennsylvania, home ranges of male bears are larger in June and July than any other time of year, whereas female home range size is largest in fall (Alt et al. 1980).

Large disparities between home range sizes of male and female bears are due to behavior and physiology, with males often moving much farther during breeding season and hyperphagia than females (Garshelis and Pelton 1981, Lindzey and Meslow 1977, Smith and Pelton 1990). Male home ranges (both seasonal and annual) are often larger than female home ranges in non-urban bear populations in North America (Alt et al. 1980, Powell et al. 1997, Offenbuttel 2005). Movements of females with cubs are often limited by mobility of their cubs in spring (Alt et al. 1980). Males and non-breeding females are not encumbered by physical limitations of cubs or risk of mortality for cubs, and therefore can roam farther.

There has been little research documenting the effects of urban fragmentation and development on size and seasonal shifts in home range of black bears. In a Florida population near Ocala, female home ranges were largest in summer, but male home ranges did not vary among seasons (Ullrey 2008). In southern California, female bears used city habitat during all seasons of the year, while males only used city habitat during summer (Lyons 2005). Managers need to know how bears use urban habitats to develop management plans. Bear complaints start in spring when bears emerge from dens and are in a negative foraging period (a period in which bears continue to lose weight because of low food resources on the landscape after den emergence; Noyce and Garshelis 1998) and peak in summer with moderate inter-annual variation. Nuisance complaints in Pennsylvania peak in June and do not vary among years (Ternent 2006); In West Virginia, nuisance complaints peak in May, with some variation, and periodically have another peak in August (West Virginia Division of Natural Resources 2013). It is not known if bears use urban and suburban habitats seasonally or year-round. It is also not known if bears in urban and suburban habitats shift their home ranges closer to town when food resources are scarce (early spring or at times of mast failure).

Our objectives were to determine if: (1) urban black bears shift home ranges seasonally, (2) proximity of black bear home ranges to the urban edge differ with respect to sex or jurisdiction, (3) urban black bear home range size changes seasonally, (4) urban black bear home range size differs with respect to sex or jurisdiction, and (5) whether nuisance bears in urban/suburban areas are residents to the area or transient. We hypothesized urban and suburban black bears would respond to resources similarly to non-urban bears. If true, we would predict the following: (1) their home ranges would shift seasonally nearer to urban habitats during spring to supplement low caloric availability and would shift away from urban habitats during summer (breeding season) and fall (hyperphagia), (2) home ranges of urban female black bears would be closer to the urban edge than males because they would be using areas in which risk of cub mortality is lower, (3) home range size (both males and females) would be largest during fall because the bears are moving more to consume enough food to gain sufficient mass before hibernation, (4) home range size of female black bears would be smaller than those of males because they have lower caloric needs and can meet those needs in a smaller area, and (5) the majority of bears in urban/suburban areas were part of a resident population that spent much of their time on the city's perimeter, rather than individuals that leave the core forest and move into the city periodically.

Field site description

We conducted a longitudinal study over 3 years. Agency personnel captured and fitted bears with collars across 3 states (15 in New Jersey, 40 in Pennsylvania, and 15 in West Virginia). We divided the municipalities in West Virginia and Pennsylvania into 3 subunits; we did not divide New Jersey's municipalities into subunits because of the close proximity (15 km) between each subunit. We assumed that all bears in each urban area had an equal probability of being caught during the trapping season. We also assumed that the sample of tagged bears adequately represented the study population of bears in our urban study areas.

Study Area

The following 7 subunits (Figure 2) are general accounts of the municipalities around which the study was based. In an effort to create biologically relevant study areas, each of our study areas consisted of a minimum convex polygon (Mohr 1947) that included the composite annual home ranges of resident, telemetered animals within each urban area (Storm et al. 2007).

We wanted to ensure that we captured all possible habitats in which bears near urban areas exist in each study area; therefore, we included exurban habitats as suburban. Exurbia is residential land used outside of the urban edge, situated among working farms or undeveloped land (Nelson 1992). Human population density and mean property size in exurbia fall between levels found in suburbs and rural areas. The difference between exurban and suburban landscapes is that human dwellings in exurbia are interspersed throughout wildlife habitat rather than habitat existing in patches within suburban non-habitat (Odell and Knight 2001). In our analysis of urban bears, we make inference to bears found in urban, suburban, and exurban habitats.

New Jersey.— This study area is located in the northcentral portion of New Jersey. It is bounded in the west by the state border with Pennsylvania, in the south by I-78, in the east by I-287, and in the north by the state border with New York. The urban areas, including the townships of West Milford, Vernon, Rockaway and Blairstown, the towns of Newton, Boonton, and Hacketstown and the boroughs of Bloomingdale, Sussex, Rockaway, and Washington are interspersed with public lands (Wayanda State Park, Delaware Water Gap National Recreation Area, Stokes State Forest, and numerous Wildlife Management Areas including Sparta Mountain and Wildcat Ridge WMAs) and quasi-public lands (Newark Watershed Conservation Corporation).

Scranton/Wilkes-Barre, Luzerne, Lackawanna, and Wyoming Counties, Pennsylvania.— This study area is primarily within the Wyoming Valley, extending northeast from the town of Mountain Top, north of Interstate 80, to the town of Clark's Summit. The Scranton/Wilkes-Barre study area (hereafter, Scranton) contains parts of Luzerne, Wyoming, and Lackawanna counties. It is bisected by Interstate 81 and contains urban/suburban areas surrounded by the forested ridges of the Wyoming Valley.

State College, Centre County, Pennsylvania.— This area lies within the Nittany Valley, extending from the suburbs of State College east-northeast to the town of Pleasant Gap and includes portions of the Penns Valley between the towns of Centre Hall and Boalsburg. The area is less urbanized than Scranton and contains more suburban areas interspersed with agricultural lands. The ridge between the two valleys is forested. There are no major interstates crossing the area, but 3 heavily traversed routes (Routes 322, 144, and 220).

Johnstown, Cambria County, Pennsylvania.— This area is the smallest of the three Pennsylvania study areas and is not situated in a mountain valley, but rather the Allegany Plateau. It contains the city of Johnstown and the surrounding municipalities. State Route 219 runs through the area and the study area is located within the bounds of Cambria County. Additionally two interstate highways (I-76 and I-99) occur within the study area bounds.

Morgantown, Monongalia County, West Virginia.— This study area is located in the Monongahela River valley. It contains the cities of Morgantown, Star City, Sabraton, Granville, and Westover and is wholly contained within Monongalia and Preston counties. It is bounded in the south by I-68, in the west by I-79, and the east by the town of Hopewell. This area (as with all of the West Virginia study sites) is more forested and less urban than the Pennsylvania study areas. There is little agricultural production in the area. Development has increased over the last decade due to population change in the greater Morgantown area.

Beckley/Oak Hill, Fayette, and Raleigh Counties, West Virginia.— This study area includes the cities of Beckley, Mabscott, MacArthur, Sophia, Bradley, Glen Jean, Mount Hope, Pax, Eccles, Beaver, Grandview, and Stanaford. The study area is located in a mountain valley and is bisected by WV-16 and US 19. The study area is bounded by forested ridges and has had much development over the past decade. Two major interstates cross the area (I-77 and I-64) and active coal mining is present on the study site.

Charleston, Kanawha County, West Virginia.— This study contains West Virginia's largest city and is located at the confluence of the Elk and Kanawha rivers. It contains the cities of St. Albans, Charleston, South Charleston, Kanawha City, Dupont City and Dunbar. This study area is located 100 km to the northwest of the Beckley site. The development of the area spans 6 km north and south of the Kanawha River which follows along I-64. Interstate 64 bisects the study area and US-119 runs through the study area from southwest to northeast. Outside the core developed area, forested ridges dominate. The Kanawha State Forest borders the southern boundary.

Methods

State agency personnel captured bears opportunistically in barrel-style, culvert-style, or Aldrich wrist-snare traps. Agency personnel baited and set traps at residences or commercial properties where bears had been sighted or human-bear conflicts had occurred. State agency employees checked traps daily. Agency personnel moved traps when a bear was captured or bear activity subsided. In Pennsylvania, pamphlets explaining the purpose and process of the study were distributed to residents and business owners near the trap sites.

Captured bears were immobilized with a mixture of ketamine hydrochloride (4.4 mg/kg) and xylazine hydrochloride (1.7 mg/kg) or tiletamine hydrochloride and zolazepam hydrochloride (Telazol©, Fort Dodge Animal Health, New York, NY) delivered by a syringe-mounted pole ("jab-stick") or CO_2 propelled dart. Bears in New Jersey and Pennsylvania were tagged in both ears using a self-piercing numbered metal tag, style 56-L, size 36.5×9.5 mm (Hasco Tag Co., Dayton, Kentucky). Bears in West Virginia were tagged in both ears with Allflex 2-piece polyurethane tags (Allflex USA Inc, DFW Airport, TX). Bears were tattooed on the inside of the lip with their ear tag identification number. A premolar was pulled from each bear (except cubs) for age determination (Harshyne et al. 1998). State agency employees recorded weight, sex, reproductive status (estrous, lactation, descended testes), date, and location of capture. All attempts were made to release bears near the capture site. If relocation was required to prevent injury (traffic hazards, domestic animals), the bear was relocated typically relocated within the mean home range diameter of bears in the region from the capture site (Alt et al. 1976, Alt 1980): however, some exceptions were made when there was not a safe location to release the bear near the capture site. We excluded bears from the study that removed their collars <1 week post capture and censored locations of all bears during their first week to eliminate locations in which the bear was under the effect of anesthesia.

Bears weighing >45 kg were fitted with Global Positioning System-Global System for Mobile Communications (GPS-GSM)-equipped radio-transmitting neck collars (Vectronics, Berlin, Germany; Lotek, New Market, Ontario, Canada, Northstar, King George, Virginia, USA). GPS-GSM collars were configured to record a location at timed intervals dependent on date. During most of the year, except for bear hunting season (1 September – 31 December), location triangulation was attempted every 3.25 hours between 0600–1800 hours, resulting in 7 locations per day. During hunting season, location triangulation was attempted every 1.0 hour between 0600–1800 hours in addition to once every 3.25 hours, resulting in 20–21 locations per day. Location data was received from GPS-GSM collars daily via SMS (cell phone text message) and maintained in a central data repository. Any bear transmitting from the same location for more than one week was investigated to assess cause-specific mortality.

We compiled all locations into a geodatabase in ArcGIS 10.0 (ESRI, Redlands, CA). We calculated seasonal estimates of bear home range size for bears that had >250 locations within a season, and we generated annual home ranges for bears with >500 locations. To define each study area, we calculated a 95% minimum convex polygon of all non-dispersing bears in each study area. We determined den emergence by visually identifying a cluster of locations in early spring in which a bear was located for >1 week and then left that location for the remainder of the year. We determined den entrance date by visually identifying a cluster of locations in which a bear spends >1 week in the late fall and remained there over the winter. We calculated seasonal home ranges of each bear (Annual: Den Emergence–Den Entrance, Spring: Den emergence–15 June; Summer: 16 June–15 September; Fall: 16 September–15 December/Den Entrance) with >250 locations. We subsampled 33% of all fall locations to ensure that sampling intensity remained consistent among seasons. We used the Geospatial Modeling Environment (Beyer 2012) to generate 95% fixed-kernel home ranges for each bear. We selected the "PLUGIN" bandwidth for each kernel. We used all of the available (within the subset) points for each bear and did not account for the variable number of locations in each home range. The number of points in each home range varied with each season and individual bear. We used the urban area layer (United States Census Bureau 2010) to delineate urban zones in each study area. Urban zones are defined as areas that encompass ≥2,500 people with ≥1,500 of those people residing outside of government institutions (e.g. prisons). We considered all areas within the edge of all urban areas for each study area to be urban. We generated a Euclidean distance raster from the edge of all urban areas using the distance raster tool in ArcGIS. For each home range, we extracted the centroid and calculated the Euclidean distance (m) from the edge of the urban area. We used ArcGIS to determine the size of each home range using the calculate areas tool. We were concerned that home range size and Euclidean distance between the home range centroid and the edge of the urban area may have been correlated, so we calculated Kendall's nonparametric correlation coefficient for the two variables.

We calculated nonparametric statistics to determine if the distance from urban areas (km) was different between sexes or among seasons and study areas. We conducted a Kruskal-Wallis test to determine if the distance from the urban edge to home range centroids was different between sexes. We conducted Kruskal-Wallis tests to determine if the distance of home range centroids (1) shifted nearer or farther to the urban edge, (2) from the urban edge was different among seasons or study area, or (3) if the home range sizes (km^2) were different between sexes or among seasons and study areas.

To determine if the bear was a resident or transient, we determined the mean distance from city limits for every bear location in each study area by generating a Euclidean distance layer using the spatial analyst toolbox. We also generated a 5-km buffer layer around all urban areas delineated by the US Census Bureau (2010). We considered the urban/suburban zone to be within 5 km of the city limits. We determined the proportion of points that were located within the city limits and within the urban buffer. We excluded bears with <250 locations from our analysis. For the populations in each study area, if the median distance among locations (± 95% confidence interval) to the city limits was less than 5 km (most of the points were contained in the buffer), we considered the population to be resident. If the median distance among locations (± 95% confidence interval) was >5 km (most of the points were outside the buffer), bears in that population were spending most of their time far from town and considered transient.

Results

Agency personnel captured 120 bears across 3 states (25 in New Jersey, 76 in Pennsylvania, and 19 in West Virginia). One bear was captured in New Jersey and dispersed to the Scranton/Wilkes-Barre study area, but for the context of this study is considered to be a New Jersey bear. Sex ratios (M:F) of bears in our sample varied widely among states (10:15 in New Jersey, 50:26 in Pennsylvania, and 18:1 in West Virginia). Surprisingly, the majority of the sample was comprised of adult bears (both male and females $\geq$3 years of age at capture), rather than dispersing juvenile males. The sample consisted of 62 adult males, 14 juvenile males, 39 adult females, and 5 juvenile females, resulting in a sex ratio of 76M:44F. We were able to estimate 48 annual, 17 spring, 49 summer, and 39 fall home ranges of male bears after removing bears with <250 locations. We also estimated 26 annual, 19 spring, 42 summer, and 37 fall home ranges of female bears after removing bears with <250 locations. We found no correlation (0.047) between 95% fixed kernel home range size and Euclidean distance from the home range centroid and the edge of the urban areas.

We found strong evidence (χ^2_1=16.161, P = <0.001) that the distance of home ranges to the edge of urban areas differed between sexes. We further split the dataset into 2 portions (one for male home ranges and one for female home ranges). For males, there was no evidence that distance to the edge of urban area differed among seasons (χ^2_2 = 0.391, P = 0.823), but there was strong evidence that distance to the urban edge (χ^2_6 = 25.622, P = <0.001) was different among study areas (Table 1). Male home ranges in New Jersey were 50% of the distance to the urban edge than the overall mean (all study areas) and male home ranges in Morgantown were 200% as far from the urban edge than the overall mean. For female bears, we found strong evidence (χ^2_4 = 29.351, P = <0.0001) that the distance of home ranges to urban edge varied among study areas, but no evidence that distance to the urban edge varied among seasons (χ^2_2 = 0.935, P = 0.627). Female home ranges were closer to the urban edge in Scranton/Wilkes-Barre and Morgantown than in other study areas (Table 1).

We found strong evidence (χ^2_1=112.14, P = <0.001) that home range size differed between sexes. We further split the dataset into 2 portions (one for male home ranges and one for female home ranges). For the males, there was no evidence that home range size varied among seasons (χ^2_3 = 4.062, P = 0.255), but there was strong evidence that home range size was different (χ^2_6 = 42.023, P = <0.001) among study areas (Table 2). Male home ranges in Morgantown were smaller and those in Johnstown were larger than in the other study areas. For females, we found no evidence (χ^2_3 = 0.684, P = 0.141) that home range size varied among season, but moderate evidence that home range size varied among study areas ($\chi^2_5 = 42.023$, $P < 0.001$). Female home ranges were smaller in New Jersey than in other study areas (Table 2).

All 7 study populations were considered resident populations for each year of the study, except for Charleston, West Virginia during 2011 (Table 3). In the Charleston study area, 95% confidence intervals did not overlap the 5-km urban buffer during 2011. This population consisted of few individuals (3 bears) in 2011 due to low success trapping. In addition, the configuration of Charleston is linear due to the Kanawha River, with steep slopes surrounding the city limits. Telemetered bears spent a majority of their time on the southern edge of the city. Overall, bears from all study populations remained close to city limits.

New Jersey.— Twenty-two of the 25 bears in the study area were residents within the 5-km buffer (Figure 1, right panel). The 3 that were not within the 5-km buffer were adult females. Of the remaining bears (22), 3 males left and returned to the study area. The first bear ended up in New York, near the Tappan Zee Bridge on the Hudson River. The second bear left the study area and made an exploratory bout into Pennsylvania, and the third bear left the study area during the breeding season of 2012, spending 2 months on the border of the greater Philadelphia suburbs (Figure 1, right panel).

Pennsylvania.— In the Johnstown study area, most (12) of the bears were found within the 5-km urban buffer, except for 2 individuals (Figure 2, left panel). The first bear was a solitary female that left the Johnstown area for 3 weeks, visited the northeast suburb of Pittsburgh, and returned to Johnstown. The second bear (an adult male) left the study area and traveled to the greater Pittsburgh area suburbs where it was killed in a vehicle collision a year later. The bears in the State College study area were resident within the 5-km buffer (Figure 2, right panel). The vast majority of bear locations in State College were found on the north and south sides of town, with a number of locations coming from Mount Nittany. In the Wilkes-Barre study area, most (30) of the bears were found within the 5-km buffer, except for 4 individuals. Two males left the area and moved southeast to the Poconos and resided there. The other 2 males left the area and traveled west and southwest. One of the males was a juvenile bear that traveled from the Scranton Airport to an area southwest of Johnstown near Ohiopyle State Park (a distance of ~320 km in 5 months).

West Virginia.— In the Beckley study area, 2 adult male bears spent the majority of their time outside of the 5-km urban buffer on a Boy Scouts of America Camp property (Figure 3, left panel). In the Charleston area, most (2) of the bears remained in urban buffer on the south side of town; however, during 2011, one bear left the study area to visit a reclaimed mountaintop mine site during the fall (Figure 3, right panel). In the Morgantown study area, most (4) of the bears remained within the 5-km buffer, however, due to the mosaic of forest, farmland, large tracts of public land, and housing, the 5-km buffer may not accurately depict the suburban zone (Figure 4). The vast majority of bear locations in the Morgantown area were located within forests that are adjacent to town, agriculture, or housing developments. The remaining 2 bears (both adult males) remained just outside of the 5-km buffer, in forests adjacent to a limestone quarry.

Discussion

We found no support for our prediction that bears in urban habitats shift their home range closer to urban habitats during spring and farther from urban habitats during summer and fall. This is contrary to the body of literature from "non-urban" bears (Garshelis and Pelton 1981, Offenbuttel 2005), but was not unexpected. Animals that travel outside their normal home range are susceptible to heightened mortality risk (Nicholson et al. 1997). An animal's unfamiliarity with an area, increased metabolic cost of travel and the potential risk of selecting an area of lower habitat quality can reduce foraging efficiency (Brown et al. 1999) or can increase risk of mortality (John and Roskell 1985, Nicholson et al. 1997). Some urban wildlife species shift their spatial distributions closer to town to access refugia from predation or in response to abundant resources. Red foxes (*Vulpes vulpes*) in urban areas will shift closer to town to avoid displacement and predation from coyotes (*Canis latrans*; Gosselink et al. 2010). Raccoons (*Procyon lotor*) will move farther into the center of town (from the periphery) to establish populations when anthropogenic foods are abundant (Prange et al. 2003).

We found considerable support of our prediction that home ranges of female black bears would be closer to urban areas than males. We found the effect varied among study areas, but generally, female home ranges were closer to urban areas than males. This could be due to the influence of cubs. Typically, risk of non-hunting mortality is higher for cubs in urban areas due to vehicle collisions or human-bear conflicts (Wooding and Hardisky 1994, Beckmann and Lackey 2008); however, much of the area that our bears used was directly adjacent to urban areas and primarily consisted of private land (in which human access and risk of disturbance was limited). Males were farther from urban areas and had larger home ranges than females. Male bears also require a higher amount of calories than females, so they may be spending more time in areas with a higher abundance of food (Robbins 1992, Welch et al. 1997, Rode and Robbins 2000). Summer is breeding season for male black bears and they often travel long distances to maximize their reproductive potential by spending most of their time looking for mates (Rogers 1987). The difference among study areas in distance to the urban edge could also be a function of urban centers, rather than bear behavior. Urban bears in our study may have been avoiding other areas may have affected the shape of bear home ranges (e.g., a bear's home range in Johnstown, PA, may have been influenced by the close proximity of the Altoona and Ebensburg, PA, rather than solely the proximity to Johnstown).

We found no support for our prediction that home range size would be largest during fall. Increased home range size is usually indicative of poorer-quality habitat or an increase in caloric uptake (Powell et al 1997, Robbins 1992). We found no seasonal differences in the home range size of urban bears in our study after accounting for the difference between sexes. Our results contradicted reports from Garshelis and Pelton (1981) of non-urban bears in the Great Smoky Mountains National Park. Male bears in their study had 37% larger home ranges in fall than summer; female home ranges were similar between fall and summer (Garshelis and Pelton 1981).

Bears in our study had similar home range sizes among seasons. Bears in higher-quality habitats may not need to move to find large amounts of food. If the habitat is productive and has abundant food available, bears will remain in a small area due to the high energetic costs of movement and searching for food (Robbins 1992). We are not certain if the urban areas had a high abundance of natural foods or if bears were supplementing their caloric intake with anthropogenic food sources (e.g., birdseed, corn, trash, etc.). In areas with low natural food abundance (e.g., the Tahoe Basin), urban and developed areas act as an attractant because anthropogenic food sources are abundant (Beckmann and Lackey 1998). In our study areas, forests with natural foods occurred near suburbs or urban areas. We hypothesized that in areas near towns, the mortality risk of moving to new areas during hyperphagia outweighed the potential caloric gain of finding “core” forests with abundant mast. Additionally, some of our study areas may have produced enough mast (in average to good mast years) to accommodate all of the caloric needs of bears.

We found that median home range size of urban bears in our study was smaller than that of non-urban bears in the region, with exception. Median home range size of our male urban bears was about 11% smaller than documented estimates of other Pennsylvania male bears (155 km^2 vs. 173 km^2, respectively), and home range size of our urban female bears was ~37% smaller than documented estimates of other female bears in Pennsylvania (41 km^2 vs. 26 km^2; Alt et al. 1980). Our urban bears had larger home range sizes than non-urban bears in the southern Appalachian Mountains for both sexes; urban male home ranges were 386% larger than non-urban males in Tennessee and urban female home ranges were 73% larger than non-urban females in Tennessee (Garshelis and Pelton 1981). Variation in home range size among studies was not unexpected. Home ranges have been reported as an index of habitat quality for mammals (Ochiai et al. 2010, Bjørneraas et al. 2012). Habitat quality for bears in the mid-Atlantic and Appalachian regions fluctuates substantially each year and depend on food abundance (Koenig et al. 2000, Vaughan 2002). Variability among study sites and years explains why urban bear home ranges were smaller than some home ranges of non-urban bears, but not others.

We found considerable support for our hypothesis that bear populations in urban areas are resident and spend much of their time adjacent to city limits. Bears were resident to the periphery of urban areas in each study area during all years (except Charleston during 2011). Lyons (2005) and Merkle et al. (2011) documented a similar phenomenon in urban bear populations in California and Montana, respectively. Human-bear encounters occurred where humans lived close to forests and major watersheds and in moderate housing densities (~ 6 house/ha; Merkle et al. 2011). In Durango, Colorado, Baruch-Mordo et al. (2008) documented that human-bear interactions (based on bear and roadkill locations) occurred near the edge of town , or where high-density stands of oak occurred (along the front range of the Rockies). In Colorado and other western states, urban bears use urban and suburban areas as supplemental habitat that provide an anthropogenic source of food when hard mast is patchy or scarce (Baruch-Mordo et al. 2008). The major difference between forests in the western United States and forests in the mid-Atlantic region is mast production; forests in the mid-Atlantic region have more abundant mast production (Vaughan 2002). Because of this difference, urban bears in our study did not spend considerable time using habitats on the edge of city limits as supplemental habitat. Bears in our study spent nearly all their time on the periphery of city limits, year-round. This is because those areas likely are high-quality habitat. We have no evidence that these areas are sub-optimal habitat because bear mortality was low and bear reproduction was fairly high. If habitat quality was sub-optimal, we would have expected bears to leave the areas near the city limits when mast production was poor to find food.

Our results have some interesting management implications. We found bears at similar distances from town throughout the year. We found no evidence that bears shifted their home ranges closer to the edge of the urban area seasonally. Our bears lived near town, but this distance varied among study areas. Managers seeking to predict where potential bear conflicts may occur should focus their efforts on the edge of urban and suburban areas (known as the exurban areas) in the Mid-Atlantic region. Bears consistently spent the bulk of their time (and the majority of their home range) in the transition from suburban to the exurban zones.

Acknowledgments

We thank the New Jersey Division of Fish and Wildlife, Pennsylvania Game Commission, and the West Virginia Division of Natural Resources for collecting this data and funding the research. We thank West Virginia University and the West Virginia Division of Natural Resources for funding supporting A. Tri's doctoral program.

Literature Cited

Alt, G. L., F. W. Alt, and J. S. Lindzey. 1976. Home range and activity patterns of black bears in northeastern Pennsylvania. Proceedings of the Northeast Section of the Wildlife Society 33:45–56.

Alt, G. L., G. J. Matula, Jr., F. W. Alt, and J. S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Ursus 4: 131–136.

Baruch-Mordo, S. 2007. Black human-bear conflicts in Colorado: Spatiotemporal patterns and predictors. M. S. Thesis. Colorado State University, Fort Collins.

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

Baruch-Mordo, S. 2012. Black bear ecology and human-bear interactions in an urban system. PhD Dissertation. Colorado State University, Fort Collins.

Beckmann, J. P., and C. W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human–Wildlife Conflicts 2:168–174.

Beeman, L.E., and M.R. Pelton. 1980. Seasonal foods and feeding ecology of black bears in the Smoky Mountains. International Conference on Bear Research and Management 4:141–147.

Beyer, H.L. 2012. Geospatial Modelling Environment (Version 0.7.2.0). http://www.spatialecology.com/gme. Last accessed: 23 October 2013.

Bjørneraas K., Herfindal I., Solberg E.J., Sæther B-E., van Moorter B. and Rolandsen C.M. 2011. Habitat quality influences population distribution, individual space use and functional response in habitat selection by a large herbivore. Oecologia 168: 231–243.

Brown, J.S., Laundré, J.W., Gurung, M. 1999. The ecology of fear: optimal foraging, game theory, and trophic interactions. Journal of Mammalogy 80:385–399.

Costello, C. M. 1992. Black bear habitat ecology in the central Adirondacks as related to food abundance and forest management. Thesis, State University of New York.

Garris, R.S. 1983. Habitat utilization and movement ecology of black bears in Cherokee National Forest. M.S. Thesis. University of Tennessee, Knoxville.

Garshelis, D. L., and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountain National Park. Journal of Wildlife Management 45: 912–925.

Gosselink, T.E., T.R. Van Deelen, R.E. Warner, and M.G. Joselyn. 2003. Temporal habitat partitioning and spatial use of coyotes and red foxes in east central Illinois. Journal of Wildlife Management 67: 90–103.

John, A.W.G. and J. Roskell.1985. Jay movements in autumn 1983. Breeding Birds 78:611–637.

Jonkel, C. J., and I. McCowan. 1971. The black bear in the spruce-fir forest. Wildlife Monographs 27.

Kamil, A.C., Roitblat, H.L. 1985. The ecology of foraging behavior: implications for animal learning and memory. Annual Reviews of Psychology 36:141–169.

Koenig, W.D., Knops, J.M.H. 2000. Patterns of annual seed production by northern hemisphere trees: a global perspective. American Midland Naturalist 155:59–69.

Lindzey, F.G., Meslow E.C. 1977. Home range and habitat use by black bears in southwestern Washington. Journal of Wildlife Management 41:413–425.

Lyons, A. J. 2005. Activity patterns of urban American black bears in the San Gabriel mountains of southern California. Ursus 16:255–262.

MacArthur, R.H., Pianka, E.R. 1966. On optimal use of a patchy environment. American Midland Naturalist 100:603–609.

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

Nelson, A. C. 1992. Characterizing exurbia. Journal of Planning Literature 6:350–368.

Nicholson, M.C., Bowyer, R.T., and Kie, J.G. 1997. Habitat selection and survival of mule deer: tradeoffs associated with migration. Journal of Mammalogy 789:483–504.

Noyce, K. and D. L. Garshelis. 1998. Spring weight changes in black bears in northcentral Minnesota: the negative foraging period revisited. Ursus 10:521–531.

Noyce, K. and D. L. Garshelis. 2010. Seasonal migrations of black bears (*Ursus americanus*): causes and consequences. Behavioral Ecology and Sociobiology 65:823–835

Ochiai, K., K. Susaki, T. Mochizuki, Y. Okasaka, and Y. Yamada. 2010. Relationships among habitat quality, home range size, reproductive performance and population density: Comparison of three populations of the Japanese Serow (*Caprocornis crispus*). Mammal Study 35:265–276.

Odell, E. A., and R. L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. Conservation Biology 15:1143–1150.

Offenbuttel, C. 2005. Home range dynamics of black bears in the Alleghany Mountains of western Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Powell, R. J. W. Zimmerman, and D. E. Seaman. 1997 Ecology and behavior of North American black bears: home rangers, habitat, and social organization. Springer.

Prange S., S. D. Gehrt, and E. P. Wiggers. 2003. Demographic factors contributing to high raccoon densities in urban landscapes. Journal of Wildlife Management 67:324–333

R Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Robbins, C. T. 2000. Wildlife Feeding and Nutrition. Academic Press. San Diego, CA.

Rode, K.D., and Robbins, C.T. 2000. Why bears consume mixed diets during fruit abundance. Canadian Journal of Zoology 78: 640–645.

Rogers, L. L. 1987. Effects of Food Supply and Kinship on Social Behavior, Movements, and Population Growth of Black Bears in Northeastern Minnesota. Wildlife Monographs 97.

Smith, T. R., and M. R. Pelton. 1990. Home range and movements of black bears in a bottomland hardwood forest in Arkansas. International Conference on Bear Research and Management 8: 213–218.

Storm, D. J., C. K. Nielsen, E. M. Schauber and A. Woolf. 2007. Space use and survival of white-tailed deer in an exurban landscape. Journal of Wildlife Management 71:1170–1176.

Ulrey W. 2008. Home range, habitat use, and food habits of the black bear in southcentral Florida. Master's Thesis, University of Kentucky, Lexington.

Vaughan, M.R. 2002. Oak trees, acorns, and bears. Pages 224–240 in W.J. McShea and W.M. Healy, editors. Oak forest ecosystems: ecology and management for wildlife. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Welch, C.A., Keay, J., Kendall, K.C., and Robbins, C.T. 1997. Constraints on frugivory by bears. Ecology 78: 1105–1119.

Wooding, J. B. and T. S. Hardisky. 1994. Home range, habitat use, and mortality of black bears in north-central Florida. Bears: Their Biology and Management 9:349–356.

Young D. D., and J. J. Beecham. 1986. Black bear habitat use at Priest Lake, Idaho. Bears: Their Biology and Management 6:73–80.

Young, B. F., and R. L. Ruff. 1982. Population dynamics and movements of black bears in east central Alberta. Journal of Wildlife Management 46: 845–860.

Table 2-1. Median distance from center of the annual and seasonal home ranges (km) and standard errors to the edge of the nearest urban area from urban and suburban black bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012. The total number of seasonal and annual home ranges per study areas is denoted by n.

	Male			Female		
Study Area	*n*	Median	SE	*n*	Median	SE
Beckley	15	2.82	0.87	0	–	–
Charleston	10	2.52	0.54	0	–	–
Morgantown	16	6.98	0.60	1	0.48	–
Johnstown	14	3.03	0.38	12	2.85	0.68
State College	30	2.50	0.42	21	2.47	0.31
Scranton/Wilkes-Barre	33	2.01	0.72	39	0.62	0.23
New Jersey	21	0.98	0.46	33	0.89	0.93
Overall mean		2.31	0.29		0.92	0.31

Table 2-2. Median annual home range size (km^2) and standard errors of urban and suburban black bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012. The total number of annual home ranges per study areas is denoted by *n*.

	Male			Female		
Study Area	*n*	Median	SE	*n*	Median	SE
Beckley	15	97.85	14.82	0	–	–
Charleston	10	73.57	46.32	0	–	–
Morgantown	16	64.55	11.49	1	–	–
Johnstown	14	264.23	58.57	12	46.78	30.59
State College	30	300.00	49.26	21	27.68	31.42
Scranton/Wilkes-Barre	33	241.88	81.46	39	31.42	11.00
New Jersey	21	115.61	92.19	33	11.37	12.88
Overall mean		155.87	28.63		27.68	7.55

Table 2-3. Median (± 95% CI) distance from city limits of urban/suburban bear populations in New Jersey, Pennsylvania, and West Virginia, 2010–2012.

	Year		
Mean distance to city limits (km)	2010	2011	2012
New Jersey	2.81 (0.56)	2.88 (0.02)	1.90 (0.02)
Johnstown	2.68 (0.08)	2.89 (0.04)	3.79 (0.12)
State College	2.76 (0.04)	2.71 (0.04)	2.66 (0.42)
Scranton/Wilkes-Barre	2.23 (0.34)	2.56 (0.04)	1.42 (0.08)
Beckley	–	3.45 (0.08)	3.97 (0.06)
Charleston	–	5.38 (0.20)	3.56 (0.06)
Morgantown	–	1.60 (0.06)	4.10 (0.06)

FIGURE CAPTIONS

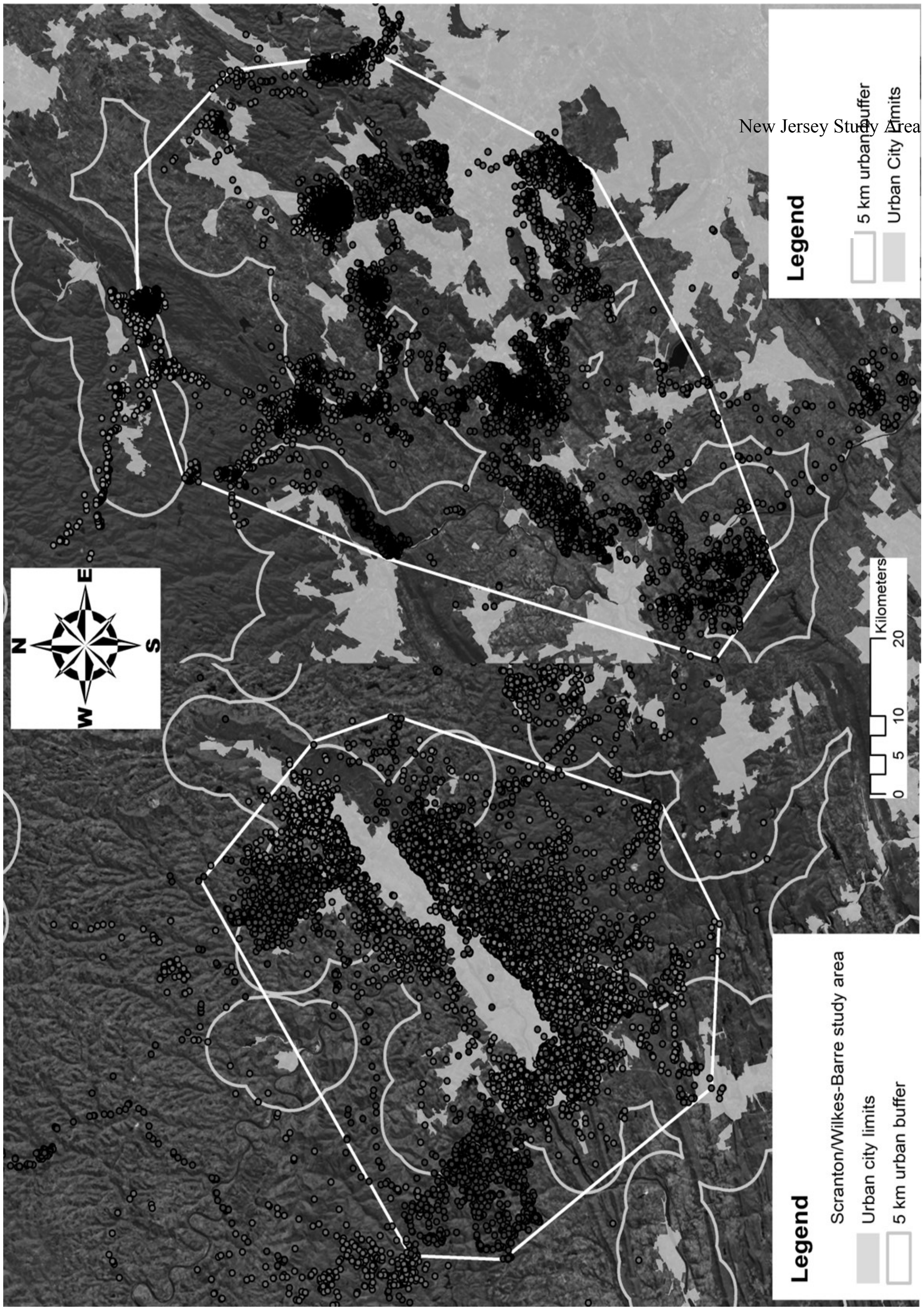
Figure 2.1. Map of the study areas in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

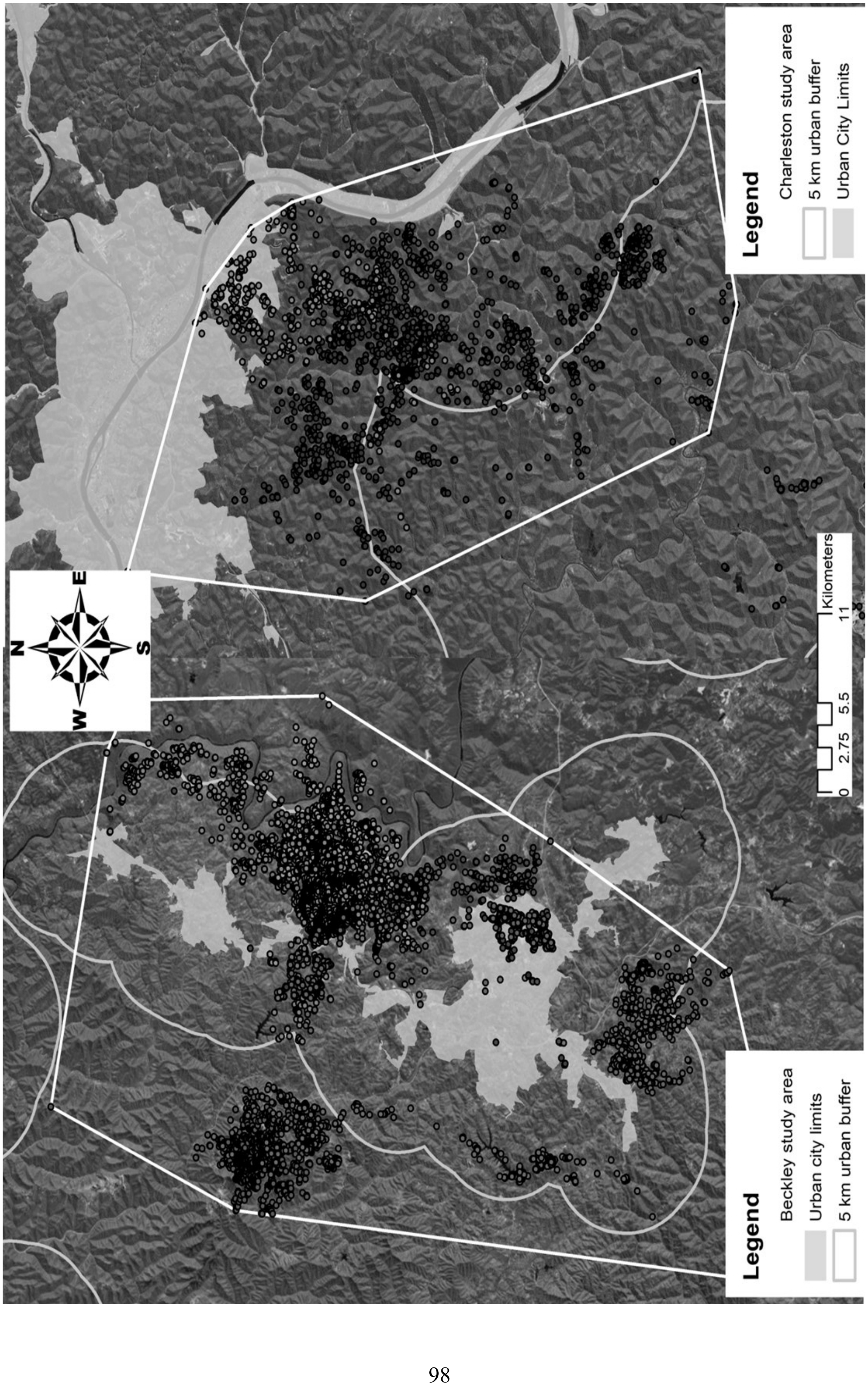
Figure 2.2. GPS fixes of urban/suburban bears in the Scranton/Wilkes-Barre (left panel) and New Jersey (right panel) study areas during 2010–2012. Each dot denotes a GPS fix of a bear and each different color denotes a different bear.

Figure 2.3. GPS fixes of urban/suburban bears in the Johnstown (left panel) and State College (right panel) study areas during 2010–2012. Each dot denotes a GPS fix of a bear and each different color denotes a different bear.

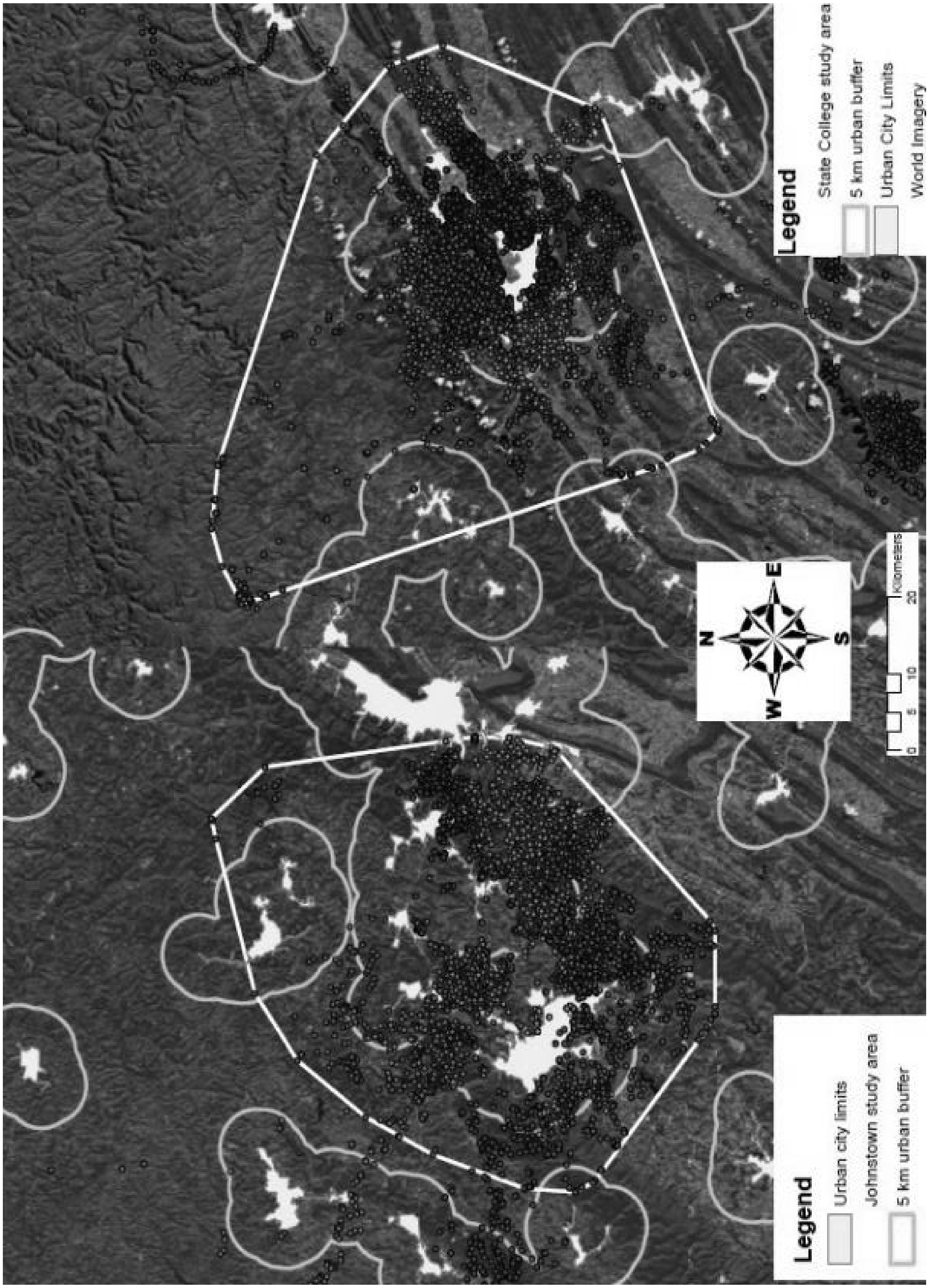
Figure 2.4. GPS fixes of urban/suburban bears in the Beckley (left panel) and Charleston (right panel) study areas during 2011–2012. Each dot denotes a GPS fix of a bear and each different color denotes a different bear.

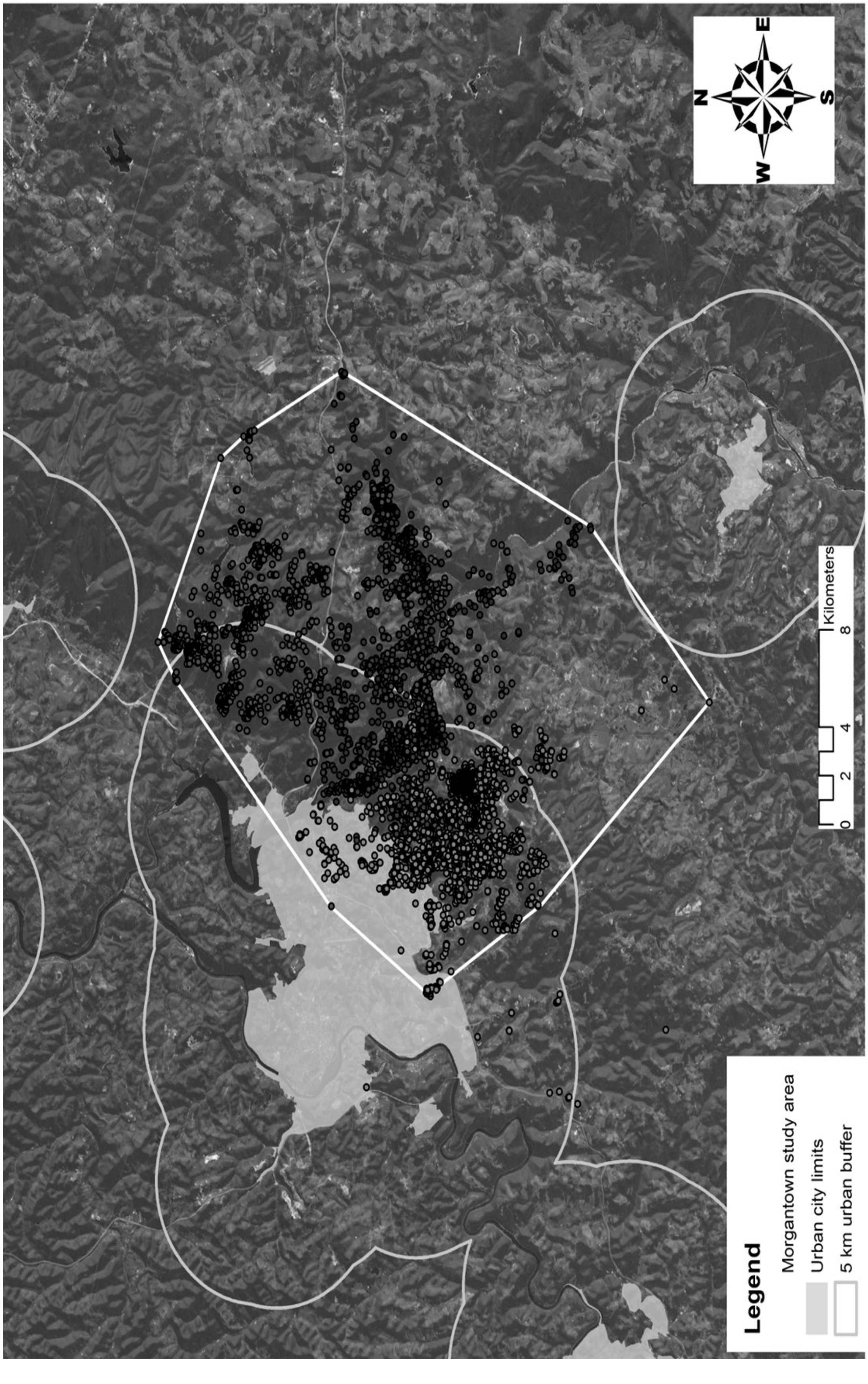
Figure 2.5. GPS fixes of urban/suburban bears in the Morgantown study area during 2011–2012. Each dot denotes a GPS fix of a bear and each different color denotes a different bear.


New Jersey Study Area
Legend
5 km urban buffer
Urban City limits
Legend
Scranton/Wilkes-Barre study area
Urban city limits
5 km urban buffer
Kilometers
0
5
10
20
N
E
S
W



Legend
Charleston study area
5 km urban buffer
Urban City Limits
N
E
S
W
0
2.75
5.5
11
Kilometers
Legend
Beckley study area
Urban city limits
5 km urban buffer


Legend
State College study area
5 km urban buffer
Urban City Limits
World Imagery
N
E
S
W
0 5 10 20
Kilometers
Legend
Urban city limits
Johnstown study area
5 km urban buffer


Legend
Morgantown study area
Urban city limits
5 km urban buffer
Kilometers
0
2
4
8
N
E
S
W

Chapter 3.

Spatial Harvest Vulnerability of Urban Black Bears in the Mid-Atlantic Region

25 October 2013
Andrew N Tri
West Virginia University
Davis College of Agriculture, Natural Resources and Design
Division of Forestry and Natural Resources
322 Percival Hall, P.O. Box 6125
Morgantown, WV 26506
763/210-8939; Fax: 304/293-2441
andrew.n.tri@gmail.com

Chapter 3. Spatial Harvest Vulnerability of Urban Black Bears in the Mid-Atlantic Region

ANDREW N. TRI[2], Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

JOHN W. EDWARDS, Division of Forestry and Natural Resources, 322 Percival Hall, PO Box 6125, West Virginia University, Morgantown, WV 26506, USA.

MICHAEL P. STRAGER, Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

J. TODD PETTY, Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

CHRISTOPHER W. RYAN, Wildlife Resources Section, West Virginia Division of Natural Resources, 324 Fourth Avenue, South Charleston, West Virginia 25303, USA

COLIN P. CARPENTER, Wildlife Resources Section, West Virginia Division of Natural Resources, 2006 Robert C. Byrd Drive, Beckley, West Virginia 25801, USA

MARK A. TERNENT, Bureau of Wildlife Management, Pennsylvania Game Commission 2001 Elmerton Avenue, Harrisburg, PA 17110

PATRICK C. CARR, New Jersey Division of Fish and Wildlife, Mail Code 501-03, PO Box 420, Trenton, NJ 08625-0420

[2] This manuscript has been formatted in the style of The Journal of Wildlife Management. The singular I has be replaced with the collective "we" to allow for ease in preparation for journal submission.

Management and regulated harvests have reduced mortality and allowed black bear populations to increase throughout the eastern United States over the past 30 years. The rapid and dramatic recovery in population size has led to increased interactions between humans and bears in New Jersey, Pennsylvania and West Virginia. Harvest vulnerability of black bears is dependent on a variety of factors and therefore difficult to estimate. We measured harvest vulnerability of urban bears by generating MaxEnt models of bear occurrence during the prehunting period and hunting season. Agency personnel captured and fitted bears with GPS-GSM collars across 3 states during 2010–2012. Bear occurrence decreased from prehunting period to hunting season in both public hunting lands and urban areas. Probability of urban bear occurrence shifted from public hunting areas to the periphery of the public hunting areas between the prehunting period and hunting season. Average harvest vulnerability of urban bears was highest in Pennsylvania (20.2%) and West Virginia (17.4%), and lower in New Jersey (5.9%). Average overall mortality rates of urban bears were highest in Pennsylvania (28.1%) and lower in West Virginia (17.5%) and New Jersey (15.1%). DU the short timeframe of the study, regulated hunting was effective in killing a high number of urban black bears in New Jersey, Pennsylvania, and West Virginia, when all mortality sources were taken into account.

KEY WORDS Bayesian, black bear, harvest vulnerability, maximum entropy, New Jersey, Pennsylvania, West Virginia

Journal of Wildlife Management **XX(X):XXX–XXX, 201X**

The American black bear (*Ursus americanus*; hereafter, black bear) is the most common and widely distributed bear species in North America (Schieck et al. 2011). From the time of European settlement until the mid-20th century, black bears were killed indiscriminately and excessively in an attempt to limit damage to crops and livestock. Management and regulated harvests have reduced mortality and allowed bear populations to increase in the eastern United States over the past 30 years (McConnell et al. 1997, Doan-Crider 2003, Clark et al. 2005, Garshelis and Hristienko 2006). The rapid and dramatic recovery in population size (~2% per year; Garshelis and Hristienko 2006) has led to increased interactions between humans and bears in jurisdictions that manage bears. In the mid-Atlantic region (New Jersey, Pennsylvania and West Virginia), bear populations are expanding into areas of human development as human populations are expanding into wildlife habitat, which is leading to increased human-bear conflicts.

Increased numbers of reported human-bear conflicts have directly influenced management decisions for bears in New Jersey, Pennsylvania, and West Virginia for at least the last decade. As a result of increased bear population growth, hunting opportunities have been provided to reduce bear abundance in eastern states in which high numbers of nuisance complaints have been logged (Spiker and Bittner 2004, Wolgast et al. 2005, Ternent 2006). Hunting is a management tool recommended for reducing some types of human-bear conflicts (Treves and Karanth 2003, Treves et al. 2010). Historically, there was no management distinction between urban and wild bears, so management recommendations were predicated on the assumption that reductions in the numbers of bears overall would decrease the numbers of urban bears and their associated human conflicts. The efficacy of hunting near urban areas to reduce nuisance complaints is unknown due to a lack of fundamental understanding of bear home range use and seasonal bear activity in urban and suburban areas. Understanding black bear spatial ecology and mortality in urban and suburban habitats is critical to developing and implementing a comprehensive bear management program. Harvest vulnerability of black bears is difficult to estimate due to the wide number of variables involved. Harvest success, harvest pressure, bear population size, abundance of mast, sex, age, and hunter density all influence the vulnerability of black bears to harvest (Noyce et al 1997). These data are difficult to obtain and may be impossible to estimate. Bear hunting seasons and bag limits vary by state. An alternative approach is to examine spatial patterns of bears prior to and during the hunting season. It is unknown where urban bears go during hunting season, but it is often posited that bears use urban areas as refuges from harvest pressure.

Much of the mortality in non-urban bear populations is caused by humans (Bunnel and Tait 1981, Beck 1991, Ryan 2009). Harvest vulnerability (the annual proportion of marked bears in the harvest) of non-urban bears varies depending on sex and age (Alt et al. 1980, Noyce et al. 1997). Non-urban male bears are generally harvested at a higher rate than females due to their larger home range areas, harvest restrictions protecting females with cubs, and increased vulnerability to different forms of take (e.g., baiting) (Rogers 1976, Kasworm and Their 1994). Young bears (2–3 years old) tend to have almost twice the vulnerability of older bears in non-urban populations. Young females are more vulnerable than young males, and female vulnerability decreases with age. Vulnerability of male bears decreases very little with age (Alt et al. 1980). Many studies have addressed the effects of hunting on bears (Powell et al. 1997, Lee and Vaughan 2004, Obbard and Howe 2008). Research has shown that regulated hunting of non-urban black bear populations is a cost-effective management tool that is often one of the only pragmatic options for controlling bear populations (Diefenbach et al. 2004).

We hypothesized that urban bears would react negatively to hunting pressure similarly to non-urban bears. Bears have been documented to shift their distribution spatially (McIlroy 1972) away from harvest pressure. We predicted that urban bears would respond by shifting from areas in which public hunting was allowed to private lands where hunting may have been restricted and disturbance would have been less likely. Moreover, we expected their response to be particularly strong in West Virginia where dog trainers can run hounds year-round when compared to New Jersey and Pennsylvania in which bear dog training is prohibited. We also predicted that urban bears would shift from outlying areas to areas near town that serve as refugia from increased human presence in the woods. We hypothesized that harvest numbers would be related to food abundance in urban areas. When mast conditions were poor, we expected bears to forage in higher-risk areas, resulting in higher harvest of both males and females. Lastly, we hypothesized that urban black bears would have a low harvest vulnerability ($\leq$10%) because they would be using urban areas as refuges during the hunting season.

METHODS

Study Design

We conducted a longitudinal study over 3 years. Agency personnel captured and maintained bears with collars across 3 states. West Virginia and Pennsylvania were divided into 3 subunits; New Jersey's subunits were pooled due to the close proximity (15 km) between each subunit. We assumed that all bears in each urban area had an equal probability of being caught during the trapping season. We also assumed that the sample of tagged bears adequately represented the study population of bears in our urban study areas.

Study Area

The following 7 subunits (Figure 1) are general accounts of the municipalities around which the study was based. We wanted to ensure that we captured all possible habitats in which bears near urban areas exist in each study area; therefore, we included exurban habitats as suburban. Exurbia is residential land use outside of the urban edge, situated among working farms or undeveloped land (Nelson 1992). Human population density and mean property size in exurbia fall between levels found in suburbs and rural areas. The difference between exurban and suburban landscapes is that human dwellings in exurbia are interspersed throughout wildlife habitat rather than habitat existing in patches within suburban non-habitat (Odell and Knight 2001). In our analysis of urban bears, we make inference to bears found in urban, suburban, and exurban habitats.

New Jersey.— This study area is located in the northcentral portion of New Jersey. It is bounded in the west by the state border with Pennsylvania, in the south by I-78, in the east by I-287, and in the north by the state border with New York. The urban areas, including the townships of West Milford, Vernon, Rockaway and Blairstown, the towns of Newton, Boonton, and Hacketstown and the boroughs of Bloomingdale, Sussex, Rockaway, and Washington are interspersed with public lands (Wayanda State Park, Delaware Water Gap National Recreation Area, Stokes State

Forest, and numerous Wildlife Management Areas including Sparta Mountain and Wildcat Ridge WMAs) and quasi-public lands (Newark Watershed Conservation Corporation).

Scranton/Wilkes-Barre, Luzerne, Lackawanna, and Wyoming Counties, Pennsylvania.— This study area is primarily within the Wyoming Valley, extending northeast from the town of Mountain Top, north of Interstate 80, to the town of Clark's Summit. The Scranton/Wilkes-Barre study area (hereafter, Scranton) contains parts of Luzerne, Wyoming, and Lackawanna counties. It is bisected by Interstate 81 and contains urban/suburban areas surrounded by the forested ridges of the Wyoming Valley.

State College, Centre County, Pennsylvania.— This area lies within the Nittany Valley, extending from the suburbs of State College east-northeast to the town of Pleasant Gap and includes portions of the Penns Valley between the towns of Centre Hall and Boalsburg. The area is less urbanized than Scranton and contains more suburban areas interspersed with agricultural lands. The ridge between the two valleys is forested. There are no major interstates crossing the area, but 3 heavily traversed routes (Routes 322, 144, and 220).

Johnstown, Cambria County, Pennsylvania.— This area is the smallest of the three Pennsylvania study areas and is not situated in a mountain valley, but rather the Allegany Plateau. It contains the city of Johnstown and the surrounding municipalities. State Route 219 runs through the area and the study area is located within the bounds of Cambria County. Additionally two interstate highways (I-76 and I-99) occur within the study area bounds.

Morgantown, Monongalia County, West Virginia.— This study area is located in the Monongahela River valley. It contains the cities of Morgantown, Star City, Sabraton, Granville, and Westover and is wholly contained within Monongalia and Preston counties. It is bounded in the south by I-68, in the west by I-79, and the east by the town of Hopewell. This area (as with all of the West Virginia study sites) is more forested and less urban than the Pennsylvania study areas. There is little agricultural production in the area. Development has increased over the last decade due to population change in the greater Morgantown area.

Beckley/Oak Hill, Fayette, and Raleigh Counties, West Virginia.— This study area includes the cities of Beckley, Mabscott, MacArthur, Sophia, Bradley, Glen Jean, Mount Hope, Pax, Eccles, Beaver, Grandview, and Stanaford. The study area is located in a mountain valley and is bisected by WV-16 and US 19. The study area is bounded by forested ridges and has had much development over the past decade. Two major interstates cross the area (I-77 and I-64) and active coal mining is present on the study site.

Charleston, Kanawha County, West Virginia.— This study contains West Virginia's largest city and is located at the confluence of the Elk and Kanawha rivers. It contains the cities of St. Albans, Charleston, South Charleston, Kanawha City, Dupont City and Dunbar. This study area is located 100 km to the northwest of the Beckley site. The development of the area spans 6 km north and south of the Kanawha River which follows along I-64. Interstate 64 bisects the study area and US-119 runs through the study area from southwest to northeast. Outside the core developed area, forested ridges dominate the area. The Kanawha State Forest borders the southern boundary of the study area.

Methods

State agency personnel captured bears opportunistically in barrel-style, culvert-style, or Aldrich wrist-snare traps. Agency personnel baited and set traps at residences or commercial properties where bears had been sighted or human-bear conflicts had occurred. State agency employees checked traps daily. Agency personnel moved traps when a bear was captured or bear activity subsided. In Pennsylvania, pamphlets explaining the purpose and process of the study were distributed to residents and business owners near the trap sites.

Captured bears were immobilized with a mixture of ketamine hydrochloride (4.4 mg/kg) and xylazine hydrochloride (1.7 mg/kg) or tiletamine hydrochloride and zolazepam hydrochloride (Telazol©, Fort Dodge Animal Health, New York, NY) delivered by a syringe-mounted pole ("jab-stick") or CO_2 propelled dart. Bears in New Jersey and Pennsylvania were tagged in both ears using a self-piercing numbered metal tag, style 56-L, size 36.5×9.5 mm (Hasco Tag Co., Dayton, Kentucky). Bears in West Virginia were tagged in both ears with Allflex 2-piece polyurethane tags (Allflex USA Inc, DFW Airport, TX). Bears were tattooed on the inside of the lip with their ear tag identification number. A premolar was pulled from each bear (except cubs) for age determination (Harshyne et al. 1998). State agency employees recorded weight, sex, reproductive status (estrous, lactation, descended testes), date, and location of capture. All attempts were made to release bears near the capture site. If relocation was required to prevent injury (traffic hazards, domestic animals), the bear was relocated typically relocated within the mean home range diameter of bears in the region from the capture site (Alt et al. 1976, Alt 1980): however, some exceptions were made when there was not a safe location to release the bear near the capture site. We excluded bears from the study that removed their collars <1 week post capture and censored locations of all bears during their first week to eliminate locations in which the bear was under the effect of anesthesia.

Bears weighing >45 kg were fitted with Global Positioning System-Global System for Mobile Communications (GPS-GSM)-equipped radio-transmitting neck collars (Vectronics, Berlin, Germany; Lotek, New Market, Ontario, Canada, Northstar, King George, Virginia, USA). GPS-GSM collars were configured to record a location at timed intervals dependent on date. During most of the year, except for bear hunting season (1 September – 31 December), location triangulation was attempted every 3.25 hours between 0600–1800 hours, resulting in 7 locations per day. During hunting season, location triangulation was attempted every 1.0 hour between 0600–1800 hours in addition to once every 3.25 hours, resulting in 20–21 locations per day. Location data was received from GPS-GSM collars daily via SMS (cell phone text message) and maintained in a central data repository. Any bear transmitting from the same location for more than one week was investigated to assess cause-specific mortality.

Agency employees and conservation practitioners conducted mast surveys statewide to estimate annual production. Methods varied among state agencies (Ternent and Kibe 2012, Richmond et al. 2013). We standardized mast survey data from agency reports into a 3-point scale (poor = 1, moderate = 2, good = 3). Agency employees performed den checks on all collared bears during February and March 2011 and 2012.

Statistical analysis

We entered all bear locations into a Geographic Information System (GIS) in ArcGIS 10 (ESRI, Redlands, CA). We removed all bear points from bears that had entered their dens and divided bear locations into 2 categories: prehunting period and hunting season. We delineated the prehunting period as 1 September–31 October to capture bear movements during hyperphagia and at a time when hunter density is relatively low. Hunting season was delineated as 1 November–15 December to account for the various hunting seasons of big game species across all 3 states (Appendix 1). We assumed that increased human activity in the forests during hunting season (e.g., small game hunters, deer hunters, hikers during fall leaf season) would influence bear movements. We used 15 December for a cutoff as the mean denning date of bears in the region (A. Tri, unpublished data). We pooled locations among bears and years to create an overall bear occurrence dataset for each subunit and season.

We compiled 7 variables that could impact space use by bears (Table 1). For the landcover data, we used the 2006 National Agriculture Statistics Service (NASS) from the United States Geological Survey. We chose this level (30 m^2) of resolution over the National Agriculture Imagery Program (NAIP) layer (10 m^2) because NASS includes more detail in the cover types. Additionally, the accuracy, on average, of our LOTEK collars had a positional error on each GPS location of 14 m (Di Orio et al. 2003). We reclassified the forest cover type into 6 categories (forest patch, forest edge, perforated forest, and 3 sizes of core forest [<100 ha, 101–202 ha, and >202 ha]) using the Landscape Fragmentation tool and delineating an edge effect of 150 m (Vogt et al. 2008). We calculated a topographic position index surface using the land facet corridor designer tool extension (Jenness Enterprises, Flagstaff, AZ). We used ArcGIS 10.0 to calculate Euclidean distance rasters from core forest, roads, public hunting areas, and urban areas. We used public land layers from the Natural Resources Conservation Service data gateway to delineate public hunting lands and the Census 2010 (United States Census Bureau 2010) to delineate urban areas. We subset the public land layer to only incorporate areas that allow public hunting (e.g., wildlife management areas, state game lands, state forests, and national forests).

We used Maxent 3.3k (Phillips et al. 2006) to generate models of bear occurrence in the prehunting period and hunting seasons in all 7 areas. To assess the discrimination ability of each model, we generated area under the curve (AUC scores) and omission vs. prediction plots (Appendix 2). We calculated percent change in each grid cell using the raster calculator (percent change = [hunting season – prehunting period] / prehunting season) to show which areas had the largest change in occurrence between seasons. We used the zonal statistics tool to generate the mean change for each polygon for public hunting land, urban areas, and suburbs. To determine harvest vulnerability of urban black bears in these study areas, we summed the total number of harvested individuals per state and divided them by the total sample size of the state. We calculated a Pearson's correlation coefficient (ρ) for each sex and for each state to determine how well harvest correlated with mast conditions. We also calculated a Pearson's correlation coefficient (ρ) for each year, pooled among states.

To assess the harvest vulnerability of urban black bears, we divided the number of bears in our sample that were harvested by the number of bears available to be harvested on the 1st day of the statewide bear season. Bears in dens before the 1st day of the statewide bear season were not considered available to harvest. We used the location data to determine if bears had entered dens by determining if bears remained in the same location for >1 week. We calculated annual harvest vulnerability for each state and calculated the mean overall harvest vulnerability for each state. We calculated an annual (1 January–30 December) rate of mortality for 2010, 2011, 2012 in New Jersey and Pennsylvania and for 2011 and 2012 in West Virginia. We also calculated an overall mean rate of mortality for each state. We assumed that we had 100% detection of all bears harvested in each state due to mandatory harvest registration in all jurisdictions.

RESULTS

Model fit

Our maximum entropy model fit relatively well. All of the AUC scores were high and reflected a good discrimination ability (> 0.700; Table 5). The AUC scores were often higher for hunting season data than for the prehunting period data. We found that the AUC training scores were 16% lower for the prehunting period data than the hunting season in the Beckley, WV, study area (Table 2). We found that AUC training scores in the Charleston, WV, study area were better than those in Beckley, and the prehunting period scores were similar (7% less) to hunting season scores (Table 2). We found that AUC scores were similar (7% less) between prehunting period and hunting season for the Morgantown, WV study area (Table 2). The AUC training scores of the prehunting period were ~10% lower than those of the hunting season in the Johnstown, PA, study area (Table 2). We found that AUC training scores of the prehunting period models were 12% lower than the hunting season model for the State College, PA study area (Table 2). Our AUC training scores of the prehunting period were 13% lower than those of the hunting season for the Scranton/Wilkes-Barre, PA study area (Table 2). We found that AUC for the prehunting period data was 10% lower (Table 2) than the hunting season data for New Jersey.

Variable importance

We found considerable variation among states relative to the most influential variables of bear occurrence. The most important variable (via permutation importance) during the prehunting period in New Jersey was elevation and the most important variable during hunting season was distance to public hunting area (Table 3). The rank of these 2 variables reversed between the prehunting period and hunting season (elevation was most important during the prehunting period and distance to public hunting land was most important during hunting season). The most important variable in Pennsylvania, for each of the 3 study areas and both prehunting and hunting season, was distance to nearest urban area (Table 4). The most important variable in West Virginia, for each of the 3 study areas and both the prehunting period and hunting season, was distance to the nearest public hunting area (Table 5). Overall, models for hunting season had higher AUC scores than the prehunting period (Table 6).

Although we found differences in the mean probability of occurrence among study areas, the overall trend was similar (Figure 2). Bear occurrence on public hunting lands and urban areas decreased from the prehunting period to hunting season. One exception to the pattern was in Johnstown, Pennsylvania. Bear occurrence in the Johnstown study area shifted from hills on the edge of the urban area during the prehunting season to the urban areas during hunting season (Figure 3). The probability of bear occurrence was high within public hunting areas during the prehunting period, but was highest just outside the public hunting areas during hunting season (Figures 3, Figure 4, and Figure 5). This pattern was especially strong in West Virginia. Distribution around urban areas contracted between the prehunting period and the hunting season. Probability of bear occurrence within urban areas and public hunting lands shifted between the prehunting period and hunting season (Figures 3, Figure 4, and Figure 5). Bear occurrence shifted from outside the urban areas to within the urban areas of Wilkes-Barre (Southwest portion of the urban area; Figure 6). Bear occurrence was lower within public hunting areas during hunting season than during prehunting season, resulting in a lower net change to bear occurrence (Figure 6).

Harvest vulnerability and method of take

The majority of mortality of urban/suburban bears was due to legal harvest (58% of overall mortality) and vehicle collisions (24% of overall mortality; Figure 7). The remaining mortality (18%) was due to euthanasia or unknown causes. In New Jersey, Pennsylvania and West Virginia, the largest source of mortality (28.6%, 68.6%, and 66.7%, respectively) was due to harvest (Figure 7). Harvest vulnerability was <25% in each state (Table 6). New Jersey had the lowest harvest vulnerability and Pennsylvania had the highest (Table 6). Males were harvested at a higher ratio (i.e., were more vulnerable to harvest) than females in West Virginia (3 M:0 F) and Pennsylvania (4M:1F). No male urban bears were harvested in New Jersey. Average harvest rates per year were highest during 2011 and lower during 2012 (Table 7). Average mortality was highest in Pennsylvania and lower in New Jersey and West Virginia (Table 8). Annual mortality rate ranged from 4.7%–34.1% (Table 8).

Harvest vulnerability of our study animals was influenced by the timing of hunting season and method of harvest (archery vs. firearm). Most (75%) of the harvested bears in our West Virginia sample were killed during archery season. Only 1 bear in West Virginia was killed by a hunter using a firearm. Most of the bears in our sample in Pennsylvania (87%) were killed with firearms (Table 9). New Jersey prohibits the harvest of bears with archery, and as such, 100% of the bears in New Jersey were killed using firearms. Sex ratios of harvested bears remained uneven, after accounting for method of harvest (Table 9). With the exception of New Jersey (a female-biased sample), hunters using archery or firearms killed more males than females.

Mast conditions vs. bear harvest vulnerability

Mast production was variable during the course of our study. In New Jersey, 2010 was a moderate mast year; 2011 and 2012 were good mast years. Moderate to poor oak mast conditions occurred in all 3 Pennsylvania subunits during 2011; 2010 and 2012 were moderate to good mast years. Poor mast conditions occurred during 2011 in West Virginia; 2012 was a moderate to good mast year in West Virginia.

We found that annual harvest of urban bears in Pennsylvania and New Jersey was strongly related to mast index levels. We did not have sufficient sample size to calculate the relation between mast production and female harvest in West Virginia due to low sample size (n = 1 female) or for males in New Jersey because none were harvested. In Pennsylvania, we found a moderately strong, negative correlation (r = -0.63) between mast availability and harvest of males, and there was an even stronger negative correlation (r = -0.94) between food availability and harvest of female bears. There was a moderately strong, negative correlation (r = -0.50) between mast production and harvest of females in New Jersey, and there was an even stronger negative correlation (r = -1.0) between mast production and harvest of male bears in West Virginia.

DISCUSSION

We found considerable support for our first prediction that bears would have a lower probability of occurrence on public hunting lands once hunting season commenced. In all but one study area, black bear occurrence was 5–75% less in hunting season than in the prehunting period. There have been very few studies that have examined on how bear distributions respond to hunting pressure (McIlroy 1972), but there has been a long history of research on the effects of harvest pressure on deer. Researchers have documented that white-tailed deer (*Odocoileous virginianus*) respond to hunting pressure by using refuges (Kammermeyer and Marchington 1976, Nelson and Mech 1986), avoiding places with high human activity (Dorrence et al. 1975), altering their habitat selection (Swenson 1982, Kufeld et al. 1988), and movement behavior (Marshall and Whittington 1968, Downing et al. 1969). The effects of harvest pressure on a species can also affect secondary species. Janis and Clark (2002) documented that the presence of deer hunters affects the distribution of Florida panthers (*Felis concolor*); panthers were found farther from roads, moved 15% more per day, and used 12% more of the available area during hunting season (Janis and Clark 2002). Panther movement rates were elevated on both hunted and unhunted areas in their study, but movement rates remained high after hunting season on the hunted area (likely due to shifted prey distribution and reduced prey abundance). Bears shift away from harvest pressure, as well (McIlroy 1972). Ordiz et al. (2012) documented that brown bears (*Ursus arctos*) shifted their movement activity to a more nocturnal pattern as soon as hunting season commenced. In our study, the one study area that showed an increase in the use of public hunting areas had only a slight increase and was highly variable. The standard deviation of the estimate was 15 times larger than the actual estimate. This suggests that some areas within the public hunting area were used more during hunting season and some used less during hunting season.

Bears shifted away from public hunting lands to private land, but we did not know the cause of such movements. The same shift may have occurred in areas without hunting. There may have been differences in forest management or food abundance on the private vs. public lands. We posit that hunters and more people in the woods caused the potential disturbance on public lands, but the shift may have been due to the timing of hunting season corresponding to a natural shift back to home range cores in preparation for denning. We did not have a metric for the number of hunters in the woods or disturbance, but both Pennsylvania and West Virginia have a strong hunting tradition that suggested hunters would be in the woods during hunting season. To this point, harvest pressure or disturbance levels may have been higher on some private lands than public lands. We feel that this may be another reason that we found high variation in the probability of occurrence between the prehunting period and hunting season.

Our prediction that the magnitude of change in urban bear occurrence between the prehunting period and hunting season would be strongest in West Virginia was partially supported. The Beckley study area showed the most negative change between prehunting period and hunting season. This was likely due to the strong tradition of hunting bears with hounds in that study area. Running bears with hounds was permissible on public lands, but was not as common in areas near Charleston or Morgantown due to the patchwork nature of the public/private land matrix. Houndsmen were not likely to run dogs in areas in which the risk of a dog being struck by a vehicle was high. Plum Orchard Lake Wildlife Management Area is one of the only options to train and run dogs on public land in the Beckley area. There has not been a strong bear hunting tradition in Morgantown because the county just added a concurrent bear/deer rifle hunting season within the last 4 years. In the other subunits (Pennsylvania and New Jersey), dog training was not allowed whatsoever.

Our prediction that bears would move to areas on the edge of urban areas was not well supported. There was considerable variation in the probability of bear occurrence adjacent to the urban area among the study areas, suggesting that some portions of the suburbs are higher quality habitat than others. In some portions of each urban area, bear occurrence increased, whereas in others it decreased. The areas in which bear distributions shifted were patchy and were variable within and among study areas. We found a pattern similar to that documented by Connor et al. (2001) in elk (*Cervus elaphus*) whereby animals shifted to private lands away from public hunting areas to escape harvest pressure. Conner et al. (2001) documented 2 different responses of elk to harvest pressure; elk on the northern study area did not shift distribution, but elk on the southern study area shifted their distribution to outside the public hunting lands. Ordiz et al. (2012) documented that brown bears (*Ursus arctos*) alter their foraging behavior when hunting season commences in Norway. Male brown bears that were hunted altered their movement patterns during a critical time of year, hyperphagia. Females with cubs-of-the-year, a protected class of bears in Scandanavia, also modified their movement patterns, but to a lesser extent (Ordiz et al. 2012).

We found a relation between the harvest of urban bears and the abundance of mast. When mast was poor, more urban female bears were harvested. This pattern has been documented for many non-urban populations of game species (e.g., white-tailed deer–*Odocoileus virginianus*; wild turkey–*Meleagris gallopavo*) across North America (Noyce and Garshelis 1997, Clark et al. 2005, Ryan et al. 2007). Food availability is known to influence the movement and spatial distribution of non-urban bears (Garshelis and Pelton 1981, Pelton 1989, Ryan et al. 2007). When resources become scarce, bears must move farther to maintain caloric intake during hyperphagia (Rogers 1987, Powell et al. 1997). In Minnesota, Noyce and Garshelis (1997) documented an inverse relation between food abundance and harvest rate of non-urban bears with a larger number of females harvested when food was scarce. Additionally, the number of females shot was closely tied to the food index, such that, more females were killed when food was scarce (Noyce and Garshelis 1997). In Pennsylvania, Dieffenbach et al. (2004) reported that predicting female harvest is unpredictable because of some variable that they were unable to model. They speculated that the variability was caused by the inter-annual variation in denning dates of adult females, potentially due to variable mast crops, which in turn reduced the number of females available for harvest. In Massachusetts and New Hampshire, scarce food resources induced higher harvest rates of non-urban bear populations (Kane 1989, McDonald et al. 1993); however, all 3 of these states (Massachusetts, Minnesota, and New Hampshire) allow baiting for bears. When food supplies are especially scarce, hunters have an easier time of harvesting a bear due to the efficacy of attracting hungry bears with bait (Paquet 1991).

Harvest rates of urban bears were lowest in New Jersey, but were higher in Pennsylvania and West Virginia. In fact, harvest rates of urban bears were higher than non-urban bears in Pennsylvania. In a population of non-urban bears in Ontario, Kolenosky (1986) documented an overall harvest rate of 32% of males and 28% of females. Bunnel and Tait (1981) documented that given an average litter size of 3 and an age of primiparity of 4, maximum sustainable mortality of a non-urban bear population must be <24%. New Jersey and West Virginia's harvest rate of our sample bears were below both rates documented by Kolenosky (1986) and Bunnel and Tait (1981). Pennsylvania's harvest rate was above (proportionally 17%) the Bunnel and Tait (1981) threshold (+4% change). Pennsylvania's annual harvest rate statewide has been ~20% for the past 30 years (Ternent 2006). The average harvest rate in our Pennsylvania urban areas was similar (20.2% vs. 20%) to the overall mean for non-urban bears in Pennsylvania documented by Ternent (2006). In New Jersey, the harvest rate from the 2003 and 2005 hunts ranged from 19.8–22.2% (Vreeland 2010). Average harvest vulnerability of New Jersey bears in our study was proportionally >70% less (-14% change) than the overall population harvest rate in New Jersey, ~80% less (-23% change) than the Ontario study, and ~75% less (-18% change) than rates documented by Bunnel and Tait (1981). The average harvest vulnerability of urban bears in New Jersey was 2.5 times less than vulnerability of nuisance bears in New Jersey (6% vs. 20%, respectively; Carr and Burguess 2011). The lower rate of harvest vulnerability in our sample relative to those documented by Carr and Burguess (2011) was likely due to the biased sex ratio (2M:3F) of our sample. Female bears have an inherently lower harvest vulnerability (Noyce and

Garshelis 1997, Dieffenbach et al. 2004) and that was reflected in our sample. Dieffenbach et al. (2004) documented a 16.5% harvest vulnerability rate for females and 22.3% for males. The harvest vulnerability of bears in West Virginia was proportionally 45% less (-13% change) than the rates of Kolenesky (1986), 30% less (-7% change) than rates documented by Bunnel and Tait (1981). When all sources of mortality were taken into account, regulated harvest was effective in killing urban bears in our sample.

The overall mortality rates of bears in our samples may not be sustainable in the long-term. Bunnel and Tait (1981) documented that the maximum rate of mortality that a stable population can sustain is 24%. The average mortality rate of urban bears in Pennsylvania is higher than the threshold documented by Bunnell and Tait (1981). Urban bears in Pennsylvania were killed 4 times more frequently than non-urban bears in Pennsylvania (Ternent 2012). The effect of harvest in Pennsylvania was compensatory (20.2%); however, when other mortality sources were taken into account, mortality from hunting became additive (28%) and may have been unsustainable in the long term. Mortality rates in New Jersey and West Virginia were below the 24% threshold documented by Bunnell and Tait (1981) and were able to maintain those levels of harvest sustainably. Mortality rates may have been offset by higher reproductive rates than what Bunnell and Tait (1981) used for their model. The total mortality rates that we documented may have been sustainable because of earlier age of first reproduction and very high cub production.

Harvest rates can be influenced by the timing of hunting season, the harvest method, sex ratio of the bear population, the number of hunters, and harvest regulations (Ryan 2009). The differential harvest rate among states may have been due to differences in harvest regulations and hunting traditions of each state but is most likely influenced by the number of bear hunters in each state. In New Jersey, baiting was allowed and a hunter could take any bear, regardless of size or sex. In Pennsylvania, pursuit with bear dogs or the use bait was prohibited; however, the majority of bear hunters used drive hunting in which hunters formed a line and moved through cover in an attempt to flush bears toward hunters. There were no restrictions in Pennsylvania regarding the size or sex of legal bears. In West Virginia, there was a strong tradition of hunting with hounds, however, based on the proximity of bears to cities and the restrictions of bear hunting with dogs (only allowed in certain counties), harvest of an urban bear by hound hunters was unlikely. Use of bait was prohibited in West Virginia, as was harvesting a bear weighing <34 kg or a female with cubs. West Virginia had the longest bear hunting season (archery and gun season combined = 3 months) and New Jersey had the shortest (6 days; Appendix 1).

Among our urban populations, harvest vulnerability was variable between males and females. Female bears provide the critical link in population dynamics because they provide parental care and reproductive output (Bridges 2005, Ryan 2009). Female mortality is the most sensitive parameter in population growth rates of black bears (Rogers 1989, Ryan 2009). Overall, males were more vulnerable to harvest than females. In Pennsylvania, males were harvested nearly 4 times more often than females, and in West Virginia, only male urban bears were harvested. In New Jersey, the only urban bears that were harvested were female. This suggests that regulated hunting was not only an effective way to remove nuisance bears from the population, but was an effective method (in the short term) to control population size of black bears. Nearly 43% of all bears in our sample died over the course of the study.

Urban bears had relatively low harvest vulnerability in our New Jersey sample, but high harvest vulnerability in Pennsylvania and moderate harvest vulnerability in West Virginia, under current harvest regulations. Urban female bears were less vulnerable to harvest. In each study area, there were large areas of private land that likely received little to no hunting pressure and became *de facto* refuges. Our results indicated that bears likely moved from public hunting lands to private lands near urban areas between the prehunting period and hunting season, however there may be some bias to this shift. When bear occurrence on public lands did not shift to adjacent private land, bear occurrence in more remote areas (rougher topography and longer distances to roads) of public lands increased.

MANAGEMENT IMPLICATIONS

Changes in regulations may have increased harvest vulnerability of urban bears, especially in New Jersey. New Jersey's bear season is late in the year (1st week in December) and many of the female bears that are pregnant have already entered their dens. Shifting the bear season earlier in the year may have increased harvest vulnerability of urban bears in New Jersey. The effect of harvest in Pennsylvania was compensatory (20.2%); however, when other mortality sources, such as vehicle collisions, were taken into account, mortality from hunting became additive (28%) and unsustainable in the long-term. Annual average mortality in New Jersey and West Virginia were below 24% and harvest regulations were sustainable in the long-term.

Acknowledgments

We thank the New Jersey Division of Fish and Wildlife, Pennsylvania Game Commission, and the West Virginia Division of Natural Resources for collecting this data and funding the research. We thank West Virginia University and the West Virginia Division of Forestry and Natural Resources for funding support of my doctoral program.

LITERATURE CITED

Alt, G. L., G. J. Matula, Jr., F. W. Alt, and J. S. Lindzey. 1980. Dynamics of home range and movements of adult black bears in northeastern Pennsylvania. Ursus 4: 131–136.

Beck, T. D. I. Black bears of west-central Colorado. Colorado Division of Wildlife technical publication #39.

Bridges, A. S. 2005. Population ecology of black ebars in the Alleghany Mountains of Virginia. Virginia Polytechnic Institute and State University. PhD Dissertation.

Bunnel, F. L., and D. E. N. Tait. 1981. Population dynamics of bears-implications. Pages 75–98 in C. W. Fowler and T. D. Smith, eds. Dynamics of large mammal populations. John Wiley and Sons, New York.

Carr, P. C. and K. Burguess. 2011. New Jersey black bear annual status report.

http://www.state.nj.us/dep/fgw/pdf/2011/bear_status_report11.pdf. Last accessed: 25 October 2013.

Clark, J.D., F. T, VanManen, and M. R. Pelton. 2005. Bait stations, hard mast, and black bear population growth in Great Smoky Mountains National Park. Journal of Wildlife Management 69:1633–1640.

Conner, M. M., G. C. White, and D. J. Freddy. 2001. Elk movement in response to early-season hunting in northwest Colorado. Journal of Wildlife Management 6:926–940.

Di Orio, A. P., R. Callas, and R. J. Schaefer. 2003. Performance of Two GPS telemetry collars under different habitat conditions. Wildlife Society Bulletin 31:372–379.

Diefenbach, D. R., J. L. Laake, and G. L. Alt. 2004. Spatio-temporal and demographic variation in the harvest of black bears: implications for population estimation. Journal of Wildlife Management 68: 947-959.

Doan-Crider, D. L. 2003. Movements and spatiotemporal variation in relation to food productivity and distribution, and population dynamics of the Mexican black bear in the Serranias Burro, Coahuila, Mexico. Ph.D. dissertation, Texas A&M University–Kingsville, Kingsville, Texas, USA.

Dorrance, M. F., P. J. Savage, and D. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. Journal of Wildlife Management 39: 563–569.

Downing, R. L., B. S. McGinnes, R. L. Petcher, and J. L. Sandt. 1969. Seasonal changes in movements of white-tailed deer. Pages 19–24 in Proceedings of a symposium, white-tailed deer in the southern forest habitat. Southern Forest Experiment Station, U.S. Forest Service, Nacogdoches, Texas.

Garshelis, D. L., and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountain National Park. Journal of Wildlife Management 45: 912–925.

Garshelis, D. L. and H. Hristienko. 2006. State and provincial estimates of American Black Bear numbers versus assessments of population trend. Ursus 17: 1–7.

Janis, M. W. and J. D. Clark. 2002. Responses of Florida panthers to recreation deer and hog hunting. Journal of Wildlife Management 55:839–848.

Kammermeyer, K. E., and R. L. Marchinton. 1976. The dynamic aspects of deer populations utilizing a refuge. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 29: 466–475.

Kane, D. M. 1989. Factors influencing the vulnerability of black bears to hunters in northern New Hampshire. Thesis, University of New Hampshire, Durham, USA

Kasworm, W. F. and T. J. Thier. 1994. Adult black bear reproduction, survival, and mortality sources in northwest Montana. International Conference on Bear Research and Management 9:223–230.

Kilgo, J. C. R. F. Labisky, and D. E. Fritzen. 1998. Influences of hunting on the behavior of white-tailed deer: Implications for conservation of the Florida panther. Conservation Biology 12: 1359–1364.

Kolenosky, G. B.1986. Effects of hunting on an Ontario black bear population. International Conference on Bear Research and Management.6:45–55.

Kufeld, R. C., D. C. Bowden, and D. L. Schrupp. 1988. Influence of hunting on movements of female mule deer. Journal of Range Management 41: 70–72.

Lee, D.J., and M.R. Vaughn. 2004. Black bear family breakup in Western Virginia. Northeast Naturalist. 11:111–122.

Marshall, A. D., and R. W. Whittington. 1968. A telemetric study of deer home ranges and behavior of deer during managed hunts. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 22:30–46.

McConnell, P.A., J.R. Garris, E. Pehek and J.L. Powers. 1997. Black Bear Management Plan. NJ Division of Fish, Game & Wildlife. Trenton, NJ.

McDonald, J.E., Jr., and T.K. Fuller. 1993. Black bear food habits: beyond the same old scats. International Union of Game Biologists 21:293–298.

McIlroy, C. 1972. Effects of hunting on black bears in Prince William Sound. Journal of Wildlife Management 36:828–327.

Nelson, A. C. 1992. Characterizing exurbia. Journal of Planning Literature 6:350–368.

Noyce, K.V., and D.L. Garshelis. 1997. Influence of natural food abundance on black bear harvests in Minnesota. Journal of Wildlife Management 61:1067–1074.

Noyce, K. and D. L. Garshelis. 2011. Seasonal migrations of black bears (*Ursus americanus*): causes and consequences. Behavioral Ecology and Sociobiology 65:823–835.

Obbard, M. E., and E. J. Howe. 2008. Demography of black bears in hunted and unhunted areas of the boreal forest of Ontario. Journal of Wildlife Management 72:869–880.

Odell, E. A., and R. L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. Conservation Biology 15:1143–1150.

Ordiz, A., O. Stoen, S. Saebo, J. Kindberg, M. Delibes, and J. Swenson. 2012. Do bears know they are being hunted? Biological Conservation 152:21–28.

Paquet, PC. 1991. Black bear ecology in the Riding Mountains, Manitoba, April 1987 – April 1990. Final Report Prepared for Manitoba Natural Resources and Canadian Park Service, John/Paul and Associates.

Pelton, M.R. 1989. The impacts of oak mast on black bears in the southern Appalachians. Pages 7–11 in C.E. McGee, editor. Proceedings of the Workshop: Southern Appalachian Mast Management. University of Tennessee, Knoxville, Tennessee, USA.

Pilcher, B. K., and G. E. Wampler. 1981. Hunting season movements of white-tailed deer on Fort Sill Military Reservation, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:142–148.

Philips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190:231–259.

Powell, R.A., Zimmerman, J.W., and D.E. Seaman. 1997. Ecology and behavior of

North American black bears: home ranges, habitat, and social organization. Chapman & Hall, London.

Richmond, E., C. W. Ryan, R. L. Tucker, and M. L. Peters. 2013. 2013 West Virginia mast Survey and hunting outlook. West Virginia Division of Wildlife Resources Wildlife Resource Bulletin #13–3.

Rogers, L. L. 1987. Effects of Food Supply and Kinship on Social Behavior, Movements, and Population Growth of Black Bears in Northeastern Minnesota. Wildlife Monographs 97.

Rogers, L. L. 1989. Black bears, people, and garbage dumps in Minnesota. Pages 48-51 In: M. Bromley and P. A. Gray, eds. Proc. Symp. Bear-people conflicts. Yellowknife, N.W.T. Canada.

Ryan, C. W. 1997. Reproduction, Survival, and Denning Ecology of Black Bears in Southwestern Virginia. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Ryan, C. W. 2009. Population ecology, residents' attitudes, hunter success, economic impact, modeling management options and retention time of Telazol of West Virginia black bears. PhD Dissertation. West Virginia University.

Ryan, C. W., J. C. Pack, W. K. Igo, and A. B. Billings. 2007. Influence of mast production on black bear non-hunting mortalities in West Virginia. Ursus 18: 46–53.

Ryan, C. W., J. W. Edwards, and M. D. Duda. 2009. West Virginia residents' attitudes and opinions toward American black bear hunting. Ursus 20:131–142.

Schieck, B., W. McCown, and M. Orlando. 2011. Updated distribution of black bears in North America. Proceedings of the Eastern Black Bear Workshop 20:11.

Spiker, Jr. H. A., and S. Bittner. 2004. Wildlife and Heritage Service, Black Bear Management Plan, 2004 – 2013. Maryland Department of Natural Resources, Annapolis. DNR-03-0105-0031.

Storm, D. J., C. K. Nielsen, E. M. Schauber and A. Woolf. 2007. Space Use and Survival of

White-Tailed Deer in an Exurban Landscape. The Journal of Wildlife Management 71:1170–1176.

Swenson, J. E. 1982. Effects of hunting on habitat use by mule deer on mixed-grass prairie in Montana. Wildlife Society Bulletin 10:115–120.

Ternent, M. A. 2006. Management and biology of black bears in Pennsylvania: Ten Year Plan (2006–2015). Pennsylvania Game Commission, State College, PA.

Ternent, M. A. and E. Kibe. 2012. Statewide wildlife food survey report. Pennsylvania Game Commission. http://www.portal.state.pa.us/portal/server.pt/document/1371390/23000-12z_pdf. Last Accessed: 20 November 2013.

Treves, A., and K. U. Karanth. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology 17:1491–1499.

Treves, A., K. J. Kapp, and D. MacFarland. 2010. American black bear nuisance complaints and hunter take. Ursus 21: 30–42.

Wolgast, L.J., W. S. Ellis, and J. Vreeland. 2005. New Jersey Fish and Game Council comprehensive black bear (*Ursus amercianus*) management policy. New Jersey Fish and Game Council, New Jersey Department of Environmental Protection, Trenton, New Jersey.

Vogt, P., K. H. Riiters, C. Estreguil, J. Kozal, T. G. Wade, and J. D. Wickham. 2007. Mapping spatial pattern with morphological image processing. Landscape Ecology 22:171–177.

Table 3-1: Environmental variables calculated for the Maxent model.

Variable	Data Type	Details	Data Source
Elevation	Continuous	m	National DEM dataset
Slope	Continuous	Degrees (transformed into percent)	GIS State DEM layers
Topographic Position Index	Continuous	Index of ruggedness	National DEM dataset
Landcover	Categorical	30 × 30m grid cells	Reclassified from NASS Dataset
Forest patch			
Forest edge			
Perforated forest			
Core forest			
Exurban/grassland			
Urban/suburban			
Row crops/orchards			
Barren			
Open water			
Other			
Distance to core forest	Continuous	meters	Euclidean distance raster
Distance to roads	Continuous	meters	Euclidean distance raster
Distance to public hunting	Continuous	meters	Euclidean distance raster
Distance to urban area	Continuous	meters	Euclidean distance raster

Table 3-2. Area under the curve of Maxent models for urban bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

Study Area	Prehunting period		Hunting Season	
State	Training	Test	Training	Test
New Jersey	0.721	0.715	0.821	0.810
Pennsylvania				
Johnstown	0.762	0.750	0.859	0.845
State College	0.769	0.767	0.887	0.876
Scranton-Wilkes/Barre	0.705	0.697	0.835	0.821
West Virginia				
Morgantown	0.828	0.821	0.895	0.885
Charleston	0.856	0.847	0.929	0.908
Beckley	0.752	0.743	0.915	0.906

Table 3-3. Comparison of important variables in Maxent modeling of black bear occurrence between prehunting period and hunting season in New Jersey, 2010–2012.

New Jersey prehunting period			New Jersey hunting season		
Variable	Percent contribution	Permutation importance	Variable	Percent contribution	Permutation importance
Elevation	49.0	38.7	Elevation	27.7	21.7
Distance to urban area	17.4	14.4	Distance to public hunting land	21.6	30.3
Distance to public hunting land	17.2	19.0	Distance to urban area	19.8	15.7
Land use landcover	6.7	8.4	Distance to core forest	15.3	17.4
Distance to core forest	4.4	10.3	Land use landcover	9.9	7.6
Distance to road	3.0	4.9	Distance to road	2.2	3.8
Topographic Position Index	2.1	3.8	Cosine(aspect)	1.9	2.0
Cosine(aspect)	0.3	0.6	Topographic Position Index	1.5	1.5

Table 3-4. Comparison of important variables in Maxent modeling of black bear occurrence between prehunting period and hunting season in State College, Pennsylvania, 2010–2012.

State College prehunting period			State College hunting season		
Variable	Percent contribution	Permutation importance	Variable	Percent contribution	Permutation importance
Distance to urban area	67.2	66.7	Distance to urban area	39.9	47.7
Distance to public hunting land	19.1	18.2	Distance to public hunting land	22.1	16.5
Land use landcover	4.8	5.6	Elevation	21.0	14.9
Distance to core forest	3.0	1.8	Distance to road	5.0	7.1
Elevation	2.4	3.0	Distance to core forest	4.5	8.4
Distance to road	1.4	1.8	Land use landcover	3.1	2.3
Topographic Position Index	1.1	1.5	Cosine(Aspect)	3.0	1.8
Cosine(Aspect)	1.0	1.4	Topographic Position Index	1.4	1.3

Table 3-5. Comparison of important variables in Maxent modeling of black bear occurrence between prehunting period and hunting season in Beckley, West Virginia, 2010–2012.

Beckley prehunting period			Beckley hunting season		
Variable	Percent contribution	Permutation importance	Variable	Percent contribution	Permutation importance
Distance to public hunting land	52.6	54.8	Distance to public hunting land	79.8	84.3
Elevation	23.6	20.9	Distance to core forest	6.9	4.5
Land use landcover	9.7	7.7	Elevation	5.8	5.3
Distance to road	8.4	7.2	Land use landcover	4.0	2.4
Distance to core forest	5.2	8.3	Distance to road	2.6	1.5
Cosine(Aspect)	0.4	1.0	Cosine(Aspect)	0.7	1.0
Topographic Position Index	0.0	0.0	Topographic Position Index	0.2	0.2
Distance to urban area	0.0	0.0	Distance to urban area	0.0	0.8

Table 3-6. Annual and overall mean harvest vulnerability of urban bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

	Harvest vulnerability			
Year	2010	2011	2012	Average
New Jersey	12.5	0.0	5.3	5.9
Pennsylvania	24.2	24.4	12.1	20.3
West Virginia	—	22.2	12.5	17.4

Table 3-7. Urban bears harvested in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

	New Jersey		Pennsylvania		West Virginia	
Year	Male	Female	Male	Female	Male	Female
2010	0.0	1.0	7.0	1.0	–	–
2011	0.0	0.0	8.0	3.0	2.0	0.0
2012	0.0	1.0	3.0	1.0	2.0	0.0
Total	0.0	2.0	18.0	5.0	2.0	0.0
Average/year		0.7	6.0	1.7	2.0	
SE		0.3	1.3	0.7	–	

Table 3-8. Mortality rate of urban bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

State	Mortality rate			
	2010	2011	2012	Average
New Jersey	14.3	4.8	26.3	15.1
Pennsylvania	34.1	28.6	21.6	28.1
West Virginia	–	4.0	12.5	17.5

Table 3-9. Method of harvest of urban bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

State	Year	Method	Sex Ratio (M:F)
West Virginia	2011	Archery	2:0
		Firearm	–
	2012	Archery	1:0
		Firearm	1:0
Pennsylvania	2010	Archery	2:0
		Firearm	5:1
	2011	Archery	1:0
		Firearm	7:3
	2012	Archery	–
		Firearm	3:1
New Jersey	2010	Firearm	0:1
	2011	Firearm	–
	2012	Firearm	0:1

FIGURE CAPTIONS

Figure 3.1. Map of the study areas in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

Figure 3.2. Comparison of mean percent change (± SD) in probability of occurrence of black bears between urban areas and public hunting areas in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

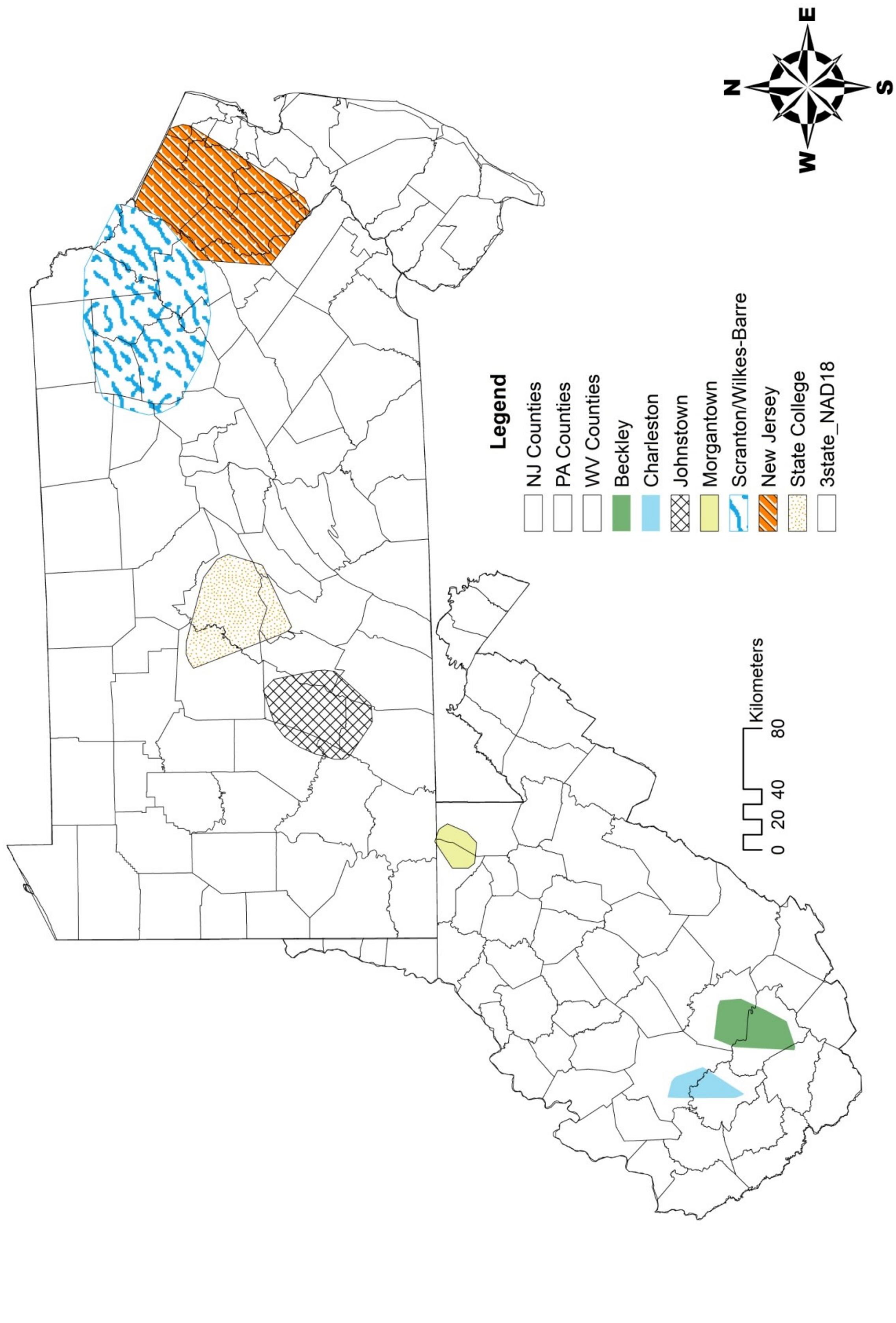
Figure 3.3. Change of black bear occurrence on public hunting areas and urban areas between prehunting season to hunting season in Beckley (left) and Charleston, West Virginia study areas (right) during 2010–2012.

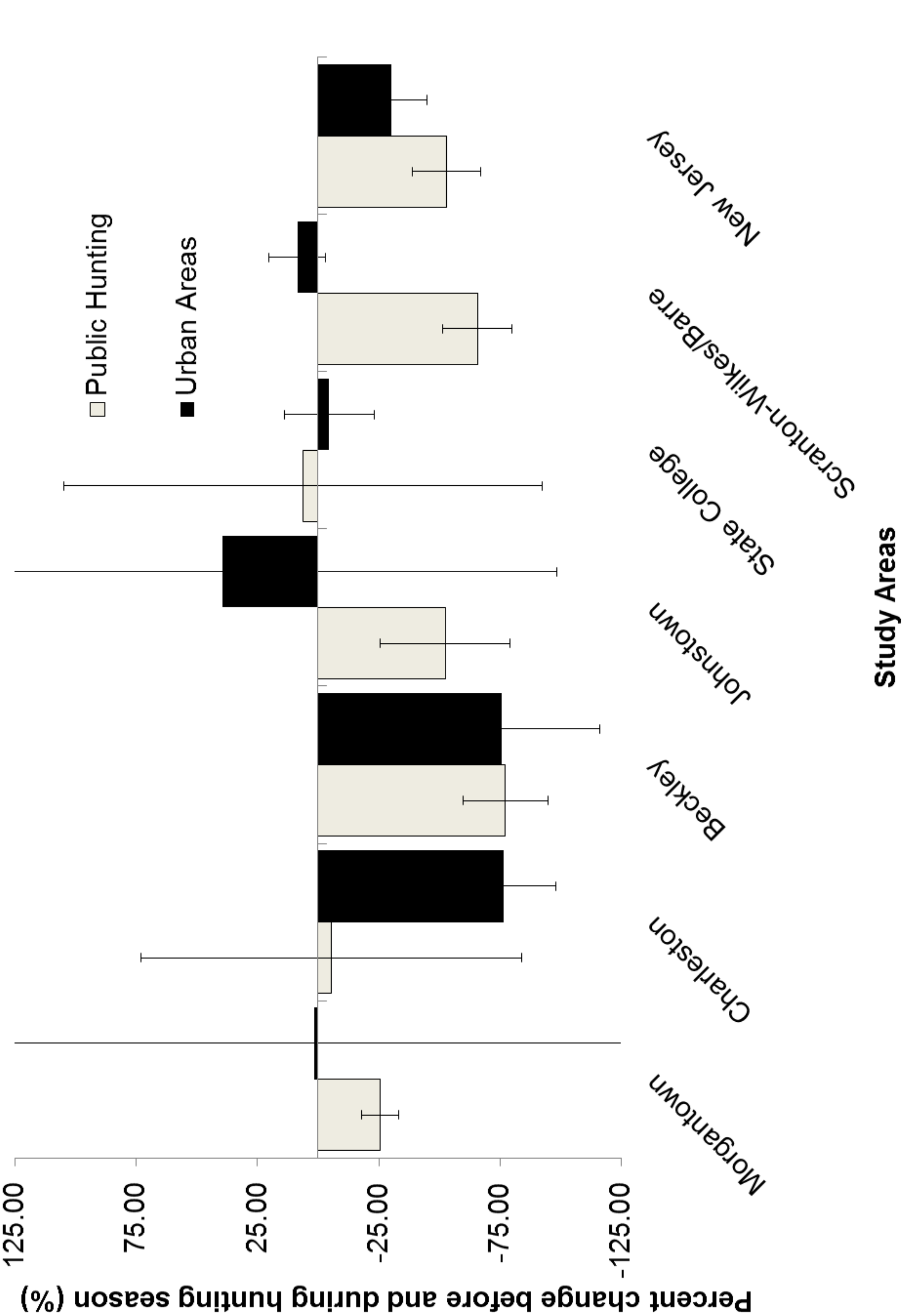
Figure 3.4. Change of black bear occurrence on urban areas and public hunting lands between prehunting season to hunting season in Morgantown, West Virginia (left) and Johnstown, Pennsylvania study areas (right) during 2010–2012.

Figure 3.5. Change of black bear occurrence on urban areas and public hunting lands between prehunting season to hunting season in State College, Pennsylvania (left) and New Jersey study areas (right) during 2010–2012.

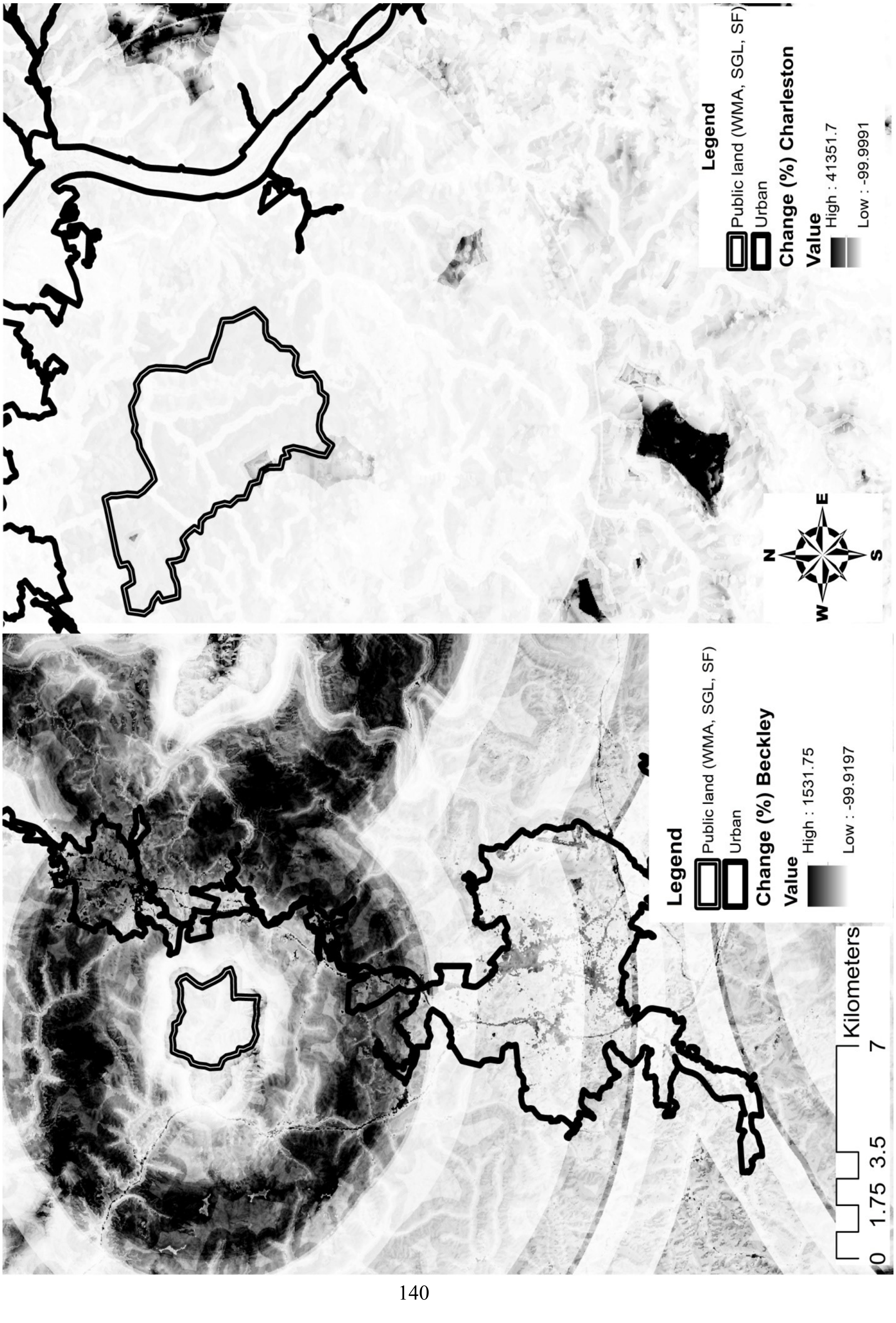
Figure 3.6. Change of black bear occurrence on urban areas and public hunting lands between prehunting season to hunting season in Scranton/Wilkes-Barre, Pennsylvania study area during 2010–2012.

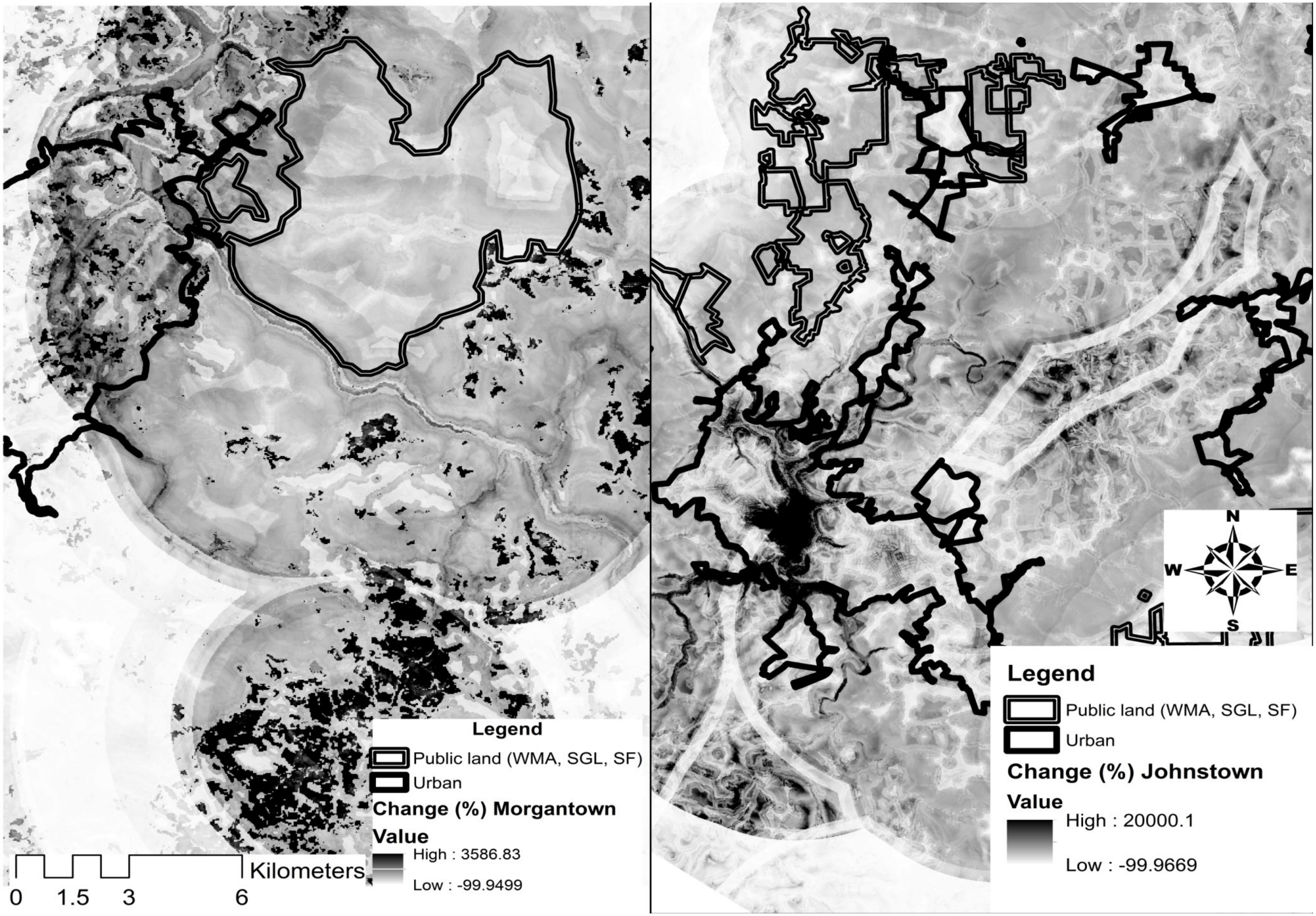
Figure 3.7. Cause-specific mortality of urban and suburban black bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.

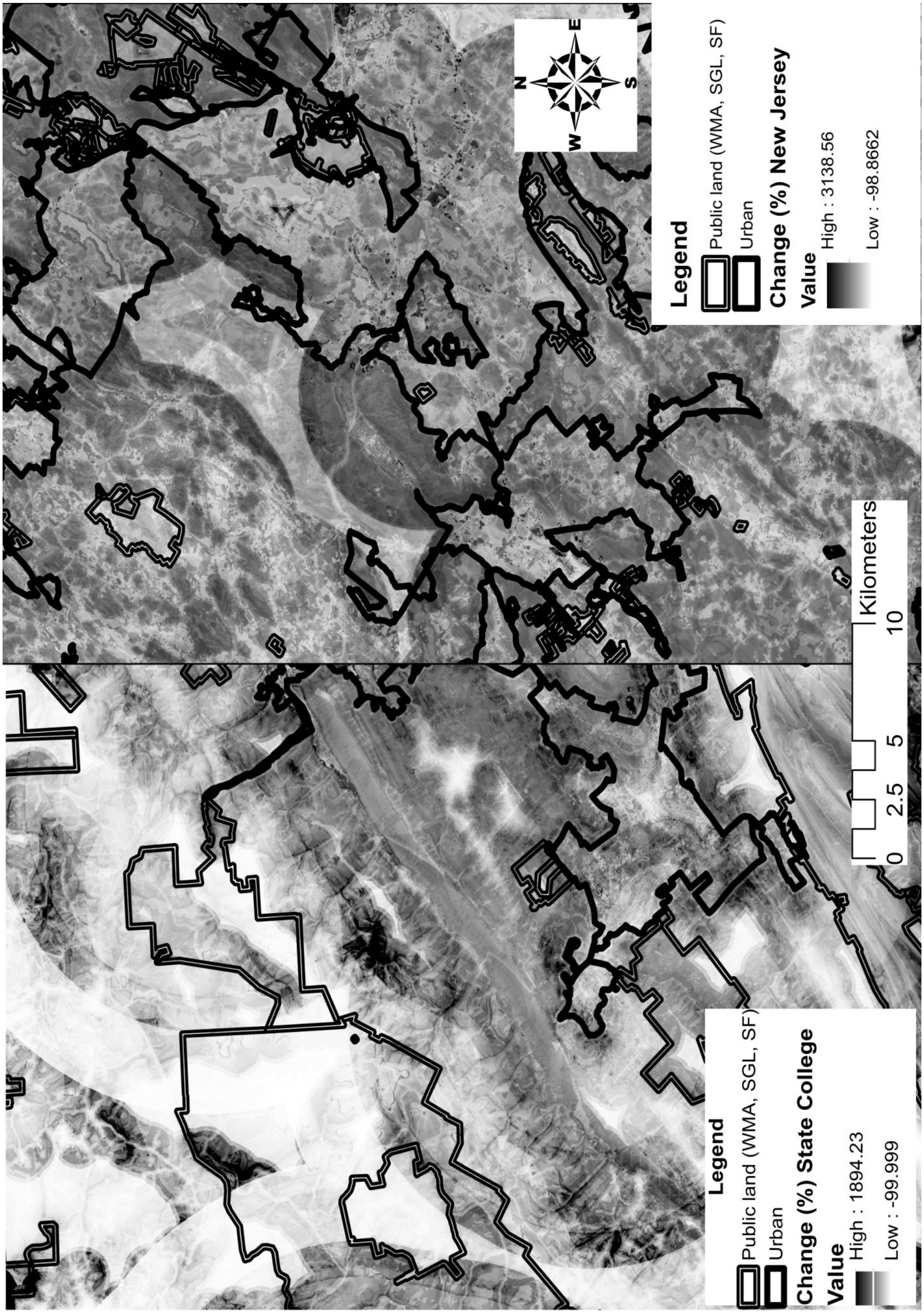

Legend
NJ Counties
PA Counties
WV Counties
Beckley
Charleston
Johnstown
Morgantown
Scranton/Wilkes-Barre
New Jersey
State College
3state_NAD18
0 20 40 80
Kilometers
N
E
S
W

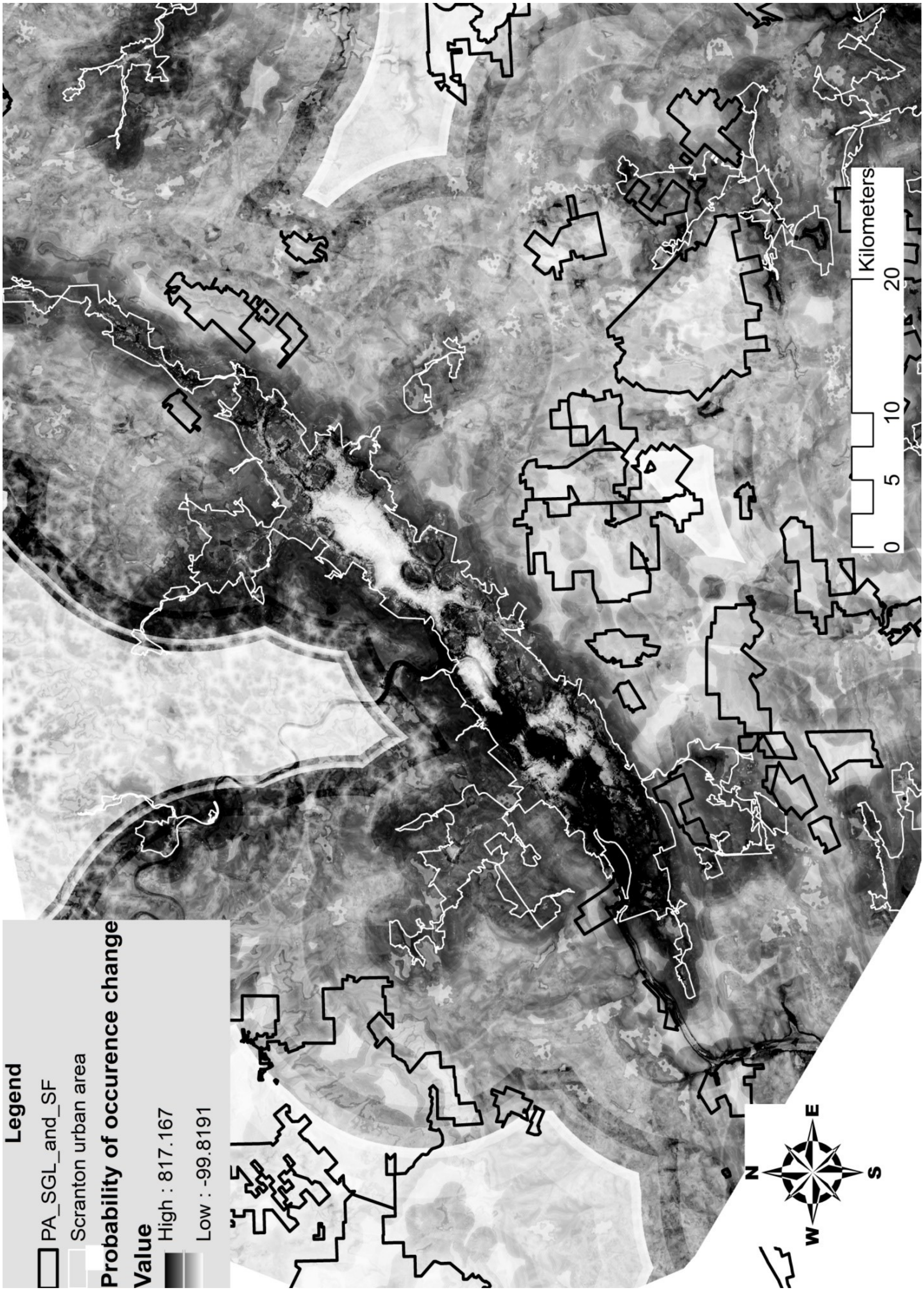


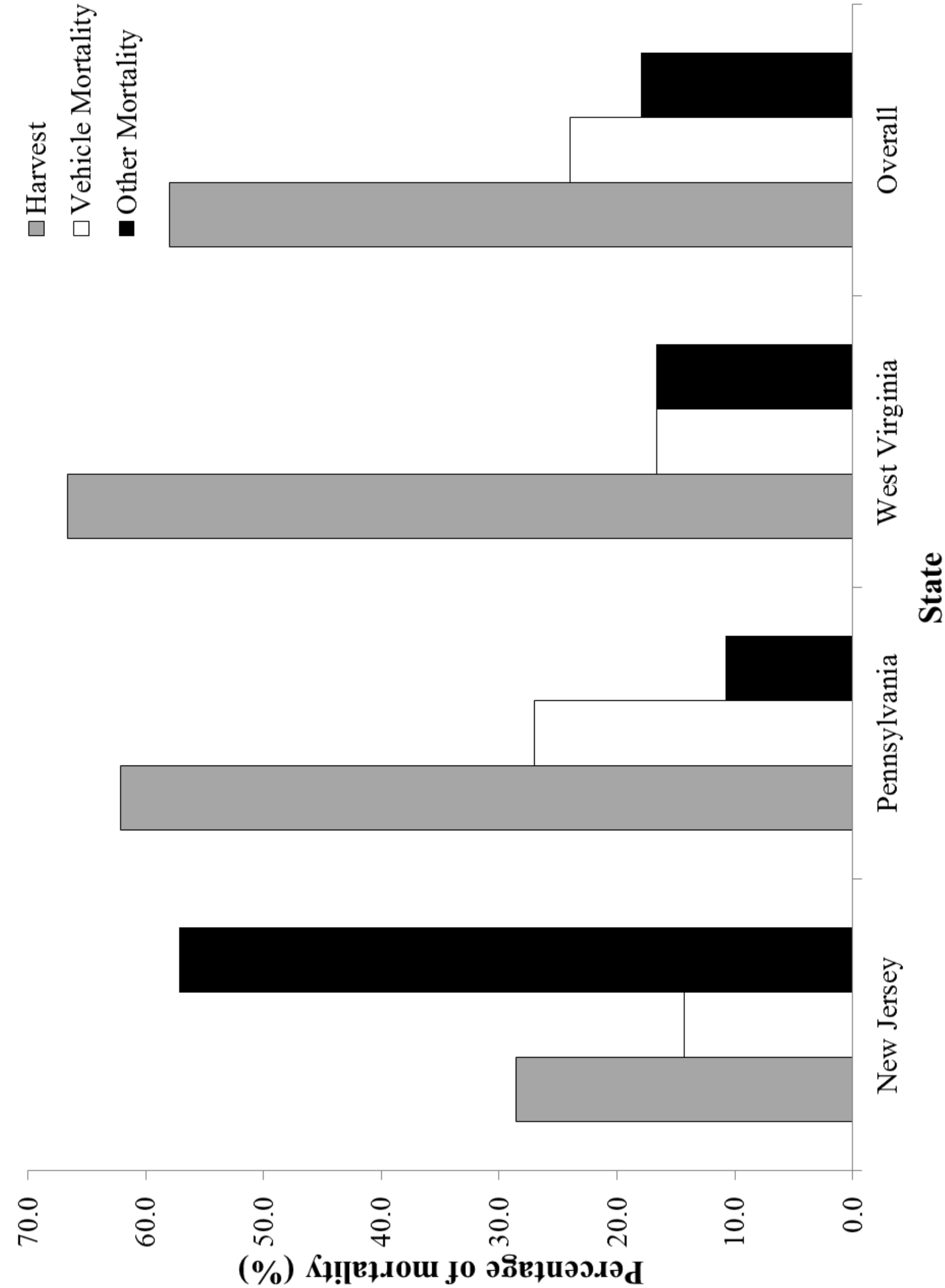
Public Hunting
Urban Areas
125.00
75.00
25.00
-25.00
-75.00
-125.00
Percent change before and during hunting season (%)
Morgantown
Charleston
Beckley
Johnstown
State College
Scranton-Wilkes/Barre
New Jersey
Study Areas


Legend
Public land (WMA, SGL, SF)
Urban
Change (%) Charleston
Value
High : 41351.7
Low : -99.9991
N
E
S
W
Legend
Public land (WMA, SGL, SF)
Urban
Change (%) Beckley
Value
High : 1531.75
Low : -99.9197
0 1.75 3.5 7
Kilometers


Legend
Public land (WMA, SGL, SF)
Urban
Change (%) Morgantown
Value
High : 3586.83
Low : -99.9499
0
1.5
3
6
Kilometers
Legend
Public land (WMA, SGL, SF)
Urban
Change (%) Johnstown
Value
High : 20000.1
Low : -99.9669
N
S
W
E


Legend
Public land (WMA, SGL, SF)
Urban
Change (%) New Jersey
Value
High : 3138.56
Low : -98.8662
N
E
S
W
0 2.5 5 10
Kilometers
Legend
Public land (WMA, SGL, SF)
Urban
Change (%) State College
Value
High : 1894.23
Low : -99.999


Legend
PA_SGL_and_SF
Scranton urban area
Probability of occurence change
Value
High : 817.167
Low : -99.8191
Kilometers
0
5
10
20
N
E
S
W



Harvest
Vehicle Mortality
Other Mortality
Percentage of mortality (%)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
New Jersey
Pennsylvania
West Virginia
Overall
State

Chapter 4.
Modeling urban and suburban black bear occurrence in the Mid-Atlantic Region using boosted regression trees

4 September 2013
Andrew N Tri
West Virginia University
Davis College of Agriculture, Natural Resources and Design
Division of Forestry and Natural Resources
322 Percival Hall, P.O. Box 6125
Morgantown, WV 26506
763/210-8939; Fax: 304/293-2441
andrew.n.tri@gmail.com

RH: Predicting urban bear occurrence

Chapter 4. Modeling urban and suburban black bear occurrence in the Mid-Atlantic region using boosted regression trees[3]

ANDREW N. TRI, Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

JOHN W. EDWARDS, Division of Forestry and Natural Resources, 322 Percival Hall, PO Box 6125, West Virginia University, Morgantown, WV 26506, USA.

MICHAEL P. STRAGER, Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

J. TODD PETTY, Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, PO Box 6125, Morgantown, WV 26506, USA.

CHRISTOPHER W. RYAN, Wildlife Resources Section, West Virginia Division of Natural Resources, 324 Fourth Avenue, South Charleston, West Virginia 25303, USA

COLIN P. CARPENTER, Wildlife Resources Section, West Virginia Division of Natural Resources, 2006 Robert C. Byrd Drive, Beckley, West Virginia 25801, USA

MARK A. TERNENT, Bureau of Wildlife Management, Pennsylvania Game Commission 2001 Elmerton Avenue, Harrisburg, PA 17110

PATRICK C. CARR, New Jersey Division of Fish and Wildlife, Mail Code 501-03, PO Box

[3] This manuscript has been formatted in the style of The Journal of Wildlife Management. The singular I has been replaced with the collective "we" to allow for ease in preparation for journal submission.

420, Trenton, NJ 08625-0420

There exists a paucity of information on how black bears use urban and suburban habitats. We used boosted regression trees to create two predictive models of bear occurrence in urban and suburban habitats for (1) New Jersey and Pennsylvania, and (2) West Virginia. We separated West Virginia from New Jersey and Pennsylvania in the modeling process because West Virginia's topography is more rugged and the population density of people was the lowest of all three states. We randomly selected a subset of 40,000 bear locations in New Jersey and Pennsylvania, as well as, 30,000 bear locations in West Virginia from the full database of locations. We generated 40,000 random points within the study areas in New Jersey and Pennsylvania and 30,000 random points within the study areas of West Virginia. We built three models (1) for New Jersey and Scranton/Wilkes-Barre, PA, (2) State College and Johnstown, PA, and (3) West Virginia. We found that probability of bear occurrence was highest in New Jersey and Scranton/Wilkes-Barre study areas when bears were: (1) <1 km from edge forest, (2) <7.5 km from the nearest road, (3) <7.5 km from the nearest urban area, (4) land use/ land cover was forested, (5) <12 km from public land, and (6) NDVI < 0.3. We found that probability of bear occurrence was highest in Johnstown and State College study areas when bears were: (1) <1 km from edge forest, (2) <1 km from the nearest road, (3) <7 km from the nearest urban area, and (4) <7 km from public land. The highest probability of bear occurrence in West Virginia occurred when (1) NDVI was $\geq$0.6, (2) distance to public land was >22.0 km, (3) distance to urban areas was between 1–5 km, (3) topographic position index was >100 (steep, rugged terrain), (4) land use land cover was forested or "other", (5) distance to roads was >1.4 km, and (6) distance to core forest was >1.5 km. We found no evidence that urban bears use corridors. Bears spent nearly 95% of their time on the edge of city limits and <5% of their time within city limits. We found no evidence that habitat quality on the edge of city limits was lower than that of "non-urban" bear habitat. There is likely not a physiological need for bears to traverse urban areas when they can remain in habitats that are safe from human disturbance.

KEY WORDS: black bear, boosted regression trees, New Jersey, Pennsylvania, predictive modeling, suburban, urban, *Ursus americanus*, West Virginia

A paucity of research exists on space use of urban and suburban black bears (*Ursus americanus*) in the United States. Of the three major, research studies on urban black bear ecology, one focused on the human dimensions and human-bear conflicts in Aspen, Colorado (Baruch-Mordo 2007, Baruch-Mordo et al. 2008, 2009, 2011). The second focused on human-bear conflicts and demographic parameters in the Lake Tahoe basin (Beckmann and Lackey 2003, Beckmann and Lackey 2005) of Nevada. The third study focused on predicting human-bear interactions using a GIS framework in Missoula, Montana (Merkle et al. 2011). All 3 studies focused on an individual municipal area, had relatively limited spatial scales, and were based in the western United States. To date, there have been no intensive studies of urban bear ecology east of the Mississippi river

Increased numbers of reported human-bear conflicts have directly influenced management decisions for bears in New Jersey, Pennsylvania, and West Virginia for more than 20 years. This pattern is reflected in most jurisdictions that manage bears in the eastern United States. Concomitant with increasing numbers of nuisance complaints, growing bear populations in eastern states have resulted in natural resource agencies expanding hunting opportunities in an effort to reduce bear numbers (Spiker and Bittner 2004, Wolgast et al. 2005, Ternent 2006). Hunting is a management tool recommended for reducing some types of human-bear conflicts (Poelker and Parsons 1980, Treves et al. 2010). However, the efficacy of hunting near urban areas to reduce nuisance complaints is unknown due to a lack of fundamental understanding of bear home range use and seasonal bear activity in urban and suburban areas. Understanding black bear spatial ecology in urban and suburban habitats is critical to developing and implementing comprehensive bear management programs.

Because space use of urban bears is poorly understood, it is unknown if bears use movement corridors in the mid-Atlantic region. Corridors are areas of habitat – often linear – that facilitate the movement of wildlife among habitat patches (Hass 1995, Haddad 1999), increase rates of recolonization (Hale et al. 2001) and mitigate some of the effects of fragmentation (Tewksbury et al. 2002). Wildlife that use corridors can potentially have higher survival and population viability (Fahrig and Merriam 1985, Beier 1993, Beier 1995, Coffman et al. 2001). In endangered sub-populations of black bear, corridors show some success in linking populations and increasing gene flow (Dixon et al. 2004). At Yellowstone National Park, black bears use movement corridors to feed during diurnal hours. Bears using corridors along roads create potential for vehicle accidents, safety issues due to human habituation and human-caused bear mortality (Gunther 1994).

Interstate highways are often barriers to bear movement, thereby isolating bear populations from one another (Wooding and Maddrey 1994). Additionally, Proctor et al. (2005) suggested that female bears are more strongly influenced by anthropogenic factors such as roads and associated human development than males, not because of their dispersing ability but because of high mortality and their avoidance of these areas. Not all roads degrade bear habitat, however, unimproved roads with low vehicle traffic (forest service roads, county roads) may facilitate bear movements and provide foraging areas with abundant food (Carr and Pelton 1984). In developed areas in Florida, urban bears regularly crossed roads with lower traffic density with higher success (3.1 times higher odds) than in the areas with higher traffic volume (McCown et al. 2004). Development can cause disturbance and fragmentation of wildlife habitat, especially when urban areas encroach into rural areas.

Habitat selection of black bears in rural habitats has been intensively studied in the mid-Appalachian region of the United States (e.g., Garshelis 1978, Carr 1983, Brody 1984, Clevenger 1986, Vaughan 2002). Habitat quality of rural areas is a function of many landscape components—elevation, topography, vegetation community structure, road density, distance to urban areas, etc. (Van Manen 1994). Quantifying and modeling these habitat components can be challenging because bears are habitat generalists that rely on several different food sources and landscape components.

Inherent flexibility in both caloric and habitat requirements allows black bears to use a wide variety of foods and habitat types across their range. One of the biggest influences of bear habitat selection is food (Doan-Crider 2003). In mid-Appalachian habitats, black bears tend to use mixed-hardwood forests as habitat. Their diet is predominantly vegetation, with blackberries, cherries and other soft–mast species providing the vast majority of spring and summer forage (Pelton 1982, Pelton 1985, Elowe and Dodge 1989, Pelton 1996). Hard mast (oak, hickory and beech) provides high energy needed by bears during hyperphagia (Nelson et al. 1983). Oaks are the most important food source to black bears in the southern Appalachian region (Huntley 1989). Interestingly, squawroot (*Conopholis americana*) is the second most important bear food in the southern Appalachians. Squawroot is a parasitic plant that grows on the roots of oak trees in early summer (Vaughan 2002). Therefore, two of the most important bear foods grow in the oak forests of the Appalachians. In the absence of anthropogenic direct mortality, oaks are primary influence for black bear movements and population dynamics (Pelton 1989, Vaughan 2002, Ryan et al. 2007).

Bears in California, Nevada, and Colorado have been documented using city/urban habitat for food resources (Lyons 2005, Beckman and Lackey 2008, Baruch-Mordo et al. 2012). In California, male bears use urban areas in summer exclusively (Lyons 2005). In California and Colorado, females use urban habitats in most other seasons (Lyons 2005, Baruch-Mordo 2007). There have been no studies in the eastern United States on habitat selection of urban bears, however, other wildlife species such as raccoons (*Procyon lotor*) and coyotes (*Canis latrans*) use urban habitats in the eastern United States because of abundant, anthropogenic food sources and bears are likely no exception (Gehrt 2004).

Predicting bear occurrence in urban and suburban habitats on the landscape has been problematic in the past, due to a lack of high-quality location data from urban and suburban bears.

Until the advent of satellite or GPS-GSM collars (collars that transmit GPS data via the cellular telephone network), datasets of bears near urban areas were too sparse to glean information about fine-scale space use of bears in urban areas. The combination of low-quality data with a dearth of research studies spurred the wildlife management agencies of New Jersey, Pennsylvania, and West Virginia to start a landscape-scale research project.

To date, there has not been a landscape-scale model to predict urban and suburban bear habitat use. The primary objective of our study was to determine if we could reliably predict bear occurrence using remote sensing and habitat modeling at a regional scale. We wanted our model to explain a substantial portion of the variation in the dataset, coupled with a high predictive ability. We hypothesized that bears in urban habitats would select resources in a similar manner to that of non-urban bear populations. Our secondary objective was to determine if black bears were using specific areas within urban habitats as movement corridors. If bears used movement corridors, we would be able to identify them visually from the boosted regression output as cells that were oriented in a linear fashion across urban zones. We predicted that urban and suburban bears would not use corridors due to the juxtaposition of high-quality habitat next to and within city limits, as well as, the intensity of development in eastern cities. We predicted, instead, that bears would intensively use areas adjacent to town and would not use areas within city limits.

METHODS

Study Area

We conducted a longitudinal study over 3 years. Agency personnel captured and maintained bears with collars across 3 states (15 in New Jersey, 40 in Pennsylvania, and 15 in West Virginia). West Virginia and Pennsylvania were divided into 3 subunits; New Jersey's subunits were pooled due to the close proximity (15 km) between each subunit. The following 7 subunits (Figure 2) are general accounts of the municipalities around which the study was based. In an effort to create biologically relevant study areas, each of our study areas consisted of a minimum convex polygon (Mohr 1947) that included the composite annual home ranges of resident, telemetered animals within each urban area (Storm et al. 2007).

We wanted to ensure that we captured all possible habitats in which bears near urban areas exist in each study area; therefore, we included exurban habitats as suburban. Exurbia is residential land use outside of the urban edge, situated among working farms or undeveloped land (Nelson 1992). Human population density and mean property size in exurbia fall between levels found in suburbs and rural areas. The difference between exurban and suburban landscapes is that human dwellings in exurbia are interspersed throughout wildlife habitat rather than habitat existing in patches within suburban non-habitat (Odell and Knight 2001). In our analysis of urban bears, we make inference to bears found in urban, suburban, and exurban habitats.

New Jersey.— This study area is located in the northcentral portion of New Jersey. It is bounded in the west by the state border with Pennsylvania, in the south by I-78, in the east by I-287, and in the north by the state border with New York. The urban areas, including the townships of West Milford, Vernon, Rockaway and Blairstown, the towns of Newton, Boonton, and Hacketstown and the boroughs of Bloomingdale, Sussex, Rockaway, and Washington are interspersed with public lands (Wayanda State Park, Delaware Water Gap National Recreation Area, Stokes State Forest, and numerous Wildlife Management Areas including Sparta Mountain and Wildcat Ridge WMAs) and quasi-public lands (Newark Watershed Conservation Corporation).

Scranton/Wilkes-Barre, Luzerne, Lackawanna, and Wyoming Counties, Pennsylvania.— This study area is primarily within the Wyoming Valley, extending northeast from the town of Mountain Top, north of Interstate 80, to the town of Clark's Summit. The Scranton/Wilkes-Barre study area (hereafter, Scranton) contains parts of Luzerne, Wyoming, and Lackawanna counties. It is bisected by Interstate 81 and contains urban/suburban areas surrounded by the forested ridges of the Wyoming Valley.

State College, Centre County, Pennsylvania.— This area lies within the Nittany Valley, extending from the suburbs of State College east-northeast to the town of Pleasant Gap and includes portions of the Penns Valley between the towns of Centre Hall and Boalsburg. The area is less urbanized than Scranton and contains more suburban areas interspersed with agricultural lands. The ridge between the two valleys is forested. There are no major interstates crossing the area, but 3 heavily traversed routes (Routes 322, 144, and 220).

Johnstown, Cambria County, Pennsylvania.— This area is the smallest of the three Pennsylvania study areas and is not situated in a mountain valley, but rather the Allegany Plateau. It contains the city of Johnstown and the surrounding municipalities. State Route 219 runs through the area and the study area is located within the bounds of Cambria County. Additionally two interstate highways (I-76 and I-99) occur within the study area bounds.

Morgantown, Monongalia County, West Virginia.— This study area is located in the Monongahela River valley. It contains the cities of Morgantown, Star City, Sabraton, Granville, and Westover and is wholly contained within Monongalia and Preston counties. It is bounded in the south by I-68, in the west by I-79, and the east by the town of Hopewell. This area (as with all of the West Virginia study sites) is more forested and less urban than the Pennsylvania study areas. There is little agricultural production in the area. Development has increased over the last decade due to population change in the greater Morgantown area.

Beckley/Oak Hill, Fayette, and Raleigh Counties, West Virginia.— This study area includes the cities of Beckley, Mabscott, MacArthur, Sophia, Bradley, Glen Jean, Mount Hope, Pax, Eccles, Beaver, Grandview, and Stanaford. The study area is located in a mountain valley and is bisected by WV-16 and US 19. The study area is bounded by forested ridges and has had much development over the past decade. Two major interstates cross the area (I-77 and I-64) and active coal mining is present on the study site.

Charleston, Kanawha County, West Virginia.— This study contains West Virginia's largest city and is located at the confluence of the Elk and Kanawha rivers. It contains the cities of St. Albans, Charleston, South Charleston, Kanawha City, Dupont City and Dunbar. This study area is located 100 km to the northwest of the Beckley site. The development of the area spans 6 km north and south of the Kanawha River which follows along I-64. Interstate 64 bisects the study area and US-119 runs through the study area from southwest to northeast. Outside the core developed area, forested ridges dominate the area. The Kanawha State Forest borders the southern boundary of the study area.

Methods

State agency personnel captured bears opportunistically in barrel-style, culvert-style, or Aldrich wrist-snare traps. Agency personnel baited and set traps at residences or commercial properties where bears had been sighted or human-bear conflicts had occurred. State agency employees checked traps daily. Agency personnel moved traps when a bear was captured or bear activity subsided. In Pennsylvania, pamphlets explaining the purpose and process of the study were distributed to residents and business owners near the trap sites.

Captured bears were immobilized with a mixture of ketamine hydrochloride (4.4 mg/kg) and xylazine hydrochloride (1.7 mg/kg) or tiletamine hydrochloride and zolazepam hydrochloride (Telazol©, Fort Dodge Animal Health, New York, NY) delivered by a syringe-mounted pole ("jab-stick") or CO_2 propelled dart. Bears in New Jersey and Pennsylvania were tagged in both ears using a self-piercing numbered metal tag, style 56-L, size 36.5×9.5 mm (Hasco Tag Co., Dayton, Kentucky). Bears in West Virginia were tagged in both ears with Allflex 2-piece polyurethane tags (Allflex USA Inc, DFW Airport, TX). Bears were tattooed on the inside of the lip with their ear tag identification number. A premolar was pulled from each bear (except cubs) for age determination (Harshyne et al. 1998). State agency employees recorded weight, sex, reproductive status (estrous, lactation, descended testes), date, and location of capture. All attempts were made to release bears near the capture site. If relocation was required to prevent injury (traffic hazards, domestic animals), the bear was relocated typically relocated within the mean home range diameter of bears in the region from the capture site (Alt et al. 1976, Alt 1980): however, some exceptions were made when there was not a safe location to release the bear near the capture site. We excluded bears from the study that removed their collars <1 week post capture and censored locations of all bears during their first week to eliminate locations in which the bear was under the effect of anesthesia.

Bears weighing >45 kg were fitted with Global Positioning System-Global System for Mobile Communications (GPS-GSM)-equipped radio-transmitting neck collars (Vectronics, Berlin, Germany; Lotek, New Market, Ontario, Canada, Northstar, King George, Virginia, USA). GPS-GSM collars were configured to record a location at timed intervals dependent on date. During most of the year, except for bear hunting season (1 September – 31 December), location triangulation was attempted every 3.25 hours between 0600–1800 hours, resulting in 7 locations per day. During hunting season, location triangulation was attempted every 1.0 hour between 0600–1800 hours in addition to once every 3.25 hours, resulting in 20–21 locations per day. Location data was received from GPS-GSM collars daily via SMS (cell phone text message) and maintained in a central data repository. Any bear transmitting from the same location for more than one week was investigated to assess cause-specific mortality.

Statistical analysis

We entered all bear locations into a Geographic Information System (GIS) in ArcGIS 10 (ESRI, Redlands, CA). We compiled 7 variables that could affect space use by bears (Table 1). For the land cover data, we used the 2006 National Agriculture Statistics Service (NASS) from the United States Geological Survey. We chose this level (30 m^2) of resolution over the National Agriculture Imagery Program (NAIP) layer (10 m^2) because NASS includes more detail in the cover types. Additionally, the accuracy, on average, of the LOTEK collars in the study had a positional error on each GPS location of 14 m (Di Orio et al. 2003). We reclassified the forest cover type into 6 categories: (1) forest patch, (2) forest edge [land cover <250m from the forest edge], (3) perforated forest, and core forest [(4) <100 ha, (5) 101–202 ha, (6) and >202 ha]) using the Landscape Fragmentation tool and delineating an edge effect of 150 m (Vogt et al. 2007; Table 1). We calculated a topographic position index surface using the land facet corridor designer tool extension (Jenness Enterprises, Flagstaff, AZ) as a way to quantify the effect of topography. The topographic position index provides an index of elevation and slope simultaneously. We used ArcGIS 10.0 to calculate Euclidean distance raster layers from core forest, edge forest, roads, public hunting areas, and urban areas. We used public land (Natural Resource Conservation Service 2013) and urban layers (US Census Bureau 2010) to delineate public hunting lands and urban areas. We subset the public land layer to incorporate areas that allow public hunting (wildlife management areas, state game lands, state forests, and national forests). We used normalized vegetation difference index data (NDVI; National Air and Space Administration 2013) from the MODIS satellite and used the ArcGIS raster calculator to average each cell among years as an index of net primary productivity.

We randomly subset points into 3 groups to create a biologically-relevant model because some study areas were more similar in their topography, human population size, or shared bear populations. We randomly subset 40,000 urban bear locations in the New Jersey and Scranton/Wilkes-Barre study area, 40,000 for State College and Johnstown study areas, and 30,000 for the 3 study areas in West Virginia using the Geospatial Modeling Environment (Beyer 2012). Because the sample size of bear locations was smaller in West Virginia, we generated 30,000 random points in the West Virginia study areas. We created 3 models (1 for New Jersey and Scranton/Wilkes-Barre study areas, 1 for Johnstown and State College study areas, and 1 for the West Virginia study areas) to accommodate the different UTM zones, bear populations that are common between study areas, and allow for potential differences in topography and habitat. We calculated descriptive statistics for used vs. random points for Scranton/Wilkes-Barre and New Jersey (Table 2), Johnstown and State College (Table 3), and West Virginia (Table 4). Pixel size was generalized to a 1-ha cell size to accommodate computing limitations. The final models were merged in ArcGIS to locate potential urban and suburban areas of bear use.

Animal space use and movement ecology has been a growing branch of ecology, but the quantitative tools that are used have not necessarily caught up with the research questions. Often, spatial data are auto-correlated and do not meet the assumptions for linear modeling techniques

(Cressie and Wikle 2011). Ensemble methods such as boosted regression trees are free from assumptions and incorporate categorical or continuous data. They can handle collinearity between predictors, can model high-level interactions between predictors, and allow researchers to incorporate stochasticity into models (Elith et al. 2008). Elith et al. (2006) demonstrated that boosted regression trees, a machine-learning technique consistently outperformed other predictive methods (e.g. GLM, GLMM, and GAM). In addition, if the use of generalized additive models is still desired, boosted regression trees provide a way to determine which interactions among predictor variables are important and which are trivial for inclusion in a linear model context (Hastie et al. 2009). These machine-learning methods are becoming more popular in ecology, but very few studies in wildlife ecology use this technique.

We used the "dismo" and "gbm" libraries in R 3.1.0 (R Development Team, 2013) to generate boosted regression tree models of areas used by bears. We used a learning rate of 0.1 to balance speed and thorough exploration of the dataset (>1,000 trees). We ran stump models (not allowing for interactions) and a bag fraction of 50%. Interaction strength was modeled using the method described by Elith et al. (2008). We used the simplification algorithm in the gbm package to reduce the number of parameters in the models. After deriving the simplified predictive model, we used it to generate a statewide model (1-ha cell size) of bear habitat use for New Jersey, Pennsylvania, and West Virginia. For each model, we generated the proportion of deviance explained by the model (1–(cross-validated deviance/total deviance)). We also generated a receiving operator curve (ROC) for each model. If the nature of the dataset was overly complex, the algorithm may require a high number of trees (>5,000 trees) to converge. We compared the CV ROC and the training ROC scores as a check against model overfitting. We used the BRT models to predict probability of urban bear occurrence to all areas within a 13-km buffer from each urban polygon within each state. We chose to limit our predictive inference of the final model to only urban bears by only predicting to areas <13 km from cities, based on the average radius of male bear home ranges from this study (A. Tri, unpublished data).

RESULTS

The Johnstown and State College model predicted 84.8% (*n* trees = 38,700) of the total variation in the dataset. The ROC score for the model was 0.997% ± 0.001 SE, indicating very good discrimination of used points from random. The training ROC score was 0.998 and the CV ROC score was 0.997, which indicated that the model was not likely overfit. The simplified model for Johnstown and State College explained bear use based on distance to edge forest (41.54% relative influence), distance to roads (36.73% relative influence), distance to urban area (16.49% relative influence) and distance to public land (5.24% relative influence; Figure 2). We found that probability of bear occurrence was highest in Johnstown and State College study areas when bears were: (1) <1 km from edge forest, (2) <1 km from the nearest road, (3) <7 km from the nearest urban area, and (4) <7 km from public land (Figure 3).

The Scranton/Wilkes-Barre and New Jersey model predicted 81.2.8% (*n* trees = 34,500) of the total variation in the dataset. The ROC score for the model was 0.994% ± 0.001 SE, indicating very good discrimination of used points from random. The training ROC score was 0.997 and the CV ROC score was 0.994, which indicated that the model was not likely overfit. The simplified model for Scranton/Wilkes-Barre and New Jersey explained bear use based on distance to edge forest (38.86% relative influence), distance to roads (35.95% relative influence), distance to urban area (11.68% relative influence), distance to public land (2.83% relative influence), and NDVI (2.58%; Figure 4). We found that probability of bear occurrence was highest in Scranton/Wilkes-Barre and New Jersey study areas when bears were: (1) <1 km from edge forest, (2) <7.5 km from the nearest road, (3) <7.5 km from the nearest urban area, (4) land use/ land cover was forested, (5) <12 km from public land, and (6) NDVI < 0.3(Figure 5).

Our West Virginia model predicted 56.4% (*n* trees =19,000) of the total variation in the dataset. The CV ROC score for the model was 0.944% ± 0.001 SE, indicating a similar level of discrimination of used points to the Pennsylvania and New Jersey model. The CV ROC and the training ROC were similar (0.944 vs. 0.967, respectively), which indicated that the models were not overfit. The simplified West Virginia model showed that bear use was influenced by: (1) NDVI (29.9% relative influence), (2) distance to public land (m; 22.0% relative influence), (3) distance to urban areas (m; 19.3% relative influence), (4) topographic position index (12.0% relative influence), (5) land use and land cover (10.8% relative influence), (6) distance to roads (m) (4.6% relative influence), and (7) distance to core forest (m; 1.5% relative influence) (Figure 6). Probability of bear occurrence increased most when: (1) NDVI was $\geq$0.6, (2) distance to public land was >22.0 km, (3) distance to urban areas was between 1–5 km, (3) topographic position index was >100 (steep, rugged terrain), (4) land use land cover was forested or "other", (5) distance to roads was >1.4 km, and (6) distance to core forest was >1.5 km (Figure 7).

Urban bears in our study spent a majority of their time on the edge of urban areas. Probability of bear use of a given hectare was highest on the periphery of city limits and low within city limits (Figure 8). Our model predicted bear use in areas that we expected bears to occur from anecdotal reports or expert knowledge. Probability of urban bear occurrence was lower than expected in West Virginia and this may have been due to a male-biased sample. Roughly, 85% of the input locations of the West Virginia model came from male bears. Male bears were located farther from cities in West Virginia. In New Jersey and Pennsylvania, there was a more balanced sex ratio for the input locations so any bias resulting from the sex of sample bears was small.

DISCUSSION

We found NDVI to be the most useful metric in predicting space use by black bears in urban areas of West Virginia; however, this variable had low influence in the Scranton/Wilkes-Barre and New Jersey study area. We posit that the reason that NDVI had low influence in this study area because this study area is the most developed and has the highest population density. The NDVI has been commonly used as an index of habitat quality throughout animal ecology (Pettorelli et al. 2011). The NDVI served as an index of "greenness" and is highly related to net primary productivity, leaf area index, active photosynthesis, and carbon assimilation (Hicke et al.

2002). This index has been used with black bears (Baldwin and Bender 2010), Asiatic black bears (*Ursus thibethanus*; Doko et al. 2001) and brown bears (*Ursus arctos*; Zedrosser et al. 2011) as a predictive variable for habitat selection in North America and abroad (Weigland et al. 2008). Doko et al. (2011) used NDVI as an index of natural food production in Japan for Asiatic black bears. Baldwin and Bender (2011) used the index as a predictor variable to indicate abundance of natural bear foods for predicting black bear den chronology. Zedrosser et al. (2011) evaluated NDVI as an overall index of habitat quality for brown bears across their range and found it reliable. We reason that NDVI functions as an index of black bear habitat quality because it is a reliable predictor of brown bear habitat quality, although the pattern did not hold true for the Scranton/Wilkes-Barre and New Jersey study area. Brown bears outside of Alaska consume less fish and are more omnivorous than Alaskan brown bears, which suggest that the NDVI levels of their habitats would be more similar to that of black bears (Hildebrant et al. 1999, Swenson et al. 2007). Zedrosser et al. (2011) documented that mean NDVI for all brown bear populations was 0.625 ± 1.28; mean NDVI of our West Virginia sites was slightly higher (0.650) than the Zedrosser study. We found that NDVI levels in our study were lower within city limits but was high on the edge of city limits.

As we hypothesized, urban bears in our study used habitats similarly to non-urban bears in the eastern United States. Urban bears consistently used habitats that were near or in edge forests, far from roads, closer to public land; however, our bears used habitats that were close to town, suggesting that our bears may have used these habitats due to their easy access to anthropogenic foods. Most of our bear locations were within forests that were adjacent to the edge of town or subdevelopment. We had anecdotal reports that bears will walk up roads in subdivisions and rummage through trash cans the night before garbage day. Bear problems did not return until the following week's trash pickup day. Jones (2012) reported that non-urban bears in rural Maryland used forested ridges, steep slopes, and habitats that were far from roads. Feckse (2002) documented that non-urban female bears in Maryland used mixed forest, wetlands, and some residential areas but avoided primary highways and heavily used roads. Costello and Sage (1994) reported that non-urban bears in the Adirondack Mountains of New York used extensive tracts of public land that contained forested habitats with abundant food sources.

We did not find evidence that bears use movement corridors to traverse urban areas. Nearly 97% of our bear locations occurred outside of city limits. We found no pixel patterns of high bear use within any of the urban areas that would constitute a corridor; however, we did find areas near towns that represented concentrated bear use (Figure 8). For example, probability of bear occurrence in the State College, Pennsylvania, study area was highest on Mount Nittany and on the forested ridges outside of town (Figure 9). Bear habitat was concentrated near city limits in all of the study areas. We have no evidence that habitat quality in our study areas was lower than that of "non-urban" bear habitat. There likely was not a physiological need for bears to traverse urban areas when they could remain in habitats that were safe from human disturbance and therefore, corridors were not used.

We posit that bears spent their time on the edge of town (and did not use travel corridors) because the habitat quality was good and human disturbance was lower. Our results were somewhat similar with those of Baruch-Mordo (2012) because bears in both studies lived on the edge of town. Our results differ from Baruch-Mordo's (2012) findings because our bears spend most of their time on the edge of town and rarely ventured into city limits. Our results were also dissimilar from those reported by Lyons (2005). Lyons (2005) reported that male bears in the San Gabriel Mountains of California used urban habitats during the summer and females used urban areas throughout the year. Our bears remained on the edge of town all year, irrespective of sex. Males in our study were farther from town and had few points within city limits. We posit that habitat quality on the edge of city limits in our study areas was of high quality. We had no evidence suggesting that forested habitat on the edge of city limits was of lower quality than that of the surrounding area. Both natural foods (mast) and anthropogenic food sources (e.g., trash, bird feeders, agriculture) were abundant in these areas. Additionally, the areas near town provided protection from disturbance. Moreover, urban bears spent the majority of time on private lands near the edge of city limits. Bears in those areas were less likely to encounter high traffic volume and other hazards that occur in urban areas and high volumes of hikers and hunters that occur in the fall on public lands. Animals perceive most human disturbance stimuli as predation risk (Frid and Dill 2002) and bears are likely no exception. Black bears near salmon streams in Alaska behave similarly; they remain in safer habitats during increased human disturbance (e.g., combat fishing) and return during night hours when disturbance is reduced (Chi and Gilbert 1999). Bears will tolerate some disturbance, but there are definite thresholds (groups of people, dogs, etc.) in which bears will seek safer habitats (Chi and Gilbert 1999).

MANAGEMENT IMPLICATIONS

Our findings suggest that space use by urban and suburban bears in the Mid-Atlantic region can be reliably predicted with estimates of distance to urban zone, distance to roads, and distance to edge forest, with some exception. The importance of each variable varied with each study area. Boosted regression tree models give managers a landscape scale view as to where bear occurrence is likely and where bear problems may occur. They also provide managers with a tool that can be used to indicate areas in which bears are likely to occur. This is valuable for policy makers and managers when trying to institute managed hunts in urban zones.

Acknowledgments

We gratefully acknowledge all of the state agency employees who assist with the trapping and monitoring of the bears in the study: M. Peters–West Virginia Division of Natural Resources, M. Madonia–New Jersey Division of Fish and Wildlife, K. Burguess–New Jersey Division of Fish and Wildlife, and the wildlife conservation officers of the Pennsylvania Game Commission. We would also like to acknowledge our cooperating agencies for logistical support and data collection: New Jersey Division of Fish and Wildlife, Pennsylvania Game Commission, West Virginia Division of Natural Resources and West Virginia University. We extend a special thanks to the West Virginia Division of Natural Resources and the Wildlife and Sport Fish Restoration Program for project funding.

LITERATURE CITED

Baldwin, R. A., and L. C. Bender. 2010. Denning chronology of black bears in eastern Rocky Mountain National Park. Western North American Naturalist 70:48–54.

Beckmann, J. P., and J. Berger. 2003. Rapid ecological and behavioural changes in carnivores: The responses of black bears (Ursus americanus) to altered food. Journal of Zoology 261:207–212.

Beckmann, J. P., and C. W. Lackey. 2005. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human–Wildlife Conflicts 2:168–174.

Baruch-Mordo, S. 2007. Black bear-human conflicts in Colorado: spatiotemporal patterns and predictors. M.S._Thesis, Colorado State University, Fort Collins.

Baruch-Mordo, S. 2012. Black bear ecology and human-bear interactions in an urban system. PhD Dissertation. Colorado State University, Fort Collins.

Baruch-Mordo, S., S.W. Breck, K.R. Wilson, and J. Broderick. 2011. The carrot or the stick? Evaluation of education and enforcement as management tools for human-wildlife conflicts. PLoS ONE e15681.

Baruch-Mordo, S., S.W. Breck, K.R. Wilson, and J. Broderick. 2009. A tool box half full: how social science can help solve human-wildlife conflict. Human Dimensions of Wildlife 14:219–223.

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

Beckmann, J.P., and C.W. Lackey. 2008. Carnivores, urban landscapes, and longitudinal studies: a case history of black bears. Human-Wildlife Conflicts 2:168–174.

Beier, P. 1993. Determining minimum habitat areas and habitat corridors for cougars.

Conservation Biology 7:94–108.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59:228–237.

Beyer, H.L. (2012). Geospatial Modelling Environment (Version 0.7.2.0). (software). URL: http://www.spatialecology.com/gme. Last accessed: 9 September 2013.

Brody. J.A. 1984. Habitat use by black bears in relation to forest management in Pisgah National Forest, North Carolina. M.S. Thesis, Univ. Tennessee, Knoxville.

Carr, P.C. 1983. Habitat utilization and seasonal movements of black bears in the Great Smoky Mountains National Park. M.S. Thesis. University of Tennessee, Knoxville.

Carr, P.C. and M.R. Pelton. 1984. Proximity of adult female black bears to limited access roads. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:70–77.

Chi, D.K., and B.K. Gilbert. 1999. Habitat security for Alaskan black bears at key foraging sites: are there thresholds for human disturbance? Ursus11:225-238.

Clevenger, A.P. 1986. Habitat and space utilization of black bears in Cherokee National Forest. M.S. Thesis, University of Tennessee, Knoxville.

Coffman, C. J., J. D. Nichols, and K. H. Pollock. 2001. Population dynamics of *Microtus pennsylvanicus* in corridor-linked patches. Oikos 93:3–21.

Costello, C. M., and R. W. Sage. 1994. Predicting black bear habitat selection from food abundance under 3 forest management systems. International Conference on Bear Research and Management 9:375-387.

Cressie, N. and C.K. Wikle. 2011. Statistics for Spatio-Temporal Data. 2011. Wiley, Hoboken, NJ.

Di Orio, A. P., R. Callas, and R. J. Schaefer. 2003. Performance of two GPS telemetry collars under different habitat conditions. Wildlife Society Bulletin 31:372–379.

Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCown, and D. Paetkau. 2006.

Effectiveness of a regional corridor in connecting two Florida black bear populations. Conservation Biology 20:155–162.

Doan-Crider, D. L. 2003. Movements and spatiotemporal variation in relation to food productivity and distribution, and population dynamics of the Mexican black bear in the Serranias Burro, Coahuila, Mexico. Ph.D. dissertation, Texas A&M University–Kingsville, Kingsville, Texas, USA.

Doko, T., H. Fukui, A. Kooiman, A. G. Toxopeus, T. Ichinose, W. Chen, and A.K. Skidmore. 2011. Identifying habitat patches and potential ecological corridors for remnant Asiatic black bear (*Ursus thibetanus japonicus*) populations in Japan. Ecological Modelling 222, 748–761.

Elith, J., G. H. Graham, R.P. Anderson, M. Dudík, S. Ferrier, and A. Guisan, A. .2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29: 129–151

Elith, J., J. R. Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. Journal of Animal Ecology 77: 802–813.

Elowe, K. D. and W.E. Dodge. 1989. Factors affecting black bear reproductive success and cub survival. Journal of Wildlife Management 53:962–968.

Fahrig, L., and G. Merriam. 1985. Habitat patch connectivity and population survival. Ecology 66:1762–1768.

Feske, D. M., R. E. Berry, F. L. Precht, H.B. Quigley, S. L. Bittner and T. Webster. 2002. Habitat use by female black bears in western Maryland. Southeastern Naturalist 1:77–92.

Frid, A., and L. Dill. 2002. Human-caused disturbance stimuli as a form of predation risk. Conservation Ecology 6:11–26.

Garshelis, D. L. 1978. Movement ecology and activity behavior of black bears in the Great Smoky Mountains National Park. M.S. Thesis, University of Tennessee, Knoxville.

Gehrt, S. D. 2004. Ecology and management of striped skunks, raccoons, and coyotes in urban landscapes. Pp. 81–104 in N.Fascione, A. Delach, and M. Smith, editors. Predators and people: from conflict to conservation. Island Press,Washington, D.C., USA.

Gunther, K.A. 1994. Bear management in Yellowstone National Park, 1960–93. Ursus 9:549–560.

Haddad, N. M. 1999. Corridor use predicted from behaviors at habitat boundaries. The American Naturalist 153:215–227.

Hastie, T., R. Tibshirani, and J. Friedman. 2009. The elements of statistical learning: data mining, inference, and prediction. Springer, New York.

Hale, M. L., P. W. W. Lurz, M. D. F. Shirley, S. Rushton, R. M. Fuller, and K. Wolff. 2001. Impact of landscape management on the genetic structure of red squirrel populations. Science 293:2246–2248.

Harshyne, W. A., D. R. Diefenbach, G. L. Alt, and G. M. Matson. 1998. Analysis of error from cementum-annuli age estimates of known-age Pennsylvania black bears. Journal of Wildlife Management 62:1281–1291.

Hass, C. A. 1995. Dispersal and use of corridors by birds in wooded patches on an agricultural landscape. Conservation Biology 9:845–854.

Hilderbrand, G.V., C.C. Schwartz, CT. Robbins, M.E. Jacoby, T.A. Hanley, S.M. Arthur, and S. Servheen. 1999. The importance of meat, particularly salmon, to body size, population productivity, and conservation of North American brown bears. Canadian Journal of Zoology 77:132–138.

Huntley, J.C. 1989. Importance of mast species other than oaks. Pages 74–80 in C.E. McGee, editor. Proceedings of the workshop: Southern Appalachian Mast Management. University of Tennessee, Knoxville, Tennessee, USA.

Lyons, A. J. 2005. Activity patterns of urban American black bears in the San Gabriel mountains of southern California. Ursus 16:255–262.

McCown, W, P. Kubilis, T. Eason, and B. Schieck. 2004. Black bear movements and habitat use relative to roads in Ocala National Forest. Final Report Contract BD-016. Florida Department of Transportation and Florida Fish and Wildlife Commission.

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

Odell, E. A., and R. L. Knight. 2001. Songbird and medium-sized mammal communities associated with exurban development in Pitkin County, Colorado. Conservation Biology 15:1143–1150.

Pettorelli, N., S. Ryan, T. Mueller, N. Bunnefeld, B. Jędrzejewska, M. Lima, and K. Kausrud. 2011. The normalized difference vegetation index (NDVI): unforeseen successes in animal ecology. Climate Research 46: 15–27.

Natural Resource Conservation Service. 2013. Public land layer. http://datagateway.nrcs.usda.gov/. Last accessed 9 September, 2013.

Nelson, A. C. 1992. Characterizing exurbia. Journal of Planning Literature 6:350–368.

Nelson, R. A., G. E. Folk, E. W. Pfeiffer, J. J. Craighead, C. J. Jonkel, and D. L. Steiger. 1983. Behavior, biochemistry, and hibernation in black, grizzly, and polar bears. Ursus 5:284–290.

Pelton, M.R. 1982. Black Bear. Pages 504–514 in J.A. Chapman and G.A. Feldhammer, eds. Wild Mammals of North America: Biology, Management and Economics. John Hopkins University Press, Baltimore, MD.

Pelton, M.R. 1985. Habitat needs of black bears in the east. Pages 49–53 in Kulhavy, D.L. and R.N. Conner, (eds.), Wilderness and Natural Areas in the Eastern United States: A Management Challenge, p. 49–53. Nacogdoches, Texas: Center for Applied Studies, Stephen F. Austin State University.

Pelton, M.R. 1996. The importance of old growth to carnivores in eastern deciduous forests. In M.B. Davis, ed., Eastern Old Growth Forests. New York: Island Press.

Poelker, R. and L. Parsons.1 980. Black bear hunting to reduce forest damage. International Conference on Bear Research and Management 4:191–193.

Proctor, M. F., B. N. McLellan, C. Strobeck, and R. M. R. Barclay. 2005. Genetic analysis reveals demographic fragmentation of grizzly bears yielding vulnerably small populations. Proceedings of Royal Society of London B Biological Sciences 272:2409–2416.

Ryan, C. W., J. C. Pack, W. K. Igo, and A. B. Billings. 2007. Influence of mast production on black bear non-hunting mortalities in West Virginia. Ursus 18: 46–53.

Spiker,Jr. H. A., and S. Bittner. 2004. Wildlife and Heritage Service, Black Bear Management Plan, 2004 – 2013. Maryland Department of Natural Resources, Annapolis. DNR-03-0105-0031.

Storm, D. J., C. K. Nielsen, E. M. Schauber and A. Woolf. 2007. Space Use and Survival of White-Tailed Deer in an Exurban Landscape. The Journal of Wildlife Management 71:1170–1176.

Swenson, J. E., M. Adamic, D. Huber, and S. Stokke. 2007. Brown bear body mass and growth in northern and southern Europe. Oecologia 153:37–47.

Ternent, M. A. 2006. Management and biology of black bears in Pennsylvania: Ten Year Plan (2006–2015). Pennsylvania Game Commission, Harrisburg, PA.

Tewksbury, J. J.,D. J. Levey,N.M. Haddad, S. Sargent, J. L. Orrock, A.Weldon, B. J. Danielson, J. Brinkerhoff, E. I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals and their interactions in fragmented landscapes. Proceedings of the National Academy of Sciences of the United States of America 99:12923–12926.

Treves, A., K. J. Kapp, and D. MacFarland. 2010. American black bear nuisance complaints and hunter take. Ursus 21: 30–42.

United States Census Bureau. 2010 Census data. www.census.gov. Last accessed 9 September, 2013.

Van Manen, F. T. 1994. Black bear habitat use in great smoky mountains national park. PhD. Dissertation, University of Tennessee, Knoxville.

Vaughan, M.R. 2002. Oak trees, acorns, and bears. Pages 224–240 in W.J. McShea and W.M. Healy, editors. Oak forest ecosystems: ecology and management for wildlife. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Vogt, P., Riitters, K.H., Estreguil, C., Kozak, J., Wade, T.G., Wickham, J.D., 2006. Mapping spatial patterns with morphological image processing. Landscape Ecology 22.171–177.

Wolgast, L.J., W. S. Ellis, and J. Vreeland. 2005. New Jersey Fish and Game Council comprehensive black bear (*Ursus amercianus*) management policy. New Jersey Fish and Game Council, New Jersey Department of Environmental Protection, Trenton, New Jersey.

Wooding, J.B. and R.C Maddrey. 1994. Impacts of roads on black bears. Eastern Black Bear Workshop 12.

Zedrosser, A. S.M.J.G. Steyaert, H. Gossow, J.E. Swenson. 2011. Brown bear conservation and the ghost of persecution past. Biological Conservation 144:2163–2170.

Table 4–1: Environmental variables calculated for a predictive model of black bears in urban and suburban areas in the Mid-Atlantic Region.

Variable	Data type	Details	Data source
Topographic Position Index	Continuous	Index of ruggedness	National DEM dataset
Landcover	Categorical	900 meter grid cells	Reclassified from NASS Dataset
Forest patch		Coded as #1	
Forest edge		Coded as #2	
Perforated forest		Coded as #3	
Core forest (<100 ha)		Coded as #4	
Core forest (101–202 ha)		Coded as #5	
Core forest (>202 ha)		Coded as #6	
Open water		Coded as #7	
Exurban/grassland		Coded as #8	
Suburban (low/medium dev.)		Coded as #9	
Urban (High dev.)		Coded as #10	
Barren		Coded as #11	
Row crops/orchards		Coded as #12	
Other		Coded as #13	
Distance to core forest	Continuous	meters	Euclidean distance raster
Distance to roads	Continuous	meters	Euclidean distance raster
Distance to public hunting	Continuous	meters	Euclidean distance raster
Distance to urban area	Continuous	meters	Euclidean distance raster
Normalized Vegetation Difference Index	Continuous	meters	NASA MODIS satellites data

Table 4–2: Descriptive statistics of environmental variables (points used by bears vs. random) calculated for a predictive model of black bears in urban and suburban areas in Scranton/Wilkes-Barre, Pennsylvania and New Jersey study areas.

Variable	Bear locations (± SE)	Random points (± SE)
Distance to core forest (m)	143.24 ± 1.32	154.61 ± 1.37
Distance to edge forest (m)	479.77 ± 2.74	512.11 ± 3.74
Distance to urban area (m)	3,047.25 ± 11.53	5,689.66 ± 22.57
Distance to roads (m)	4,70.54 ± 1.86	483.63 ± 2.57
Topographic position index	2.30 ± 0.09	-0.18 ± 0.10
Distance to public land (m)	1,466.67 ± 10.18	2,787.33 ± 14.24
Normalized difference vegetation index	2,931.04 ± 0.01	7.64 ± 0.01

Table 4–3: Descriptive statistics of environmental variables (points used by bears vs. random) calculated for a predictive model of black bears in urban and suburban areas in Johnstown and State College, Pennsylvania.

Variable	Bear locations (± SE)	Random points (± SE)
Distance to core forest (m)	143.24 ± 1.32	154.61 ± 1.37
Distance to edge forest (m)	479.77 ± 2.74	512.11 ± 3.74
Distance to urban area (m)	3,047.25 ± 11.53	5,689.66 ± 22.57
Distance to roads (m)	4,70.54 ± 1.86	483.63 ± 2.57
Topographic position index	2.30 ± 0.09	-0.18 ± 0.10
Distance to public land (m)	1,466.67 ± 10.18	2,787.33 ± 14.24
Normalized difference vegetation index	2,931.04 ± 0.01	7.64 ± 0.01

Table 4–4: Descriptive statistics of environmental variables (points used by bears vs. random) calculated for a predictive model of black bears in urban and suburban areas in West Virginia.

Variable	Bear locations (± SE)	Random points (± SE)
Distance to core forest (m)	68.85 ± 0.76	117.39 ± 0.80
Distance to edge forest (m)	489.55 ± 2.46	383.38 ± 2.59
Distance to urban area (m)	3,860 ± 18.07	5,604.00 ± 19.05
Distance to roads (m)	346.25 ± 1.59	272.84 ± 1.68
Topographic position index	3.00 ± 0.19	0.28 ± 0.20
Distance to public land (m)	3,561.61 ± 24.99	6,105.69 ± 26.34
Normalized difference vegetation index	0.63 ± 0.11	0.61 ± 0.11

FIGURE CAPTIONS

Figure 4.1: Map of the study areas in New Jersey, Pennsylvania, and West Virginia.

Figure 4.2: Relative influence of covariates for predicting urban and suburban black bear space use in Johnstown and State College, PA, during 2010–2012.

Figure 4.3. Partial dependence plots of covariates for predicting urban and suburban black bear space use in Johnstown and State College, PA, during 2010–2012.

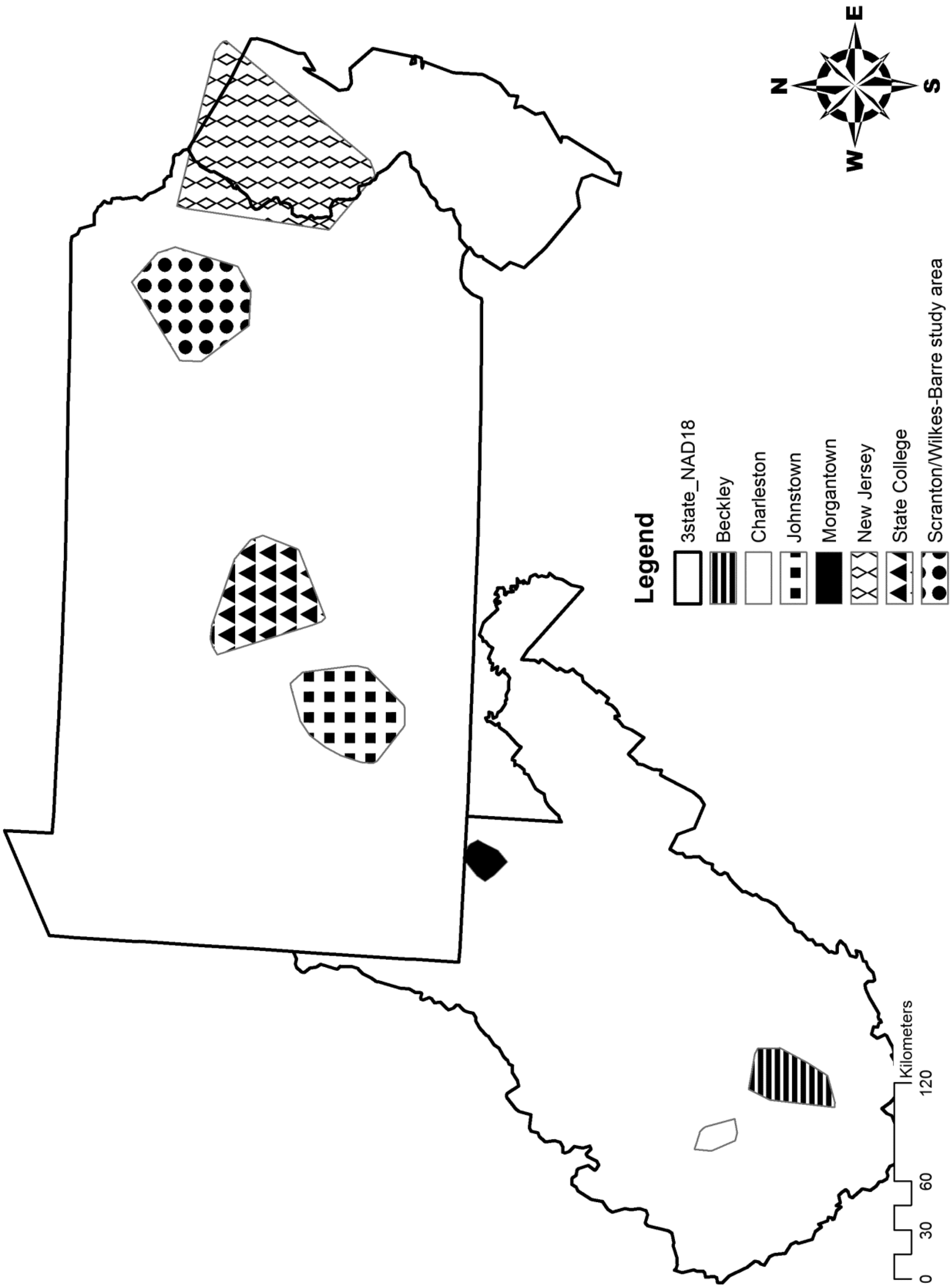
Figure 4.4: Relative influence of covariates for predicting urban and suburban black bear space use in New Jersey and Scranton/Wilkes-Barre, PA, during 2010–2012.

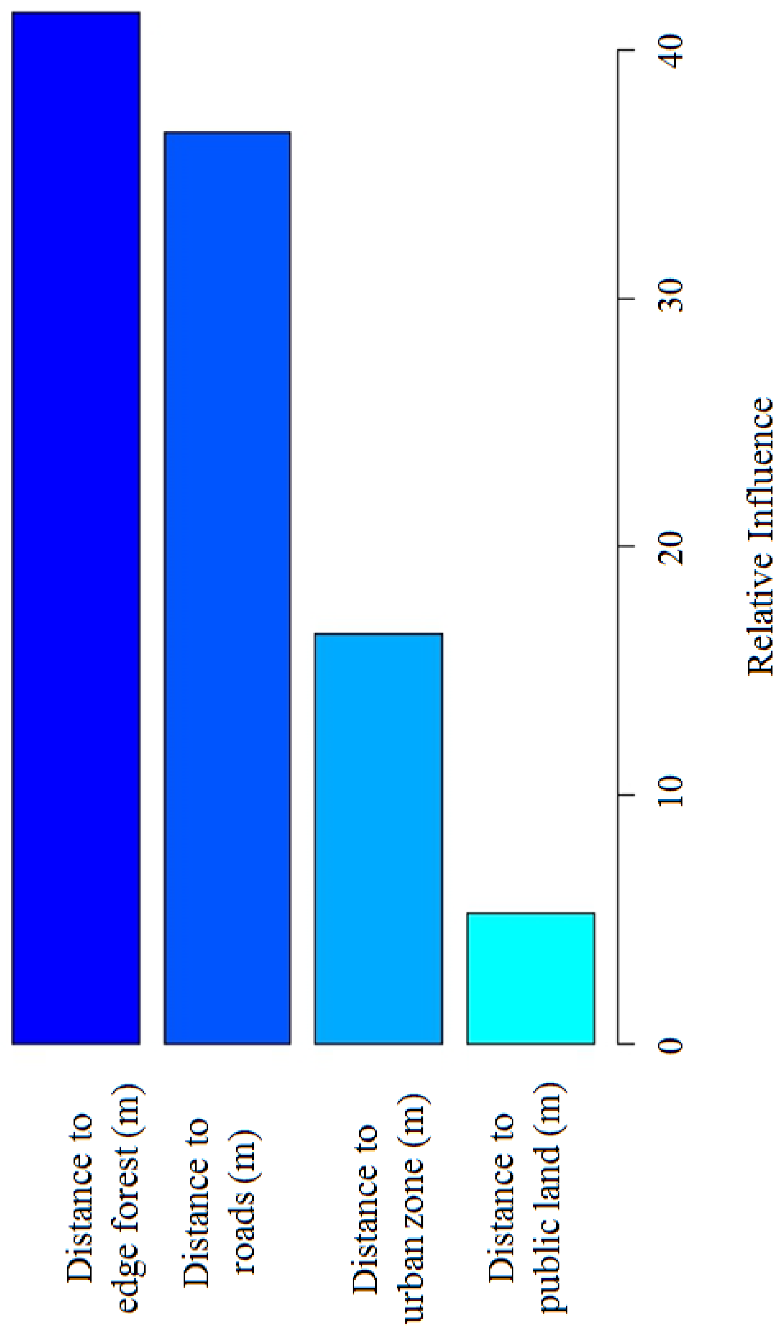
Figure 4.5: Partial dependence plots of covariates for predicting urban and suburban black bear space use in New Jersey and Scranton/Wilkes-Barre, PA, during 2010–2012.

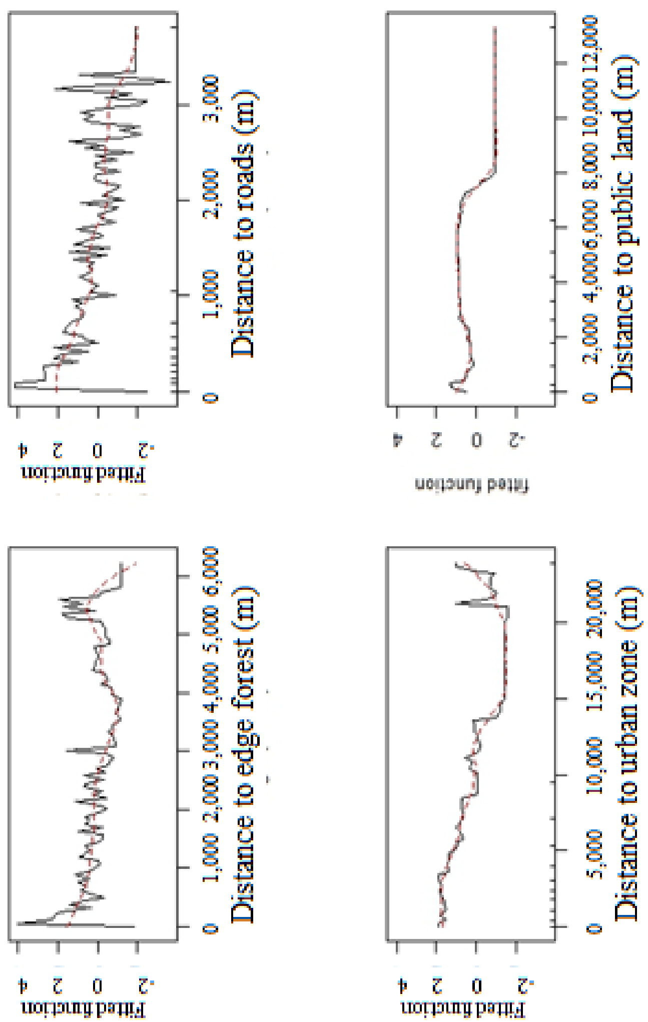
Figure 4.6 Relative influence of covariates [NDVI: normalized difference vegetation index, publand: distance to public land (m), urban: distance to urban area (m), tpi: topographic position index, roads: distance to roads (m)] for predicting urban and suburban black bear space use in West Virginia during 2011–2012.

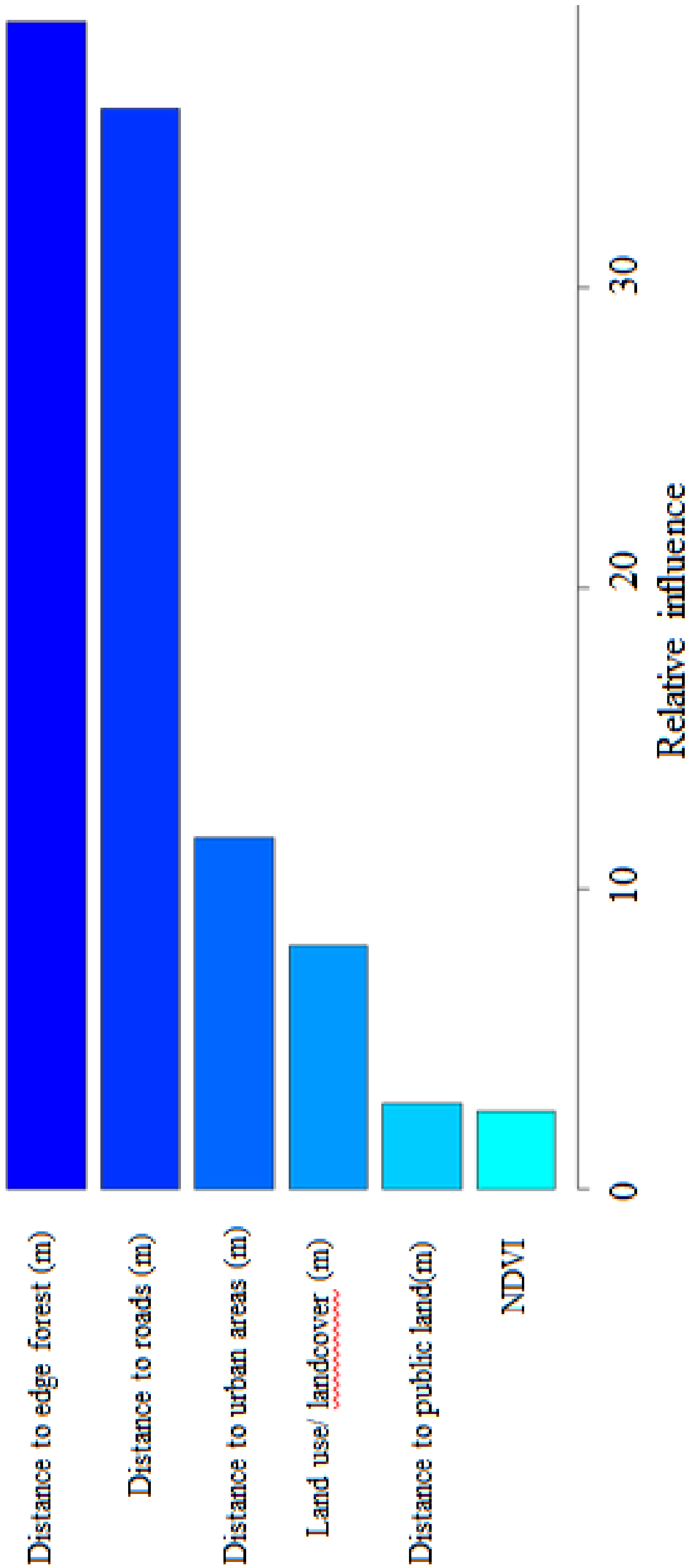
Figure 4.7. Partial dependence plots of covariates [NDVI: normalized difference vegetation index, publand: distance to public land (m), urban: distance to urban area (m), tpi: topographic position index, roads: distance to roads (m)] for predicting urban and suburban black bear space use in West Virginia during 2011–2012.

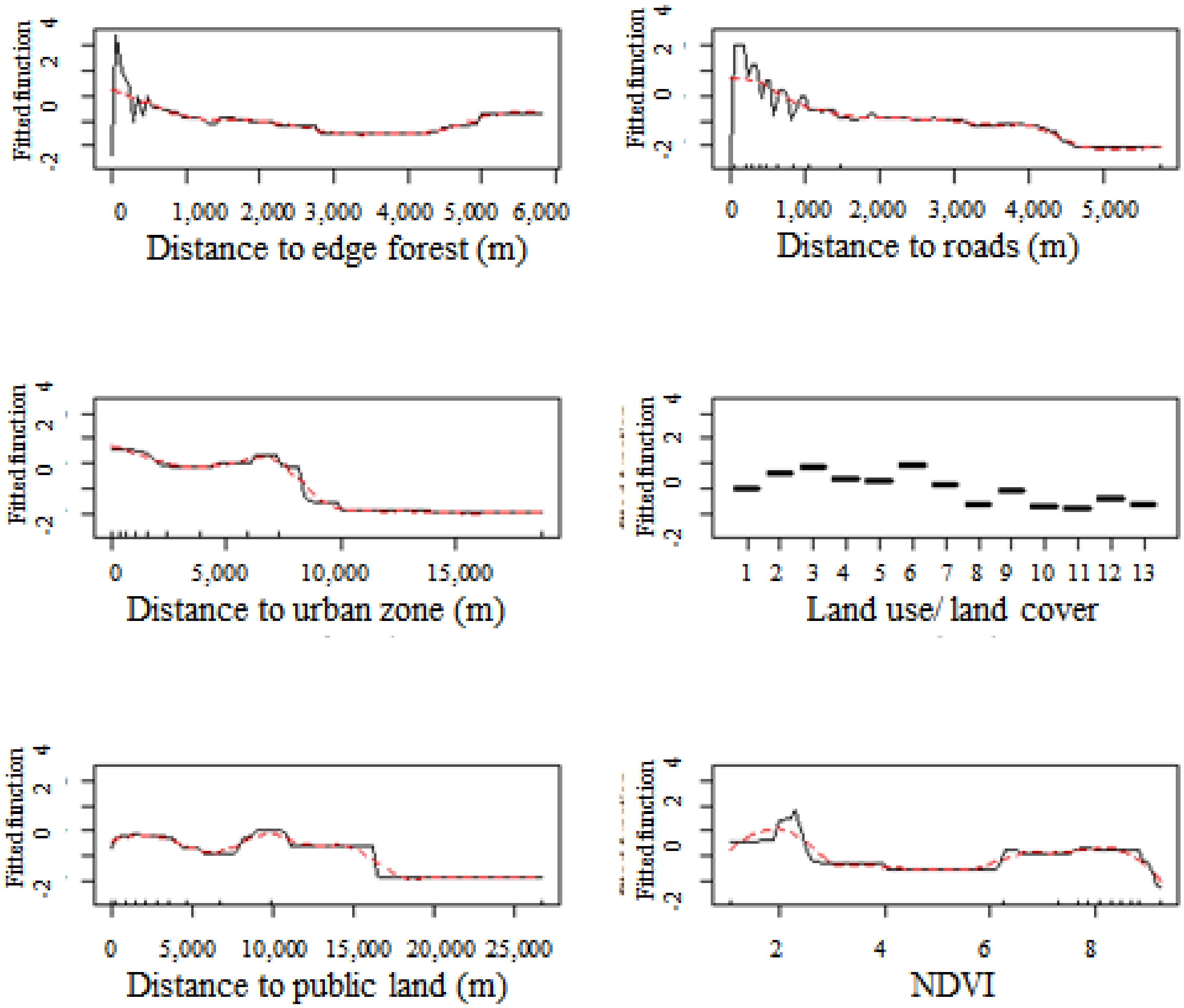
Figure 4.8. Map depicting predictions made from a boosted regression tree model of the probability of use by urban and suburban bears in New Jersey, Pennsylvania, and West Virginia during 2010–2012.


Legend
3state_NAD18
Beckley
Charleston
Johnstown
Morgantown
New Jersey
State College
Scranton/Wilkes-Barre study area
N
E
S
W
0
30
60
120
Kilometers

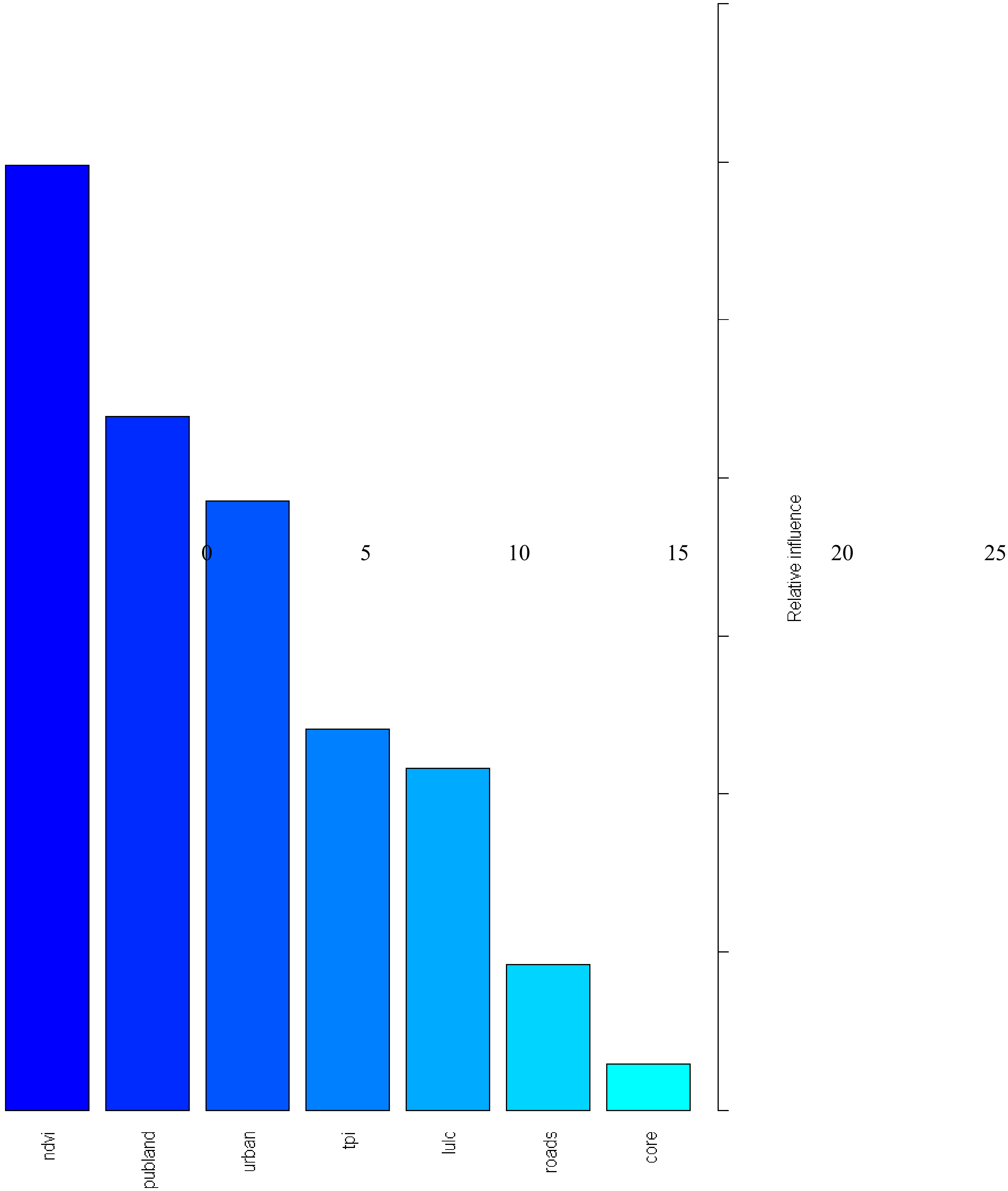

Distance to edge forest (m)
Distance to roads (m)
Distance to urban zone (m)
Distance to public land (m)
0
10
20
30
40
Relative Influence

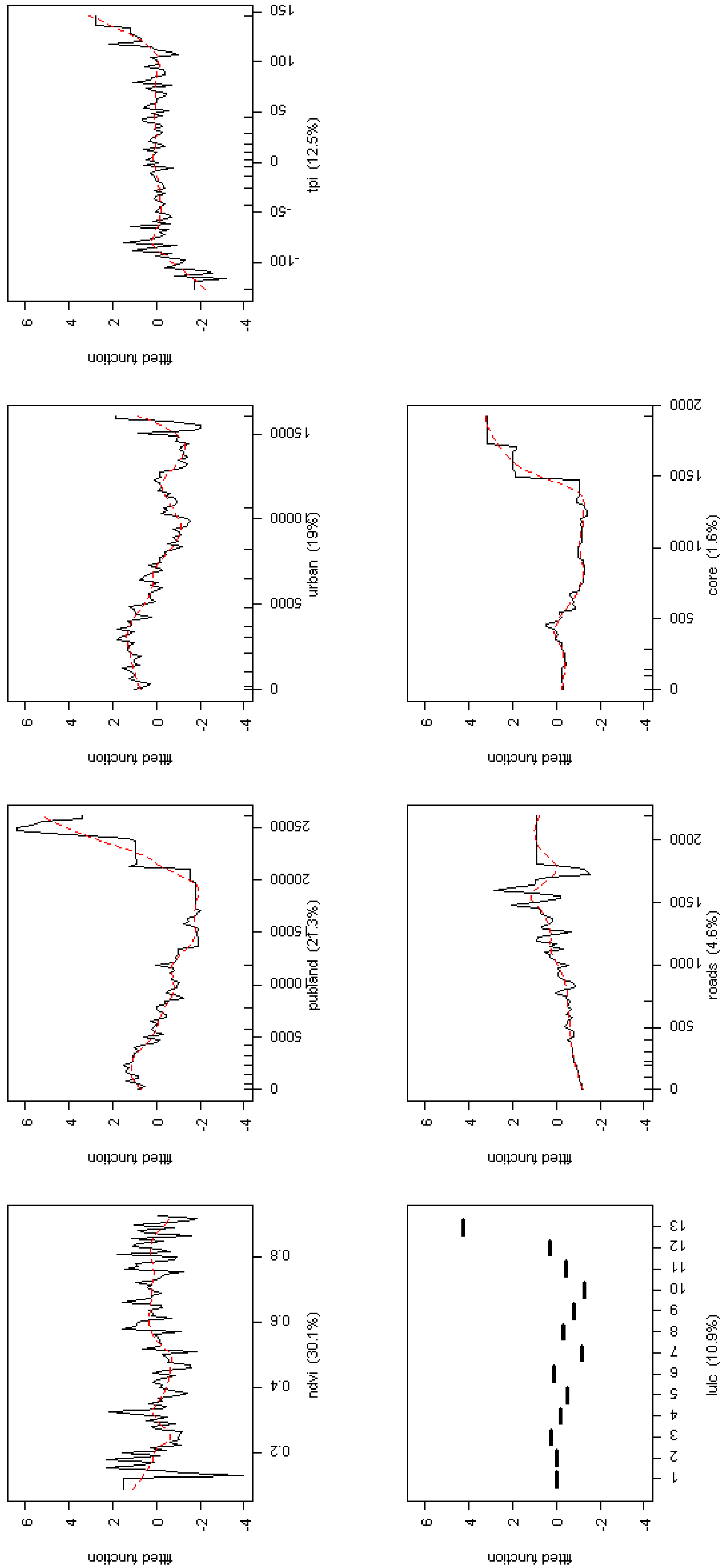

Fitted function
Distance to roads (m)
Distance to public land (m)
Distance to edge forest (m)
Distance to urban zone (m)

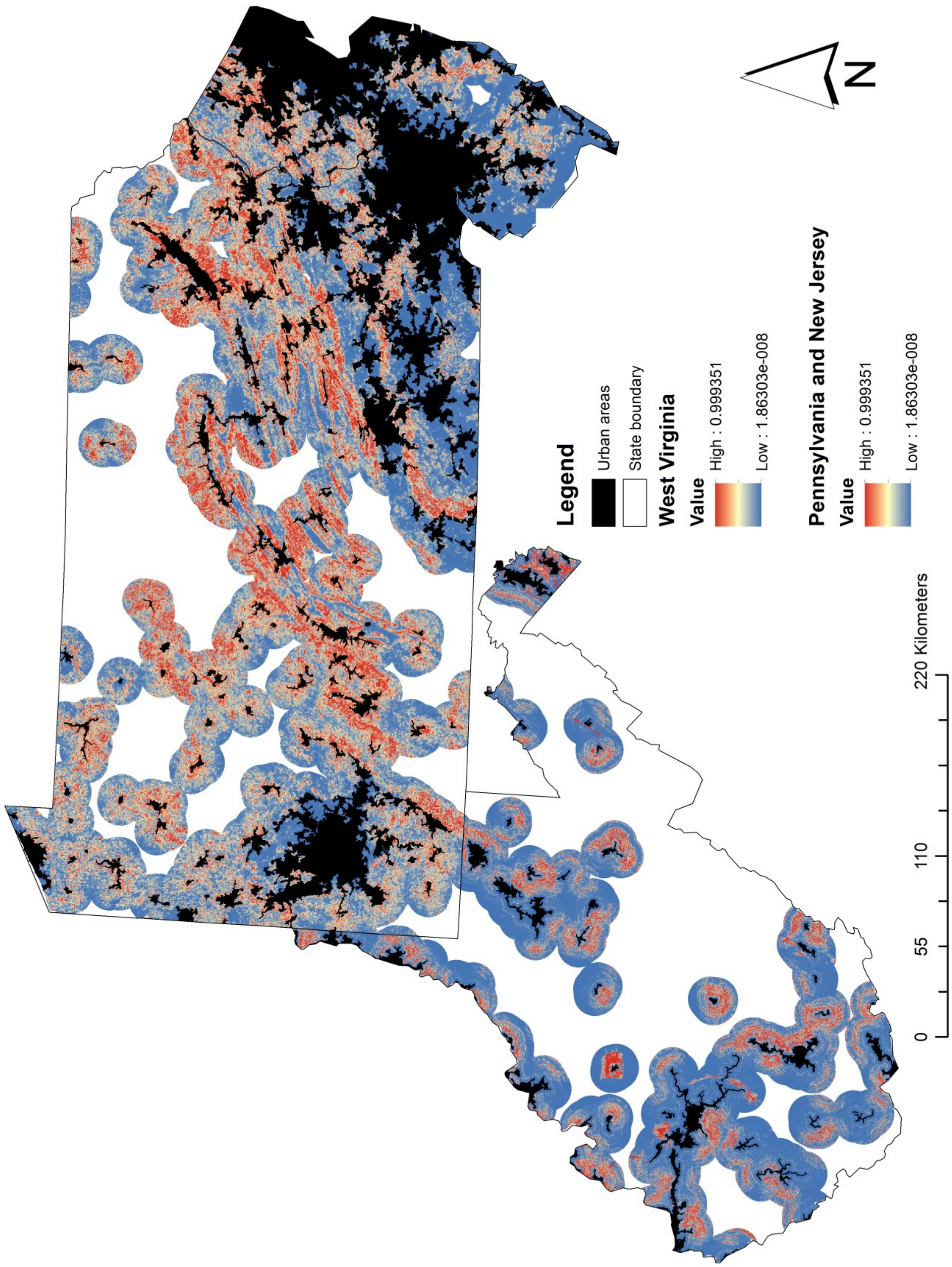

Distance to edge forest (m)
Distance to roads (m)
Distance to urban areas (m)
Land use/ landcover (m)
Distance to public land(m)
NDVI
0
10
20
30
Relative influence



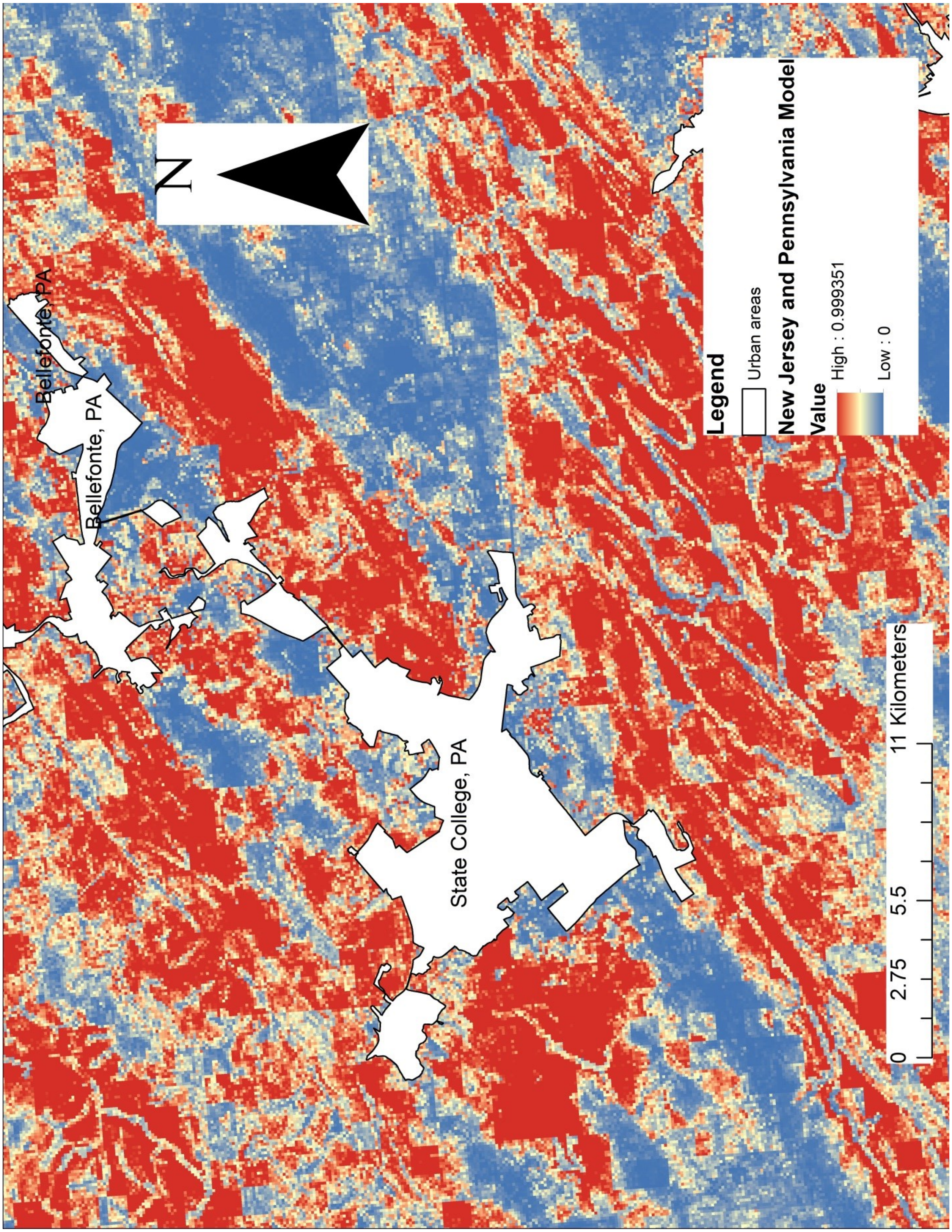
Fitted function
Distance to edge forest (m)
Distance to roads (m)
Distance to urban zone (m)
Land use/ land cover
Distance to public land (m)
NDVI


ndvi
publand
urban
tpi
lulc
roads
core
Relative influence
0
5
10
15
20
25


fitted function
ndvi (30.1%)
publand (21.3%)
urban (19%)
tpi (12.5%)
lulc (10.9%)
roads (4.6%)
core (1.6%)

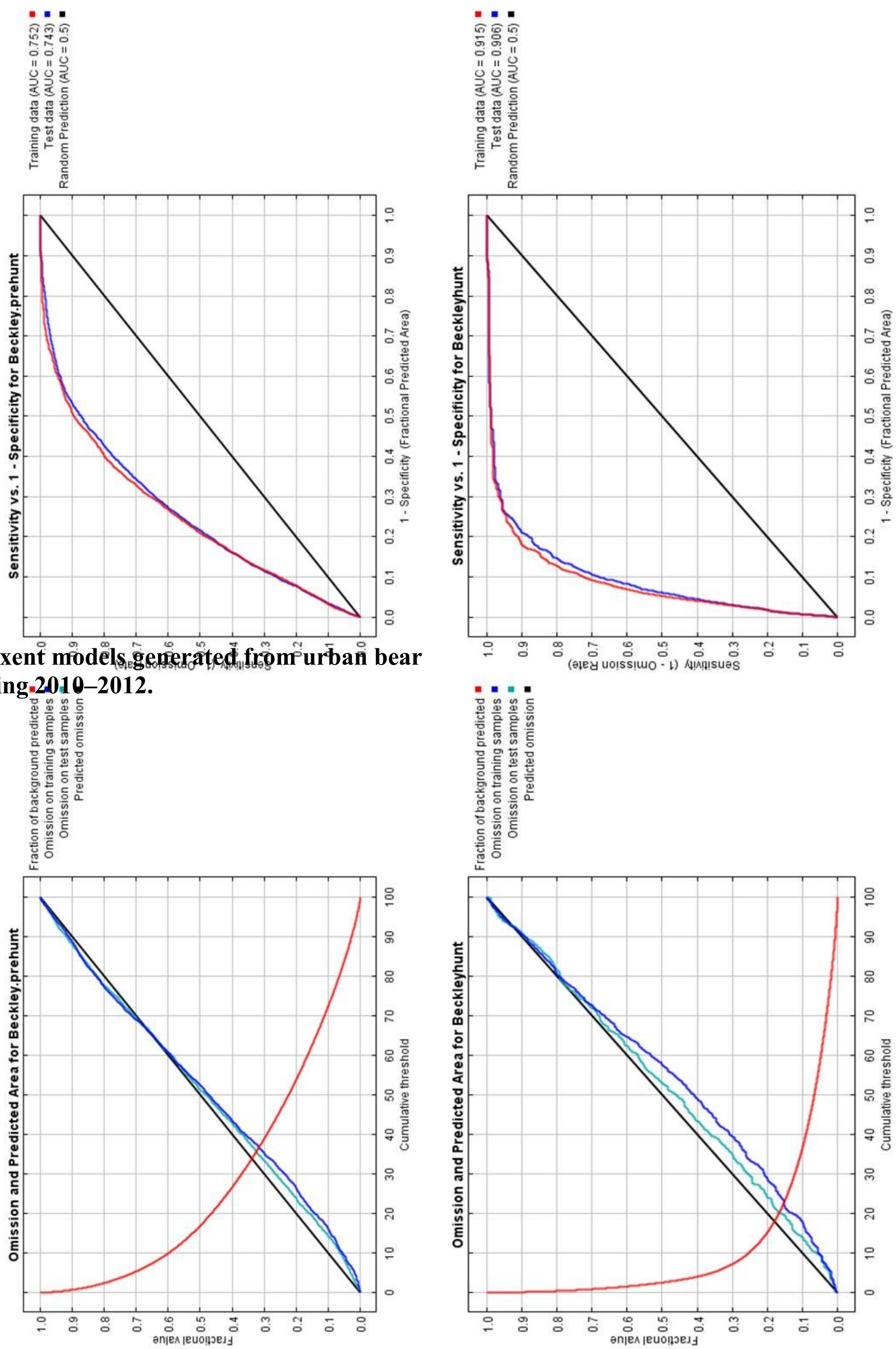


Legend
Urban areas
State boundary
West Virginia
Value
High : 0.999351
Low : 1.86303e-008
Pennsylvania and New Jersey
Value
High : 0.999351
Low : 1.86303e-008
0
55
110
220 Kilometers
N


N
Bellefonte, PA
Bellefonte, PA
Bellefonte, PA
State College, PA
Legend
Urban areas
New Jersey and Pennsylvania Model
Value
High : 0.999351
Low : 0
0
2.75
5.5
11 Kilometers

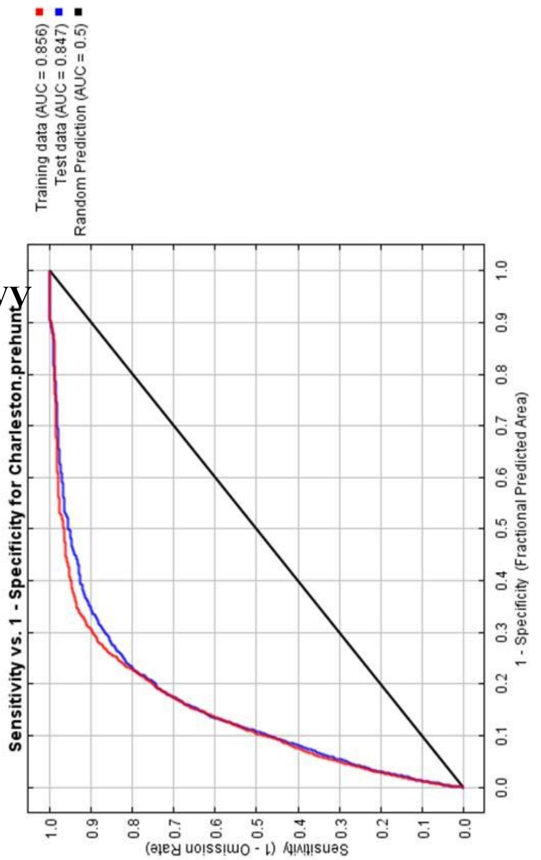
Appendix 1. Bear hunting seasons during 2010–2012 in New Jersey, Pennsylvania, and West Virginia. The * denotes that the annual bag limit of black bears in West Virginia is 2, if $\geq$1 is harvested in the intensive harvest zone (Boone, Fayette, Kanawha, Logan,McDowell, Mingo, Raleigh or Wyoming counties).

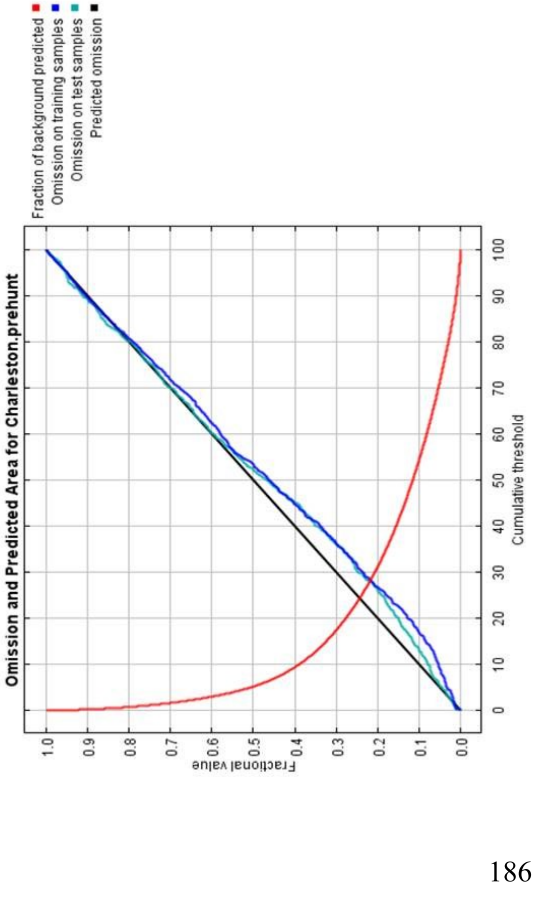
State	Year	Method	Dates	Bag Limit
New Jersey	2010	Firearm	12/6-12/11	1
	2011	Firearm	12/5-12/10	1
	2012	Firearm	12/3-12/8	1
Pennsylvania	2010	Archery	11/15-11/19	1
		Firearm	11/20-11/23	1
	2011	Archery	11/14-11/18	1
		Firearm	11/19-11/23	1
	2012	Archery	11/12-11/16	1
		Firearm	11/17-11/21	1
West Virginia	2011	Archery	10/15-11/19	2*
		Firearm	9/26-10/1, 11/21-12/3 and 12/5-12/31	2*
	2012	Archery	9/29-11/17 and 12/3-12/31	2*
		Firearm	9/24-9/29, 11/19-12/1 and 12/3-12/31	2*

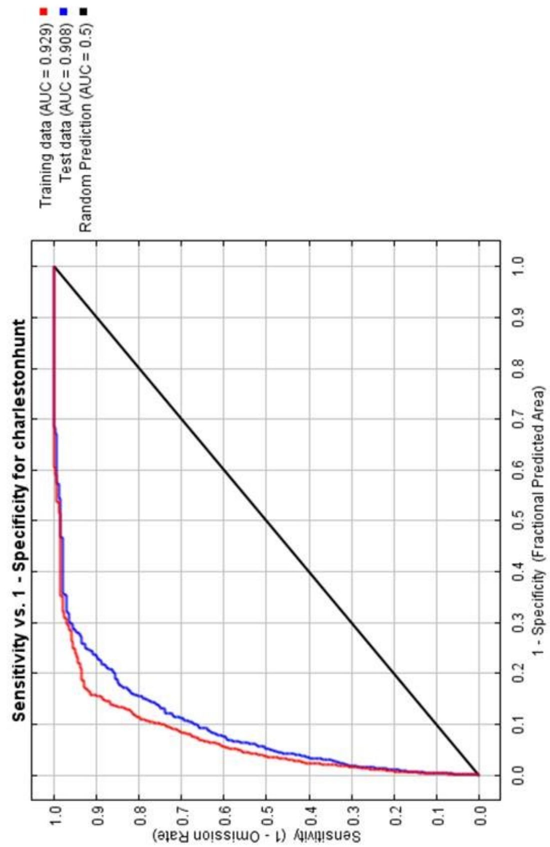


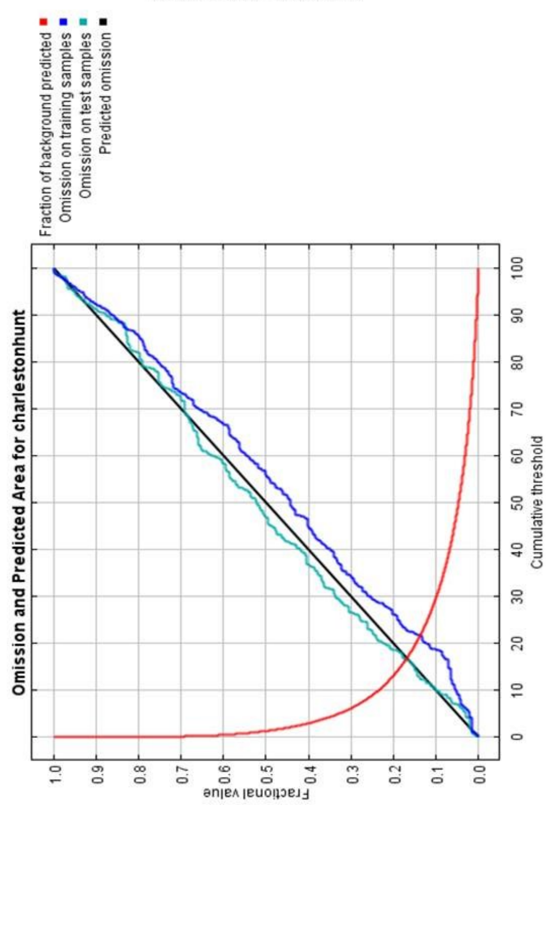
on and predicted area graphics of maxent models generated from urban bear
Pennsylvania, and West Virginia during 2010–2012.

Charleston, WY

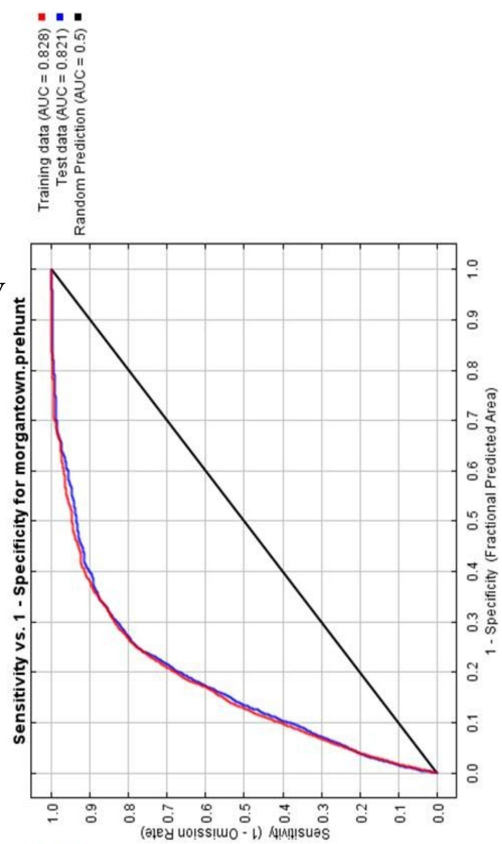


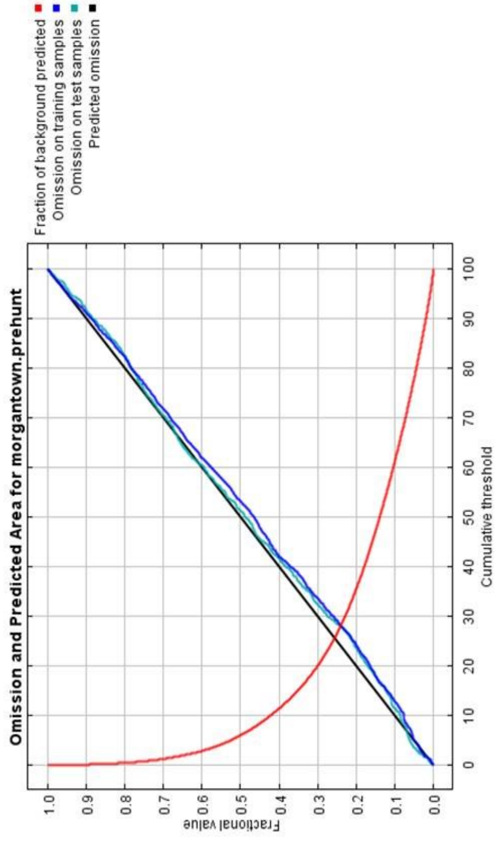


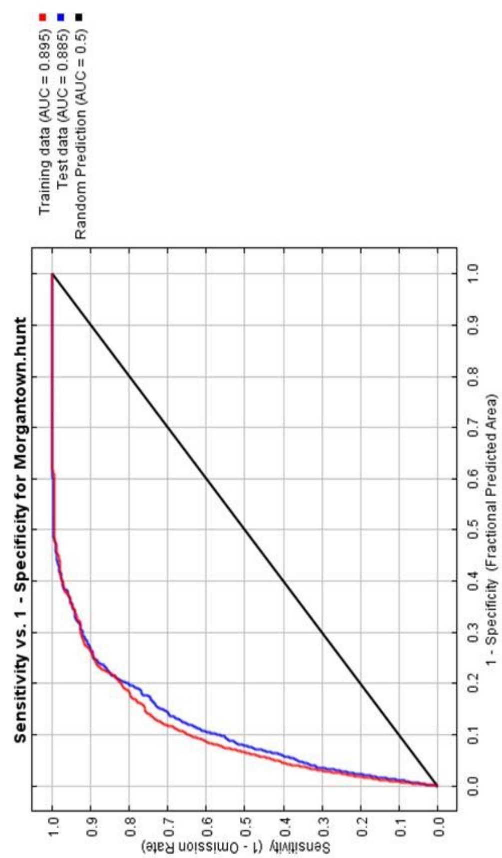


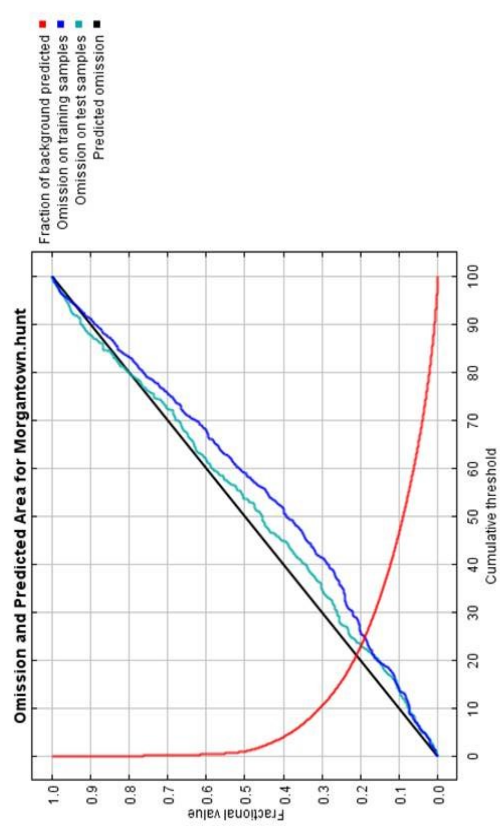


Morgantown, WV

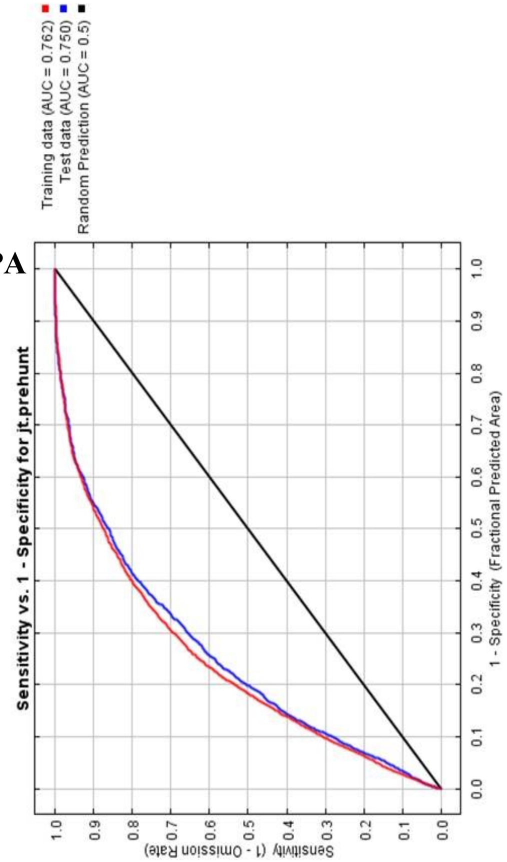


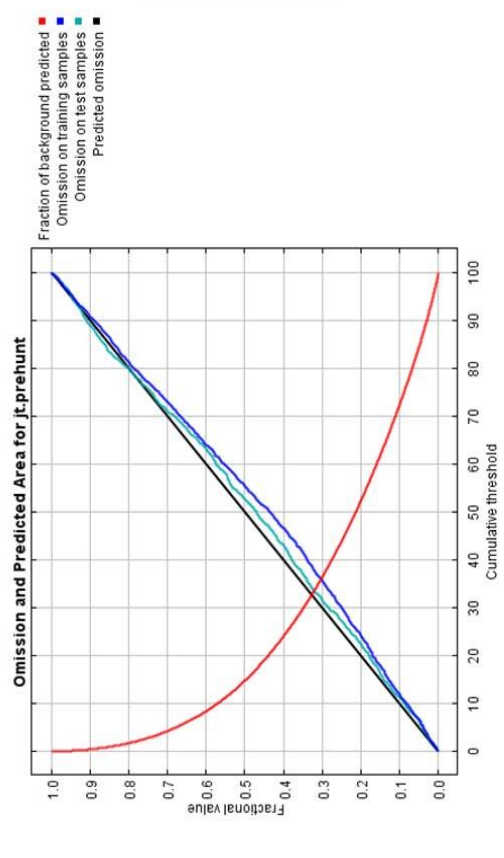


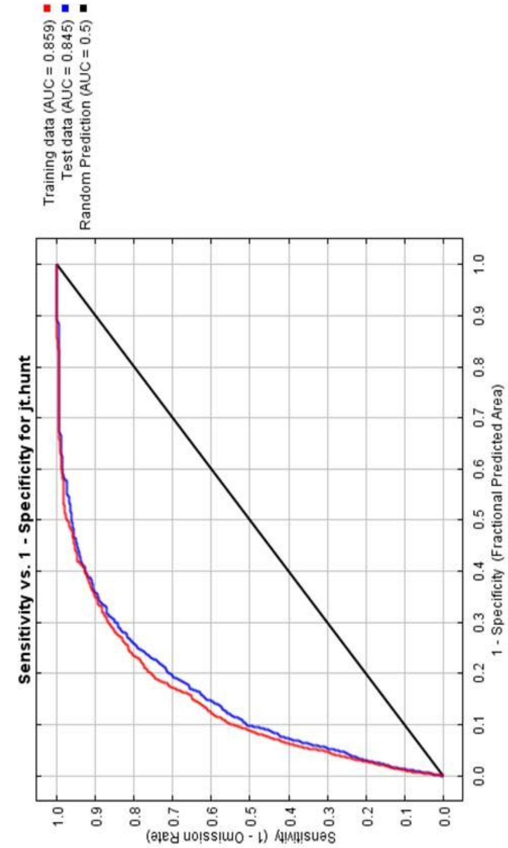


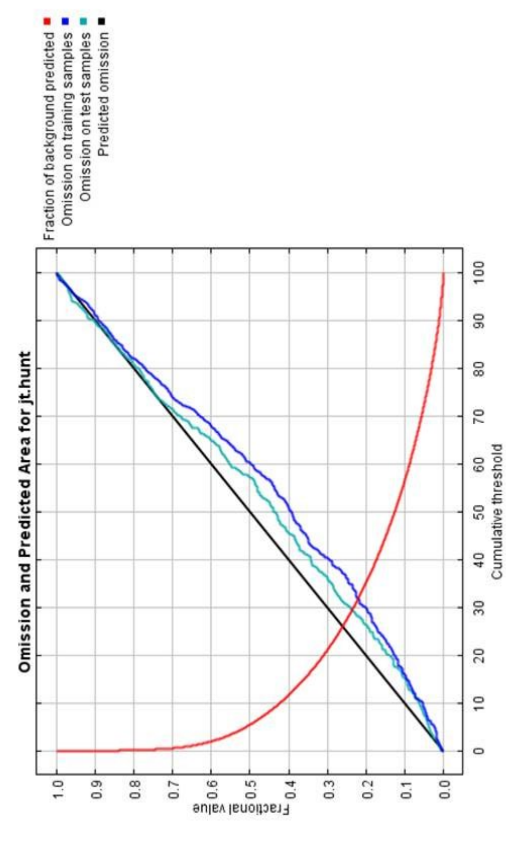


Johnstown, PA

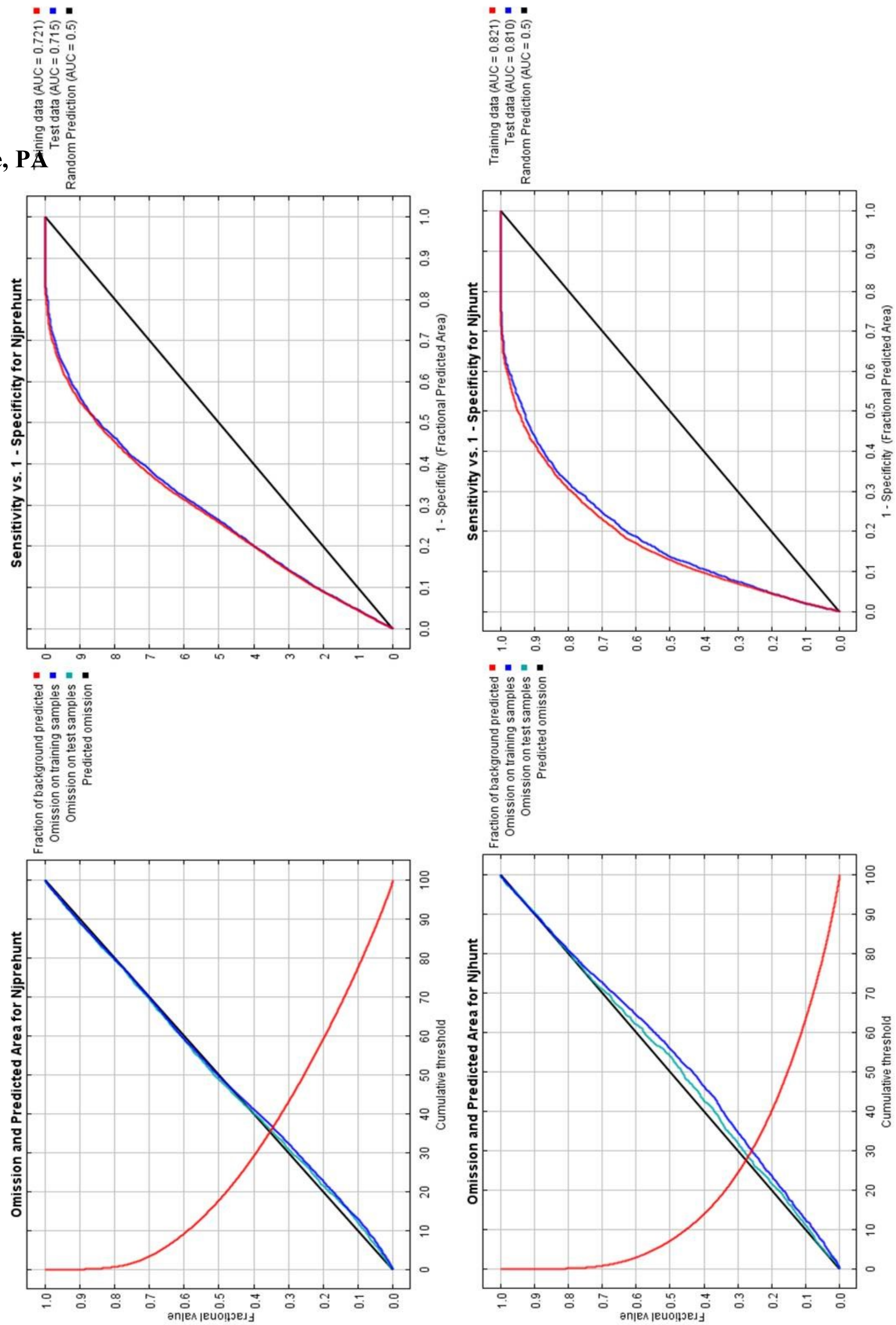




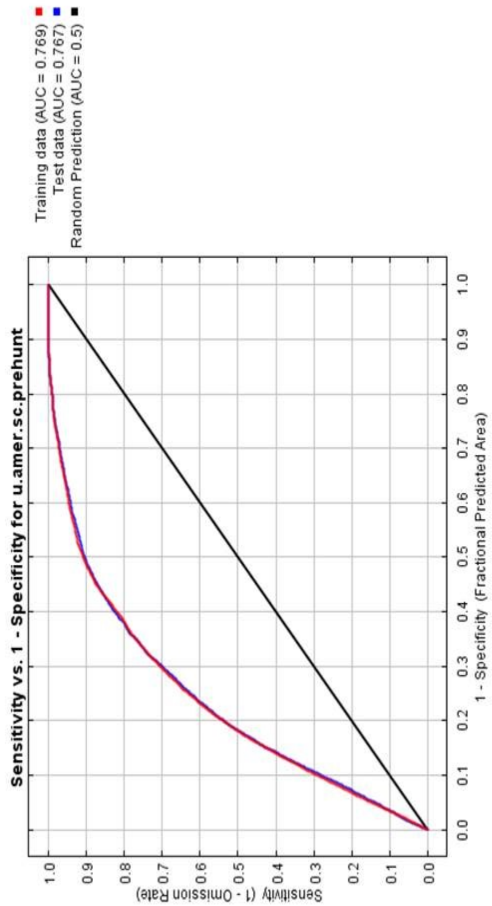


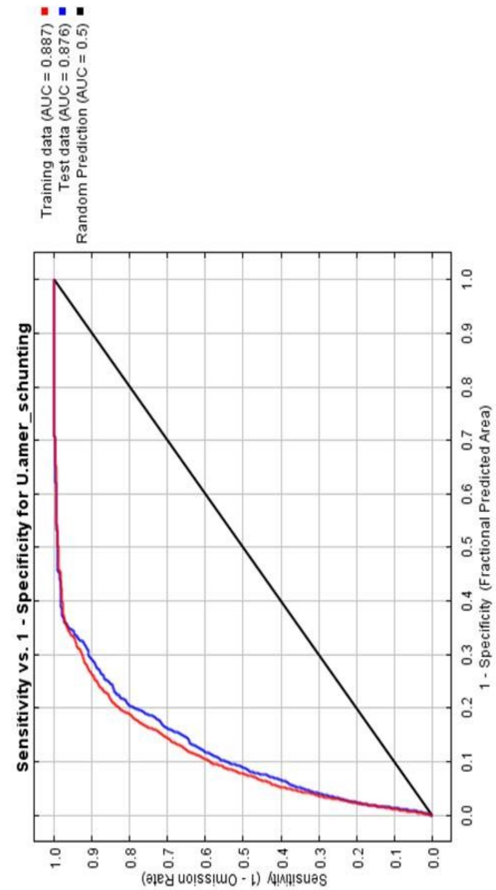


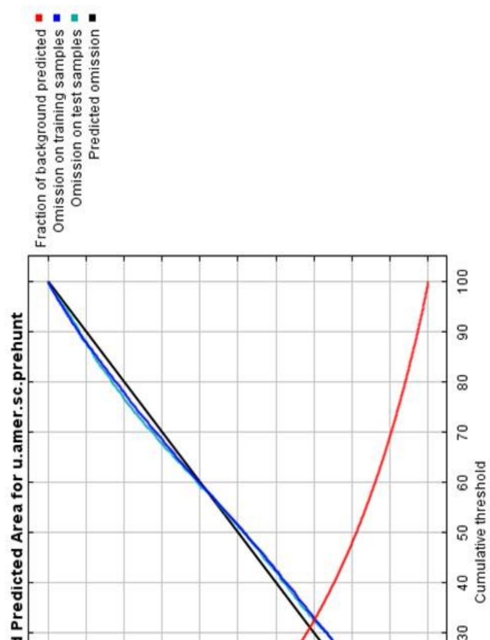
State College, PA

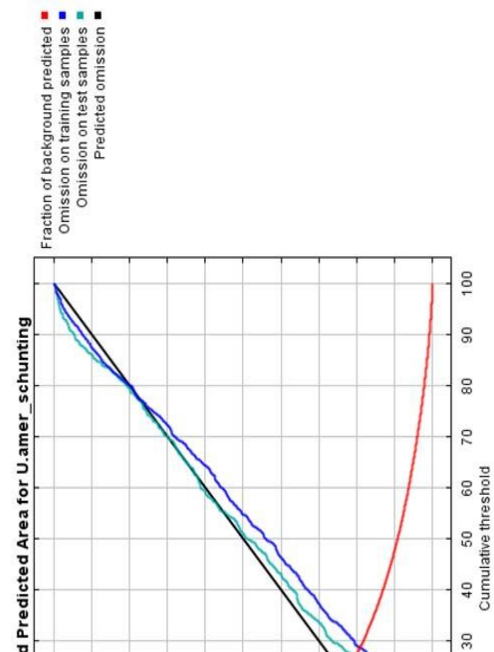


New Jersey


Sensitivity vs. 1 - Specificity for u.amer.sc.prehunt
Training data (AUC = 0.769)
Test data (AUC = 0.767)
Random Prediction (AUC = 0.5)
Sensitivity (1 - Omission Rate)
1 - Specificity (Fractional Predicted Area)


Sensitivity vs. 1 - Specificity for U.amer_schunting
Training data (AUC = 0.887)
Test data (AUC = 0.876)
Random Prediction (AUC = 0.5)
Sensitivity (1 - Omission Rate)
1 - Specificity (Fractional Predicted Area)


d Predicted Area for u.amer.sc.prehunt
Fraction of background predicted
Omission on training samples
Omission on test samples
Predicted omission
Cumulative threshold


d Predicted Area for U.amer_schunting
Fraction of background predicted
Omission on training samples
Omission on test samples
Predicted omission
Cumulative threshold

Appendix 3: Capture records for each urban black bear in New Jersey, Pennsylvania, and New Jersey during 2010–2012.

ID	State	Sex	Age	Capture Latitude	Capture Longitude	Capture Date	Harvested?	Date	Vehicle Collision	Date	Other Mort	Capture Mass
801	WV	M	J	37.86666	-81.19030	6/1/2011	0		0		0	146
802	WV	M	J	37.68803	-81.21118	7/29/2011	1	11/2/2011	0		0	115
803	WV	M	A	37.97390	-81.17439	8/1/2011	0		1	8/8/2011	0	302
804	WV	M	A	37.90775	-81.28167	8/2/2011	0		0		0	295
805	WV	M	A	37.79394	-81.11150	8/21/2011	0		0		0	231
806	WV	M	A	37.77990	-81.12200	11/3/2011	1	11/5/2011	0		0	229
809	WV	M	A	38.28200	-81.59984	8/17/2011	0		0		0	190
810	WV	M	J	38.30850	-81.62497	8/18/2011	0		0		1	130
820	WV	M	J	37.78315	-81.11192	8/12/2012	1	10/31/2012	0		0	105
1525	WV	M	A	39.60472	-79.87003	6/8/2011	0		0		0	301.5
1529	WV	F	A	39.60472	-79.87003	9/9/2011	0		0		0	179
1606	WV	M	J	39.61534	-79.82950	6/22/2012	0		0		0	148.5
1607	WV	M	J	39.60973	-79.85548	6/19/2012	0		0		0	160
1608	WV	M	A	39.61534	-79.82950	6/20/2012	0		0		0	183.5
1609	WV	M	A	39.64059	-79.84729	6/22/2012	0		0		0	266
1694	WV	M	J	38.28369	-81.60643	6/26/2012	0		0		0	130
1753	WV	M	A	39.71813	-81.13729	4/12/2012	0		0		0	335
1754	WV	M	A	37.91855	-81.13754	4/13/2012	0		0		0	319
1757	WV	M	A	37.91519	-81.14750	4/13/2012	0		0		0	173.5
2746	NJ	F	A	41.00250	-75.10711	7/8/2011	1	11/14/2011	0		0	164
3994	NJ	F	A	41.29261	-74.74579	8/9/2010	0		0		0	229
4832	NJ	F	A	41.20545	-74.46245	11/11/2010	1	12/6/2010	0		0	208.5
5192	NJ	M	A	41.06558	-74.59680	8/18/2011	0		0		0	314
5417	NJ	M	A	41.09643	-74.57710	7/14/2012	0		0		0	273
5538	NJ	F	A	41.18529	-74.51073	4/11/2012	0		0		0	
5665	NJ	M	A	40.82801	-74.86409	5/17/2011	0		0		0	262

5667	NJ	F	A	41.04156	-74.60501	5/26/2011	0		0		0	182
5894	NJ	F	A	41.03242	-74.89778	8/4/2010	0		0		0	138
5905	NJ	F	A	41.09687	-74.89401	7/25/2012	0		0		0	
6313	NJ	F	A	40.83050	-74.86862	6/21/2011	0		0		0	180
6838	NJ	F	A	40.78849	-74.93308	6/9/2011	0		0		0	184
7296	NJ	F	A	41.08749	-74.89692	9/30/2010	0		0		1	194
7311	NJ	F	A	41.08455	-74.89778	10/3/2010	0		0		0	157
7338	NJ	F	A	40.99311	-74.75119	10/17/2010	0		0		0	195
7351	NJ	F	A	40.99319	-74.75128	10/16/2010	0		0		0	162
7630	NJ	M	A	40.80643	-74.66869	9/25/2011	0		0		0	508
7707	NJ	F	A	41.04156	-74.60501	5/31/2011	0		0		1	292
7721	NJ	M	J	40.74074	-74.54122	2/24/2012	0		0		1	236
7757	NJ	M	A	41.05593	-74.39197	9/8/2011	0		0		0	
7859	NJ	M	J	41.06888	-74.85421	7/8/2011	0		0		0	136
7861	NJ	M	J	41.06888	-74.85421	7/8/2011	0		0		1	172
7863	NJ	M	A	40.60435	-75.21058	2/22/2012	0		0		0	350
8103	NJ	M	A	41.04268	-74.38017	8/27/2012	0		0		0	215
8953	NJ	F	A	41.06368	-74.38897	8/12/2012	0		0		0	238
12392	PA	M	A	40.80520	-77.80878	8/26/2010	0		1	11/22/2010	0	320
16259	PA	M	A	40.72372	-77.90064	6/12/2012	0		0		0	173
21520	PA	F	A	41.26662	-75.96888	5/14/2010	0		0		0	210
21595	PA	F	A	41.24363	-75.83660	6/3/2010	1	11/23/2010	0		0	152
21799	PA	M	A	41.11158	-75.91678	6/3/2010	0		0		0	420
22310	PA	F	A	40.88055	-77.86850	7/15/2010	0		1	12/28/2010	0	167
23516	PA	M	A	40.83799	-77.84422	5/14/2011	0		1	6/9/2010	0	289
25163	PA	M	A	40.42172	-78.90315	5/27/2010	0		0		0	360
26471	PA	M	A	41.22858	-75.84808	5/8/2010	1	11/20/1010	0		0	208
26473	PA	M	A	41.20007	-75.78777	5/13/2010	0		0		0	575
26537	PA	F	A	41.45938	-75.65995	5/12/2010	0		1	6/20/2010	0	191

26755	PA	F	A	41.21952	-75.84493	5/12/2010	0		0		0	259
26765	PA	M	A	41.17143	-75.87070	5/14/2010	0		0		0	300
26776	PA	M	Y	41.40365	-75.61548	5/6/2010	0		1	6/3/2010	0	109
26778	PA	F	A	41.40365	-75.61548	5/7/2010	0		0		0	211
26780	PA	F	A	41.49555	-75.58827	5/10/2010	0		0		0	140
26784	PA	M	A	41.33325	-75.73605	5/22/2010	1	11/20/2010	0		0	127
26791	PA	M	A	41.45988	-75.65487	6/11/2010	0		0		0	374
26793	PA	M	A	41.40212	-75.62070	6/11/2010	0		0		0	213
26797	PA	F	A	41.54195	-75.73325	10/4/2010	0		0		1	120
26942	PA	M	A	41.13602	-75.87290	5/14/2011	0		0		0	280
27170	PA	F	A	40.25770	-78.82773	6/18/2010	0		0		0	249
27340	PA	M	A	40.68363	-78.74113	6/17/2010	0		0		0	188
27466	PA	M	A	40.36290	-78.63576	7/24/2010	0	11/19/2011	0		0	185
27910	PA	F	A	40.25030	-78.97700	10/14/2012	0		0		0	202
27961	PA	F	A	40.34602	-78.80303	5/26/2010	1	11/21/2011	0		0	156
28015	PA	M	A	41.38760	-75.65228	6/7/2010	0		0		0	345
28111	PA	M	A	41.37649	-75.74667	5/18/2011	0		0		0	247
28113	PA	F	A	41.39144	-75.64995	5/19/2011	0		0		0	110
28119	PA	M	A	41.36489	-75.75480	6/8/2011	0		0		0	269
28123	PA	M	A	41.53040	-75.66374	8/27/2011	0		0		0	290
28257	PA	M	A	41.37243	-75.72447	3/24/2012	0	11/15/2010	0		0	200
28259	PA	M	A	41.37691	-75.74738	4/28/2012	0		0		0	350
28263	PA	F	A	41.49598	-75.58837	5/11/2012	0		0		0	180
28303	PA	M	A	41.36889	-75.68596	8/16/2011	0		0		0	173
28726	PA	M	A	41.22527	-75.79380	5/15/2010	1	11/21/2011	0		0	355
28730	PA	F	A	41.29173	-75.77383	6/8/2010	0		0		0	220
28733	PA	M	A	41.29173	-75.77383	6/10/2010	1	11/15/2010	0		0	145
28735	PA	M	A	41.22408	-75.93395	6/18/2010	0		0		0	146
28737	PA	M	A	41.33642	-75.72070	7/22/2010	0		0		0	114

28739	PA	M	A	41.33642	-75.72070	7/24/2010	1	11/23/2010	0		0	141
28836	PA	M	A	41.23615	-75.87795	5/9/2011	1	11/14/2011	0		0	213
29380	PA	M	A	40.84690	-77.69192	7/21/2010	1	11/16/2010	0		0	209
31130	PA	M	Y	40.91174	-77.77211	5/23/2012	0		0		0	99
31530	PA	M	A	40.25767	-78.82755	8/3/2011	0		0		0	117
31716	PA	F	Y	40.35585	-78.62838	6/2/2012	0		0		0	115
32726	PA	M	A	40.43333	-78.81742	3/29/2011	0		0		0	290
32781	PA	M	A	40.32917	-78.73018	9/20/2010	0		0		0	153
33110	PA	F	A	40.79715	-77.98708	5/25/2010	1	11/22/2010	0		0	210
33113	PA	F	A	40.80975	-77.81025	5/29/2010	0		0		0	125
33115	PA	M	A	40.84845	-77.70753	6/23/2010	0		0		0	219
33119	PA	M	A	40.84845	-77.70753	6/29/2010	1	11/21/2011	0		0	388
33121	PA	F	A	40.80520	-77.80878	7/8/2010	0		0		1	115
33123	PA	M	A	40.80520	-77.80878	7/9/2010	0		0		0	232
33125	PA	F	A	40.84845	-77.70753	7/9/2010	0		1	10/26/2010	0	106
33127	PA	M	A	40.43498	-78.67026	7/9/2010	0		1	8/5/210	0	118
33129	PA	M	A	40.80520	-77.80878	7/16/2010	0		0		0	100
33131	PA	M	A	40.81772	-77.80246	7/17/2010	0		0		1	168
33148	PA	M	A	40.35592	-78.62852	10/12/2010	0		0		0	205
33151	PA	F	A	40.83799	-77.84422	4/26/2011	1	11/19/2012	0		0	222
33153	PA	M	A	40.26610	-78.99238	5/3/2011	1	11/19/2011	0		0	187
33201	PA	M	A	40.35638	-78.62737	4/10/2011	0		0		0	262
33207	PA	F	A	40.89183	-77.86812	4/26/2012	0		0		0	134
33209	PA	M	A	40.89012	-77.85528	5/20/2011	0		0		0	205
33211	PA	M	A	40.23577	-78.78460	5/21/2011	0		0		0	195
33213	PA	M	A	40.85388	-77.88363	5/23/2011	1	11/21/2011	0		0	250
33215	PA	M	A	40.80471	-77.95875	6/1/2011	0		0		0	267
33219	PA	M	A	40.89012	-77.85528	6/21/2011	0		0		0	351
33221	PA	M	A	40.84361	-77.93378	7/16/2011	0		0		0	208

33359	PA	F	A	41.14353	-75.88213	5/14/2011	1	11/19/2011	0		0	176
33361	PA	F	A	41.14353	-75.88213	5/17/2011	0		1	5/17/2011	0	206
33366	PA	M	A	40.26603	-78.99315	7/1/2011	0		1	8/18/2012	0	129
33369	PA	F	A	40.25767	-78.82755	7/18/2011	0		0		0	108
33836	PA	F	A	40.27098	-78.77345	7/16/2010	1	11/19/2011	0		0	184
33838	PA	M	A	40.25758	-78.82759	8/25/2010	0		0		1	106
35709	PA	F	Y	40.79898	-77.95525	5/23/2012	0		1	10/4/2012	0	84
35711	PA	F	A	40.80520	-77.80878	5/25/2012	0		0		0	176
35713	PA	M	A	40.79909	-77.98687	6/7/2012	1	11/21/2012	0		0	346